Supervisor:
Prof. Dr. Michael Stadler,
University of Bremen

DISSERTATION

CREATIVE PREDISPOSITION AND CREATIVE ACTIVITY IN THE CONTEXT OF BRAIN FUNCTIONAL ASYMMETRY

by Iourii Gribov

Berlin, 2001

Tel./Fax: 0049 30 2167010
Email: igribov@aol.com

I. SUBJECT AND SIGNIFICANCE OF THIS STUDY

1. ***The nature of the creative abilities*** of human beings forms the subject of this study. Educational applications in the fields of the development of human creative potential and the protection of that creative potential are also considered.

2. It is proposed that creative abilities have a fundamental *neuro-psychological basis*, related to ***Brain Hemispheric Functional Asymmetry*** (BFA). Due to this connection, it was necessary to introduce a detailed discussion on the nature of BFA, and to consider some general questions related to neuroscience studies.

This study involves two scientific fields (the psychology of creativity and BFA data) and is therefore *interdisciplinary*. The area studied is a relatively new, but developing field within the disciplines of psychology, psychophysiology, and pedagogical psychology, and the available data is currently being analyzed and reanalyzed.

BFA is widely accepted as one of the basic paradigms of modern psychology. Most of the research into BFA commenced in the 1960s following R. Sperry's historical study, and is a well-established field of cognitive psychology and the psychology of creativity. However, intensive studies of the BFA paradigm in these fields have only occurred in the last two decades.

Since the Second World War, only a few scientists in Germany have worked on the subject of the psychology of creativity and there are no scientists who have carried out scientific research in this growing and important interdisciplinary field of psychology, connecting BFA and creativity.

As noted above, the core question of this study is the *nature of BFA*. A better understanding of BFA is fundamental for modern psychology and could be a key to the understanding of the nature of human cognitive, and especially creative, abilities. BFA has a deep relationship with human biology and cultural ontogenesis and is specific to existing cultures. As a teacher, I have attempted to apply some of my theoretical findings to my practical pedagogical work on creative development. Discussed in this study are some new cultural perspectives on *the liberation of creative potential* and some new methods for the *ecology of creativity* (part of the so-called *psychoecology* that follows the *ecological paradigm*, an idea established in the late 20th century).

There are three important interrelated aspects to my thesis, namely:

(a) The general neuronal features of the human brain structure and the nature of BFA;
(b) personal creative predisposition (psycho-physiologically facilitated);
(c) outside sociocultural background – namely sociocultural factors which foster or suppress human creative potential.

Neuro-scientific aspects. The basic functions of the cortex and the corresponding nature of BFA is analyzed from the modern position of the so-called neuropsychological *Fourier paradigm* and the relationship between the *Fourier paradigm* and the Gestalt School of Psychology and Cognitive Psychology is considered. Related data of cortical neuronal organization, corresponding models, and Electroenzephalography (EEG) correlates, connected with the organization of perception and motor activity, are also considered.

The neuro-scientific nature of creative abilities is connected here to the *complementary, adequate brain hemispheric functional balance* in the cognitive processes. It appears to be *the key* to the understanding of the nature of creative ability. The neuro-psychological factors and the cultural conditions, which potentially promote such a functional balance, will be discussed.

Cultural-pedagogic aspects. My *pedagogical research into the fostering of the creativity of pupils* (aged 7–11, in art) over some years shows one basic, instructive sociocultural phenomena, related to the *traditional school system*: namely the *unconscious, spontaneous collective hostility of traditionally educated children to creative self-expression.* In the new pedagogical situation, which I tried to develop, which was based on the regular encouragement of creative activity, my aim was to eliminate such hostility and to change it into the opposite – i.e. the collective fostering and protection of individual creativity in school classes. It is not so difficult to analyze some of the sociopsychological conditions, which have resulted in this “anti-creative” cultural stagnation. Evidently, it is connected to a deep disparity between the traditional school system (as the basic instrument of socialization, fostering almost exclusively *reproductive ways of cognition*) and the coming *creative revolution*, which will involve the liberation of the human creative potential. It is possible to propose, following Norbert Wiener (1948), that as the Industrial Revolution liberated the *human body* from mechanical slavery, the *modern cybernetic revolution* will now liberate the *human soul* from *routine intellectual slavery*. This will lead to the realization of the *biblical paradigm of man*, transparently expressed in Genesis as the paradigm of *“human-creative”*.

Multi-level concept of creative abilities. My earlier school study (Gribov, 1987, 1988) showed a high correlation between creative activity and the *non-right-handedness* of children and my earlier study is not contradicted by the results of my latest research at the University of Chicago with *extremely creative* American adults.

Both studies support the *multi-level concept of creative abilities* as proposed in this study. However, every level has a common link, namely the “functional mixing paradigm”. The functional mixing is connected to a “distortion” of the typical BFA by a particular mixing of the brain functions in the same hemisphere. It is possible to distinguish different creative potential levels by adding additional neuro-psychological factors such as *double consciousness, connected with two opposite, verbally operating Left Hemispheric (LH) vs. Right Hemispheric (RH) cognitive systems.*

It is also possible to increase human creative potential by methods of cultural activation of the RH functional involvement, working independently to the level of the psychophysiological creative predisposition.

Psycho-technical aspects. Presented in this study are corresponding studies showing some psychotechniques for the correction of the functional involvement in integrative brain activity, for example, research connected with *moving programs transferring* from one hemisphere/effector to another (drawing and writing with the right and the left hand). If the moving program is a function $f(x,y,t)$ as the drawing is transferred across a corpus callosum from one hemisphere to the other, it leads to the horizontal mirror inversion, $f(x,y)$ □ $f(-x,y)$ and produces a straightforward method of facilitating the interpretation of right or left hemispheric functional activity (especially useful in the case of creative self-realization in art). In this context, the old and almost-forgotten drawing training method, which was discovered at the beginning of the 20th century by the famous American pedagogue Liberty Tadd (1899), is discussed. This method is based on ideas deriving from the Greek philosopher Plato, and on anatomical information on so-called hands-hemispheric connections.

Aesthetic aspects. A comparative study of drawings made by left and right-handed individuals reveals a specific “left-handed” style of drawing. This aesthetically preferable style in conjunction with additional introspective data, provided ideas on the *psychological nature of aesthetic feeling*. In this context, left-shifted and right-shifted compositional centers in drawings from school students and in paintings from very famous artists were also analyzed.
In the context of the BFA two opposite cultures, namely Chinese Eastern and European Western, were compared.

A corresponding psychoecological program (connected with the ecology of creativity) is proposed on the basis of the presented BFA data.

II. STATE OF INVESTIGATIONS – THEORETICAL ANALYSIS

1. NATURE OF BRAIN HEMISPHERIC FUNCTIONAL ASYMMETRY (BFA) – STATE OF INVESTIGATION AND HYPOTHESIS

Summary

This chapter clarifies some basic principles of the cortical neuronal organization. It is reasonable to argue that our brain seems to be *the polymodal neuronal Fourier processor* (or based on it neuronal parallel operator, containing relatively *very slow* neuronal units, assembled in *parallel synchronized neuronal fields.* The natural neuronal-fiber – Fourier operator – is compared to the common optical lens. Since the holistic neuronal Fourier transformation is not realizable (because of the neurons/fibers N² problem), the brain can function only as a limited piecemeal F-processor within mosaic-like Fourier neuro-space. This neuro-structural limitation leads to a relative division of the spectral information between two brain hemispheres (Global-RH vs. Local-LH) with their precious cross-callosal reciprocal coordination. The biggest advantage of this evolutionarily developed informational split is the establishment of human speech, thinking by categories, and the enlargement of ontogenetically accumulated libraries of sensory-motoric cultural stereotypes (LH). But, normal behavior is provided by their situative assembling connected with the holistic function of the RH.

1.1 STRUCTURAL PRINCIPLES OF NEURONAL ORGANIZATION

Principle of Parallel Neuronal Constellations

The brain's microstructures are very complicated and grow in ontogenesis "on the inside" according to natural biotechnology. It looks like a specific structural neuronal cosmos, and has the ability to sense and store innumerable micro-events, from both within and without sensory spaces *simultaneously*.

Our neurons (which can be compared to the modern silicon chip) are *very slow-working biological units*, but evolution created their very wide parallel neuronal nets so that they can easily keep information about outside space distributed structures. Such nets *complement* the parallel, continual space structure of the world. This *parallel, continuous type* of natural stream of information has a very large capacity, but it is simultaneously distributed among billions of relatively slow neuronal units, working in the *parallel neuronal structures of memory* known as the *"quasicontinuum of simultaneity"* (Gribov, 1981). This complementary, continual parallel neuronal architecture yields the ability to deal with the huge variety of information about the external continual world *"in real time."* This architecture is roughly complementary to the physical continual space structures, existing as "quasicontinuum of simultaneity" with physical streams – potential informational flows –, which have the same space-distributed structure.

This yields the ability to deal with the huge variety of the external world. The brain has a very fast associative and space distributed memory, even at the level of the macromolecular structures of neurons. These parallel neuronal structures provide a unique sensitivity and intellectual potential, sources of human individuality and creative self-expression. The "parallel structural" principle was proposed and tested in many brain studies and these data will be reviewed below (in EEG and cellular data).

Principle of Coherent Functional Group of Neurons

This principle can be sufficiently proven if we accept the above-mentioned principle of *parallel neuronal nets*, necessarily assembled from *very slow-* working units – neurons. Only rhythmical *coherent neuronal groups* reflect *consequent (in time) segments* of the natural sensorial informational flow, and at the same time form adequate memory patterns of this space-time continuum (because of the corresponding "continuum of simultaneity" in the cortical neuronal space). Exploration of both these principles seems to be necessary for all brain neuronal structures, but it is not enough to understand the hemispheric functional asymmetry, since both hemispheres *must* use this parallel (continuous in-space) processing of information. These specific differences will be discussed below. Still it allows, for example, for an explanation of the functional role of Alpha- and Beta- EEG rhythms (see below).

Population Coding Paradigm

Hebb (1949) was the first scientist who attempted to create an economical model for neuronal coding structure. He proposed:

(a) that a specific constellation of features should be represented by a dynamically associated assembly of cells represented either by sharply tuned cells or, more economically, by population codes,
(b) that the same cells can be bound successively into different assemblies.

Comments on the Hebb Model

It is easy to note that the Fourier transformation (FT) for any visual image, is simultaneously represented by the "sharply tuned cells" – spatial harmonics detectors and also the population codes, regardless of the enormous amount of sensory variety, while each natural image has a rich Fourier spectrum, presented by a definite neuronal Fourier population. Thus, Fourier coding is an elegant, much less abstract, constructive, and effective basis for the population-coding paradigm. The same neuron in the neuronal Fourier space could detect *different sensory images*. It means that Fourier memorizing will synaptically connect the Fourier-detecting population of neurons in the neuronal constellation, in the self-activated neuronal Fourier-Gestalts.

Singer (2000) suggested, on the basis of theoretical arguments and experiments with mammalian cell-ensembles, that coding assemblies are formed by rapid and transient *synchronization* of the responses of the associated neurons and that this arising synchrony is a sign of their relatedness.

This position does not contradict our hypothesis about the working neuronal Alpha-groups (Gribov, 1977a, 1977b), and with the more general principle of "continuum of simultaneity" for external/internal sensory units, realizing very dense informational flows (Gribov, 1981). This informational density is not realizable without universally parallel neuronal spaces, based on very slow neurons. It is important to note that the working Alpha-group is postulated to have a *"pre-synchronization" of neurons* in the "waiting" neuronal group, a necessary condition for their immediate ensemble-like reaction. In the evoked state of relaxation there is only one "waiting" coherent and dense group of neurons (with a very high amplitude Alpha-rhythm within it). It is proposed that this group is divided into several working sub-groups with regularly shifting sensitive Alpha-phases for guaranteeing the fastest perception in the probable sensorial world. In this way, the common Alpha-desynchronization in EEG, during the time of *active attention* "in the probable world", is explained (Gribov, 1977b).

Thus, we propose that summary EEG desynchronization during "active attention" is the contrary cortical process of neuronal EEG Alpha-synchronization, masked by the regular Alpha-phase shift.

Singer summarized some basic rules connected with the neuronal network:

(1) "feature-selective neurons bind-in variable constellations into different assemblies;
(2) the rules of binding correspond to common Gestalt principles;
(3) particular perceptual objects always activate the same assembly, once learning has taken place, and the association connections favoring stabilization of this assembly have been strengthened;
(4) the joint responses of cells comprising of an assembly are distinguishable by subsequent processing stages as components of one *coherent* representation, thereby, avoiding confusion with simultaneous responses of cells belonging to other assemblies, and preventing the signaling of otherwise unrelated contents" (Singer, 2000, p. 329).

How can assemblies organize themselves on the basis of cooperative interactions within associative neuronal networks? Some famous theoretical ideas are proposed by Hebb (1949), Braitenberg (1978), Edelman (1987), Palm (1990), and Gerstein and Gochin (1992).

Neuronal Cortex as Multidimensional Coding "Fourier Windows"

Singer (2000) stressed a critical theoretical question: How are the responses of cell assemblies tagged as related?

In the case of the spectral Fourier coding, this question is not so difficult. Another no less important question arises – namely, why the Fourier-frequency space could be so convenient for neuronal structures? Now, the answer arises if we propose the following basic function for any neuronal system: *patterns recognition*. For recognition, the FT has definite, very strong advantages familiar in physical optics: Parallel I(X,Y) image movement does not shift its Fourier image – in the Fourier spatial frequency space any such movement is eliminated. To illustrate this, we can use FT in the thin optical lens. Visible analog – if any single sinusoidal grate change position in the (X,Y), perpendicular to the lens axes, its focal image (in the focal plate) will be exactly the FT – two symmetrical points-frequencies (+f, –f) in the same place for all parallel grate shifts. For example, if f=0, it corresponds to a bright homogenous beam, directed parallel to the lens axes. It will focus on the central axial point of the focal plate of the lens. This Fourier point is the Fourier frequency f=0. If we were to shift a similar beam parallel to itself in (X,Y), it would not change its axial focal point position f=0 in the Fourier space (i.e., in the focal plate of the lens). The same paradoxical *static effect* is also for all frequency points f≠0. Thus, for detecting any Fourier component ω of a sensorial image (connected with the *continuum* of all possible parallel shifted positions of the sensorial image) we need no secondary *continuum* of Fourier detectors, we need only one corresponding neuronal detector f, having a single Fourier-neuron! Thus, the FT is able to exchange enormous sensory continuum of "shifting superfluity" into the single detecting neuronal point. In this case, the neuronal recognizing structure would be surprisingly compact. This is how FT serves as the basic coding transformation in all cortical space, independently of sensory modality, or a cortical projection area. Thus, it is possible to generalize that not only the visual cortex (Field 17), but all other cortical areas are local spatial *Fourier analyzers* – FTn for corresponding secondary input patterns I(Xn, Yn). For example, it could be FT1 for emotional face expression, or FT2 for face recognition; correspondingly FT3 could be for speech recognition, FT4 for musical tone processing, and FT5 for tactile neuro-muscular sensory streams, etc. Thus, it is possible to summarize that our cortex is a complicated multidimensional Fourier coding "machine" or a Fourier coding *"neuronal Fourier window."*

The Proposal of Fractal Mechanisms in the Cortex

The overlapping of the sensory fields of the cortical Fourier neurons allows the realization of the very effective fractal mechanism of the selection of sensory signals from neuronal noise. In reality, in the fractal process (e.g., for a one-dimensional linear signal) the signal/noise superposition is divided in consequent time units, and each pair of any two consecutive units are compared with each other. It may be the most effective method for the selection of signals from the background noise. It has been found that the Fourier-neurons in the right hemisphere (RH), have wider sensory fields than in the left hemisphere (LH). This means that the RH can select global signals better (and the LH can select local signals better) from the noise. The fractal comparison mechanism (inside the same visual image/noise composition) may use different frequency-shifting pairs of the working Fourier-Alpha-groups, building alphon-like Alpha-spindles in the EEG.

Both Livanov (1940) and Lebedev (1976) proposed, and experimentally detected the existence, in EEG, of such step-wise Alpha-waves. These waves have step-wise Alpha-frequencies fa, fa±1Hz, fa±2Hz, fa±3 Hz,.... Livanov even proposed that superposition of these step-wise Alpha-waves could lead to the common EEG desynchronization in the Alpha-diapason. But, these authors never connected these step-wise Alpha-groups with our neuronal mechanism of neuronal patterns comparison, (Fig. 6.1–6.3 in this study). Thus, it is possible that signal comparison and signal/noise selection processes could be realized by our neuronal comparison mechanism, mentioned above (Gribov, 1977b), and these two basic recognition processes are parallel in the same cortical sub-strate.

An additional proposal could be that neuronal gamma-waves express two basic cortical functions – signal-comparison and signal/noise selection. This could explain the intensive gamma-interaction between local cortical elements.

Electrophysiological data confirm, very well, the ability of neuronal networks to encode, transmit, and evaluate the temporal structure of stimuli, with astounding precision, in the millisecond range (Carr, 1993; Nalcaci, Basar-Eroglu, & Stadler, 1999).

Many research findings confirm that such timing of discharges could be transmitted over several synaptic stages with low temporal dispersion and resolution in the milli-second range, at least when the discharges in parallel channels are *precisely synchronized* (Engel, Roelfsema, Fries, Breght, & Singer, 1997; Rager & Singer, 1998; Singer & Gray, 1995).

Synchronized responses are selected from responses that follow a different time course (Singer, 2000). This is possible only on the basis of reciprocally coupled parallel channels, that is, if a population coding strategy is used (Diesmann, Gewaltig, & Aertsen, 1996). Only population coding could compensate common, low, discharge rates and fluctuations in firing probability.

Reaction times, evoked potentials, and latencies of single-cell response data suggest that many sensory patterns can be recognized within less than 100 milliseconds. Studies conclude that this leaves only a few tenths of milliseconds per processing stage to perform the computations necessary for the selection and grouping of responses (Rolls & Tovee, 1994; Thorpe, Fize, & Marlot, 1996).

Rates of discharge-spikes vary between 0 and 100 Hz and inter-spike intervals follow a Poisson distribution. This means that a neuron can emit a maximum of 3–4 spikes on average within the interval of interest (100 milliseconds), plus a few more spikes if it is bursting. Shadlen and Newsome (1998) proposed that such very fast recognizing can take place only by population coding.

Note: In our model this very fast process, in the probable sensory surrounding, is predetermined by the simultaneous existence of different (about 7±2) working (waiting) Alpha-groups and neuronal Alpha-modules, with the step-wise shifted phases of their Alpha-waves in the time of sensorial attention. This state expresses pre-sensory neuronal readiness to perceive probable signals (in time). This model simply explains common EEG Alpha-rhythm desynchronization in perception and motor activity. It also explains the evoked state of relaxation (large amplitude of the EEG Alpha-waves) when the sub-modules have the same Alpha-phase of periodical activity (a type of “evoked sensory break”).

Do neurons in the central nervous system encode spatial and temporal information only by varying their discharge rate (Shadlen & Newsome, 1994, 1998), or do they have additional coding mechanisms for the temporal information? (Buracas, Zador, Dewse, & Albright, 1998; König, Engel, & Singer, 1996; Mainen & Sejnowski, 1995; Softky, 1995; Softky & Koch, 1993; Stevens & Zador, 1998).

Singer (2000) supposed that rate and temporal codes are complementary while temporal and non-temporal features must be encoded in the same, very short (millisecond) intervals.

Phase Detection in the Fourier Transformation

For example, sensory signals of a moving retinal object formally could be described as a function of its coordinates and time f(x,y,t). The sensory system transforms spatial and temporal components into a corresponding Fourier image F(ωx, ωy, ωt), containing distinct superposition of spatial sinusoidal-waves with different *frequencies and phases* for each wave and also temporal sinusoidal-waves with different time frequencies and phases (Gafni & Zeevi, 1977). In the Fourier image, information about phases play no less an important role in the coding process than frequencies. Different initial images could have the same Fourier-frequencies, but different wave-phases. For example, when we see several different objects, specific phase information could easily describe *metric* relations between them (i.e., distances) and their relative space positions in the visual field. It is especially easy to see this for relatively low space frequencies in these visual objects, (RH-operations). These low frequencies are connected with relatively large receptive fields for neurons sensitive to them. Relatively high space frequencies describe smaller, local objects on the retina. If such sinusoidal-grates move with constant velocity, their phases will be changed periodically (slowly for the RH and quickly for the LH). This will be a type of inside neuronal Fourier flashing. Low temporary harmonics are connected here with *the global space metric* and high temporary harmonics to the *local space metric*.

If an object moves, the space metric involves temporary (dynamic) phase information and it is not possible to divide these static and dynamic features. Something similar is happening with the special relativity theory of Albert Einstein. This theory is described by the united space-time continuum. Remember, for example, his famous mirror watch. It contains two parallel mirrors and a reflecting beam of light flowing between them periodically.

In the Fourier coding paradigm, as described above, the spatial and temporal aspects of information-processing go through a distinct and very interesting transformation: Partially spatial features correspond to the Fourier space frequencies and temporal features (movement) are connected with the Fourier time frequencies coding, which is connected (if it is normal external movement) with the changing of *phases*. It is surprising, but there are only a few studies about phase aspects in the sensory Fourier-frequencies field. The phase information study is, today, a *neglected* area in cognitive psychology. It was found that the RH estimates the phase's relation between wave-components of complicated two-dimensional grades much better than the LH (Fiorentini & Berardi, 1984). This experimental data corresponds to our description of the phase information for low frequencies, connected with the *global* metric in the visual scene (related to the RH processing, as indicated in many different studies).

Is the Cortex a Hologram-like Processor?

Pribram (1975) compared the architecture of the brain with that of the computer, and argued that the brain is a parallel and holistic processor where "many related events occur simultaneously" (p. 164). This is not a strict mathematical definition for the brain neuro-structure. For many computer scientists, two, three, and more parallel, consecutive, linear inputs symbolize this neuronal "simultaneity." In our study (Gribov, 1981), this parallel brain structure was named, more strictly, as the "quasi-continuum of simultaneity" because each single sensory, or another neuropsychological "event," has this *continual* structure, and involves millions of parallel working and connected neurons, even for physically linear sound inputs. For example, each single neuronal sensory input has the "continuum of simultaneity" form (each line, spot, sound, etc.). On the contrary, PC-computer input and inside architecture, and inside informational streams are strictly linear, consequent, and non-continual (in the space coordinates). Today's computer industry now understands this fundamental weakness of "hardware anatomy," compared to the super-parallel brain neuroanatomy. Some large firms (e.g., Siemens) have attempted to develop brain-like parallel super-computers by changing the linear hardware architecture into simultaneously, parallel working nets, including many thousands of parallel microprocessors with thousands of parallel "sensorial" inputs. These parallel nets are very expensive today, but it is the visible future in qualitative hardware evolution. These computers are able to account in "real-time" enormously large, simultaneous accounts necessary for many modeling systems (the weather, stock-market prognosis, excellent immediate visual orientation in complicated natural space, modeling of human visual thinking processes, etc.).

The so-called bionic neuronal-net computers will never be effective before the clear understanding of basic functional macro- and micro-aspects of the natural brain neuroanatomy. After understanding this, it will be possible to realize some of these functions more or less easily, without a repetition of the complicated natural neuronal net structure.

Traditional neurology claims the well-known "point by point" connection between sensory and cortical spaces. However, Lashley (1960) found that sensory input is not projected strictly "point-to-point" in the cortex, but is distributed over large areas. For example, even large holes in the cortex do not disturb important behavioral functions. He named this cortical capacity as "equipotentiality."

In the physical theory of optical recognition, it is very well known that in the Fourier space so-called Fourier holograms could be created. In reality, in the

Fourier transformation, quasi-holographic distributed neuronal memory structure could be realized, as predicted by Karl Pribram (Pribram, 1975).

Neuroanatomical Advantages of the Neuronal Fourier Hologram

Fourier holograms have important neuro-anatomical advantages, connected with two basic properties of the Fourier transformation:

(1) A single, point-like input sensory signal, looking like the so-called sensorial $\delta(x,y)$-function will be "projected" by the Fourier transformation into the most wide possible spectrum of space frequencies (i.e., involve enough large neuronal Fourier-space in the cortex). The optical Fourier-image of this δ-point will have the form of a homogeneously filled (theoretically unlimited in the Fourier space) spectral area. In the case of an optical lens, it will transform the "sensory" light point into the homogenous and very wide collinear beam of light. This means that each single sensory point, theoretically, is uniformly distributed between all neurons in the Fourier space, and also means that the Fourier hologram has a large surplus of storage space for information, while information on each input sensorial point is distributed along all surfaces of the hologram. It is one of the most important advantages of the Fourier hologram. It provides high storage safety and also safety against local defects in this hologram. This could explain why behavior can only be partially affected despite a considerable amount of damage to the cortex, as investigated by Lashley (1960).

(2) The shifting of the input $\delta(x,y)$ function (shifting of the point-like retinal image) will not change the corresponding Fourier-image (concrete Fourier-neurons activated in these cases). It will have strictly the same distribution of Fourier-frequencies (activation of the same Fourier-neurons), but only with corresponding phase-shifts in the Fourier space. This means that, for example, local retinal image shifts will activate the same Fourier-neurons, solving the problem of monstrous continuum of possible retinal image shifts for their neuronal identification as the same image.

Modified Cartesian neuronal Fourier-space (f_x, f_y) allows us to solve, not only the problem of the retinal *shifts*, but also similarly important problems of image identification independently to different possible image *turns*. To this end, it is necessary to transform the coordinates (f_x, f_y) into polar coordinates (ρ,θ), where $\rho=\sqrt{[(f_x)^2 + (f_y)^2]}$ and θ – is an angle-orientation of the corresponding sinusoidal-wave with frequency (f_x, f_y) in the retinal Cartesian coordinates (X,Y). It may be one of the most impressive for physicist neuro-scientific discovery (Maffei & Fiorentini; 1977) that, namely, neuronal columns (that we propose to name – the basic *Neuronal Fourier Micro-Module*) has this polar-like neuronal Fourier-space architecture.

Thus, it seems that nature, choosing the neuronal Fourier transformation, realizes the optimal "mini-max." principle in the neuronal architecture: a large surplus in information storage and, at the same time, a minimum of neuronal space, involved in the image recording and space-invariant recognition.

Basic Cognitive Advantage of the Neuronal Fourier Hologram

The most important additional *cognitive advantage* of the neuronal Fourier hologram is connected to the possibility of realizing distributive associative memory. It is, for example, the ability to reanimate full image in memory by representing only part of it in the sensorial space. It is also the ability to reanimate the image by using part of the cortical holographic space. This quasi-holographic neuronal property intrigued Karl Pribram (Pribram, 1975). We will consider later how these neuro-holograms in the LH differ from those realized in the RH. For example, global Fourier-elements of the RH have a mosaic presentation. It looks as if many small lenses make a Fourier image of a very large sensory image instead of an adequately large lens. Unification of these Fourier-parts requires dense and *long horizontal* cortical mediating fibers, connecting these Fourier-pieces into a holistic neuronal pattern. This horizontal net has been evidenced by neuro-anatomical studies. It has a larger quantity of gray cortical substance – long horizontal fibers in the RH (Woodward, 1988). Because of this unique structure – namely a widely unified neuronal Fourier-space – the RH becomes a very powerful generator of the straight quasi-holographic neuronal pattern associations, which is extremely useful in creativity.

The LH, in contrast, analyzes relatively small visual images, and it can have local and more complete, relatively disconnected local Fourier spaces. In reality, the neuronal columns in the LH are denser; they have better developed vertical fiber-connectors inside the column, and these columns have greater autonomy, than in the RH (Woodward, 1988). It provides much better opportunities for image classification in the LH and for the construction of some kind of neuronal "drugstore" with a very large library of memory elements, although each element has a strictly divided box. It provides a sort of dry, analytical thinking style, and it maintains the stereotypes of "neuronal entropy," although the LH is relatively poor from the point of view of the flexible, wide associative power of the RH. For the LH, classificatory mechanisms, such as associations, could be destructive.

Fourier Hologram versus Associative Net Neuronal Models

Neuroscientists have attempted to develop different alternatives to the Fourier concept. They argued that the Fourier hologram has not such a high signal/noise relation and proposed some parallel associative net-like models instead. Some concrete alternatives for the parallel-like nets with associative memory were discussed in Hinton and Andersen (1989).

Comment as a proposal for neuronal *structural polyphony*. Evidently each neuronal column is a local, elementary Fourier-space module. The significant advantages of this concept were discussed above. The cortex plate contains millions of these modules. It is possible to propose that they are connected with each other in additional associative nets, with specific additional properties. That is, it is possible that the cortex realizes some sort of synthetic poly-model that accumulates and realizes, simultaneously, different advantages of different structural principles. These principles could have been selected during the brain's evolutionary development and the result was the architecture of the modern cortex. But, in all possible variants, the neuronal Fourier space has outstanding (experimental and theoretical) chances to be implanted in each co-operative neuronal model.

1.2 THE WHOLE/PART DISTINCTION IN HEMISPHERIC STUDIES AND IN GESTALT PSYCHOLOGY

Constructional Apraxia

Constructional apraxia is an important example of qualitative hemispheric differences in Spatial Cognition. The standard Rey-Osterrieth figure test showed that the patient with left hemispheric damage drew the overall form with little detail. The patient with right hemispheric damage drew many local details, but organized them incorrectly (Robertson & Lamb, 1991).

Constructional apraxia, for parts and wholes, was studied by many scientists (McFie, Piercy, & Zangwill, 1950; McFie & Zangwill, 1960). They connected the constructional apraxia for wholes, more with right, than with left hemispheric damage (Black & Strub, 1976; Costa & Vaughan, 1962; Gainotti & Tiacci, 1972; Piercy, Hacean, & Ajuriaguerra, 1960; Piercy & Smyth, 1962).

The Influence of the Gestaltists

This influence was widespread not only during the early part of this century. They continue to have an influence on current cognitive theory because the part/whole distinction is the central point of it (Robertson, 1986). For example, it is one of the most important distinctions in the psychological Fourier paradigm and the key element in BFA (and correspondingly, the psychology of creativity). These aspects will be analyzed in our study.

The part/whole distinction, which shows reliable hemispheric differences, has a long history in the psychological study of cognition and perception.

Max Wertheimer was one of the first prominent psychologists who left the narrow behavioristic approach that built the whole as the sum of its parts. He demonstrated that the perception of the whole could not always be predicted on the basis of its perceptual parts (Wertheimer, 1938). For example, a melodic sequence of notes will be perceived as the same melody, whether played in a higher, or lower key. The melody can be quickly recognized even when each of the parts has been substantially changed. It was found that the *relationship between the parts* is more significant for the whole than the identity of these parts.

For example, the visual perception of a diamond can be changed to the perception of a square when the shape is surrounded by a rectangle (Koffka, 1935). The key factor is the relationship between the parts (between the diamond and the rectangle).

Physicists Necker (1832) and Haken (1983), and psychologists Stadler and Kruse (1990) stressed the opposite to Wertheimer's cases of Gestalt theory (Köhler, 1920, 1940) where parts of the whole have no visible change, but the global visual concept is changed dramatically (and periodically) from one to the other visual paradigm (e.g., two faces vs. a vase). Modern authors explain this as an activity of two competitive attractors (Haken, 1983; Stadler & Kruse, 1990).

Note: This periodical visual Gestalt switching could be the result of perceptual neuronal adaptation. In this case, the brain has two potentially equal, but *incompatible*, perceptual variants of recognition (e.g., faces vs. vase). In the beginning, one of these two alternatives arises spontaneously and probably it would be two human faces. At this moment, other possible alternatives could be suppressed. After a short time, the neuronal recognizing system *is adapted* to this perceptual reaction and this Gestalt will be blocked – switched off. After that, it will switch on the second clear visual variant – the vase. After certain adaptation to the second Gestalt, the perceptual system will be returned to the first facial Gestalt, that is, the switching process will have unlimited periodical form.

Indirect evidence for this explanation is the EEG study of Basar-Erogly, Strüber, Stadler, Kruse, & Greitschus (1995). In the first study multistable phenomena of the so-called stroboscopic alternative motion was used. Other research investigated the perceptually reversal Necker cube (Elbert, Hommel, & Lutzenberger, 1985). Both studies showed that observed perceptual switching induces the large positivity of perception-related potential in parietal sites, similar to a P300 wave.

The P300 wave is produced in perception in cases of low probability of the task-relevant stimuli that occur unexpectedly. This means that in the switching perceptual experiments, at the beginning, the perceptual system detects the "face", but simultaneously totally ignores (does not note) the other alternative, namely, the "vase". After fast perceptual adaptation to the "face," the perceptual system comes to a perceptual "uncertainty" and, in this moment, the second perceptual alternative – that which was previously ignored and invisible – suddenly arises "from perceptual nothing" as something unexpected, as a large perceptual surprise (with the corresponding P300 wave in EEG).

This explanation could be tested by a short presentation of the visual reversible image and later by choosing between different, normally presented images (at least two possible images) that a person could see in the short presentation. It is possible that not only one "face" will be chosen and maybe the "vase" will be the second chosen Gestalt.

Kruse, Strüber, & Stadler (1995) wrote that the perceptual multistability phenomenon is an outstanding methodological window for the measurement of the *dynamics* of the visual system.

Comments

From the view of the psychology of creativity, it is evident that multistable perceptual switching is a very important psychological phenomena, because it is an experimentally testable local key element, compatible with the general process of dynamics in creativity, connected to the sudden paradigm switching in the creative insight. Similar processes of the scientific paradigm switching in the scientific society was described by Kuhn (1962).

The switching period in multistable perception is specific to different personalities, and looks like a cognitive-style variable, a so-called *cognitive flexibility* (Stadler, Kruse, 1995). It is significant that this dynamic parameter includes originality in thinking (Klintman, 1984) and ability to imagine (Kruse, Stadler, Pavlekovic, & Gheorghui, 1992).

We propose that the perceptual switching could be connected with both the Global (RH) and the Local (LH) perception aspect.

This depends on the type of experimental reversing Gestalt. For example, if the case “face” versus “vase” will be realized as the Global visual element, the process will be periodically reversed in the RH. If the same Gestalt were to be implanted into another Global Gestalt as the Local part of it, the perception in the LH could be periodically reversed. For example, a simple verbal reversal process in speech, or a motoric reversal stereotype will be realized in the LH.

The Whole/Part Distinction in the Learning Process

Krechevsky (1938) found that animals (rats) learning a maze, first demonstrate knowledge of the general layout of the maze, and only later exhibit the learning of individual turns and alleys.

Krech and Calvin (1953) obtained similar effects with people’s perceptual learning tasks. They found that people learned the visual wholes faster than the parts.

Hierarchical Visual Stimuli

Important innovations in the field were made by Navon (1977), who started to investigate artificial visual patterns built as *hierarchical stimuli.* In this image, a large global form was made from several smaller local forms. It could be, for example, larger letters and forms created from the repetition of smaller letters and forms. Navon discovered that identification of the global forms is faster than for the local forms. Perception of the whole was totally consistent with the paradigms of the Gestalt school – it was independent of successful, or unsuccessful identification of the parts.

Broadbent (1977) was the first to propose that the global level of visual form is connected to lower spatial frequency. Later, more complicated nuances in the global/local perception were found. For example, if the global shape was too large, perception of the parts became faster (Kinchla & Wolfe, 1979).

1.3 "NEURO-FIBERS COMPROMISE" IN FOURIER SPACE

In this chapter a *neuro-anatomical hypothesis of BFA* is proposed. Our hypothesis will try to explain experimental data, showing that definite forms of BFA exist, not only in the human being, but also in animals and even singing birds (Springer & Deutsch, 1998).

A simple question: Why do all cortical perceptive neurons have narrow receptive fields? Why is the neuronal Fourier transformation not complete along the whole primary receptive space (as it is with the lens in optics)? Part of the answer could stem from the analysis of the integrative two-dimensional Fourier transformation in the thin optical lens. This transformation is a grandiose physical process of parallel mathematical calculation, building a Fourier image simultaneously in all Fourier spaces behind the lens in its focal plate. Physically, it is necessary to connect together, that is, to focus simultaneously, all points of input image I(x,y) with each point (fx,fy) of the Fourier – focal plate of the lens. Namely, the light has a miracle property: the necessary continuum of non-interacting light beams, crossing each other in each point of vacuum or transparent body, does not break this monstrous "all I(x,y) with all (fx,fy)" *connection*. They are packed and crossed super-densely everywhere between the two physical plates I(x,y) and (fx,fy). But, it is impossible for the corresponding neuronal "plates" I(x,y) and (fx,fy), bounded by *neuronal axon-cables,* to realize the same Fourier process.

Let us imagine the same complete (as in optics) neuronal integral Fourier operator. It means, for example, that for two "neuronal plates" I(x,y) and (fx,fy), with enough modest numbers of neurons (e.g., N=1,000,000) in each, we need to have N^2=1,000,000,000,000 fibers, connecting them in the "all with all" manner for this complete Fourier-operation (F-operation). It requires a very rapidly growing number of long enough fibers, with their very rapidly (as N^2) growing total space volume. Thus, this "all with all" neuronal structure is not realistic and is impossible with many millions of neurons and N^2 of fibers between them. In this case, there must be such a large volume of white matter (N^2 Fourier fibers) in the brain that there will simply not be space for the neurons themselves.

On the other hand, there is another very serious limitation for the "all with all" optical-wise connection – each single cortical neuron has approximately 1,000–10,000 synaptic inputs and this additional natural limitation also does not allow the construction of complete "all with all" neuronal Fourier-operators.

Thus, ***only piecewise neuronal Fourier-operations are possible.*** It is now clear that Fourier-realization is possible only for enough modest, *particular F-operations* with economical, *advisable compromise with an optimal number of neurons/dendrites and connecting fibers* between them (if neuronal cortex evolution follows the neuronal analog of integrative Fourier-operations). It means that cortical neurons with limited straight connections (fibers) *must* serve only enough *small receptive fields* (for high space-frequencies), these fields being large enough only for low space frequencies. That is, in the cortex only so-called *piecewise local Fourier-operations* can be realized, which later could be economically combined together in the integrative image. Brain neuronal evolution *partially* simplified this problem by dividing two (low and high) sides of the Fourier-spectrum for secondary cortical analysis into *two symmetrical and autonomic* hemispheres.

It is important that this hemispheric specialization allows autonomous cortical elaboration for sensory reality, which is connected to two very different sensory-motor areas: with Global and Local individual spaces. This “partial problem solving” evolution was not absolutely random – since it gives an additional, very important, behavioral, communicative advantage even in a singing bird's life. It is especially useful in the case of the social human being, since on the basis of this, the most expressed hemispheric Fourier splitting was developed – namely, human speech, communication, and categorical thinking.

Why is the LH/RH Division Useful?

(a) Each hemispherical neuronal architecture, after division, can much more effectively transfer and differently process corresponding, relatively autonomous, informational parts related to the Local and Global sensory aspects in the whole F-spectrum;
(b) at the same time the most powerful corpus callosum highway allows the hemispheres to integrate these particular advantages.

Note: This also explains why the corpus callosum has its outstanding size and symmetrically connecting fibers.

RH and LH have the same *primary sensitivity* to different Fourier frequencies. But, on the secondary neuronal level, the RH operates with the Global *(relatively low frequency)* part of Fourier harmonics, and the LH operates with the Local *(relatively high frequency)* harmonics of the same input image.

LH cortical neurons have *smaller receptive fields* and sense *higher harmonic parts.* It allows us to focus (locate) each LH-Fourier area in the relatively compact, autonomous cluster of cortical columns. The dominance of a large quantity of short local connections between them means that there *is not enough inter-neuronal space* also for long global fibers, which could effectively connect these local areas to each other.

RH neurons serve *larger receptive* fields *(lower harmonic parts).* This leads to a wider overlapping of local receptive fields (as it is in the LH). It causes the more diffuse structure of cortical columns in the RH, than in the LH. However, even the larger and better-overlapped receptive fields of the RH cannot serve the full global Fourier transformation. It will be, even in this case, the piecewise structure, built out of many local sub-transformations.

The LH Local *(compact)* image group of Fourier columns could also be compactly displaced in the cortex. Short, horizontal, cortical connections between them could be enough for the creation of the corresponding autonomy, that is, integrated Fourier-image in the LH.

In the case of the RH, the Global space presentation requires much more space-distributed columnar ensemble for the Fourier-image integration. This neuronal integration requires longer, horizontal cortical fibers in the RH.

Cognitive (RH vs. LH) Advantages of the Cortical Differences

As mentioned above, neuro-structural (RH/LH) cortical differences (wide overlapping for the RH) result in richer associative potential within it, than is possible in the LH. This is *important in creativity*.

The LH advantage is the opposite – it can much better separate perceptual units and realize the process of their classification, and is *important in the abstract thinking*. Corresponding mechanisms of LH-classification are discussed below.

1.3 ALTERNATIVE BRAIN FUNCTIONAL ASYMMETRY (BFA) CONCEPTS IN THE CONTEXT OF THE FOURIER PARADIGM

Today, in the modern psychology of visual perception, there are two practical *opposing concepts* and opposing interpretations, connected with hemispheric differences, based on the Fourier paradigm:

(a) the approach as expressed by a Russian scientific group (Glezer, 1985; Glezer, Ivanoff, & Tscherbach, 1973; Nevskaja & Leushina, 1990),
(b) the approach of Western psychologists (Ivry & Robertson, 1998; Sergent, 1982).

The group of Russian scientists proposes that the RH is connected with the *high frequency* side of the Fourier transformation and the LH with the *low frequency side*.

The Western group has the opposite proposal: the RH/low and the LH/high Fourier-transformation splitting, which was systematically used also in this study (see above).

Note: It is difficult not to agree with the fact that the Global space has larger sizes/low frequencies and the Local space has the reverse (smaller sizes/high frequencies) within it.

How is this discrepancy possible? Who is right? Or may be the solution is somewhere in the middle?

The Discrepancy Analysis

The fundamental discrepancy in these theories is difficult to understand, given that both interpretations agree that there is a correspondence between the RH/Global and LH/Local image.

There is one unsolved question in the basically correct Western psychological version: *How* do two hemispheres realize the basics – LH/classificatory, RH/iconic memorizing, and recognition functions? It is symptomatic that this (fundamental for BFA) question is simply systematically ignored in all the corresponding Western versions. For a review see, for example, the book by Ivry and Robertson (1998). The Western concept, in its superficial form, cannot explain this "how." While the higher Fourier frequencies are naturally associated with the more-detailed, fuller-image description, it is a "dead end" for explaining how the LH "rough" classification mechanism could be combined with this "more precise" LH cortical description in the Western concept. The same problem arises with the iconic, precise individual image description in the RH where the "low Fourier-frequencies" are located.

On the other hand, the Russian group (led by Glezer) attempted, from the beginning, to build a deep and broad BFA concept that could be able first to answer all these questions "fundamental" for BFA on classification (LH), and give a precise iconic description (RH). To this end, it seemed to be natural to "send" the "high Fourier-frequencies" area to the RH and the "low Fourier-frequencies" to the LH. The correct theoretical intention later consolidated the incorrect basic proposal (RH/high and the LH/low Fourier-Transformation splitting).

1.5 THE SPATIAL FOURIER-PARADIGM – BASIC WESTERN STUDIES

Spatial Frequency Hypothesis for Global versus Local Selection

Initial studies with normal healthy subjects suggested that the differences were due to the different spatial frequency spectra that define global and local objects. This difference is roughly equivalent to spatial resolution (blurry vs. fine) or spatial scale (large vs. small). The spatial frequency hypothesis was originally proposed by Sergent (1982) who used hierarchical letter patterns presented briefly in either the right or left visual field in normal, college-aged students. Left visual field presentation (projecting stimuli directly to the right hemisphere) produced faster responses for global letters, while right visual field presentation (projecting stimuli directly to the left hemisphere) produced faster responses for local letters.

Kitterle, Christman, and Hellige (1990) tested the spatial frequency hypothesis in healthy normal subjects. They studied the detection of sinusoidal gratings. These authors found no evidence of visual field differences. However, when subjects had to determine which grating was presented (i.e., attend to the spatial frequencies in the stimulus in order to determine which one it was), response times differed:

(a) Response times for lower frequencies were better when presented in the RH-left visual field (LVF) than in the LH-right visual field (RVF),
(b) while response times for higher frequencies were better when presented in the LH-RVF, rather than in the RH-LVF. As global objects include lower frequencies than local objects, these data are consistent with the global/local differences found by Sergent, but occur only when the object

level is important in performing the task (i.e., attention to particular frequencies is useful).

Recent imaging studies have found more activation of the right hemisphere when responding to global hierarchical patterns, and more activation of the left hemisphere when responding to local patterns (Fink et al., 1996; Martinez et al., 1996).

Relativity of Spatial Frequency in the BFA

But, how can the asymmetry of visual perception over stimulus size and eccentricity be explained? Actually, a hierarchical pattern of the global object (independent of the absolute size) contains lower frequencies *relative* to local objects independent of visual angle.

Presented in the study of Christman, Kitterle, and Hellige (1991) were compound stimuli with two spatial frequency gratings, superimposed on one another. They discovered the *relativity effect* of the RH/LH asymmetry: The grating of the same frequency could show a LH-right or RH-left visual field advantage depending on whether it was the relatively high – or the relatively low – frequency component.

The data from Ivry and Robertson (1998) are also consistent with the concept that the global/local hemispheric asymmetry may be a function of the analysis of relative spatial frequencies or spatial scales at the two levels of object structure.

1.6 OUR FOURIER-CONCEPT OF BFA – BASED ON THE WESTERN MODEL

Global Part of the Fourier Spectrum

Lamb and Robertson (1987) investigated some cases of perceptual "relativity." For example, when the stimulus set contained stimuli between 1.5 and 6 degrees of the visual angle, the global part was presented at 3 degrees. When the set contained stimuli between 3 and 12 degrees of the visual angle, however, the local part was presented at 3 degrees and global precedence then appeared at 6 degrees.

Comments

This study shows that, in the large range of the image sizes, the absolute size of the visual image for global versus local selection is not significant. It is possible to propose that only the ratio between the global and local space frequencies of visual images is significant. If we transfer (roughly in this case) the mentioned sizes into corresponding space frequencies of Fourier, possibly, we will have the same global/local ratio for space frequencies for both cases. The size of image gives at least its first Fourier-harmonic, that is, the size equal to the length γ of this sinusoidal spatial wave.

The corresponding frequency of this harmonic is f= $1/\gamma$. Each image size, presented above, has:

(a) 12, 6, 3 (degrees)
(b) 6, 3, 1.5 (degrees) and has corresponding frequencies f_a and f_b:

(f_a) 1/12, 1/6, 1/3 [cy/degree]; (f_b) 1/6, 1/3, 1/1.5, [cy/degree]

The *ratio* between two corresponding frequency *intervals* is:

(1/6–/12)/(1/3–1/6)= ½, for (f_a); (1/3–1/6)/(1/1.5–1/3) = ½, for the f_b.

This means that the ratio is the same. It also means that the global Fourier characteristics are not on the lowest end of the presented frequencies band, but are on the approximate 1/3 of the whole spectral interval for (a) and (b) cases, and it appears as an *invariant* for two different image sizes, as presented above.

Selective Fourier Filter for the Global Part – Right Hemisphere

RH - relative contouring or fining effect. It is possible to propose that the perceptual global Fourier sub-interval works as a selective filter. It filters the high frequency side of this interval better, but it could slightly reduce the lowest frequencies within it. The high frequency side has many densely distributed secondary spatial harmonics, which effectively describe the Global visual image. Such Fourier filtering realizes the common optical effects of *global image contouring*. This process could be very important because it eliminates continual tone-like pictorial information that is not necessary, and accentuates contrasting geometrical contours.

Here, the same “mini-max.” principle of neuronal organization is realized, as mentioned above, while it reduces, dramatically, the quantity of information in the “iconic” Global structure and effectively *accentuates its geometry*.

This filtering not only eliminates regular tone fields, it transforms their usual fluctuations into net-like *linear textures* (regular or non-regular), filling the Global structure. Now, people working even with simple Microsoft computer graphic programs know that the exchanging of a continual tone by the linear texture in the picture will dramatically reduce the quantity of information in a corresponding computer file (from a few Mb to a few Kb information in the computer memory). These textures and contours in the Global image are useful for *effective economical recognition* of the real Global space and orientation within it. For example, Kimchi and Palmer (1982) demonstrated that global precedence was limited to cases in which the local forms were not perceived as texture.

Perfect Global (RH) contouring ability was found also in the *drawings made by the left hand* by right-handers (Gribov, 1980), and later it was repeated in the study by Nikolaenko (1982) with unilateral studies (see chap. 7.1 in this study). The Global contouring creates particularly important artistic effects in art, and in decorative art especially. It is the basic style-like element in the worldwide decorative art tradition. It is also realized in some schools of modern art, which have reanimated this decorative tradition – first of all in impressionism, in the works of art of van Gogh and Matisse (Alpatov, 1963; Gribov, 1980, 1988). Interestingly, van Gogh used both elements – contouring and textures - extensively, as discussed above. In his best art period he used both contouring and expressive textures with his famous dynamic, mosaic-like strokes of the paintbrush. The contouring-like lines also built the common visual language in geometry. Data concerning brain-damaged patients show that RH damage disrupts (eliminates or slows) the perception of global objects. LH damage disrupts the perception of local objects (or what is typically called parts) (Delis, Robertson, & Efron, 1986; Robertson & Lamb, 1991).

Selective Fourier Filter for the Local Part – Left Hemisphere

LH-relative defocusing or blurring effect. The Local Fourier frequency (for example for fa) is fa =1/3 cy/degree and is located at the end of the whole frequencies interval. We propose that normally in the Local Fourier sub-interval (in opposition to the Global Fourier sub-interval) only a few first harmonics are analyzed, because the highest harmonics, for reduced objects, could be usually above the border of frequency sensibility – f_{max}., (Fig. 1.6–1).
This figure shows two linear Fourier-spectrums for the same *rectangular grade*. We use this grade for a better illustration because it has a very simple Fourier spectrum. This grade consists of periodical white and black parallel lines and has a common *linear* Fourier spectrum (e.g., as with the strings of a guitar). If the grade is near to an observer and is observed as the Global object, the observer will sense many dense spectral lines, giving maximum information about this grade (see Fig. 1.6-1 – the Global grade at the bottom on the left-hand side with the corresponding Fourier spectrum on the right-hand side). If the grade is at a distance from the observer, it becomes small and the observer will sense only a few left spectral lines *of the same grade.* Now it looks like the Local object with the *relative defocusing effect* (see Fig. 1.6-1 - the Local grade at the top on the left-hand side with the corresponding Fourier spectrum on the right-hand side). These few harmonics (few spectral lines above) are displaced in the Fourier space much less densely (as it was with the harmonics of the Global part). They *have less absolute quantity* and usually smaller amplitudes; that is, they describe this grade, essentially, less precisely.

Thus, we propose that in the *Local Fourier part* a kind of *relative filtering process* takes place – in this case it works in opposition to the Global filter – it *reduces the presence of high frequencies* in the Fourier spectrum (for the same removed or reduced object). This type of Fourier filtration simply cuts off the high harmonics by the fixed F_{max}. and provides an opposite effect (to the sharp and contrast contouring visual effect for the Global filter) – it provides a relative *defocusing* or *blurring* of the local (reduced) images. This operation is decisive for the very important cognitive operation – *rough classification of images.* In this case small differences between more or less similar images will be ignored in visual perception and it could establish relatively rough *mechanisms of visual classification*. This operation seems to be basic for the *LH classificatory function* (e.g., necessary, for the development *of abstract thinking and verbal communication* between people).

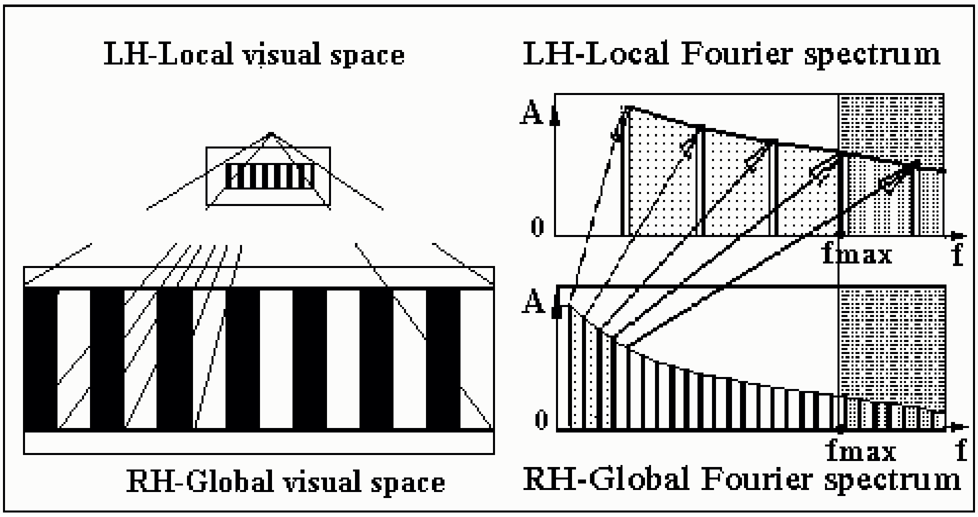


Fig. 1.6–1 shows, schematically, two rectangular grades (left) with corresponding Fourier spectrums (right). The grade *below* has a large space-period T and *dense spectral lines* with 18 sensible harmonics with f<fmax. The grade *above* has a smaller space-period T/5 and has a 5 times greater distance between the spectral lines in the Fourier spectrum (with only the first 3 harmonics with f<fmax being visually perceptible).

1.7 FOURIER PARADIGM AND ATTRACTORS

Synergetics was developed for statistically chaotic complicated physical systems, in which "attractors" could exist. 'Attractors' are unusual, but theoretically predicted macro-ordered, "attractive" states (Haken, 1983). Modern psychology now involves synergetics as a theoretical instrument in brain research (Haken, 1983; Kruse & Stadler, 1990; Stadler & Kruse, 1990, 1995). Stadler and Kruse (1995, p. 11) wrote, "Attractors are ordered states of high stability surrounded by instability." In physics, chemistry, and other areas, there are different types of attractors (fix-point, periodic, quasi-periodic, and chaotic attractors). In psychology they are known as the fix-point attractors of perception (Stadler, Richter, Pfaff, & Kruse, 1991) and periodic attractors of behavior (Stadler, Vogt, & Kruse, 1991; Vogt, Stadler, & Kruse, 1988). The stable states of perception are associated with "good Gestalts."

Fourier transformation appears as a no less powerful and effective cognitive platform in the psychology of perception than the synergetic concept of attractors. For example, even geometric visual illusions have been elegantly explained by a two-dimensional Fourier transformation followed by the truncation of high frequency components (Perlman, 1972). It also seems to be possible that the nature of some "strong" visual attractors could be explained by corresponding F-spectral effects.

The Nature of the "Strong 90°" Attractor – as a Loss of Low Fourier Frequencies

Stadler and Kruse (1995) described an example of the "strong" perceptual attractor, connected to the perception of an angle between two straight lines (e.g., it arises, in the perception of angle α=90°). This angle α=90° behaves as a perceptual "magnet." If it is slightly changed (α=±1°), there is always a systematic perceptual bias toward 90°.

It is not difficult to explain this "attractive 90°" phenomenon in the context of the Fourier paradigm (Fig. 1.6–1). We suppose that the 2 perpendicular perceptual lines are axes OX and OY in the Cartesian system of coordinates (X,Y). In the corresponding Cartesian system of frequency coordinates (fx,fy), a Fourier image of two perceptual perpendicular straight lines (X,Y) contains two similarly perpendicular straight lines (axes Ofx, axes Ofy). Small changes to ±α' between lines OX and OY will similarly change the angle between the lines in the Fourier image. For example, if we turn the axes OX it will turn its Fourier image – along the axes Ofy appearing as a segment between 2 points (fx=0, fymin) and (fx=0, fymax). These borders (fmin, fmax) are determined by our visual limitations – by limited optical aperture of the human eye. We are not only unable to perceive very small (fymax) wavelengths, but are also unable to perceive *very long* (fymin) waves. The minimal measurable wavelength could be approximately the linear size of retina.

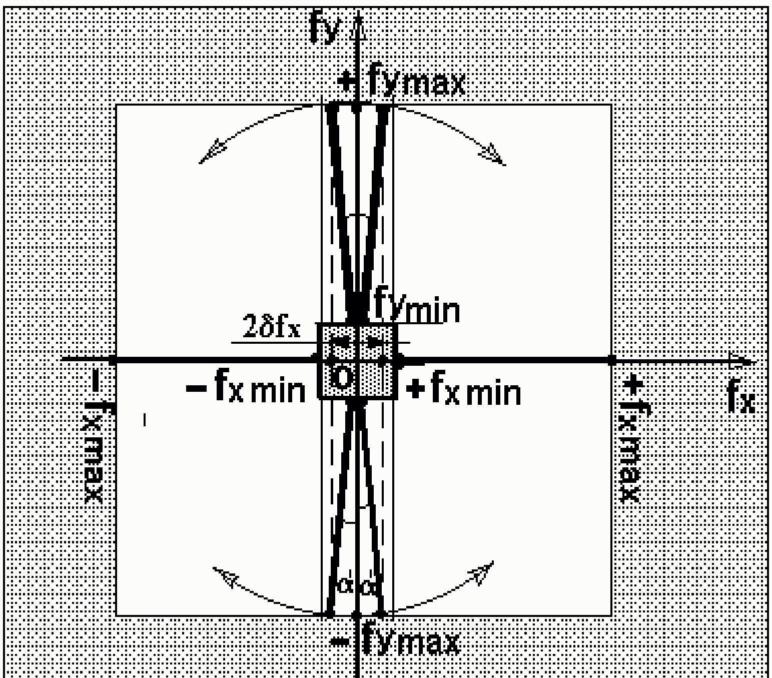


Fig. 1.7–1. This shows a Fourier plate (fx,fy) with Fourier transformations (thick lines) for two perpendicular straight lines in the perceptual visual field. This Figure also shows the small turn ±α' for the corresponding Fourier spectrum, where one line is slightly turned on the ±α'. We can see that for this turn 2δfx < 2fx min. and yet it is too small for its perception. Thus, a phenomenon of the "strong perceptual 90°-attractor" arises.

Very *small* turns of the OX on the angle $\alpha'=\pm1°$ will make the same turn ($\alpha'=\pm1°$) of the Fourier image – the segment between two points: ($f_x=f_y=0$) and point ($f_x=0$, $f_y=f_{y\ max.}$). In these cases only the highest frequency point ($f_x=0$, $f_{y\ max.}$) will be approximately displaced into a point ($f_x=\pm\delta f_x$, $f_{y\ max.}$). If this displacement $|\delta f_x| < f_{x\ min}$, we are not able to note both these turns, but will conclude, yet, that it is *the same* angle $\alpha=90°$.

The "90° attractor" is very interesting for the Fourier concept in visual perception, because, as shown in own analysis:

(a) The visual system could measure Fourier image deviations in the Cartesian system coordinates (f_x,f_y) for Fourier frequencies, and
(b) the visual system uses, for these, two stable, selected perpendicular projections (two orthogonal basic Fourier-vectors). Thus, it is possible to propose that the visual system has only a few such basic vectors in the Fourier cortical space.

An Analogy Between Visual and Motor Fourier Transformation

There could be a distinct *analogy between visual and motor systems*, because the motor behavior is based on the few muscular modules (MM), muscular units, and muscular primitives. These modules are also connected to the Cartesian system coordinates, as it was assumed earlier (Gribov, 1977a).

Note: The MM-model was later verified at the neuronal level of the spinal cord of a frog by Bizzi and Mussa-Ivaldi (2000). For motor system organizations, see chapter 6.5 of this study.

For example, the one-dimensional movement along axes OX could be described as a function of time x(t). This function x(t) could also be described as the Fourier transformation – F[x(t)]. By analogy with the visual system, a single limb movement could be described by the superposition of *two* independent and orthogonal MMs. It could be functions $\alpha(t)$, $\beta(t)$ for variable limb angles with corresponding two-dimensional Fourier spectrum $F(f_\alpha,f_\beta)$. For small amplitudes it is equal to the Cartesian space (x,y) with corresponding functions x(t) and y(t) of the limb movements. Thus, for movements of the single limb we have basically a *two-dimensional Fourier spectrum*, *the same as in the case of a two-dimensional retinal visual image I(x,y).* It means that formally the two-dimensional Fourier spectral space $F(f_x,f_y)$ for the limb movement could have a *similar neuronal column-like structure of neo-cortical representation!*

It could explain why the motor and visual cortexes also have universally similar column-like structures.

Different sensory modalities also have two-dimensional (surface-like) sensory spaces. This means that practically *all sensory modalities* (now, also including the very complicated motoric system) could have the *uniform two-dimensional cortical Fourier transformation*, *compatible with the uniform cortical column-like structure.*

Experimental proposals. It is interesting to test different directions (i.e. differently turned axes OX,OY) where the "attractor 90°" exists. It is possible that it is only connected to the horizontal and vertical axes OX, OY, and that, in other positions, the attractor disappears. It is also possible that all axes' positions will generate the same 90° attractor. In this case, the basic Fourier vectors, as proposed above, will be different for each axes' position.

The State of Relaxation as a Generator of Virtual "Associative Attractors"

In a relaxed state, external information tends to be blocked off. In this situation, many involuntary, different inside images arise. These images arise on the background of the internal and external sensory noise. Different attractors could be actualized by these noise-like statistical patterns, and by fluctuations in the inside perceptual space. This noise could virtually realize plenty of perceptual opportunities for the slightly awake perceptual interpreter, but these (possibly near the perceptual threshold) patterns have many ways of interpretation.

This noise could also play the role of an unpredictable, involuntary *source for association* between images that were never associated previously. It could play an important role by provoking new creative ideas. Important associations could be selected and filtered in the background of general mental activities (an artist will find some new aesthetic motivation, a physicist will select interesting ideas for physical models, etc.). It is not difficult to predict that these virtual associative attractors will be realized by the RH. (Some neuro-anatomical arguments supporting this proposal will be discussed later in this study).

1.8 THE NATURE OF UNIFORM, COLUMN-LIKE, CORTICAL ARCHITECTURE

(a) Cortical tissue has approximately 500,000 neurons for each square millimeter of cortical surface, or approximately 10 billion neurons! The cortex is *morphologically rather uniform* in two of its dimensions. Most of the sensory and motoric areas contain systematic, *two-dimensional maps* of the world they represent. The visual world is mapped onto the primary visual cortex that covers only approximately 15 cm^2 (Hubel & Wiesel, 1979).

(b) The visual world is divided between two primary neuronal half-spaces by the middle vertical line. The left visual field is projected onto the right cerebral cortex and the right visual field is projected onto the left cortex. The map of the body is similarly crossed, with the right side of the body projected onto the left hemisphere and the left side of the body projected onto the right hemisphere. Hubel and Wiesel (1979) stated that, "it is worth remarking that no one has the remotest idea why there should be this amazing tendency for nervous-system pathways to cross" (p. 84).

Remark. Why is the cortex morphologically "rather uniform" along all cortical areas? For example, the primary visual cortex has well investigated neuronal *column-like* regular architecture (Maffei & Fiorentini, 1977). Each column realizes approximately a local, two-dimensional integral Fourier transformation of corresponding local areas (perceptive fields) of the retina. We will name it as piecewise "Fourier-mapping" in the primary Fourier-cortex.

As mentioned above, the cortex morphological uniformity stresses the proposal that not only the visual cortex, but all the other cortex zones realize similar (by principle) Fourier transformation. Why the Fourier transformation? Because it allows radically condense quantities of neurons for neuronal pattern recognition (which provides some basic invariants, namely, in Fourier-transformation), and it allows easy manipulation with neuronal images in Fourier-space (reduce noise, increase contrast, investigate high [local] or low [global] spectral pattern parts [see earlier in this study]). But, in this case, it could not be the "primary Fourier-mapping" of primary visual fields or body mapping – in these cases it could be Fourier-projections of previous cortical fields onto corresponding secondary cortical zones, which could now be named hypothetically "secondary Fourier-projections." This projection, in different associative zones, could also realize "Fourier hologram-like," space distributed, neuronal memory, as predicted by Pribram (1975), at least for the associative cortical zones. This schema could easily explain the amazing morphological cortical uniformity in all cortical zones, and could contribute new and useful ideas to the methodology of research into these secondary neuronal zones.

1.9 THE NATURE OF THE LEFT/RIGHT CROSSING PATHWAY MORPHOLOGY

Hubel and Wiesel (1979) noted that there is no answer to why nervous pathways have basic left/right crossings. Indeed, the first part of the problem – common body symmetry for all vertebral organisms – is predictable for physical reasons, connected with gravitation (e.g., left/right symmetry for 4 legs, working against falling in the gravity field), and also good equality of moments of forces for these symmetrically placed manipulator-effectors. But, these very easily predictable left/right body brain sides do not cover the question of the basic crossing pathway structure in organisms. It seems that an explanation of this crossing could be connected to the creation of the optical *eye-lens*. It was a great and fascinating "sensory hardware revolution" in the early stages of the evolution of organisms.

Fish, mollusks, insects, and more evolutionary developed creatures have two left/right eyes that open an evolutionary possibility to build effective binocular vision. Binocular vision itself needs the cross-section of the left/right visual pathway. But, the most important cause for the total pathway crossing appears to be the straight adaptation to the evolutionary invention of the transparent optical eye lens. The optical lens, as a physical mediator between the visual world and the brain (retina), creates physical (optical) mechanisms of amazing – point-by-point – projections of the outside visual world sector points onto a two-dimensional neuronal retinal surface. But, the optical lens, arising evolutionarily in front of the retina, turns external visual scenes from the left to the right and backwards – right to the left side of the retina. It means that the *optical lens inversion* could provide corresponding cross-like morphological adaptation of all left/right symmetrical nervous systems to this physical lens effect in the early stages of evolutionary eye lens "implantation." In this case, corresponding cortical sensory-motor areas (for the right hand) must also be evolutionarily shifted to the left (planting in the LH) and reversed for the left hand (planting in the RH).

Decisive tests could be carried out with a view to comparing the anatomy of pre-lens and post-lens eye creatures. If pre-lens creatures have nothing in common with the lens creatures "left body/right brain" and "right body/left brain" partways cross-section, it could mean that our hypothesis is correct, if the crossing is the same, it will mean that this crossing has another nature (e.g. better left/right-sided defense security).

1.10 THE NEURONAL, ANATOMICAL – HISTOLOGICAL HEMISPHERICAL SPECIFIC

Visual perception appears to be the most important and instructive type of cortical neuronal processing, obviously involving parallel neuronal nets.

The neuronal, anatomical, and histological hemispherical specific connected to right-handers (Goldberg & Costa, 1981):

(a) *primary motoric and sensory zones* better developed in the LH
(b) *associative zones* are better presented in the RH
(c) in the LH *short-axonal fibers inside local areas* predominate
(d) in the RH *long axonal fibers between different local areas* predominate.

The visual form generalization /adult right-handers (Franco & Sperry, 1977):

(a) in the LH, *only geometrically similar figures are generalized*
(b) in the RH, *not only similar figures are generalized*, but also figures differentiated by *more complicated transformations, including topological ones.*

The visual form, placement, orientation, and size description/adult right-handers (Nevskaja & Leushina, 1990):

The LH of adults automatically realizes the *invariant form description*, and *independently* of the form description it describes the other characters (placement, etc.) in the perceptive visual field, but as it is shown in Farber and Beteleva (1985), LH-invariance description arises only between the ages of 13–14 years and correlates with maturation of the frontal-associative cortical zones:

(a) The RH does not divide (form, placement, orientation, size) characters in the beginning of a description, but *after some training* the invariant form

description can be achieved on the basis of initial (variable) whole descriptions.
(b) The LH has *different channels* for different character descriptions.
(c) Approximately 20% of right-handers *have opposite hemispherical specialization.*

The RH, easier than the LH, elaborates *associations between images* of different objects, differentiated by the exterior form or by the structure (Levy & Trevarthen, 1976).

Recognition of visual images. Visual and all other basic cortical functions are based on the ability to compare new sensory images with images stored in memory. The two hemispheres use different types of images for comparison and categorization. Nevskaja and Leushina (1990) show that:

(a) The RH stores the *characteristics of complete images* – comparison standards, and retains individual structural information on them.
(b) The LH stores only *separating characters* between these standards (without their individual structural information). The LH contains metrical space of visual images organized as their "alphabet" *equally* in different people.

The LH-discrimination method of recognition is an analog of the so-called *categorical perception* in psychology. In this case, the discernibility between two categories (two images) is changed spasmodically, but only on the border between them, although within the same category where is no discernibility (Macmillan, Kaplan, & Creelman, 1977).

Important Invariants in the Fourier-transformation

Fourier space frequencies and LH/RH perception differences. Each two-dimensional space pattern I(x,y) has a formally, mathematically determined Fourier-image $F(f_x,f_y)$, containing a corresponding two-dimensional distributions of sinusoidal space frequencies (f_x,f_y) with different amplitudes and phases. For example, thin lens makes this F-transformation: Fourier-image $F(f_x,f_y)$ arises in the focal plate of the lens, focusing beams, connected with the input image I(x,y). It is a very important operation for image recognition, while any parallel shifts of the input image I(x,y) in I(x+a,y+b) will not shift the position of Fourier-image $F(f_x,f_y)$. This position is an *invariant to this shifting*. The neuronal analog of this Fourier-operation could significantly simplify the recognition process *for moving (shifting) perceptual images*: In reality, each image, with a continuum of it's possible shifting positions I(x+a,y+b), requires, for recognition, *only one space-fixed frequency filter* $F(f_x,f_y)$.

A linear scale transformation of the input image I(x,y) will give $I_s=I(ax,ay)$ and the corresponding Fourier-image will be $F(f_x/a,f_y/a)$. If we change $F(f_x,f_y)$ into $F_s=F[\ln(f_x),\ln(f_y)]$, using a logarithmic scale, instead of the linear scale (f_x,f_y), it will give an F_s-Fourier invariant for the same input image with *different similar sizes*: $\ln(f_x/a)=\ln(1/a)+\ln(f_x)$, $\ln(f_y/a)=\ln(1/a)+\ln(f_y)$ and $F_s=F[k+\ln(f_x), k+\ln(f_y)]$, $[k=\ln(1/a)]$, and it is now only, as mentioned above, *shifting* $k_{x,y}=\ln(1/a)$. If we make a second Fourier operation with an F_s image, looking like $\mathbf{F}\{F_s\}=\mathbf{F}\{F[\ln(f_x),\ln(f_y)]\}$, we obtain $F\{F_s\}$-space with a double invariant (of the shift and the scale transformation).

The rotation transformation invariant could be reached if we change the Cartesian system coordinates (f_x,f_y) in the polar one, where instead of (f_x,f_y) in the same Fourier space polar coordinates (φ,ρ) will be used, therefore, $\rho=\sqrt{(f_x^2+f_y^2)}$. In the new system coordinates, the initial *input image rotation* $\Delta\varphi$ will look like the *common parallel shifting* $\Delta\varphi$. If we additionally exchange $\rho \to \ln\rho$, we will transform the above mentioned scale-size variation $(\varphi,a\rho)$ into the shift in this new Fourier-space. The second Fourier transformation $F=\mathbf{F}\{F_s\}=\mathbf{F}\{F[(\varphi,\ln\rho)]\}$ will eliminate this shift and will give the F-filter *invariant to the rotation, scale, and shift* of initial input image I(x,y). Thus, it is possible to build basic recognition invariances in the neuronal net with corresponding neuronal Fourier-architectures, as mentioned above.

Particular verification (cortical cellular data). A comparison of these properties, with corresponding experimental data from Maffei and Fiorentini, (1977) shows that two micro-electrode directions (parallel and perpendicular to the cortex surface) in the 17 primary visual fields of cats could correspond to the *(rotation invariant)* polar system coordinate (φ,ρ) or $(\varphi,\ln\rho)$ in the cortical Fourier space. Authors have examined the functional architecture of this cortical area with respect to the spatial frequency of the visual stimulus (sinusoidal gratings) at which each neuron is most sensitive. The neurons response is as follows:

(a) In penetrations *perpendicular to the surface of the cortex* ("vertical" direction along cylindrical columns) the cells of the various layers, or even of the same layer, *have the same preferred orientation, but different spatial frequencies,* and it looks exactly like the coordinate $\rho=\sqrt{(f_x^2+f_y^2)}$;

(b) in penetrations *parallel to the surface of the cortex* the cells of the same layer, or sub-layer, present a *variety of preferred orientations*, but maintain *the same preferred spatial frequency* and visual acuity over a long micro-electrode track distance.

1.11 "SPLIT-BRAIN" STUDIES

Nineteenth century scientists named the *LH* the *dominant or major* hemisphere. It was this, according to the traditional European verbal paradigm in which, predominantly, speech and language are closely linked to thinking, reasoning, and the higher mental functions that set human beings apart from other creatures. The right-brain functions, were named as minor, and considered not so important for the human intellect. Neuroscientific studies, research into the psychology of thinking, and theories of education in the past usually focused on the left-brain function. The fundamental significance of the right-brain function was not known until recently.

The most important data were found in the 1960s when R. Sperry (later a Nobel laureate) and his students, M. Gazzaniga and J. Levy, began their historic split-brain experiments. They were able to test, separately, the thinking abilities of the two surgically separated halves of the human brain. They found that the left-brain tends "to think" in *words* and the right brain tends "to think" directly in sensory *images*.

Neuroanatomic studies showed that two hemispheres are connected by commissures containing over 200 million nerve fibers. Sperry discovered that they connect two different psychological worlds. He noted later that "brains can no longer be assumed to be qualitatively similar at birth, with equal potentiality for becoming a Beethoven or a Shakespeare, an Edison or a Michelangelo, etc. Different mental disciplines employ qualitatively different forms of cognitive processing that require different patterns of neural circuitry, the basic cerebral requirement for which are largely varied. Even the potentialities of the two hemispheres of the same brain, with respect to verbal and spatial functions, are already at birth found to be qualitatively different" (Sperry, 1985).

Data from Zenkov (1978) show that creatively active professionals (mathematicians, poets and chess-players) lost their creative abilities after distortions in their RH, but, at the same time, they did not lose formal professional skills. Data from R. Sperry (1964) on the "split-brain" discovered the *psychophysiological* base of the fundamental dualism of our consciousness. Gazzaniga (1970) and Gazzaniga and LeDoux (1978) show, for example, that just the right hand (i.e., LH) loses the *ability to draw* even very simple spatial objects (a cube, a house in oxonometry) when the brain has been split. Pictures disintegrated into disconnected fragments (although they are produced very exactly). However, drawing pictures using the left hand (i.e., RH) are not even precise, although they preserve the integrity of the special structure of drawing objects. At the same time, *writing* is normal with the right hand (i.e., LH), but impossible with the left hand (i.e., RH).

Such simple, but very important examples makes it possible to generalize about the fundamental differences between the two hemispheres of the human brain: Isolated elements of integrative structures of the human activity are exactly built from programs from the LH; but their plastic integration – connecting them into adequate "right now" working configurations – is the basic function of the RH (Gribov, 1988, 1992). Figuratively speaking, the "left" function is reminiscent of collecting *"abstract, unified"* fragments of houses: producing and collecting different standard panels and bricks (the material for assembly). But, the function of the architect or builder, who assembles these uniform and safety blocks into *"concrete"* houses, is performed by the RH which synthesizes this constructive activity (on the basis of the existing sensory information about the world in the concrete, actual space). Moreover, it can create, as can a small child, new types of "blocks," but their polishing is a function of the other hemisphere. Such points of view help to understand the similarity of creative processes in different areas of human activity (from simple orientation in space, to science and art).

The discovery and exploration of our functional bipolarity will have much more impact on the future of the human being, than many other neuro-psychological discoveries. It is connected directly with the duality of human thinking and cognition mechanisms; will lead to a deeper understanding of the human creative nature, and will stimulate positive social conditions, fostering creativity. In the modern civilization it is not so difficult to note different cultural intentions, ignoring the duality of our consciousness and suppressing human creative potential. Such tendencies are, for example: (1) the almost total *standardization* of human life and the surroundings; (2) the *reproductive* character of *education*; (3) increasingly *robot-like work*; (4) upbringing, a purely *consumption-oriented* mass artistic *culture* that expelled traditional *improvisational* folk art; (5) the growing of abstract-sign informational flow that increases the separation between people from the direct emotional contact with the world and with each other. This seems to be a paradoxical characteristic, above all, of industrial and contemporary postindustrial European civilizations, now reaching the era of the *information* revolution.

It is clear that not only creative nature, but also care of the emotional *humanistic* nature is viable only when the sensitive, non-logical sides of human beings, are active. This is connected to the development of the "right brain" creative culture and specific sides of the emotional culture (i.e., love, feeling, faith, empathy). The total weakening of this general basis could lead to the degradation of the creative and humanistic roots of human beings and human society and could threaten these with catastrophical consequences.

2. AN ANALYSIS OF THE BASIC CONCEPTS OF BRAIN ASYMMETRY

Summary

The analysis below shows that the traditional BFA-conceptual dichotomy *"verbal versus nonverbal process"* is transformed into the BFA-conceptual dichotomy as the *"stereotypic versus unique process"*. On the one hand, there are *"stereotype units"* /left hemisphere (LH)/ with their discrete and compact alphabet, and on the other hand, there are *"unique processes"* /right hemisphere (RH)/, having a large alphabet of units, or even a countless continuum of their possible configurations (e.g., in the case of motoric activity). In the case of visual perception it is a *compact alphabet of roughly distinguishing filters (LH) versus a much larger alphabet of subtly recognizing filters (RH).* This contradiction appears to be more adequate, constructive, and with a unified point of view, connected to the understanding of the nature of BFA. In the context of the proposed functional dichotomy it is easy to solve *contradictions* between the classical BFA theory and the experimental data discussed below. On the surface, these data appear as very serious contrary arguments to the classical theory, but it will be shown that corrected Conception-I allows us to *improve and rehabilitate classical theoretical positions*, established by such pioneers as R. Sperry, Gazzaniga, and others.

Creative processes, functionally, *are not balanced*. They are connected with some kind of *functional "status quo" breaking*. It could be more correct to consider creativity in the theoretical frames of the *"non-equilibrium functional dynamics."* The psychology of creativity also stresses problems on the border between the LH and the RH functional competence in persons with well-separated functions, and also in people with different types of RH/LH functional mixing.

2.1 CONCEPTION-I: QUALITATIVELY DIFFERENT INFORMATION

Vadim Rotenberg (1993) writes that BFA is one of the most basic problems of modern psychology, and despite the great number of publications, some theoretical aspects of this problem remain unresolved. It is possible to find, in the literature, many different explanations of BFA. The most famous and well enough verified classical (pre-Fourier) psychological concept will be named, here, the "Conception-I." This could be, in short, described as *"qualitatively different information"* or *"a difference in processed information"* in different hemispheres of the human brain.

Conformation Data to the Conception-I

According to the most impressive results of the first investigations performed by Sperry, Gazzaniga, and Bogen (1969) and Gazzaniga (1970) on split-brain patients, it was suggested that the RH and the LH process qualitatively different information.

The *function of the LH* is connected to verbal material, signs, symbols, and writing stereotypes, all of which provide verbal communication.

The *function of the RH* is connected to nonverbal material, namely:

- perception of nonverbal images;
- melodies, intonations;
- space and body position orientation;
- visual field dependence;
- identification of complicated patterns (such as human faces);
- performance of kinesthetic functions etc.

Clinical Evidence of the Conception-I

The data of the functional differences obtained by the functional analysis of split-brain patients, correspond to the results of clinical observations.

Damages to the LH lead to speech disorders. However, the creative artistic abilities remain unaffected and can even be improved. In some cases, the speech disorder can be combined with the ability to draw.

Damages to the RH lead to the following changes:

- body scheme distortion;
- spatial disorientation;
- distortion of musical reception;
- decline in creative abilities in a wide range of fields including painting, poetry, music, chess playing, and mathematics (Zenkov, 1978).

Visual Field Activation Evidence

When presented with space-image perception tasks, subjects initially turn their eyes to the left, which indicates the activation of the RH.

In the case of simple arithmetical and phrase construction tasks, the first involuntary eye movement is turned to the right, which is a sign of the LH activity. (Kinsbourne, 1972).

Analysis of Data Contradicting Conception-I

All the above-presented data show that the functional differences between the hemispheres arise as differently processed information. However, other authors refute this point of view as being too simplified.

Contradiction 1 – LH Processing of a Simple Verbal Construction

In split-brain subjects, the right hemisphere is able to process verbal constructions if they are not too complicated (Ellis, Young, & Andersen, 1988).

My Analysis of Contradiction 1

Split-brain studies contain a very small number of brain patients. It could be possible, for example, that:

(a) Some of these subjects simply are not total right-handers, and do not have such a strict isolation of the verbal functional representation in the LH,

(b) early learning of verbal movement-stereotypes (such as speech and later writing) in the human ontogenesis requires involvement of the RH, but mostly at the beginning, when such simple verbal constructions initially develop.

Contradiction 2 – RH Sense of Humor and Processing of Metaphors?

It has been demonstrated that preverbal interpretation is a function of the RH (Benton, 1968), as is having a sense of humor (Wapner, Hamby, & Gardner, 1981), and the processing of metaphors (Miller, 1999; Winner & Gardner, 1977).

My Analysis of Contradiction 2

This preverbal interpretation is not contradictory to the "Conception-I" of BFA if we bear in mind that having a sense of humor is connected to an evaluation of the *nonformal,* verbal context. Moreover, even normal sentence production could involve nonverbal meanings and grammatical formalisms. Miller (1999) wrote, "There is a variety of evidence that 'the meaning of a sentence' is represented in the right hemisphere. This comes from the effect of unilateral brain damage on a subject's appreciation of things such as a metaphor, humor, or indirect inferences in sentences. Such meanings, accumulated over the span of a sentence, appear to be a form of Gestalt, which, like visiospatial Gestalts, has a predominant right hemisphere representation. Such Gestalts has complex 'simultaneous' structures, but no temporal structure" (p. 298). The temporal structuring of linguistic elements (such as word endings, functional words, etc.) is more a function of the LH. Miller added that really fluent speech is achieved by "a synergy" of these two aspects of sentence planning, the RH providing "the semantic framework for the sentence (a slow succession of Gestalt-like ideas), while the LH coordinates the finer structure of the actual words in the sentence" (p. 298). He hypothesized that the synergy between these RH/LH elements is realized across corpus callosal interhemispheric communication.

Verbal context is connected to the nonverbal information background, especially for the nonformal, verbal material such as humor and metaphors. For example, metaphors can be created usually from the straight image – image associations, produced by the RH. An analogy could be drawn to holographic association effects: enough small parts of any image can stress this full image in memory. This associative mechanism could be named the RH *mechanism for spatial structural associations.* It appears to be the rich source of intuitive thinking. It can provide, for example, poetic, polymodal, visual, or some other sensorial, unlimited quantity of structural associations that is outside the normal left-hemispheric *"image-function"* or *"image-category"* classification. Such a process easily destroys formal logical order and, *at the same time*, can stress some outstanding aesthetic (art) feelings and a new cognitive (science) experience.

Contradiction 3 – LH/RH Verbal Activity in EEG

It was found that EEG activity of the RH predominates during the reading of stories, while EEG activity of the LH predominates during the reading of science textbooks. However, both involve verbal information (Ornstein, Herron, Johnstone, & Swencionics, 1979).

My Analysis of Contradiction 3

As mentioned previously, the *nonformal,* verbal context is "a priori" directly, or indirectly, connected to the rich nonverbal information and addresses the RH. Verbal neuronal structures, genetically and onto-genetically (culturally), are "a priori" secondary, compared to nonverbal, neuronal structures.

The reading of poetical stories, artistically and deeply connected to the rich nonverbal *"real iconic world,"* requires rich *nonverbal context reconstruction* - its effective dynamic informational modeling being made by the RH (i.e., connected to the RH EEG activity). It also requires RH *emotional involvement*, far more than the scientific, analytic texts, which tend to be more logically organized.

On the other hand, typical scientific text attempts to be some kind of mathematical theorem dealing with the *"artificial schematic world,"* with well-established artificial objects of manipulation, strict operators, and rules of operation. They attempt to be determined, convertible, "non-dissipate" mental machines (easily and economically transmitted from one person to the other without *loss of information*). In the artificial context of these ideal operations, with the ideal objects, it is possible to produce some kind of new information – for example, to predict the behavior of such objects.

In this context, EEG activity of the LH (dealing mostly with such ideal objects and ideal operations) could predominate during the reading of science textbooks.

Contradiction 4 – LH-Dreams

Split-brain subjects are periodically able to report their dreams (verbal LH reports), although the dreams are usually a visual experience *connected to the RH* where, normally, one is not able to make these reports (Hoppe, 1977).

My Analysis of Contradiction 4

According to the corrected Conception-I, the LH can also operate with images in memory, but it loses the richness of "individual faces" in the right brain image. LH images are ordered by functional characters in memory, but RH images are ordered by the straight similarity of images (LH functional, RH-image structure similarity), as it was shown in bisected brain experiments (Gazzaniga, 1970). The possible LH *dreams* could look like an abstract, which is rigid, poor, and emotionally empty, and may be absurd from the *point of view* of the RH dreams (in the person with a bisected brain and, hence, separated hemispheric functions).

Contradiction 5a – LH Facial Recognition

The LH, under certain conditions, may be more accurate at identifying faces if these contain some definite outstanding features, such as a very long nose, etc. (Parking & Williamson, 1987).

My Analysis of Contradiction 5a

The LH has absolutely the same sensorial "quasicontinual interface" as the RH. Regardless of the nature of the image, image recognition in the LH *must* "categorically" *ignore* some concrete small nuances, *small differences, and fine distinctions* between these images. However, this information ignorance blocks image recognition in the case of human faces (this is a well-known fact from the bisected brain experiments). The well-known LH *function of unification and classification* of images is not possible without this ignorance. But, this *rough* filtering can only be more sensitive where there are *very large differences between the faces* such as a very long, or very short nose. On the other hand, the RH is much more sensitive to fine distinctions (e.g., to the different expression of emotions in the human face). At the same time, the RH can be *relatively* less sensitive to very large differences, compared to the LH, as shown by the data of Parking and Williamson (1987).

Contradiction 5b – Facial Expression of Emotions

Many studies show a left visual field/right hemispheric advantage for processing facial expressions (e.g., Ley & Bryden, 1979; Wedding & Cyrus, 1986), but these results were linked to negative expressions only (Moretti, Charlton, & Taylor, 1996), positive expressions only (Duda & Brown, 1984), or no expressions at all (Stalans & Wedding, 1985). The special studies have implicated the amygdala in the analysis of negative, primarily fearful, facial expression. Phillips et al. (1997) compared activation to two negative emotions – fear and disgust – using mildly happy faces as controls. They found that *fearful faces* evoked activity in the LH left amygdala and LH left insula. *Disgust* did not activate the amygdala; rather, the most prominent activation was found in the RH right anterior insula, where the level of activation increased with the intensity of the expression of disgust.

Studies of focal brain damage showed an overall RH role in processing facial expression (Adolphs, Damasio, Teanei, & Damasio, 1996; Bowers, Bauer, Coslett, & Heilman, 1985). For example, Adolphs et al.(1996) studied the neural systems involved in recognizing facial emotional expressions in 37 subjects with focal brain lesions to the LH or the RH. Subjects with LH lesions showed no impairment in processing facial expression. Subjects with RH lesions were less able to recognize certain *negative emotions*, such as the recognition of fear, but not the recognition of *happy expressions*. Davidson (1992) proposed that *negative emotions* are predominantly processed within the RH while positive emotions are processed by the LH.

My Analysis of Contradiction 5b

The *fearful* faces could be recognized by a relatively rough filter because they have very well-selected clearly recognizable features (e.g. elevated eyebrows, open mouth, widely opened eyes, etc.) and, thus, this emotion could be processed more easily by the simple rough filters – the LH. Facial expressions of *happiness* also have similar, very well selected clearly recognizable features (e.g. a wide smile with an extremely long lip line, narrow eyes profile). The expression of *disgust* has no such easily recognizable rough features, these being relatively thin and variable, which could explain their RH location in recognition.

This means that the theory of Davidson (1992), which strictly connects the *positive* emotions to the LH, and *negative* emotions to the RH, is not correct.

We conclude, on the basis of the above presented data that independently of a (+) or (–) sign of facial emotion, the side of its RH/LH lateralization depends only on the bright-LH or the thin-RH facial expression features relevant to it. For example, the moderate fear emotions are connected to LH recognition, but, at the same time, the recognition of the only vaguely visible emotion "*fear"* could be connected to the RH.

Contradiction 6 – LH Presentation of Deaf and Dumb Languages

Deaf and dumb language signs are nonverbal, but they are damaged by LH strokes (Bellugi, Poizner, & Klima, 1983).

My Analysis of Contradiction 6

The more complete Conception-I corresponds to a person with well developed hemispheric functional asymmetry, that is, it relates to the "ideal right-handed person." According to this conception, the LH is *associated with* the library of unified, and differentiated classes of *visual images and their perceptive filters*. The LH also has a very large library of unified, "elementary" *movement* *stereotypes*, as in the writing of letters and the production of speech phonemes, etc. (Gribov, 1980, 1988, 1992). It corresponds to the experiments of Gazzaniga (1978) and to my own data comparing left-handed and right-handed portraits (Gribov, 1980). Deaf and dumb signing is a compact system of stable *functional quasi-verbal stereotypes* with corresponding grammatical forms of language. In the context of the more complete Conception-I, these stereotypes must be localized in the *functionally adequate* LH, where they will be damaged by strokes in the LH, as the above-mentioned authors have shown.

Both the usual writing signs and deaf and dumb sign language are no more than a kind of functionally similar *hand-made stereotypical units* – typical elementary bricks of the verbal informational system. If they have a more or less compact alphabet of basic movement stereotypes (e.g., alphabetic letters) there is no principle difference between them and they must be located in the LH. This analysis is similar for other manipulative (manual) areas, and partially also for visual art (chap. 7). There can be a broad spectrum of images even in visual art – from the images that are full of life and individuality, on the one hand, to the cold combination of flat stamps on the other, produced only by mechanical, formal rules. The latter is usually connected to an inadequately strong delegation of competence in art to the LH.

It is also possible that the BFA is not only the static, already established functional interhemispheric distribution, but is the *process of an ongoing functional evolution,* the *functional interhemispheric separation in ontogenesis.* Thus, the more complete Conception-I may involve corresponding dynamic aspects, for example:

(a) The ontogenetic process of the plastic functional dynamic with different stages of functional development and functional hemispheric separation instead of the rigid functional dichotomy in the BFA;
(b) a permanent *functional separation* and *functional shifting process* – the *permanent crystallizing of new LH stereotypes* existing previously only as statistically repetitive virtual movements, and as original variable elements in the RH. It could explain, for example, differences between amateurish-emotional RH musical perception and professional, more analytical perception of music, connected with the functional shifting to the LH. This theoretical point of view is important, especially for the *correspondent theory of creativity*. In reality, creative processes change and transform the LH systems of stereotyping, and it would be more correct to consider them in the theoretical context of "*non-equilibrium functional dynamics.*"

Note: For example, it is useful to compare the very well known Chinese hieroglyphic writing with the European alphabetical one. Historically, Chinese hieroglyphics are very old, archaic signs of writing stereotypes. They have a very large, but limited number of hieroglyphs – approximately 1,000–3,000 stable signs - far more than the number of letters in most alphabetic languages – (approximately 20–30 letters). Alphabetic letters were developed later than hieroglyphs. At first, the necessary (20–30) speech phonemes were created in conjunction with early human speech. Much later, phonemes were associated with a few visual signs – writing letters. They are located mostly in the LH (in right-handers). Hieroglyphs were reduced, step-by-step, from the early hieroglyphs – pictograms – and the pictograms were reduced from quasi-iconic images. An enormous variety of iconic images, however, are located in the RH (in most right-handers). It is a very interesting and important fact that an impressive battery of China's hieroglyphs is located in the RH (in contrast, European letters are located in the LH). Such a large family of quite complicated sign-units requires a large neuronal space. These unusually located types of verbal signing (archaic only for Europeans) were named the *sign-mediators between concrete and abstract*, between verbal and nonverbal hemispheres (Gribov, 1987, 1988, 1992).

In the context of the above proposed and improved Conception-I of the BFA, specific problems still remain, namely:

(a) Where is the border between the LH and RH functional competence and functional dominance, for example, (a) in the case of people with well-separated functions, and (b) in the case of people with different types of functional mixing?
(b) Is the functional hemispheric dominance congruous or incongruous with the actual *functional competence?*
(c) How is the nature of human creativity connected to the presented concept of BFA?

2.2 CONCEPTION-II: TEMPORAL DIFFERENCES IN THE INFORMATION PROCESS

Another conception of the BFA suggests *temporal differences in the organization of information* in the RH and LH (Gordon, 1978). According to this conception, the basic function of the LH is the consecutive analysis of information, whether verbal or nonverbal, while the function of the RH is the simultaneous processing of many elements of information.

Contradiction 1 – The LH Ability to Process Data Simultaneously

Polich (1982) showed that the LH is also able to grasp series of data simultaneously and as rapidly as the RH, but only if the differences between the elements of the series are obvious and definite. If the differences are vague, indefinite and dependent on the interrelationship between elements, the RH has the advantage, however.

My Analysis of Conception-II

Polich's findings (1982) could be explained, similarly, as in the above presented contradiction data from Parking and Williamson (1987). Both hemispheres have the same basic principle of neuronal organization – "quasicontinual, parallel neuronal interfaces" prepared for the simultaneous perception in both hemispheres (Gribov, 1981, Nevskaja & Leushina, 1990). This means that each psychologically elementary visual unit (or even meaningful complexes of these units) could have the shortest single stage processing in each hemisphere. But, as proposed above, two opposite visual functional systems have different types of filters for the recognition of visual images. From this point of view, it is clear that the LH or the RH could simultaneously recognize different visual elements only if their filters are able to distinguish between them. Thus, contradictory data from Polich become trivial: (a) both hemispheres will be able to grasp data, simultaneously, in the case of a very good distinguishing ability between the presented elements, but the LH will have the preference; (b) even if these differences become indefinite and vague, and more sensitive to small differences, the RH visual filters will be able to accomplish this simultaneously.

This explanation also shows that the Conception-II has a visible consequence from the above-proposed reformulated Conception-I.

3. THE PSYCHOPHYSIOLOGICAL BASIS OF CREATIVE PREDISPOSITION

Summary

The dialectic of the BFA phenomena is controversial since typical BFA shows a *functional separation* between hemispheres and a strong LH – "interpreter" dominance (Gazzaniga, 1998), while the creative predisposition shows a relatively backward effect – *relative BFA breaking* and more tolerance between the RH and the LH "interpreters". Non-right-handedness is one of the common markers of this.

Mixed-handed (ambidextrous) males have a *56% larger* corpus callosum size in parieto-temporal cortical regions, connected to the representation of *linguistic, spatial, and musical skills.*

Some data support the *hormonal hypothesis* that prenatal male hormone testosterone is responsible for this effect by enhancing the *development of the nondominant RH hemisphere* (that could increase the incidence of left-handedness). Supportive studies show a higher percentage of left-handers among artists, architects, chess masters, mathematicians, science students, and creative schoolchildren.

Tapping, dichotic listening, and other tasks in the mathematically gifted precocious group showed bilateral involvement in tests, with a significantly stronger degree of RH involvement during basic information processing, with superior coordination of cortical resources between the hemispheres during intellectual tasks.

While *precocious talent* is not necessarily *creative talent*, we propose that the hormonal hypothesis could explain the basis of creative predisposition, especially in the case of *outstandingly creative persons* (see our Chicago data in chap. 9).

3.1 HEMISPHERIC DOMINANCE

The Interrelation Principle

Different authors such as Hellige and Wong (1983), Hines, Clista, and Bures (1985), and Kinsbourne (1970), proposed that hemispheres have reciprocal relationships. If one hemisphere is actively involved in processing information, it leads to the restraining of the other hemisphere. The more active hemisphere becomes more sensitive to outside information and the other hemisphere becomes, at the same time, less sensitive to the same information. This has been evidenced in patients with aphasia. In this case, the right hemisphere totally loses verbal ability. From the position of the reciprocal hypothesis, this loss could be explained as a prolongation of a strong restraint of the RH by the LH. That is, the non-damaged rest of verbal neuronal fields of the LH prolongs the restriction of relatively small, but existing verbal abilities of the RH across commissures.

Cerebral Dominance and the Interpreter

The commissurotomy studies discovered not only the hemispheric specialization, but also the unusual persistence, namely of the LH, in experience that it did not generate, and about which it was not informed (Gazzaniga & Hillyard, 1971; Gazzaniga, LeDoux, & Wilson, 1977). Later, Gazzaniga (1985) found that the LH showed an automatic assumption of responsibility for the complete action it had just observed.

Note: This surprising (and very important for the psychology of creativity) propensity of the LH to provide a rationale for disparate behavior has led Gazzaniga to name this the "Interpreter."

Gazzaniga proposes that such an Interpreter, which manages and interprets the work of the brain's multiple executive systems, is the LH's interpreter module, and *normally* it is informed and constrained by the RH (Gazzaniga, 1998).

Comment 1

The standard interpretation schemes, stable basic maps, and constructs of interpretations are necessary in trivial, ordinary, repetitive cases. At the same time, in many right-handed people, or in other words, in people with a strong LH-interpreter dominance, this (as we see) blind interpreting often blocks the necessary correction, plasticity, transformation, and the development of these basic Interpreter-maps in the LH. In the case of Sacharov (see below), we find the coexistence of the two different cognitive systems, each having relatively independent verbally equipped LH and RH interpreter modules. The coexistence of these relatively well-developed RH/LH interpreters could radically increase the plasticity of both hemispheres. It could be compared to a situation where two intellectually comparable persons interpret same event. The effect could be compared to a conversation between two people in that the RH-Interpreter could effectively correct the opinion of the LH Interpreter (and vice versa), and thereby generating compatible verbal interpretations. Of course, the information underlying the cognitive processes, for these two interpreter modules, could be very different.

Split-brain patients with some pre-surgery hemispheric functional mixings are interesting for our study of the highest creative abilities; connected with two left/right verbally equipped Interpreters.

In the first experiments, Gazzaniga and Sperry (1967) tested two unusual split-brain patients L.B. and N.G. who showed a "bicameral" distribution of language competence (not only in their LHs, but also with some written and auditory vocabulary, and some level of abstraction, generalization, and mental association in their RHs). In this case, the isolated LH (and RH) could continue to carry out their basic language functions, that is, speaking, reading, and writing normally. Only special experiments highlighted the effect of the split-brain, as their normal daily lives were not disrupted, and they did not report changes in their conscious perception of the world. At the same time, most of the split-brain patients (with the more one-sided presentation of functions and their dramatic disconnection) had considerable trouble carrying out ordinary behavioral tasks.

Split-brain studies show that the RH is not only conscious in the sense of awareness, but is capable of formulating some basic hypotheses regarding the relation of its actions to the world (Gazzaniga, 1998). The data, connected with the split-brain patient P.S. (a 15-year old boy) showed that he had unusually well developed *speech in the RH*, although he was a *right-hander*. He could easily confabulate about his left-hand choices when presented with bilateral pictural displays.

Comment 2

The largest study from Rasmussen and Milner (1977) showed that over 95% of all right-handers, without any history of early brain damage, had speech and language controlled by the LH; the remainder had speech controlled by the RH.

This 5% group of right-handers is relatively small and contains approximately 5% of all the right-handed population. This group could also be interesting when forming hypotheses about the extremely creative. They have two well-developed RH-interpreters, and many of these people also have LH speech abilities. This part of the population could also contain an unusually high percentage of highly creative persons (under condition, the RH speech-switching is not provoked by LH structural damage). Indeed, only few of the extremely creative persons in our Chicago-group study (see below) showed prevalent right-handed gestures. These people could gesture as right-handers with prevalent LH motoric control, but, at the same time, they could have a prevalent or comparative (to the LH) speech center in the RH.

3.2 HANDEDNESS AND BRAIN FUNCTIONAL ORGANIZATION

Anthropological Data about Handedness

Anthropological data (Ananjev, 1960; Toth, 1985) show that even more than a million years ago homo sapiens had almost the same handedness distribution as today! Scientists discovered and analyzed many hand-made stone instruments from the Stone age. It was possible to distinguish stone instruments produced by a right hand or by a left hand. These data show that handedness and, thus, the BFA of human beings has a very long phylogenetic prehistory. At least it is much longer than the history of drawing and writing. This historical picture gives clear evidence that the ability to write is not the first historical cause of the human BFA, and it is deeply connected with the sensomotoric manipulative processes in the phylogenesis and ontogenesis of the human being. Thus, writing is only the final result of this very slow, manipulative evolution connected with the production of different tools.

Handedness and Size of Corpus Callosum

Witelson (1985, 1986) showed in her famous study that different handedness corresponds to the size of the corpus callosum. The posterior part of the body, or trunk of the callosum (the isthmus or "parieto-temporal" callosal region) showed a particularly marked *difference in size between consistent right-handers and the ambidextrous, regardless of right- or left-handed writing.* Later, she studied subregions of the callosum with better statistics and found also statistically significant sex differences in the size of the callosum in some regions (Witelson, 1987). She found two sex differences, namely:

(1) Hand preference was found to be a factor in the absolute size of the isthmus *in males only. The Isthmus area in males was 56% larger in the mixed-handers!*
(2) Consistently right-handed females had a larger absolute isthmus region than consistently right-handed males; females did not have a larger area in any other callosal region.

Accordingly to Witelson's neuropsychological definition, the isthmus region specifically connects the parieto-temporal cortical areas of the two hemispheres. These regions are connected a representation of *linguistic, spatial, and musical* skills. These skills are usually represented asymmetrically in the cortex. Witelson concluded that the sex differences in brain anatomy, which interact with hand preference, are consistent with the findings of interactions between sex and laterality in psychological studies, including Benbow's data.

Witelson showed that sex differences in brain lateralization show a greater lateralization in men for both verbal and spatial tasks – yet men do better than women on spatial tasks, but worse on verbal tasks.

Prenatal Testosterone Exposure

Geschwind and Behan (1982) noted that left-handers suffer, more frequently, from immune disorders, learning disabilities, and migraines than right-handers. They proposed that this connected to prenatal testosterone exposure. They found that if the developing fetus is exposed to high levels of testosterone, or has an increased sensitivity to this male hormone, at least two sequenced biological manifestations result:

(a) Testosterone affects the development of the thymus gland and, thereby, leads to increased susceptibility to immune disorders, such as allergies and autoimmune diseases;
(b) testosterone enhances the development of the nondominant hemisphere (typically the RH) that may also lead to an increased incidence of left-handedness.

Some studies, conducted mostly with *adults*, showed a higher percentage of left-handers amongst *artists, architects* (Mebert & Michel, 1980, Peterson & Lansky, 1977), *chess masters* (Cranberg & Albert, 1988), *mathematicians*

(Annett & Kilshaw, 1983), and *science students* (Coren, 1995; Coren & Porac, 1982; Kimura and D'Amico, 1989). Newland (1981) showed a predominance of left-handed adults in Torrance's (1967) figural creativity test. Gribov (1987, 1988) also showed a high positive correlation between non-right-handedness and creative activity/musical imagination in 7–11-year old children (chap. 8).

The application of testosterone, during the critical stages of early maturation, is known to have a masculinizing effect on the mammalian brain to such an extent that, if a female fetus is exposed to testosterone, both brain and genitalia become masculinized (Kelly, 1991). Thus, testosterone can modify the relative development of the two cerebral hemispheres (Galaburda, Corsiglia, Rosen, & Sherman, 1987).

Dichotic Listening Test

Psychologists investigating BFA have accumulated differing data connected with neurologically normal individuals. For example, *verbal experiments with dichotic listening* show that syllables (Hellige & Wong, 1983), words (McGlone & Davidson, 1973), and sentences (Zurif, 1974) are more easily recognized when presented to the right ear (LH) as opposed to the left ear (RH). They also showed that the degree of LH advantage depends on stimulus type, with consonant-vowel syllable identification being the most discriminative task (Obrzut, 1995; Obrzut, Boliek, & Obrzut, 1986).

When *visual-verbal stimuli* are presented separately to the right and to the left visual field, a similar LH advantage is found (Hellige, 1980; Levy & Reid, 1976; O'Boyle, 1985; O'Boyle & Hellige, 1982).

In contrast, the RH is connected primarily with fundamental aspects of visiospatial information processing. For example, the clinical population has difficulties recognizing the human face and the ability to localize objects in coordinate space is also affected (all cases connected with insult or injury primarily to the RH) (Hellige, 1990, 1993; O'Boyle & Hellige, 1989).

Dichotic listening for *melodic pattern sounds*, (e.g., clocks ticking, dogs barking, etc.) shows higher recognition rates for the left ear (RH) compared to the right ear (LH) presentations (Knox & Kimura, 1970). *Face recognition* (Moscovitch, Scullion, & Christie, 1976) is typically faster and more accurate when such stimuli are presented to the left visual field (RH).

3.3 HEMISPHERIC LATERALIZATION AND GIFTEDNESS

Mathematically Gifted Teenagers

O'Boyle, Benbow, & Alexander (1995) propose that sex differences in brain activity among the mathematically *gifted* may be a result of this prenatal testosterone exposure. Such speculation does not minimize environmental factors, however, since they are necessary for the optimal development of any biologically based *predisposition.*

Levy and Gur (1980) also suggested that high levels of fetal sex hormones may promote the maturational rate and cognitive development of the RH more so than the LH.

In the Benbow (1986) study, it was found that intellectually precocious youths, in comparison to their parents, siblings, and a moderately gifted control group, exhibited more than double the frequency of left-handedness, allergies, and immune disorders, as well as myopia.

On the other hand, precocious children also tend to be the first-born, which may have also hormonal implications (Maccoby & Jacklin, 1974).

The identification of these physiological correlates led to a controversial proposal, originally advanced by Benbow (1986) that enhanced RH development may be associated with extreme intellectual precocity, especially in boys.

Comment 1. For my own study, it is important that the precocity is not necessarily identical to outstanding creative abilities. For example, only a few musically precocious children will grow up to be creative composers. That is, it is possible, but not obvious that precocious children also have additional, excellent creative predisposition – as was found in the American Psychology of Creativity and noted in the life-span study of some "Wunderkinder."

A famous example of relatively slow verbal development in childhood is Albert Einstein. He had relatively slower verbal (speech) development (Pais, 1982).

Comment 2. Much of Benbow's (1986) research concerns the verbal reasoning test (SAT). Such tests do not aim to discover a creative predisposition, or to measure creative ability. The percentage of left-handed people, in a verbally gifted group, was not more than 24%, and in the mathematically gifted group approximately 15%. However, the percentage of the left-handers in talented groups is approximately double that of the general population, but many of thee talented children *were not left-handers*. Benbow notes that many of the verbally gifted students were ambidextrous and, when taking into account not only strong left-handers, but also these ambidextrous persons and right-handers with left-handed family members, the percentage rises to approximately 50%. Such an unusual left-handed anomaly was not found in the average gifted control group. The other problem is that the control group, of averagely mathematically talented students, was selected mostly from strong right-handers with enough good analytical skills, but showing low RH activation in mathematical reasoning and other verbal tests.

In the case of my own research with creative activity fostering at school, it was the normal, general school students group and almost all non-right-handers (left-handers and ambidextrous persons – approximately 30% of all groups) who were in the group of creatively active 7–11-year old students. At the same time, almost all strict right-handers were in the other creatively inactive group of students (in the situation of intensive frontal fostering and very high levels of personal motivation of all students).

But, the research carried out by Benbow and others are more congruent to our data, connected to the prominent group of the most creative American people (some of whom were Nobel Prize winners) (chap. 9).

Why did Benbow and colleagues test talented students only in mathematics, but not in physics? Perhaps because mathematics in the USA is one of the major school subjects. However, effective thinking in physics requires the ability both to imagine physical processes and to visualize physical modeling.

Finger-tapping Test

O'Boyle, Gill, Benbow, and Alexander (1994) carried out, with mathematically precocious students, the finger-tapping experiment with different hands in two conditions:

(1) Only tapping and silent, that is, the baseline condition;
(2) tapping and reading a paragraph loudly (simultaneous involvement in the concurrent verbal process).

In these concurrent tasks, only the right-hand tapping rate is usually reduced, as was reported for similar experiments (Hellige & Kee, 1991; Hellige & Longstreth, 1981; Kinsbourne & Hiscock, 1983). O'Boyle et al.'s (1994) study found that:

(a) The average-ability group had the usual reduction of the right-hand tapping rate (LH), with the left-hand-RH being virtually unaffected;
(b) the gifted group showed a reduction in the tapping rate for both hands – which suggests bilateral involvement in the performance of this language-related task and corresponds to the dichotic listening study.

Chimeric Face Test

Levy and her colleagues developed the Free-Vision Chimeric Face Test (CFT), (Levy, Banich, Burton, & Heller, 1983), in which a face is photographed in a neutral expression and in a variety of smiling states. Then this photo is cut mid-sagittally. A chimeric stimulus is created by connecting:

(a) the left-side smile to the right-side, neutral, half-face,
(b) the left-side neutral to the right-side, smiling, half-face.
The participant compares each chimeric face with its mirror image and judges which of the two is the "happier."

Sackheim and Gur (1978) found that in the composite (a) the subjective impression is that it is indeed happier (i.e., connected with RH motoric emotional expression).

O'Boyle and Benbow (1990a) data show that the gifted group had a significantly stronger degree of RH involvement – that is, they considered that composite (a) was "happier" than the average-ability group. Moreover, the greater the involvement of the RH, the higher the combined SAT score.

EEG measurements, connected with 8–12 Hz Alpha activity, are parallel to the above mentioned tests (O'Boyle, Alexander, & Benbow, 1991)

EEG Data

Resting – a neutral cognitive state. EEG potential data show that, at rest, the gifted group is significantly more active than the average-ability group, particularly at the LH temporal lobe.

O'Boyle et. al. (1991) proposed that this more active LH may be connected with the hypothetical LH function of metacontrol in the coordination and allocation of cortical resources (Gazzaniga, 1985; Hellige & Mitchimata, 1989; O'Boyle, Alexander; & Benbow, 1991).

Comments

(a) Slight rest metacontrol is notable in famous thinkers (see below for the analysis of self-reports from Hadamard and Penrose). They do not lose the process of interesting combinations in free imagination of their relaxing consciousness, occurring (possibly as a spontaneous associative noise) in the resting RH. But, this metacontrol effect could be explained from the point of view of the "two verbal centers" hypothesis, presented below.
(b) In the LH of gifted persons exist slight metacontrol mechanisms that reduce corresponding LH perceptual activity in the case of more adequate tasks for the RH-functioning and delegate activity to the opposite RH. At the same time, such a mechanism is not sufficiently developed in the average group – their LH always attempts to dominate, even in cases where it has the less successful, inadequate functional application (e.g., facial

emotions recognition as shown above). Such inadequate LH dominance is presented in the study by Gazzaniga (1985). In this research, the right hand of the split-brain patient attempted, but could not solve, the form recognition task made tactually, but then as the left hand (more suitable for such a function) attempted spontaneously to carry out this task, this hand was pushed away by the right hand, as with busy teenagers, ignoring, and pushing away his "stupid, little brother."

We propose that more adequate interhemispheric cooperation of the gifted person can be connected to two obstacles:

(a) The more or less friendly, less authoritarian (by function), balanced collaboration between two opposite (LH – RH), verbally equipped consciousnesses. For example, the LH verbal functions (as in the average right-hander) could be more developed than in the RH, but the RH in gifted persons also has a notable verbal representation and, thus, the two hemispheres can successfully collaborate, and argue using the same verbal communication. It could easily and effectively eliminate cognitive one-sidedness and switch activity into the really more effective side.
(b) In such a collaboration (in the case of gifted persons), the RH functions will be effective if the RH temporal lobe cortex is larger than in the strong right-handers. This means that an additional verbal neuronal field within the RH cortex will not reduce very important RH *spatial functional areas*.
(c) Such a brain has a larger corpus callosum with a larger passing capacity, as Witelson (1985, 1987) found for the *ambidextrous*.

An analysis of the nature of BFA gives additional support to this point of view: if we remember that verbal functions are strongly connected to the motoric functions of the hand (fine movement production connected to the above mentioned library of movement stereotypes), we will understand the significance of non-right-handedness for the double-verbal consciousness development in the same personality. It is connected with the relatively larger RH temporal lobe and, as found, with the larger corpus callosum and its larger passing capacity. These neuro-anatomical peculiarities provide specific advantages for the bi-verbal, better coordinated and communicated brain structures and are especially important for creative thinking.

Sex and Laterality Differences in Brain Organization

It has been found that brain lateralization with this prototypical left-right specialization is more typical for men than for women (Hellige, 1990, 1993; McGlone, 1980; O'Boyle & Hellige, 1989). Sex differences in cognitive abilities was also discovered among the gifted (O'Boyle et al., 1991; O'Boyle & Benbow, 1990a, 1990b; O'Boyle et al., 1994):

(a) There are more male than female individuals at the extreme end of the gifted distribution in mathematics (Benbow, 1986).
(b) Precocious girls have relatively lower spatial and mechanical abilities than gifted boys (Benbow, 1986; Lubinski & Benbow, 1992; O'Boyle & Benbow, 1990a, 1990b).

O'Boyle et. al. (1995), integrating a series of studies which had been conducted over the preceding years, hypothesized that extreme intellectual precocity is related to an enhanced involvement of the RH during basic information processing (Benbow, 1986), as well as to the *superior coordination of cortical resources* between the hemispheres when engaged in intellectual tasks (O'Boyle et al., 1991).

Experimental data were obtained using a variety of neuropsychological methods, including:

– dichotic listening
– concurrent finger-tapping and words
– chimerical face processing

These studies were supplemented by electrophysiological EEG recordings. For gifted participants, EEG data showed that "the more involved the RH during information processing, the greater their manifest intellectual ability." Intellectual abilities were measured by the SAT and Ravens Progressive Matrices scores. O'Boyle et al. concluded that obtained findings support the above-mentioned hypotheses, particularly in precocious men.

Comment

In the context of the *"functional shifting hypothesis"* these data show that, for instance, talented precocious persons (at school age) perform a less established "functional shift" from the RH to the LH compared to the "normal" population, as was also found in creatively active school groups (Gribov, 1988).

For example, even a simple dichotic listening task involves RH mechanisms for the elaboration of the nonformal (emotional, contextual, etc.) semantic contextual analysis of verbal information in talented persons. Results show corresponding EEG processes in the corresponding cortical fields of the RH, as presented by O'Boyle et. al. (1995).

Chimerical face processing can also be carried out differently in the continuum of "formal/nonformal" functional analysis. Such chimeric photos, used in this research, formerly, were almost identical. The LH categorical analysis of psychical states in the task: "which face is happier?" was not able to recognize any emotional differences between "this smile" and "that smile." However, these emotional differences were successfully detected only by the finer RH analysis. By contrast, the "normal" brain, in this case, *has the intention to use, from the first steps only, the formal LH strategy and block the fine RH analysis*. This is an example of the disbalanced functional collaboration, which blocks the recognition of "happiness" in such chimerical photos.

EEG data show that in gifted men there is strong evidence of high-level RH engagement during information processing, and their EEG data also reveal a finely tuned capacity for activating (or inhibiting) the very brain regions known to play (or not to play) specialized roles in the performance of a given task. O'Boyle et. al. (1994) proposed that the discovered "orchestrated activational" and inhibitory cortical shifting in precocious men may be a physiological manifestation of what Sternberg (1986) previously described as the *superior metacognitive knowledge* associated with gifted thinking processes. That is, precocious individuals are especially gifted at knowing what steps to take to solve a given intellectual problem.

METHODS OF RIGHT HEMISPHERIC (RH) ACTIVATION

Summary

Simple methods of activating the RH were proposed by L. Tadd (Tadd, 1900). His methods are connected to the untypical, in the case of right-handers, *left-hand drawing activity*. They are very important because they open the *straight sensomotoric entrance into the RH*, which is usually under the LH control. These methods provide a more balanced *reflex* activation of both RH/LH cortical projections. It increases the involvement of the RH in integrative activity (thinking, drawing, etc.) for people with well-separated hemispherical functions and correspondingly reduces LH super-dominance, which normally blocks creative self-expression in these people.

The methods developed by Edwards (1979) and their theoretical background, which address BFA, appear to be much more superficial than Tadd's methods. Edwards did not use the left-hand artistic opportunities (that could be easily predicted by the BFA theory) and never mentioned Tadd's findings. The study from Gribov (1980), connected with left-handed and right-handed drawings, discussed some additional features and opportunities in fostering aesthetic abilities in drawing (chap. 7.1).

4.1 DRAWING TRAINING METHODS OF LIBERTY TADD (USA)

Liberty Tadd (1899, 1900, 1903) was a Director of the Public School of Industrial Art in Philadelphia. His critique of American (European) education remains important even today. He stated that the purpose of his publications was to protest against the modern methods of education, which depend primarily on abstract books of knowledge. He believed that nature and experience are the best teachers and a book must only be an aid, and not the main source of education. In other words, it was his protest against the traditional, verbal intellectual paradigm, which had invaded education in his time. He stated that the ability to understand words increases only by increasing practical nonverbal experience. "Words are empty sounds if they are not connected with the clear mental presentations and certain thoughts"...,"it is necessary:

(a) To develop the mental presentations;
(b) to find certain words for them;
(c) to connect these mental presentations and the words with corresponding acts;
(d) make it so, that this connection will be an impulse, which in each minute is ready to call for a productive and sensible act."

Tadd asserts that aesthetic culture is destroyed by the one-sided inhuman nature of industrial development, and he agitates also for a much greater involvement of art in education. He wrote about the inhuman ambition of the first industrial epoch, producing, on the one hand, great technical achievements but, on the other hand, transforming of the human being into some kind of factory bio-robot. He wrote that, in his time, all efforts were directed to depreciate manual skills, glorify richness, depress the best human abilities in the masses, and that in the end this world would be full of people who will not be able to perform the duty, will be blind to joy, will be hopeless, without trust into their own powers, and indifferent to any intellectual influences. Tadd repeated the humanistic educational principle of Emerson that great tasks of education must correspond to the task of life; first of all it must be moral; it is necessary to suggest to children that they should trust their own powers, because each human being must have an interest in himself. Using the child's natural interest in obtaining knowledge, we must lead him to the sources of mental life, explain to him what powers he has of his own and implant in him a respect for the human spirit, with which he lives (Tadd, 1899).

His ideas and methods are still interesting today. Tadd was the first teacher, in the world of education, who proposed to use and to train, not only the right hand, but also the left hand of schoolchildren in art lessons! He repeated the thought of Aristotle, that "a hand is an instrument of all instruments." Tadd was against routine mechanical hand training. But, still today, this one-sided routine hand training is almost a norm at school. He believed that such primitive training limits children's originality and creativity. He was sure that mental abilities are deeply connected with the hand development. Rudolf Steiner adapted many of his pedagogical thoughts and applied, at his Waldorf School, the practice of left-hand activation. According to Tadd, the purpose of training the left-hand is: If we use the left hand, we activate the RH and when we use the right hand, we activate the other – the LH of the human brain, activating twice as much brain mass and brain centers. The more brain centers activated, the better the hands will be trained – this was his logic. He was sure that the brain and feelings, and thought and imagination become stronger when the connection between each hand and the corresponding part of the brain is strengthened, and much easier when both hands work together. The results of my application of this method evidence this (Tadd, 1899). However Tadd only proposed the activation of the left-hand to improve right-hand training! In his time, it was too early to speak about BFA, but until now his interesting findings are far from being applied in education. Tadd developed, (as the basic method for effective training) combined symmetrical hand movements. My own explanation of the positive effects of his training method is as follows:

(a) Symmetrical movements, repeated many times, activates symmetrical sensomotoric cortical projections of both hands and then develops, after this long training, some kind of reflex activation of both cortical projections (which is useful, when later a trained student uses only the right hand).

(b) During this symmetrical training, a simple method for the movement management from the RH (across commissures) to the opposite right hand (for the right-hander) could develop, facilitating the more *holistic*, esthetical art image production, that could integrate both the global and local parts of the art image better.

(c) Working later only with the right hand, reflex activation of both the cortical projections will be induced. In this case the whole brain is more deeply involved in the picture production using the right hand by cortical commands through commissural connections between hemispheres.

This will also lead to the facilitation of all other spectrums of the RH functions (first of all it is sensomotoric, visual thought, and imagination). Tadd's method was popular in Europe, and later also in Russia at the beginning of the 20th century. Even Pablo Picasso used this partially in his artistic work. This technique was much criticized later, as a naive and formal "trick" (Rostovzew, 1980) and then was forgotten. From our point of view, Tadd's left/right-hand training method can be qualified as some unprecedented, manual psychotechnique in art education, which balanced and facilitated the adequate cooperation and realization of the brain hemispheric functions. It needs to be renewed, developed, and implemented in modern education. It is important not only for art, but also for intellectual development in general.

In the context of our analysis, it is interesting that the famous "Cube drawing before and after commissurotomy" from Gazzaniga and LeDoux (1978), shows that after commissurotomy only the left hand is capable of drawing such a simple cube in oxonometry. It is a well-known fact, but there is something more interesting in this postoperative picture: The cube drawn using the left hand is not the same –it is a cube with the horizontal inversion of the form! In the context of the muscular module (MM) principle (Gribov, 1977a) and anatomically predetermined commissural horizontal inversion of any cortical movement program, going across commissures, it is obvious that this cortical (cube) – movement program is settled in the RH in the inverted (!) position, because normally it is prepared for the activation of the right hand! This program, after transferring commissures to the right hand, will be inverted automatically and we can see a non-inverted cube picture, which is produced by a preoperative person (with the right hand). This gives a greater understanding of the usefulness of Tadd's symmetrical hand training: It facilitates cross-commissural movement's management of the right hand by the RH (with originally inverted and easily blocked RH-movement programs). In this "double cortico-motoric training" the left hand must really move *simultaneously and symmetrically* with the right hand. These movements are actually the basic training movements in the method of Tadd.

4.2 "DRAWING USING THE RIGHT SIDE OF THE BRAIN" (B. EDWARDS, USA)

In the context of Tadd's "both hands" training method (chap. 4.1), it is interesting to analyze more modern American methods of drawing and art training.

Edwards (1979) uses two basic short theoretical notations as "L-mode" and "R-mode":
L-MODE is the "right-handed" *LH-mode*. The 'L' is foursquare upright, sensible direct, true, and forceful.

R-MODE is the "left-handed" *RH-mode*. The 'R' is curvy, flexible, and more playful in its unexpected twists and turns, more complex, diagonal, and fanciful. Edwards proposes that this RH-mode is an intuitive, subjective relational, holistic, and time-free mode. This is also the disdained weak, left-handed mode which, in our culture has been generally ignored. For example, most of our educational systems have been designed to cultivate the verbal rational, on-time LH, while half of the student's brain is virtually neglected. Edwards noted that even today, although educators are increasingly concerned with the importance of intuitive and creative thought, school systems, in general, are still structured in the LH-mode. She writes that it is difficult to find courses about imagination, visualization, perceptual or spatial skills, creativity as a separate subject, intuition, or inventiveness, and we are surely losing a very large proportion of the potential ability of the other halves of our children's brains.

Analysis of the Edwards' Method

The practical rule of this method is to shift from one mode to the other, from the ordinary verbal, analytic state to the spatial, nonverbal state.

In her drawing exercises, she attempts to change usual "normal" drawing algorithms. For example:

(a) Do the same things differently – "this will be the RH-mode drawing":
  – "draw the profile in reverse";
  – apply "upside-down drawing" (as does the famous German painter Baselitz!)

(b) "Pure contour drawing" – Edwards investigated the method of Nikolaides (1941). Nikolaides recommended, "that students imagine that they were touching the form as they drew." This method has been widely used by art teachers, and applied by Edwards because the left-brain rejects the "complex perception of spatial and relational information, thus allowing access to RH-mode processing." Evidently the "pure contour drawing" was detected later as a drawing "style," connected directly with the *left-hand drawing* and with the RH art style (Gribov, 1980; Nikolaenko, 1982). In my own study, it was detected by a comparison of the real left-handed and right-handed drawings (portraits), see chapter 7. Nikolaenko detected figural activity in the process of unilateral electroshock treatment of patients, where one, or the other hemisphere was blocked by electroshock.

(c) "Negative-space drawing" when spaces take shape – Edwards reasoned: "the LH is not well equipped to deal with empty space."

Edwards' original training method in drawing is parallel to the nature for the *psychotechnical method*, developed in Buddhism (Suzuki, 1959). This element is called "koan." Koan, in Buddhism, is some kind of statement, which is logically nonsense, for example: "a dead cat is the most beautiful picture in the world." Psychologically, the koan challenges evidence of logical structures, connected with the logical "left brain" – this nonsense shocks and blocks the left brain logic and provokes other ways of reaction: "right brain" activity.

Note: It is surprising that Edwards newly applied in the "RH-mode" training the *left-hand drawing method*, as developed by Tadd.

5. DEFINITIONS OF CREATIVITY AND CREATIVE PERSONS

Summary

Common definitions of creativity include a process, which results in a *novel work* that is *accepted* as *tenable, useful, or satisfying* by a group at some point.

Wertheimer (1945) proposed the *"Gestalt changing"* as a dialectical (a kind of creative) process in perception. This is of importance in the context of BFA - reflecting dialectical unity and opposition between the static and dynamic elements in *human thinking*.

Stein (1953), Harmon (1955), and Csikszentmihalyi (1996) stress the evaluative *"End Product"*. The assessment of the *"End Product"* is realized normally by society, professional groups, and the market. Eminent creative persons who meet the criteria of the highest "*creative End Product"* will be discussed in chapter 9.

The *"Homo-creative"* humanistic paradigm, predicted in Genesis – namely, that *"God created man in his own image"* (Torah, Genesis, 1.27), established the *humanistic* roots of religious culture, and predicts the transforming of "Homo sapiens" into *"Homo-creative."*

In the case of the *"**Ego regress**"* approach, Bellak (1958) emphasizes "preconscious or unconscious material" of the RH and advocates a reduction of the dominance of the rational (LH) "ego".

The ***"Solution thinking***" definition emphasizes the personal thinking process (Duncker, 1945; Guilford, 1959) and involves the "discovery," and especially "divergent thinking" factors, such as the "ability to move in different directions when faced with a problem." It could be connected with the associative creative "structural" flow of the RH that is opposed by the "divergent thinking" of schizophrenic people (coming from the destruction of the ability to categorize in the LH).

The **"*Search activity*"** approach advocated by Rotenberg and Arshavskij (1984) is a biological view, which associates *creativity with a general biological necessity*, deeply connected with personal physiological and mental health that could be turned into a biological category of *"creative instinct."*

The ***"Positive cultural-genetic mutations"*** approach is an evolutionary orientated definition. As an *analog* of the biological evolution, it involves the metaphor of the "cultural DNA," as proposed by the eminent American economist Henderson. It accents a creative *human factor* as decisive for it, and also stresses personal responsibility in this process, keeping together two goals: *human development and the survival of our civilization and biosphere.*

A review of the literature on thinking and problem solving gives different theoretical orientations and experimental investigations in creativity. The semantics

of the word "creativity" differs from definition to definition. Approximately 60 definitions of the meaning of the word "creativity" exist today (Taylor, 1988).

5.1 "GESTALT" OR "PERCEPTION" – EMPHASIS ON PERSONAL PERCEPTION

Wertheimer (1945) stated that creativity is the "process of destroying one Gestalt in favor of a better one." Keep (1957), Duhrssen (1957), and others use a similar approach.

Comments

Wertheimer's definition of creativity is still valid, and complements the modern BFA paradigm because it expresses the dialectical aspects of creativity as a process of change in the existing personal perceptual paradigms. The LH can be associated with the accumulated "library" of fragmented cultural stereotypes, cultural instruments, and cultural invariances, which attain certain stability in human development, and resist change. It is not only a cultural, but also a perpetual, personal, and psychological barrier for innovation today.

5.2 "INNOVATION" OR "END PRODUCT" – EMPHASIS ON A NEW PRODUCT

Creativity is the process, which results in a novel work that is accepted as tenable, useful, or satisfying by a group at some point in time. (Csikszentmihalyi, 1996; Harmon, 1955; Stein, 1953).

The American psychologist M. Csikszentmihalyi (1996), in his new book "Creativity," proposes a cultural and system-orientated definition of creativity:

(a) *Creativity* is any act, idea, or product that changes an existing domain, or that transforms an existing domain into a new one.
(b) A *creative person* is someone whose thoughts or actions change a domain, or establish a new domain. It is important to remember, however, that a domain cannot be changed without the explicit or implicit consent of the field responsible for it.

He concludes that several consequences follow from this. For instance, *the creative person is not necessarily different from anyone else*. In other words, a personal trait of "creativity" does not determine whether a person will be creative. What is important is that the novelty they create is accepted into the domain. Because creativity is jointly constituted by the interaction between a domain, field, and person, the trait of personal creativity may help generate the novelty that will change a domain, but it is neither a sufficient, nor a necessary condition for it.

Comments

My own BFA/creativity study shows the opposite – that *creative personality* contains a valuable invariant, independent of any local historical change in the relativistic cultural “domain” or professional “field” assessment of such a personality. It means that the “trait of personal creativity” is a decisive and necessary element in innovation inside any domain.

Csikszentmihalyi (1996) wrote that people couldn’t be creative in a domain to which they are not exposed. No matter how gifted a child may be in mathematics, it will not be able to contribute to the field of mathematics without learning its rules. But, even if those rules are learned, creativity cannot be manifested in the absence of a field to recognize it.

The first statement is true enough. But, *relative dilettantism*, connected to interdisciplinary, inter-domain interactions, could be especially fruitful for large innovations in the domain.

The last statement is not true; remembering that one of the best artists – van Gogh – was strictly ignored by the art establishment of his day. That such gifted people are ignored could be a typical and perpetual problem in the *innovation process*.

5.3 BIBLICAL “CREATIVE CREATURE” ACCENT

Lee (1957) and Chiselin’s (1955) definitions of creativity consider “aesthetic”, “expressive” or “unique self-expression” (personality accents). The biblical formulation of creativity had been discussed by Lange, 1957; Rotenstreich, 1983; Soloveitchik, 1978. Soloveitchik writes that *God wills man to be a creator* and his first job is to create himself as a complete being.

Lange (1957) also relates the religious paradigm to human creativity: the *creative process is God, the creator, working through his creation – man.*

Comments

It is one of the basic, deepest visions of the nature of man – *“Homo creative”* as a spiritual paradigm predicted in Genesis with the words *“God created man in his own image”* (Torah, Genesis, 1:27*)*. The deeply *humanistic* religious roots of European cultures and ethics are established by this biblical verse about the human being, whereby God implanted creative potential in man.

Rotenstreich (1983) investigated the religious texts by Pico (1463–1494) – his “Oration on the Dignity of Man.” In his Oration, Pico stated that it was in man’s nature, to create a world from his own resources and that man is a creator in many small ways and is not only an imitator, that is, “retaining the notion that man is a creature, Pico turns man into a creator.” “Thus, the traditional view that man’s activity is essentially imitative comes to an end, and creativity, originality, and initiative now comes to the fore” (Rotenstreich, 1983).

5.4 "EGO" – "SUPEREGO" – EMPHASIS ON PERSONALITY

Bellak (1958) stated: All forms of creativity are permanent, operant variables of personality and, to be creative, the ego must regress in order for the preconscious or unconscious material to emerge.

Comments

Such "ego regress" in the "preconscious or unconscious material" has a more or less prosaic meaning and can be explained in the context of the (information processing) hemispheric BFA paradigm. However, formal logic and abstract verbal consciousness alone can never displace the richness of nonverbal informational mechanisms connected, for example, with free imagery associations and other nonformal brain resources.

5.5 "SOLUTION THINKING" – PERSONAL THINKING PROCESS

Wertheimer (1945) and Duncker (1945) developed the "solution thinking" approach. The first scientist to develop a many-factorial model of creativity was Guilford (1959). He proposed that creativity depends on a very large number of intellectual factors. He determined the main factors as:

(a) "discovery" factors such as the "ability to develop information from what is given by stimulation";
(b) "divergent thinking" factors such as the "ability to go in different directions when faced with a problem."

Comments

Guilford's model has, today, a wide application (e.g., in different intellectual tests and in much research into creativity [Coren, 1995]). Later, psychologists found a large difference between the verbal and nonverbal components of divergent thinking. For example, only by the mechanical manipulation of words can someone formally produce many different unusual thinking combinations and, therefore, formally such "divergent thinking" can be rich, but factually absolutely inadequate, as in schizophrenia.

Guilford's "discovery" factors are very complex, intellectual phenomena. The nature of such an "ability to develop information" cannot be scientifically investigated or described, without the BFA paradigm. Torrance (1974) developed his famous creativity tests, influenced by this paradigm. But, all test batteries are always limited by an underlying scientific paradigm. For example, there is no positive correlation between creative abilities (personal achievement) and above average result in the American IQ test.

5.6 "SEARCH ACTIVITY PARADIGM" – AS A BIOLOGICAL ANALOG OF CREATIVITY

Rotenberg and Arshavskij (1984) proposed that the so-called *"search activity"* instinct is one of the basic common features for many life forms and is important not only for the human being. They showed that artificial deprivation of the "search activity" can quickly destroy the organism of an animal on a *physiological and psychosomatic level* – it deeply destroys the immune system of organisms. They connect the *creative activity and physiological and mental health* of the human being.

Comments

Different forms of the *"search instinct"* are, through evolution, implanted in all life forms, because it substantially increases the chances of their survival. In the case of the human being, we assume that it is, through evolution, transformed into the *"instinct of creativity"* and "creative activity."

5.7 EVOLUTION-ORIENTATED DEFINITION OF CREATIVITY

We propose that evolution-orientated definitions of creativity could be constructed by *analogy with the biological evolution*: Creativity is a synthetic process (individual and social) involving the production and selection of positive innovations (*positive culture-genetic mutations*). This process determines the speed and quality of the culture-genetic development, and it is now one of the most decisive *human factors* in the world's economical competition. Human creativity is associated today with two indissoluble goals*: human development and the survival of our civilization and biosphere.* In the broader context, human creativity has developed, up to the present time, in such a way so as to expand life-space for biological and human life, at least in the context of the solar system (as was dreamt in the beginning of the 20th century by the Russian futurist and scientist Ziolkovskij).

The American economist Hazel Henderson, one of the outstanding people interviewed by Csikszentmihalyi (1996), used the term "cultural DNA." He associated every culture with a high-quality program of software, deriving from a value of institutions and a set of goals. Thus, *the evolutionary oriented definition of creativity* is connected with the process of the "*cultural DNA" improvement.*

6. HUMAN MOVEMENT AND THE FUNCTIONAL ROLE OF EEG WAVES

Summary

It is proposed that the complicated motoric system is based on nerve-muscular modules (MMs), as *universal nerves – muscular units,* producing one-dimensional movements (Gribov, 1977a, 1977b). The maximum frequency of these movements is approximately Fmax=4÷6Hz. According to the theory of information, this single MM can be precisely managed by *discrete signals* with the double frequency 2Fmax=8÷12Hz, corresponding to the EEG Alpha-rhythm. That is, it is proposed that the MM is based on a *relevant universal neuronal module (NM)* – with a synchronized functional neuronal Alpha-group of neurons.

These compatible MM and NM models explain the functional role of basic EEG rhythms in an active state and at rest. The model explains reduction of the Alpha-rhythm in the state of perceptual attention "in the probable sensory world."

It also proposes a relevant neuronal mechanism *of NM pattern comparison*. This mechanism explains the functional role of typical *Alpha-beats* in the EEG.

Beta and gamma rhythms are connected with the process *of neuronal pattern comparisons*.

These MM- and NM-concepts *correspond* to the basic EEG data. The MM-concept was experimentally *verified* recently by Bizzi and Mussa-Ivaldi (2000).

These concepts allow the formulation of manual techniques, *activating creative and aesthetic potential*.

6.1 MUSCULAR MODULE (MM) HYPOTHESIS

Definition

The MM is the universal *nerve-muscular unit* required for any voluntary one-dimensional movement (Gribov, 1977a). Empirical studies of such *one-dimensional quasi-sinusoidal rhythmical movements* show that the maximum possible frequency fm of these one-dimensional MM movements (for different amplitudes) is nearly Fm=4÷6Hz in the human population, and is more or less a stable and individual physiological parameter for each person.

If someone has Fmax=4Hz and can not voluntarily increase it and someone has Fmax=6Hz, then parameter Fm correlates with the minimum time of the motoric reaction and with the doubled individual frequency of EEG Alpha-rhythm fa (i.e., fa=2Fmax≅6÷12Hz) (Gribov, 1977a). Data from periodical swings in the elbow joint show that *the form of one-joint periodical movement* is practically *sinusoidal* (Fig. 6.1-1) in a wide diapason of frequencies and amplitudes of the joint angle (1÷6Hz, 10÷90°) (Zhukova, 1974).

Amplitude (cm)

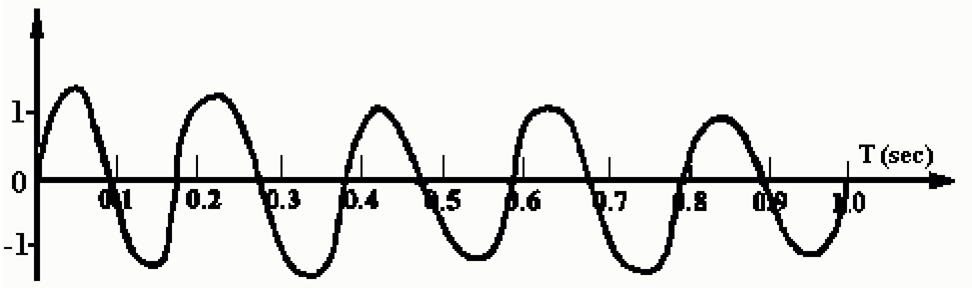


Fig. 6.1-1

Thus, the frequency diapason for the MM movement is approximately a 0,4÷6Hz interval. In the theory of information the famous theorem of Kotelnikov exists: any continual one-dimensional process Y(t) can be detected *without losing information* by *discrete* points on the curve Y(t) going minimum with the frequency $F=2F_{max}$. Frequency F_{max} is the maximum frequency in the Fourier-spectrum of the function Y(t).

For our purposes, this theorem states that any complicated one-dimensional continual movement Y(t) of the MM can be precisely managed (or measured without losing information) by discreet managing signals, going on with the maximum frequency $f=2F_{max}=8\div12$Hz. This means that the EEG Alpha-rhythm fa=8÷12Hz is immediately valid for this goal, and could be the basic frequency of such discrete managing nervous signals. It is well known that the Alpha-rhythm is the basic physiological rhythm of the neuronal activity, and from this point of view, due to this frequency, the diapason for voluntary one-dimensional MM movements is *limited* by Fmax =fa/2=4÷6 Hz.

EEG – Data

Gribov (1977b) tested the above-mentioned correspondence between the individual F_{max} and the individual Alpha-rhythm, that is, that $fa\cong2F_{max}$ for the experimental group of 8 adults is a statistical hypothesis. The hypothesis $fa=2F_{max}$ was significant with $p<0.05$. These data correspond well with many other such tests.

Motoric Program Transfer

The MM-conception allows the building of the very simple, universal mechanism of the motoric program's transfer from one effector to the other: For the successful transference, it is necessary only to establish similar one-, two- or three-dimensional MM systems of the motoric management in the effector-recipient. It looks like a very fast nerve-muscular "pre-tuning" process, associated with the so-called micro-tremor. Subsequently, the effector-recipient is ready to realize practically every transferring motoric program. It also explains why it is so easy, can continue without visible effort and, for example, why the typical features of someone's handwriting are the same even if there are different effectors – such as a hand, a head, a leg, etc.

The Global and Local Parts in Movement – Fourier and BFA Aspects

The Fmax=4÷6Hz is almost *invariant for the different sinusoidal amplitudes* (between 0.5cm÷10cm) for the elbow joint periodical movements. It means that the same figure (but at different sizes) could be drawn for *the same minimal time*.

We propose that the Global part and the Local part in the Fourier transformation, for example, for the plane movements (two orthogonal MMs) could be distinguished, not only by the relative size of the figure, as is clear for visual perception, but also by a combination of *lower frequencies – larger amplitudes for the Global part* and the opposite *combination of higher frequencies – smaller amplitudes for the Local part* of the movement structure. Indeed, the right hand (in comparison with the left hand) has better developed (high frequencies – small amplitudes) serial movements, such as quick writing or very quick rhythmical movements when playing music, correlating with high musical harmonics: remember that traditional musical keyboards are adapted to this brain-body functional asymmetry - they have low musical frequencies in the left-hand operating space and high frequencies in the right-hand operating space.

The LH operates with movements containing a high side of frequencies (writing stereotypes, typing movements, quick speech production etc.). These movements have no rich or wide harmonic spectrum and cannot realize plastic, sensitive, and unique movements in art, dance, sport, or playing music with their rich spectral diapason. Here almost a *complete analogy* can be drawn with the LH/RH visual perception (Fig. 1.6–1, chap. 1.6).

The RH operates with the opposite movements – they contain the low frequencies side (for slower unique movements) with a rich quantity of harmonics (plastic dancing, singing, creative sport movements, emotional expression through facial expression, hand and body gestures, plastic playing of music, etc.).

Senso-motoric Conformity for the Global/Local Vision and Motion

We also remember that the *Global and Local aspects of movement* can be associated with low/high frequency diapasons and the corresponding large/small space areas of this, connected with different amplitudes and frequency scales, realized, for example, by short and long limbs, and/or with different frequency areas in the movement's Fourier transformation.

This picture supposes a *senso-motoric conformity* between the Local visual field/Local motion and also between the Global visual field/Global motion in the outside space and in the inside cortical (LH and RH) Fourier transformation: So-called thin hand movements, space-local finger movements and corresponding high Fourier-frequencies are connected with writing. They could be named as Local motoric Fourier elements. Large amplitudes (large space areas and lower [slower] Fourier frequencies with a rich harmonic spectrum) could be associated with the Global motoric Fourier elements.

6.2 HYPOTHESIS OF THE COHERENT – FUNCTIONAL NEURONAL GROUP

Definition

It is proposed that every one-dimensional (MM) movement (and also each collective neuronal cortical process) could be managed by the coherent functional Alpha-group of neurons, which actually have the synchronized physiological rhythm expressed in the well known EEG Alpha-waves, having a quasi-sinusoidal form with the frequency $f_a=8\div12$Hz (Gribov, 1977a). Thus, the Alpha-group produces the elementary tact-pools of discreet coherent signals also with $f=8\div12$Hz.

We can generalize that this Alpha-group realizes a kind of *universal NM, complementary to the MM*, playing its basic role in our cortex.

On the basis of two or three one-dimensional orthogonal MMs, connected with the same effector, it is possible to realize any complicated two- or three-dimensional movements, for example:

(a) two-dimensional (plate) handwriting;
(b) three-dimensional hand-gesturing or working movements;
(c) quick two-dimensional movements for the speech-production.

Speech Production

This is connected with two different MMs (tongue-MM and lips-MM, their quasi-periodical movements displaced by the phase with $\Delta\varphi=180°$). Individually, each MM has $F_a=4\div6$Hz, but the phase displacement produces syllable segmentation in the speech flow with the double frequency $2F_a=8\div12$Hz; it is well known that we cannot speak more quickly. If we compare the fastest speech frequencies for such syllables as Pa,Pa,Pa…(lips-MM), Ra,Ra,Ra…(tongue-MM) and PaRaPaRa… (lips-MM + tongue-MM) this effect becomes clear (Gribov, 1977a).

Why do we produce syllables with the same maximum Alpha-frequency $8\div12$Hz? It is natural, because it must be:

(a) *a two-dimensional motor Fourier space* (for two MMs in the speech production);
(b) the speech must be complementary to the rhythm of cortical hearing perception: in the beginning each (unfolded in the time) syllable sound is transformed into the Quasi-Fourier-image (unfolded strictly as the neu-

ronal space distributed image, because only in this case could it be recognized). Syllables, which are “a priori”, follow successively with the very small frequency 8÷12Hz. The evolution of speech over many thousands years was connected to the development of successive micro-rhythmical neuronal-motoric processes, associating unified syllable-images with corresponding motoric programs.

State of Relaxation

It is a well-known scientific fact that an EEG Alpha-rhythm, in the state of relaxation, has maximum amplitude and the largest neuronal space of presentation in the neocortex. We propose that in this case we have the highest local neuronal density and the largest neuronal space constellation in the only “working” Alpha-group. Thus, the relaxation state could provide a virtually very dense and very wide polymodal, multifunctional, virtual “dynamic synergism” of many neuronal constellations, and create flows of almost “invisible” virtual associations, progressing as a kaleidoscopic of neuronal noise. It is a good time for free imagination and for probable insights. The Eastern cultural world (e.g., Buddhism) developed traditional psychotechniques for reaching such a state of relaxation (see below).

State of Active Perception or Action – Nature of ß-rhythm

This state requires more than one simultaneously working neuronal Alpha-group; (a) for complicated movements, and (b) for the *active perceptual attention*. It will split one coherent Alpha-group into several independent coherent Alpha-subgroups that will reduce the high amplitude of the Alpha-wave. It could explain the corresponding phenomena of the Alpha-rhythm desynchronization, connected with the activation of the *active perceptual attention*. In the total EEG-wave we will see only the superposition of these simultaneous Alpha-sub-waves. If these waves have similar frequencies and amplitudes, but different phases, it will eliminate, or reduce the first Alpha-harmonic in the summary wave. For the other waves, we will see only non-regular, but higher Fourier harmonics with relatively low amplitudes (*i.e., a corresponding motoric ß-rhythm*).

This is also similar for *voluntary movements*: Rolandic Alpha-rhythms is blocked in the sensomotoric contralateral cortical area by any voluntary movement (Kruger & Henry, 1957). This could also be necessary for the *state of active perception* (and sensorial attention). It is well known that the largest part of the physiological neuronal Alpha-period is the *“dead time”* for neuronal perception. This means that the effective sensory process requires (for “a priori” *random* in time signals) the recruiting of several simultaneous Alpha-subgroups with different Alpha-phases. It will lead to the similar mechanism of Alpha-wave desynchronization (and the emergence of the ß-rhythm) in the visible EEG. Therefore, the *concept of functional neuronal Alpha-groups* allows the explanation of the functional role of the Alpha-rhythm and the nature of its desynchronization in the EEG (emerging as the ß-rhythm) both in the motoric and perceptual processes.

State of Suggestive Perception

It is interesting to note that the state of relaxation could be extremely effective for perception if perceptual signals:

(a) are *not random* in time, and
(b) are *synchronized with the Alpha-rhythm*, or
(c) they are changing in time *slowly enough*, compared to the Alpha-period, as is, for example, the case with songs or slow melodic speech.

It is evident that small babies often have the same psychic state at the time of verbal communication with their first teacher – the mother. In this case, she instinctively attempts to speak slowly, with a melodic and soft voice. Such a psychical state is opposite to the normal state of sensorial attention and needs, evidently, the atmosphere of safety and psychical comfort. Under this condition, the reflex of the normal voluntary attention – normal in the case of very quick speech or the probable sensorial signal – could be stopped and the above mentioned, very effective *suggestive perception state* could arise. This requires only one perceptual coherent neuronal group with the maximum local density of coherent neurons and a very large cortical area for this "working neuronal group" of recruited neurons to correspond to the high amplitude of the EEG Alpha-rhythm (Gribov, 1977b). This model corresponds well with the pedagogical data of Losanov (1971) concerning the application of the *suggestive learning system*. This system widely uses the *state of relaxation* to accelerate the learning process and in this respect it radically differs from the traditional methods of learning. Losanov indicated that people, during the time of the suggestive learning process, had EEG showing the state of relaxation.

6.3 QUASI-ACTIONS AND TEMPORAL MUSICAL MICROFORM

Definition

Sinusoidal, one-dimensional hand movements (Fig. 6.1–1), could spontaneously obtain specific forms with additional periodical splashes of movement from the hand (Fig. 6.1–2). These additional periodical splashes have time-periods T=Tq and frequencies F=Fq and progress involuntary as some kind of very stable periodical self-excitations. This phenomenon was associated with the so-called *quasi-actions* (Gribov, 1977a).

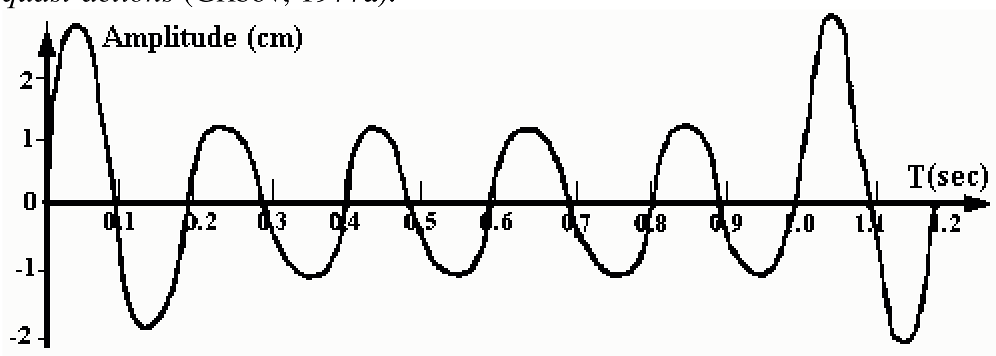


Fig. 6.1–2

A typical frequency diapason for quasi-actions is $Fq \approx 1 \div 2$Hz. This corresponds to many types of rhythmical human movements:

– rhythmical *musical microform,* (1÷2Hz)
– *cordial rhythm* (1÷2Hz)
– *walking rhythm* (1÷2Hz)

Rhythmical Musical Microform

This has very strict musical bars and strict periodical "strong parts" (appearing strictly as the above mentioned quasi-actions) associated with musical rhythms, and having the same frequency diapason.

Musical rhythms and musical intonation are connected to the expression of different ***emotional states*** of the human being. For example, *a state of ecstasy or an intensive physical fight* is expressed by the relatively higher musical rhythm (i.e., in our functional interpretation – higher quasi-actions frequency, heartbeat, and correspondingly *shorter time-periods for a signal comparison in memory*). For example, the *state of relaxation* could be expressed by relatively slower musical rhythms (i.e., slower quasi-actions frequency, heartbeat, and correspondingly *longer time-periods for a signal comparison in memory*). The pattern comparison mechanism, corresponding to the parallel neuronal fields, will be proposed below.

6.4 COMPARISON OF NEURONAL SIGNALS – FUNCTIONAL ROLE OF ALPHA-BEATS

How does one compare two typical neuronal pulls, moving periodically in time, with the frequency of an Alpha-rhythm? Assume that there are (a) sensory neuronal signal-patterns moving outside, and (b) neuronal signal-patterns recorded in the memory (Fig. 6.1–3). It has been proposed (Gribov, 1977b) that the mechanism for patterns comparison is similar to the mathematical operation of cross-correlation between two comparative signals. This correlation process could be realized by the small stable difference $\Delta f = fa - fb$ near 1Hz between (a) and (b) Alpha-rhythms in these comparable signals. In this case, two pulls will, step-by-step, *shift* in time relative to each other (Fig. 6.1–3). If they are equal and converge on any comparing neuron, the comparing neuron will have only one maximum response inside the time interval $\Delta T = 1$ second. If many parallel neurons, detecting these comparative summations, simultaneously receive this maximum summation the signals will be accepted as similar. In the graph (Fig. 6.1–3) the maximum summation is T=0 and T=1.0 second.

Usually, Alpha-waves have an EEG typical form of *beats,* with a typical period $T \approx 1$ second. Assume that $\Delta fab = 1$Hz, f(a)=11Hz, and f(b)=10Hz. In this case, the superposition of EEG Alpha-waves, corresponding to (a) and (b) synchronized neuronal subgroups, will also have the form of beats with the period T=1 second (Fig. 6.1–3). Thus, the presented neuronal model can explain the signal comparison and functional role of Alpha-beats within it. On the other hand, the beats-period corresponds to the period of the above-mentioned periodical quasi-actions.

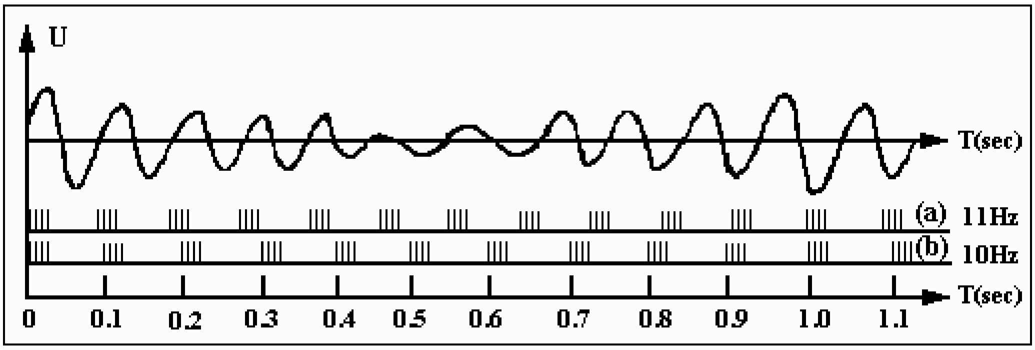


Fig. 6.1–3

Thus, the "Neuro-Muscular Module" (MM) concept helps to generalize the idea of the movement program transference and, thus, the universal application of the so-called movement stereotypes. This is important particularly in the context of BFA. It helps to formulate and enable the understanding of some of my own experiments with manual activity, connected to the commissural transmitting of movement programs between two hemispheres (as in writing and drawing with different hands, see below), and it also helps to suggest some manual methods by which the human creative and aesthetic potential can be activated.

6.5 RECENT EVIDENCES FOR OUR MUSCULAR MODULE (MM) HYPOTHESIS

A Review by Bizzi and Mussa-Ivaldi

New and decisive evidence in favour of the MM hypothesis came from recent research reviewed by Bizzi and Mussa-Ivaldi (2000). The authors suggested that the central nervous system plans movements in terms of spatial or extrinsic coordinates, rather than body-centered coordinates. The authors also reviewed a number of theoretical and experimental findings suggesting that the coordinate transformations, leading to the execution of a motoric plan, are implemented by a small number of *control modules*. In particular, some recent experiments in the spinalized frog have suggested that these control modules may be organized by the spinal cord as simple synergies of spring-like muscles. Subsequent theoretical work has revealed that a wide variety of motoric control policies can be obtained from a simple linear combination of these few control modules (as was also proposed for the MM mechanism).

The MM hypothesis includes the concept that effector movements are determined by extrinsic objective space, that is, the extrinsic "system of space coordinates." The concept that movements of the hand are planned by the central nervous system (CNS), in terms of extrinsic coordinates, is related to the hypothesis that the planning and execution of movements constitute two separate stages of information processing (Bernstein, 1967; Hogan, Bizzi, Mussa-Ivaldi, & Flash, 1987). According to this view, during planning, the brain is concerned with establishing movement kinematics – that is, a sequence of positions that the hand is expected to occupy at different times. Morasso (1981) also suggests that the planning of arm movements is carried out in extrinsic coordinates that represent the motion of the hand in space.

Recent experimental findings by Flash and Gurevich (1992) have demonstrated that the kinematics of movement is planned independently of the dynamic conditions in which movement occurs. In addition, recordings from cells in cortical and subcortical areas of monkeys have shown a correlation between the cells' firing pattern and direction of the hand's motion (Caminiti, Johnson, & Urbano, 1990; Georgopoulous, Kettuer, & Schwartz, 1988a, 1988b; Kalaska, Cohen, Hyde, & Prudhomme, 1989). It appears that the activity of certain classes of cortical cells in the motoric cortex is represented in spatial coordinates without any specification as to how the muscles should be engaged to produce the forces necessary for the movement. Taken together, the psychophysical and electrophysical evidence points toward a hierarchical organization of the motoric system with the higher centers of the CNS representing motoric goals in spatial coordinates.

There is the common problem of movement execution in the CNS: it must transform information on a small number of concrete movement variables (direction, amplitude, velocity) into a large number of signals for many muscles. Because of the many muscles surrounding each joint, the net force generated by their activation can be achieved by a variety of combinations of muscles. This involves the simultaneous activation of many thousands of motoric units belonging to a number of muscles. The complexity inherent in controlling so many degrees of freedom has led these authors, and a number of other researchers, to propose that the nervous system must have developed methods to simplify these problems (Bizzi & Mussa-Ivaldi, 2000). For instance, Hollerbach and Atkeson (1987) have suggested that the CNS first derives the motion of the joints from the planned path of the limb's endpoint (inverse kinematics).

An alternative proposal suggests that the CNS may transform the desired hand motion into a series of equilibrium positions (Bizzi, Accornero, Chapple, & Hogan, 1984). The forces required tracking the equilibrium trajectory result from the intrinsic elastic properties of muscles and from local feedback loops (Bizzi, Hogan, Mussa-Ivaldi, & Giszter, 1992; Bizzi, Polit, & Morasso, 1976; Feldman, 1974; Hogan, 1984).

In the past few years, Bizzi, Mussa-Ivaldi, and Giszter (1991), Giszter, Mussa-Ivaldi, and Bizzi (1993), Mussa-Ivaldi, Giszter, and Bizzi (1994), and Satiel, Tresh, and Bizzi (1998) proposed that the "motoric behavior of vertebrates are based on simple units (motoric primitives) that can be combined flexibly to accomplish a variety of motoric tasks" (Bizzi & Mussa-Ivaldi, 2000, p. 491). One of the most remarkable experimental evidences for spinal cord modules derived from the microstimulation of the frog's spinal cord. It was found that the force fields, induced by the focal activation of the spinal cord, follow the principle of *vectorial summation*, and that these force fields look like *modules of control.* These authors reach an overall conclusion, which corresponds to the MM hypothesis (as presented above) that the spinal premotor circuits are organized in a relatively small number of modules. Even anatomically they are identical to our MM, realizing one-dimensional movement, while "each module establishes – presumably via propriospinal connections – a common drive to a set of agonist and antagonist muscles" (Bizzi & Mussa-Ivaldi, 2000, p. 494).

Two major experimental findings also strictly verify our principle of MMs and the principle of their superposition (Gribov, 1977a) in the case of complicated (more than one degree of freedom) movements. Namely, "stimulation of several sites across the lumbar spinal cord produced only a few qualitatively distinct force fields," and "the force fields generated by spinal microstimulation were *added vectorially* when two stimuli were applied simultaneously in two different spinal sites" (Bizzi & Mussa-Ivaldi, 2000, p. 495).

On the basis of these new findings, the hypothesis was suggested (in accordance with our MM hypothesis (Gribov, 1977a) that the motoric system may create a variety of movements by the superposition of the force fields produced by a small set of independent spinal modules. This hypothesis has been tested in simulation studies by Mussa-Ivaldi and Giszter (1992) and Mussa-Ivaldi (1997).

It is interesting to compare the mechanism realizing robotic limb movements with the spinal cord modular mechanism. In robotics, a desired trajectory arises as a temporal sequence of corresponding positions of the limb and the robotic limb uses few electrical motors as ideal force generators (Brady, Hollerbach, Johnson, Lozano-Perez, & Mason, 1982). A radically different scenario is offered by the spinal cord modules: "the desired trajectory of the limb is not translated by the supraspinal circuits into a temporal sequence of force commands, but instead, into a set of commands that select and tune a corresponding set of independent modules of control" (Bizzi & Mussa-Ivaldi, 2000, p. 496).

The spinal force fields offer a simple way to generate movement, and also provide the CNS with a corresponding movement representation. "This representation is similar, geometrically, to the representation of space by a *set of Cartesian coordinates*. In the latter case, we may take three directions – represented by three independent vectors – and then project any point in space along these directions. As a result, an arbitrary point in space is represented by three numbers. The movements of a limb can be considered "points" in an abstract geometrical space. In this abstract geometrical space, the force fields produced by a set of modules play a role equivalent to that of the Cartesian axes, and the selection parameters that generate a particular movement may be regarded as generalized projections of this movement along the modules' fields" (Bizzi & Mussa-Ivaldi, 2000, p. 497).

Similar Cartesian modular representation, for a voluntary movement trajectory, was proposed in our MM-model, since it is a natural occurrence in physics (mechanics). The MM-principle of movement control, for all natural limbs, gives the CNS the opportunity to restore some learned movement programs and use them later for other limbs of the body, which explains the ability of the human species to shift any movement program from one effector to the other, or from one working muscular group to the other, e.g. realizing the movement of the same effector with more than one limb (Gribov, 1977a). Bizzi and Mussa-Ivaldi, (2000) made the same conclusion about simple learning opportunities in CNS. But, they noted that there is currently no strong experimental evidence to resolve this issue. Unfortunately, they did not discuss the mechanism of the movement program shifting from one effector to the other. They also commented briefly, but significantly, that there could be some similarities between the visual and motoric system organization, connected to "the possibility of constructing invariant representations within the motoric system resting on the existence of independent primitives – the spinal force fields – that form a basis for constructing a variety of behaviors" (Bizzi & Mussa-Ivaldi, 2000, p. 498).

For a better identification of our MM-model with the model based on the spinal cord modules it is important to note that experimental variable intensities of stimulation in the frog's spinal cord resulted only in changes of the force field amplitude, but not in changes of force directions (Giszter, Mussa-Ivaldi, & Bizzi 1993). This means that the modulation of the intensities of the cord's stimulation could generate one-directional (one-dimensional) movement with different amplitudes.

6.6 EEG-VERIFICATION OF OUR NEURONAL ALPHA-GROUPS MODEL

The Scanning Hypothesis

Pitts and McCulloch (1947) postulate the *spreading of an excitatory wave over the visual cortex with the frequency of the Alpha-rhythm*. This was tested in experiments with 27 human subjects (Shevelev & Kamenkovich, 1997). They compared the recognition of figures from different forms and sizes and the recognition of the direction of apparent light motion when they were *asynchronous or synchronized to different phases of the EEG Alpha-wave* recorded over the occipital cortex. They found the following:

(a) a better recognition of *small figures* in relatively *late phases* of the Alpha-wave;
(b) a better recognition of *large figures* – in *early phases*;
(c) the perception of constant-velocity motion was not changed by linking it to the Alpha-wave phase.

These authors concluded that the EEG Alpha-wave reflects the periodical excitatory process that evenly scans the visual cortex, from its near periphery, to its central area, and that this process plays a substantial role in visual processing and recognition.

Comments

These data do not contradict the neuronal "working functional Alpha-group" hypothesis. That is, one single Alpha-group being able to perceive a stimulus. However it depends on the Alpha-phase. Inside the Alpha-period (approximately 100ms) a process of signal comparison is realized, as proposed in chapter 6.4. The differences between (a) and (b) could be connected to a faster velocity for the axonal transmission of neuronal information, carrying the *low space frequencies* (Global aspect – large figures) compared to the high space frequencies (Local aspect – small figures), corresponding to the data of Kitterle, Christman, and Hellige (1990), as mentioned in chapter 1.5. It could also explain the functional role of the wide thickness-spectrum of callosal fibers, providing different transmission velocities for neuronal signals (Carr, 1993; Nalcaci, Basar-Eroglu, & Stadler, 1999). It appears that the Global informational aspect (relating to Global sensory space) is transmitted by the thick fibers and the Local informational aspect (relating to Local sensory space) is transmitted by the thin fibers.

Note: It is quite natural that a *larger sensory space – lower space frequency* involved in the Fourier spectral summations must have a *larger surface (size) of converging neurons* for a vast number of input dendrites and, correspondingly, *thicker axonal output* (i.e., the converging Fourier-neuron being larger in size and having *thicker fibers* could be able to realize this Global summation, which is connected to the low space frequencies).

Therefore, we propose that the behavioral (e.g., time) priority of the Global information aspect in the Gestalt psychology (identification of the global forms being faster than the local forms, Navon (1977) in chap. 1.2 of this study) is determined by the neuro-structural specific of the Fourier-transformation and that this Fourier-neuronal structure is strictly complementary to the behavioral priority!

The Hypothesis of Short-lived Cortical Excitations – Alphons

Williamson, Kaufman, Lu, Wang, and Karron (1997) discovered that Alpha-rhythms of the parieto-occipital area are expressed as *short-lived cortical excitations (alphons),* each of them exhibiting oscillations, which have a stable period within the Alpha-bandwidth. Strong Alpha-rhythms are produced by the alphons activity superposition extending over a larger cortical area. They found that local suppression of Alpha-rhythms indicates which specific cortical areas become engaged in sensory or cognitive functions (e.g., in mental imagery, visual memory, auditory memory, silent rhythming):

(a) *Visual stimulation* results in the modulation of occipital Alpha-activity, and a modulation envelope fluctuating in step with a visual stimulus (Kaufman & Locker, 1970).
(b) *Visual searching memory*, previously *seen as visual forms*, also results in the suppression of the occipital Alpha-activity and that the duration of this suppression varies with the time required for the subject to indicate the completion of a task.

(c) *Auditory searching short-term memory,* for previously heard tones, results in a suppression of Alpha. In this case, the duration of suppression correlates with the subject's reaction time and occurs over the right temporal cortex.

The authors conclude that such changes in ongoing Alpha-activity provide a new dimension for the study of brain activity that corresponds with the position of Basar (1980).

They found evidence that the occipital Alpha-rhythm, measured within the bandwidth 8–13Hz can be accounted by transiently appearing excitations of local cortical regions. These rhythmic excitations were named "alphons." This rhythmical activity is associated with thalamo-cortical and cortico-cortical interactions.

The *spatio-temporal* evolution in these rhythms is similar to patterns in the *Alpha magnetic field* outside the head.

They tested an *average local Alpha field power* on the scalp that allowed differing locations of cortical events related to sensory or cognitive processes.

They also recorded a magnetic field near the occipital scalp showing that the underlying cortical source consists of a "parade of excitations" at different locations that individually grow and subside in strength and which have a cortical area of approximately 3 cm^2.

The Nature of the Alpha-rhythm

The *physiological basis* of the occipital Alpha-rhythm is connected to the initial oscillation generated within the thalamus by a circuit involving neurons whose membranes exhibit intrinsic oscillatory behavior (Jahnsen & Linas, 1984a, 1984b; Steriade et al., 1989).

Bursts of these oscillations are projected onto different cortical locations from where they spread at a rate of 0.3–1m/s. Consequently, within one period of the oscillation, the cortical excitation could extend to a distance of approximately 3 cm.

Lopes da Silva, (1991) suggested that a function of the Alpha-rhythm may be to set the mean level of the cortical membrane potential in the local areas of the cortex.

The Alpha-rhythm is not a narrow-band filtered Gausssian noise (Dick & Vaughn, 1970).

The Typical Spindle Waveform of the Occipital Alpha-rhythm

The typical waveform of occipital Alpha-rhythm (8–16Hz) appears as a *series of spindles* (Williamson et al., 1997).

The period stability between zero crossings in the Alpha-wave formed *inside the Alpha-spindle* provides evidence that it is *not a pure random noise, although* the individual Alpha-sources of these spindles have a temporally coherent structure.

When one spindle disappears and another appears there is an abrupt change in both location and period. It motivated Williamson, Wang, and Ilmoniemi (1989) to introduce the term *"alphon"* as a generic term for these cortical excitations.

If the second harmonic component (within 16–24Hz) is not removed, by filtering, periodical oscillations will have an arcuate wave-form with sharp up- and flattened down-peaks (as it is in the *μ-rhythm* of the central sulcus (Tuhonen, Kajola, & Han, 1989).

Comments

The *"alphon"* (with the essential attribute of a typical spindle), according to our "working Alpha-group" model and proposed mechanism of neuronal pattern comparison, is the doublet of two comparing α-groups with slightly different Alpha-frequencies $\Delta f \approx 1$Hz. It provides the base for the mechanism spindle-form, and emits a *free-running* process of comparison between the sensory input pattern and a sort of memory pattern. It is connected to the readiness of the cortex to perceive i.e. to start the process of comparison between neuronal patterns. Possibly the thalamus, as an outside source of synchrony Alpha-rhythm activating, automatically generates these two Alpha-groups.

Alpha-Suppression

Alpha-waves can be suppressed when the supporting cortex becomes occupied in a sensory or cognitive task (Basar, 1980; Hari, Salmelin, Mäkelä, Salenius, & Helle, 1997; Kaufman & Locker, 1970; Klimesch, Pfurtscheller, & Mohl, 1988; Pfurtscheller & Aranibar, 1977; Pfurtscheller & Klimesch, 1992; Salmelin & Hari, 1994; Slatter, 1960).

Interpretations of Alpha Suppression (Williamson et al., 1997):

(a) It could be the disturbance of an ongoing parade of *"alphons."*
(b) It could be that two *"alphons"* have currents which are synchronous and oppositely directed, where the summated Alpha-power will be suppressed. But, authors believe that this is an *unlikely event*.
(c) The widespread assumption is that synchronization underlies Alpha-enhancement, and desynchronization underlies its blockage.

Comments

The interpretation under (b) is compatible with the above proposed mechanism of signal comparison in the probable sensorial world (Gribov, 1977b): the Alpha suppression is connected with the few parallel working α-groups, having uniformly shifted wave-phases, and an almost equal density of synchronized neurons that automatically suppresses the Alpha-harmonic in the EEG superposition. This suppression mechanism is similar to the motoric activity in the *rolandic* area according to our MM model. Williamson et al. (1997) agree with the interpretation (c) although it has no visible constructive reason. However, this is repeated in many articles as a basic empirical fact, but with the missing theoretical explanation.

EEG Data – A Review from Pfurtscheller

This review shows that:

(a) The *EEG α-desynchronization* is a reliable correlate of excited neural structures, or activated cortical areas;
(b) The *EEG α-synchronization* may be an electrophysiological correlate of deactivated cortical areas. Such areas are not processing sensory information, or motoric output, and can be considered to be in an *idling state*. One example of such an idling cortical area is the enhancement of μ-rhythms in the primary hand area during visual processing, or during foot movement. In both cases, the hand area neurons are out of visual processing, or in preparation for foot movement (Pfurtscheller, Stancäk, & Neuper, 1996).

The excitative stimulation of cortical structures, mediated by the thalamo-cortical systems, leads to a *low amplitude desynchronized* EEG pattern (Steriade & Lunas, 1988). This is, for example, the blocking of occipital Alpha-rhythms during visual stimulation and the blocking of central μ-rhythms during somatosensory stimulation or movement (Berger, 1930; Gastaut, 1952). It is the event-related desynchronization (10Hz) that is task-specific (information processing, selective attention, motoric preparation), which takes place in the task-relevant sensory and motoric areas (Pfurtscheller & Aranibar, 1977; Pfurtscheller & Klimesch, 1992). Cortical idling has both an intermodal and an intramodal basis (Pfurtscheller, et al., 1996).

The size and magnitude of ERD reflects the mass of neural networks involved in the performance of a specific task at a specific moment in time. For instance, task complexity increases the magnitude of ERD (Sergeant, & Geuze, 1984; Van Winsum,).

Comments

These data do not contradict the hypothesis of a “working α-group.”

μ-Rhythms in the Sensomotoric Cortex

The *μ-rhythm* corresponds to specific projection areas in the sensoimotoric cortex and is congruent with the primary motoric cortex, connected with different effector projections. For example, the hand, foot, and face areas show rich internal connections, but few connections between areas (Donoghue & Sanes, 1994). The hand area μ-rhythm is a prominent μ-rhythm and is desynchronized during movement.

Beta-Rhythms – Connected with μ-rhythms

Salmelin and Hari (1994) suggested that neural structures generating central ***Beta-rhythms*** are located slightly more anterior relative to the cortical areas exhibiting μ-rhythms. Beta-components are very often a first harmonic of the μ-rhythm (Huber, Kleiner, Gasser, & Dumermuth, 1971). The preparation and execution of movement results in a blocking of both frequency components.

Alpha-synchronized EEG Describing a Resting Cortical Area

In this area, no information is currently processed (there is no sensory input, or motoric output). For example, when the sensorimotoric hand area passes from ‘cortical work’ during preparation and execution of finger movement into a state of ‘nil-work’ or ‘idling,’ then no further motoric commands are sent to the muscles controlling finger movement, and no more afferent stimuli from the cutaneous touch and pressure receptors reach the somatosensory cortex (Pfurtscheller et al., 1996).

Note: The effective learning of language in the state of suggestive relaxation shows that in the suggestive, relaxing, psychic states even more effective “suggestive perception” is possible on the background of the “idling” high Alpha-rhythm in EEG than it is in case of the Alpha-rhythm suppression (Losanov, 1971). This phenomenon was discussed above in the context of our neuronal model and in chapter 6.2, where it has a natural explanation. Some recent studies also showed synchronized Alpha-band rhythms *before omitting stimuli* (Basar, Basar-Eroglu, Röschke, & Schütt, 1989).

Pfurtscheller et al. (1996) assumed that it is not contradictory to the idling hypothesis when there are always scalp electrodes showing synchronized and desynchronized Alpha- (Beta-) reference band-rhythms at the same moment of time.

Klimesch, Schimke, Ladurner, and Pfurtscheller (1990) and Klimesch, Schimke, and Pfurtscheller (1993) also showed that subjects with a good memory performance have a significantly higher Alpha-frequency component compared to subjects with bad memory performance.

Klimesch (1999) proposed that α-synchrony during mental inactivity (idling) is important to introduce powerful inhibitory effects, which could act to block a memory search from entering irrelevant parts of neural networks.

Comment: The high amplitude α-synchrony is probably connected with the *awake intermediate, pre-operative state* – then, in the awaking pre-sensory state, only one working "waiting" Alpha-group is created. This dense Alpha-group could be quickly separated into a few parallel sub-groups with regularly shifted phases of corresponding Alpha-rhythms where the α-synchrony expresses *pre-readiness* to process information in the corresponding neuronal area.

Steriade and Lunas (1988) reported that the reduction of cortical information processing could be the result of a block of synaptic transmissions through the thalamus, also when typical α-spindles during unconsciousness arise (Lopes da Silva, 1991).

Petche (1996) formulated the concept of EEG synchrony between different neuronal zones: Neuronal areas are collaborating in the case of synchrony and are not collaborating in the opposite case.

Comments

This means that *"working neuronal groups",* which have different sizes and involve different local functional cortical areas in the *cooperative cortical processing*, connect together different "Fourier-windows."

Biophysical Features of 10Hz EEG Waves

(a) The attenuation of 10Hz EEG waves from the cortex to the scalp is approximately 5000:1;
(b) the potential measured on the scalp is the spatial average over an area of some cm² (Cooper, Winter, Crow, & Grey, 1965; Lopes da Silva, 1991). This means that the cortical neurons within some cm² must display *a high degree of synchronized activity.* Disparate activation of these cortical neurons results in desynchronized EEG.

The Functional Meaning of 10Hz EEG Waves

Alpha-Desynchronized EEG is an electrophysiological correlate of activated cortical areas (Pfurtscheller, & Klimesch 1992; Pfurtscheller et al., 1996). For example, corresponding synchronized activity at approximately 40Hz indicates active involvement of a cortical area in information processing and motoric preparation.

6.7 FUNCTIONAL ROLE OF THE GAMMA BAND – 40HZ

Our Proposal: The "approximate 40Hz" activity in the *α-desynchronized EEG* could be connected with the regular collective spike segmentation inside one *α-period* in the general comparison process that involves a number of shifted Alpha-doublets (each has $\Delta f \approx 1$Hz). That is, it expresses an average number of such spikes (approximately 4 inside a Alpha-period, see Fig. 6.1–3).

Gamma waves arise "spontaneously and/or can be evoked, induced, or emitted with different latencies and relations to sensory cognitive events" (Basar-Eroglu, Strüber, Schürmann, Stadler, & Basar, 1996b, p. 101).

Basar-Eroglu, Strüber, Kruse, Basar, and Stadler (1996a) also found that gamma-wave presence is increased during the viewing of a *reversible pattern*.

Basar and Demiralp (1995) and Basar, Basar-Eroglu, Demiralp, and Schürmann (1995) hypothesized the existence of a "diffuse, distributed, and parallel processing *gamma system* in the brain."

Gamma waves have a key function in the perception of the olfactory bulb in rabbits and cats. Awake and motivated rabbits and cats show characteristic gamma-bursts of 40–80Hz (Freeman, 1975; Freeman & Skarda, 1985).

On the basis of his experimental studies with rabbits and cats, Freeman proposed that gamma waves could be indicators of *activated neuronal templates, working as a selective filter for search and detection of the expected odor* (Freeman, 1979).

According to Basar, Rosen, Basar-Eroglu, and Greitschus (1987) and Pantev, Elbert, and Lütkenhöner (1994), the 40Hz activity represents information processing of the brain similar to the 10Hz activity.

Comments

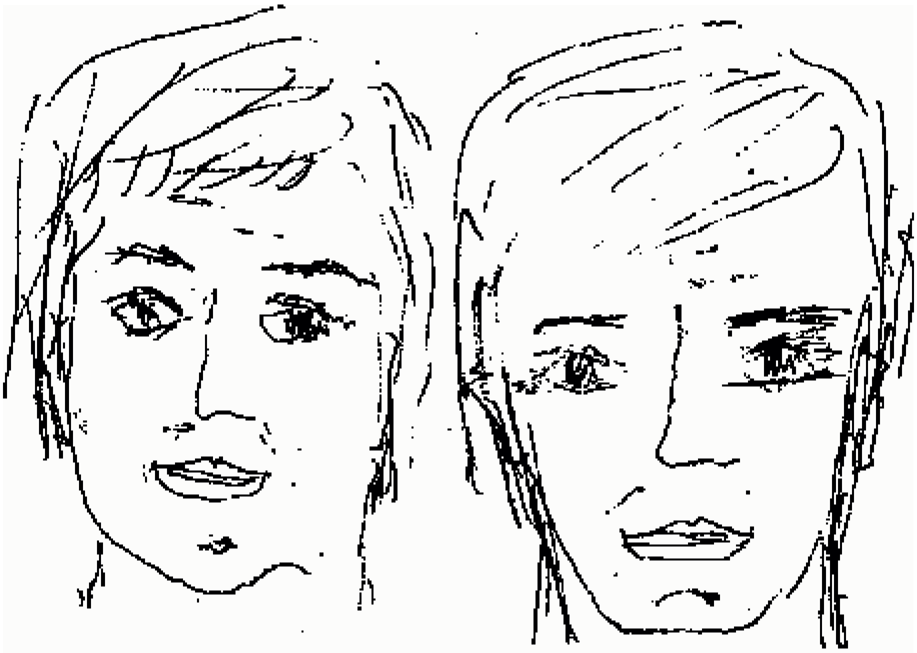
This phenomenological proposal from Freeman (1979) has a direct connection (even in terminology) to our neuronal working Alpha-group model, mentioned above, if we take into account the neuronal mechanism of the signal-template comparison (Gribov, 1977b). This mechanism is illustrated in Figure 6.3, where repetitive, neuronal Alpha-spike packets of the sensorial signal (f=11Hz) and the neuronal template (f =10Hz) are compared. They can be strictly compared because of regular timing micro-shift steps (approximately $\Delta T=0.01$ second) between these spike-packets. Superposition of such Alpha-waves and shifting packets, in these two working (Alpha-synchronized) neuronal populations, will create not only common Alpha-spindles – "alphons" – with Alpha-wave packet periods of approximately 1 second, but also the high frequency gamma-wave modulations in EEG that reflect step-by-step increasing synchronization of the shifting spike-packets in this process. Thus, it is possible to propose that gamma-wave units are connected to the above mentioned comparison process, and propose calling them "*gammons*", by the way of analogy with the "alphons". Gamma bands, with a frequency diapason of approximately 30–40–60Hz, correspond to a typical number of neuronal spikes in one Alpha-packet. Inside the Alpha-period, with $\Delta T \cong 0.1$ second, this has approximately 3–4–6 spikes.

Thus, according to our theory, this means that the activation of the comparison process (with corresponding gamma waves) corresponds to the focused cortical arousal. In this process neuronal cortical fields take part, where this is projected input information.

40–60Hz oscillations occur in synchrony with cells located within a functional column in the cat's visual cortex, and are tightly correlated with oscillatory field potentials (Gray & Singer, 1987, 1989).

Moreover, Fourier-neurons, in spatially separate columns, synchronize their oscillatory responses if they correspond to the same Fourier-image. Gray and Singer (1987) proposed that this synchronization establishes relations between features in different parts of the visual field.

It appears that a block of the above-presented basic EEG data could be correctly explained by our neuronal hypothesis (Gribov, 1977a, 1977b).

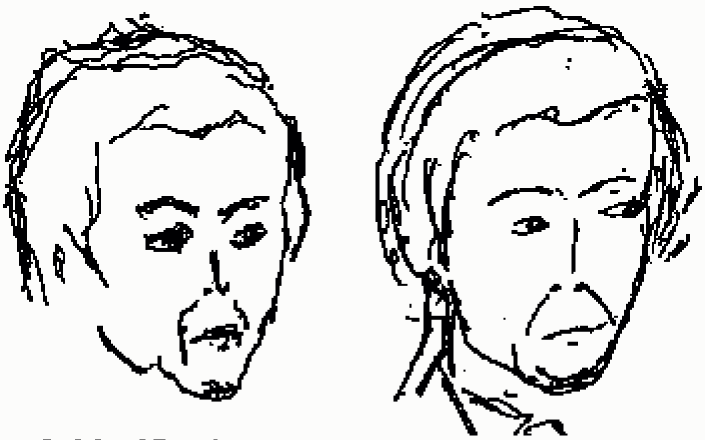


Left-hand Drawing Right-hand Drawing

Fig. 7.1-1

Left-hand Drawing Right-hand Drawing

Fig. 7.1-2



Left-hand Drawing Right-hand Drawing

Fig. 7.1-3

III. EXPERIMENTAL STUDIES – CONNECTED WITH BFA

7. ARTISTIC CREATIVITY AND BRAIN FUNCTIONAL ASYMMETRY (BFA)

Summary

In this part, some simple mechanisms of hemispherical *functional correction* are shown to influence the aesthetic quality and style of artistic work (left-handed drawing, drawing, and arithmetic calculation).

Right-handed portraits from right-handers look like stamps, and have a kind of negative emotional impression, but their *left-handed portraits* are integrative, individual, and emotionally sympathetic.

The compositional center of pictures has leftward shifting in pictures of *famous artists* and in *non-professionals* (children and students) showing, here, the dominance of the RH visual perception. These data are useful for compositional art design, in advertising, etc.

"The secret of artistic visual form": an integrative, flat, laconic, "left-handed" drawing style is similar to the style of many eminent artists, which could be explained by the deep RH involvement in outstanding art.

The nature of aesthetization of visual forms, typical in outstanding art, could be explained by an account of two opposite psychic states: relaxing and imaginative (RH dominance) and the active outside attention (LH dominance). In a state of relaxation, usual, spatial, and analytical dismemberment of the visual field becomes more leveled, holistic, and more flat-like. These space transformations are often found in great works of art. Such visual features work on onlookers as a *reflex key* and an *inductor* to a corresponding psychic state. In synthetic art (cinema), the "secret of artistic form" was formulated by Eisenstein (1980) as a "*correlation between affective and rational.*" In other words, as a dynamic correlation between the RH and LH functional poles.

7.1 PORTRAIT DRAWING – USING THE RIGHT AND LEFT HAND

These data (based on a normal population) were yielded by research into the drawing process (Gribov, 1980, 1988). Large samples *of right-handed children* (7–11-years old) *and adults* (18 years old), with approximately 70 people in each age group, produced two portraits from nature (using the left and right hand), (Fig. 7.1–1, 7.1–2, 7.1–3).

The left- or right-*handedness* of each student was tested using the standard test, indicating the preferred hand in specific activities (writing, drawing, throwing, using scissors, applauding, and the crossing of fingers and hands). The subjects were also asked, "Are you a right-hander or a left-hander?" Additionally, the leading eye was tested. For further left-handed and right-handed portrait comparisons we selected portraits made by students with the leading right hand and right eye.

The drawing task started with students of each age group using the left or the right hand so that the first hand used and side of the sheet of paper was random. Persons drawing these portraits completed the first portrait on the sheet of paper and then turned this sheet over and started drawing the second portrait. Thus, they could not see the first portrait.

These pairs of portraits (Fig. 7.1–1, 7.1–2, 7.1–3) were compared by a *group of professional experts*. These experts (11 persons) were *professional artists*, who were chosen from a group of artists with high artistic abilities. These experts did not know the purpose of the study. Each expert received instructions to choose the better portrait between the two portraits (according to their personal artistic preference).

The *statistical hypothesis that the left-handed portraits* (for groups of the right-handed students) *would be preferred* was tested. This hypothesis was verified by the group of professional artists.

Prevalence of the left-handed portraits (they were chosen to be better), for all age groups of students, was *statistically significant* for all ages with $p<.01$.

After their assessment, each expert was requested to explain their reasons for selecting the respective portraits. It was found that experts preferred the left-handed portraits because these tended to be *more integrated* and with harmonious proportions. They showed *laconic*, less unbroken contours, and *more lively lines*. They had *more individual expression and were more sympathetic emotionally* (compared to the right-handed portraits).

The *right-handed portraits* were described, usually, as emotionally barren and schematic, looking like *stamps*, and even giving a more *aggressive impression*; these portraits were often described as having loose compositional unity and proportions, with *lifeless and rugged coarse lines*, corrected many times.

Interesting emotional assessments of these portraits were given by a group of children (ages 7–8). They usually rated the left-handed portrait as “good,” “kind,” “sweet,” “clever,” and the right-handed portrait as “angry,” “wicked,” “stupid,” and “misunderstood.” But, it is interesting that, at the same time, they often preferred the right-handed portrait because it was “more accurate.”

Nikolaenko (1982) also detected the figural activity of the LH and the RH, but he examined this during the time of the unilateral electroshock treatment of right-handed patients, so one or the other hemisphere was blocked by electroshock. His patients made drawings from their imagination. He found very similar differences in the right-handed and left-handed drawings as described above (Gribov, 1980). If the RH was normal, but the LH was blocked by the electroshock, the corresponding left-handed drawings had a distinct form with a closed contour made by one unbroken, confident line. The RH was able to form an *integral perceptual image*, which was *original and individual*. Remote elements of the three-dimensional object were drawn in the *reverse perspective*. In the opposite case (active LH and blocked RH) figures had an improper asymmetrical form with broken uncertain lines and degraded contours. They *had no plasticity and the picture was badly composed,* it was often only part of the whole pictured object, and they looked like *schematic templates*. They could also be only symbolic replacements of images, and even words, instead of the picture.

Our data, together with the portrait drawing and data from Nikolaenko, illustrated *two different paradigms in art* relating to the LH and to the RH art expression. It correlates with our general theoretical approach relating to the Fourier model of BFA (chap. 1.6), namely, that:

(a) The laconic RH-style of drawing, accentuating the Global aspect of visual fields, uses the Global motoric Fourier lower frequencies, creating more individual, holistic, and emotional images. This structure works as the *Global sensomotoric Fourier-complex.*
(b) The "verbose" LH-style of drawing, losing this spatial integrity, plasticity, and emotional completeness, gives portraits less individuality and works as the *Local sensomotoric Fourier-complex.*

These Fourier-complexes are extremely important, because the sensory system serves corresponding (Global space-time and/or the Local space-time orientated) motoric actions.

This data also confirms the *superiority of the left-hand* – for example when subjects *match unseen objects* with unassembled, geometric forms presented in free vision by hand: the right hand made a significantly greater number of errors compared to the left hand. As the object contours became less geometrical and more free form, the right-hand matching skills seriously decreased, whereas the left hand continued to show the same strong level of response (Franco & Sperry, 1977).

Our data could be *useful for art education and aesthetic and intellectual development, in general*, because using the left hand provides easy, direct access to the "Global visual resources of the RH" for right-handed children and adults. In collaboration with the methods proposed by L. Tadd, it could be used to increase the RH/LH functional balance and functional cooperation.

7.2 WRITING WITH INVERSION OF HANDS

The concept for this experiment originated in our study concerning the *MM hypothesis* (chap. 6.1), and is related to the corresponding principle of transferring movement programs from one effector to another (Gribov, 1977a).

We have previously investigated *the transference of writing stereotypes* (from the right hand to the left hand) (Gribov, 1980, 1988). The task of writing normal oriented letters of the Russian alphabet was given *to right-handed* persons.

However, in these experiments *each hand had two writing positions*: the first being usual (Right, Left) hand-posture and the second with palms turned longitudinally through ✻180° (Right*, Left*). In postures Right* and Left a tendency to invert the letters horizontally (as speed increased) was this found (Fig 7.2–1), but it was not the case in positions Right and Left*. Moreover, in the position Left*, writing with the left hand appeared to be facilitated in comparison to its usual position (Left).

This can be explained as follows: *Writing stereotypes are localized in the LH* and are connected directly to the right hand (this is typical for the right-hander); if they pass to the left hand – a mechanism of symmetrical commissural inversion (180° in the horizontal direction) of writing stereotypes commences to work. If writing is not fast, the brain has time to correct this inversional distortion, but in fast writing it has no time to do this and, therefore, inverts the letters. However, the turning of the left hand through 180° adds another 180° of horizontal inversion and, therefore, 180°+180°=360° (no inversion).

These data deliver a simple, *practical method* of correction of the interhemispherical connections, that is, the *block or facilitation* of the realization of moving stereotypes in the left-side, or right-side of the brain. In figurative work, for instance, it is better to have a Right* position of the right hand or Left position of the left.

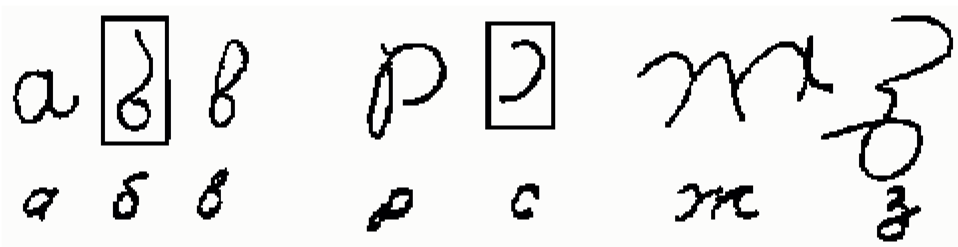


Fig. 7.2–1 shows an example of seven particularly inverted Russian letters (above) and for comparison the same letters written in their usual form (below).

7.3 DRAWING AND ARITHMETICAL ACCOUNT INTERFERENCE

Another mechanism of inter-hemispherical correction was found in experiments with interference of two polar kinds of activity. Artists, who preferred to draw lines by *"small strokes,"* were chosen for these experiments. They had the task of drawing the figure of a man (from nature) with the right hand, and, at the same time, solving verbal arithmetical tasks presented at high speed (orally) by the experimenter. This interference changed the analytical drawing strategy – painters spontaneously began to produce large elements, drawing forms in one, fast, complete line.

Evidently, at this moment, the active, analytical mechanism (LH) needed to draw was suppressed (by the focus on arithmetical problems) and the supportive (more adequate for this type of task) mechanism of complete RH-sensomotoric dominance was facilitated.

7.4 LEFT/RIGHT SHIFT PREFERENCES IN ART COMPOSITION

These experimental data correspond well to our general theoretical approach related to the Fourier model of BFA (chap. 1.6).

The functional difference of the left-sided and right-sided visual field is well known. We investigated the leftward shifting of the compositional center in visual art: (a) in connection with great artists, and (b) in connection with the right-handed and the left-handed portraits of right-handed children and adults (from our previous study in chap. 7.1).

The experimental procedure indicating the left/right compositional shift followed where we indicated two compositional states: (1) a shift to the left of the middle, vertical, straight line, and (2) a shift to the right of the middle, vertical, straight line, which symmetrically divided the picture into two rectangular fields. A small number of compositions, which were strictly centered in the investigated samples, were symmetrically (50%–50%) added to state (1) and to state (2) (Fig. 7.4–1).

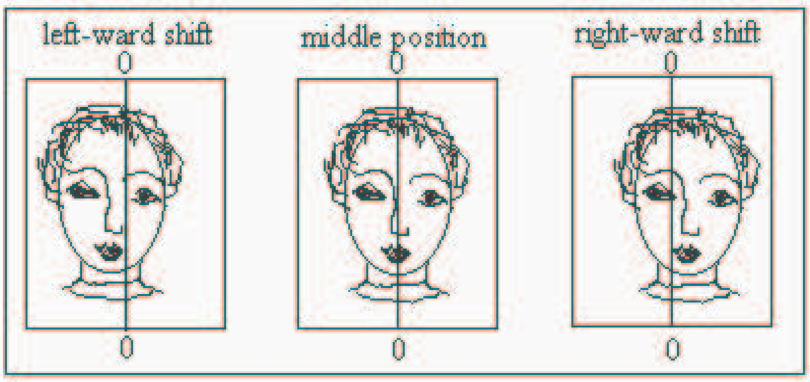


Fig. 7.4–1 shows possible variants of the portrait shift in comparison to its middle position (the line 0-0 symmetrically divided the sheet of paper after the portrait was drawn).

In this study we found a definite tendency to the left in the compositional center of works of art by famous artists and in naive folk-art. For example, in A. Modigliani – 78% of his compositions; M. Chagall – 71% of his compositions; A. Matisse, N. Pirosmani, P. Kusnetzov, B. Kustodiev – 63% of the compositions. Portraits in the album "Soviet portraiture of 1917 – beginning of 1930" – 71% of the compositions and in the album "Naive folk-art" – 66% of the compositions. But, with respect to painters working with the orthodox academic tradition, more right-side compositions were found (Gribov, 1980, 1988).

The majority of right-handed and left-handed portraits by right-handed children (approximately 150 portraits from every age group) also show tendency to the left (Table 1 and corresponding Fig. 7.4–1). These data show that the tendency to the left side is an important element of natural compositional aesthetics and is connected to a strong activation of the RH (nonverbal) and the *left visual field of painters*. It should be included in compositional design and in art education.

Table 1 Proportions of the *left-side compositions* at different ages of school pupils (in %) (150 drawings in each age group were used).

Age (years)	7	7,3	8	9	10	11	18
Right hand	63%	92%	90%	90%	91%	85%	82%
Left hand	65%	65%	67%	70%	67%	70%	76%

All correlations are significant with ($p<.01$)

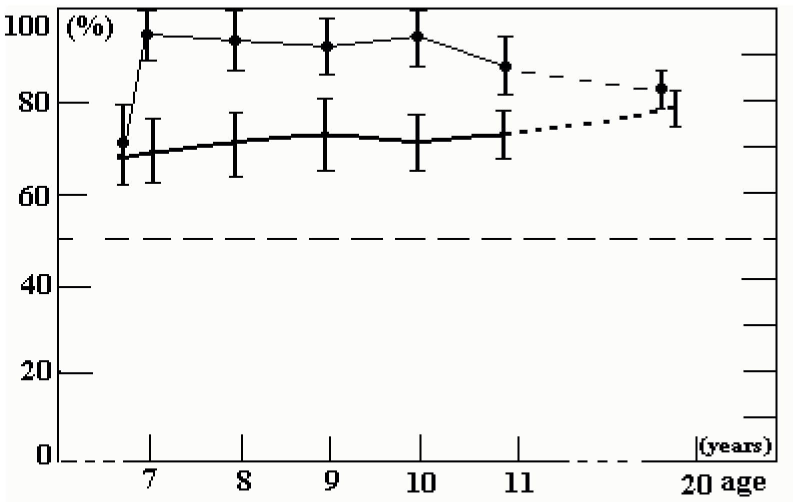


Fig. 7.4–2 shows the percentage of *leftward shifted* portraits made by the *left hand* (thin line above); and the percentage of *leftward shifted* portraits made by the *right hand* (thick line below) for different age groups of students.

These data demonstrate a rapidly growing RH/LH specialization connected to an elaboration of the Global visual aspect of the pictured image by the RH, because due to the intensive, opposite occupation of the LH by the abstract, verbal (Local visual aspect) learning commences at school.

7.5 THE PSYCHOLOGICAL NATURE OF AESTHETIC FEELING (in visual art)

The prominent art psychologist Rudolf Arnheim wrote that "so-called experimental aesthetics have missed their more relevant data by being based on the question: 'Do you like it?' rather than: 'What do you perceive?'" He proposed that "art presents sensory patterns, images, …not for their own sake, but as forms capable of transmitting something else," and he concluded that art "deals with the kind of mental state, so far, where psychology has failed to investigate" (Arnheim, 1966). Arnheim asked himself "What is the nature of aesthetic experience? Is art only a transmitter of information about visible objects or audible invents, or are they the significant patterns of forces inherent in such material?" He mentioned the "difference between the mere apprehension of information" and the "fuller artistic experience that could be identical with the difference between static and dynamic properties of percepts" and notes that this "dynamic of the art product engulfs the self of the performer, creator…." Arnheim could not find the answer relating to the "self," because for him "a psychology of the self does not yet exist," (Arnheim, 1966).

I agree with this view of aesthetically charged psychic mental states, mentioned by Arnheim and will attempt to describe one below. Left-handed portraits show a special "left" style of drawing (Gribov, 1980). Many elements of this, namely – integration, flatness, laconic character – are also characteristic of a large number of great artists (Rublev, Chagall, Petrov-Vodkin, Botticelli, Matisse, etc.). The famous Soviet art critic M. Alpatov (1963) wrote that "lines give the pictures of Matisse mobility, they run as streamlets and rivers. They are marked by continuous breathing and pulsation of flesh." At the heart of such paintings lies "some ambiguity: spatial forms of reality become elements of the floating articulation field of the picture."

What is the Nature of the Aesthetization of Art Forms?

We know that the attention of awake human beings may concentrate on:
(1) real external events, or
(2) inner directed events, distorted by pictures of the imagination.

The results of introspective investigations (Gribov, 1988) show that, in the second psychic state of perception, the usual spatial and analytical dismemberment of the visual field becomes more leveled, holistic, and more flat-like. This state is associated with security, relaxation, and rest (the individual may be aware of the environment, but is estranged from it). Vision is focused on infinity, and the angle between the optical axes begins to fluctuate spontaneously. This causes the visual effect of softness, plasticity, and a pulsation of the contours of external visual objects. This psychological state is not far from that of the "fast dream," and is normal for every person, but people are not usually aware of such transformations of the visible field.

This analysis leads to an interpretation of the psycho-aesthetic nature of visual art. Artistic productions in which such transformations (connected with the *second psychic state*) are expressed intensely can be (for the observer) a *reflex* *key*, or an *inductor* to a corresponding psychic state. This state is close to the creative one of the artist and can be referred to as the "creative state." This is common in children – they often find inspiration from imagination.

However, the traditional orthodox academic approach (which proceeds by the mechanical, copying of objects, and explores the definite, rational methods of depiction of a three-dimensional space) destroys the two-dimensional perception (plane integrity) of the picture and initiates the first *analytical state* of perception (namely when you have three-dimensional rational information about the outside object, but cannot pass into the second psychic state because these two psychic states are opposite to each other).

Important positive changes in art (Cezanne, Matisse, van Gogh, Modigliani, Chagall, etc.) appear to be connected to the shift to the RH holistic, intuitive, subjective pole.

It would be important to apply this revolution in art to traditional education. There is a need for a profound revision of the theory and practice in traditional education, which promote only the ability to reproduce an object (and knowledge) and suppress creative potential.

In this (BFA) context, I would like to refer to the "Psychology of Art" by Eisenstein (1980). He was one of the greatest theorists about art and cinema producers of the 20th century. Luria asked him to prepare some lectures on the psychology of art at Moscow University. Eisenstein's concepts came from his extraordinarily creative experiences in art, and are most interesting in the context of this work, because in his version of the "Psychology of Art" he intuitively used not only the modern dichotomy of the polar brain functional systems, but also exceptionally understood how important it is to keep their dialectical unity. For Eisenstein, one fundamental problem ("Grundproblem") for his own artistic endeavors and for his theory of art was the *correlation between affective and rational*. The most interesting problem for the psychology of art was, for him, the secret of the artistic form, which concerns the difference between events and the artistic performances of those events. Where is the source of artistic influence? He formulates a specific rule: each time we translate the "logical" thesis into the language of affective speech – affective thinking, we obtain a higher affective result. Further, he proposes that the impact of art is connected with two polar lines, which develop simultaneously: namely, the line of flow in the highest levels of "ideal consciousness" and the other flow (across an artistic form) into the levels of the deepest "affective thinking." The contrast between these two lines produces the remarkable tension of unity between form and content that distinguishes a piece of genuine art. He believes that this interference is performed in the context of art as an "expressive movement" – as a fight between affective-instinctive motives and conscious-will intention. In other words, original art activates both brain functional systems, making cyclically one as the background impulse for the other. Art demonstrates the dialectic of such informational interference, harmony, or the fight between these two polar parts of the whole brain functional system.

8. FOSTERING CREATIVITY IN SCHOOL

Summary

The fostering of creative activity in pupils shows that the group of creative children (approximately 30% of all children) consisted mainly of *non-right-handers (left-handed and the ambidextrous*). This group showed the additional ability of *creative musical imagination.*

The beginning of creative initiation in school causes *collective hostility to individual creative self-expression*. This hostility does not arise only in the first school grade. The collective hostility to individual creative self-expression is *invisible* in traditional, normative, reproductive education, and appears to be a result of the tendency to foster the only one-sided, reproductive activity in school. This means that traditional education works as a mechanism of socialization, renewing the *sociopsychological base for the repression of creative abilities and innovation and protecting the conservative, reproductive culture.*

My own teaching experience showed that after a few months of trying to foster *creative activity* in pupils (only one hour per week) the collective hostility could be easily switched into a *collective protection of creative self-expression.* This shows that, if modern school systems were to *combine* reproductive education (normative knowledge, *normative development*) with the stimulation of creativity *(creative development),* the school system could be a both progressive instrument of socialization, and a catalyst for *creative development, for development of the innovative culture).*

During several years as an instructor of art (at a typical school in Moscow) I began a research program to encourage creative activity in pupils (7–11-years old) (Gribov, 1987, 1988, 1992). I attempted to do this during my lessons (one hour per week with each grade) by providing a varied context for creative self-expression (fantasy and aesthetic in figurative art, inventing, poetry, stories, songs, and even musical improvisations using the voice). At the same time, the children were exposed to traditional (reproductive) education in their other lessons, which promoted only reproductive abilities.

The principles of my work with the children were: voluntary, creative self-expression; a low level of criticism; a high level of positive, emotional reaction to creative initiatives, and high marks. Showing the children's creative achievements to other grades also proved effective. I also organized permanent public school exhibitions of the children's creative works (pictures, poetry, etc.) and attempted to transform the more traditional aspects of each lesson by linking the reproductive elements of the school program with tasks involving improvisation and creativity. I instructed five grades (with two parallel classes at each age level).

8.1 CREATIVE ACTIVITY AND HANDEDNESS

I now turn to the other experimental data obtained through my own research on creative initiation. I noticed very soon that the group of creatively active children consisted mainly of pupils who are left-handed or ambidextrous. These pupils displayed a tendency to involve the left hand in drawing etc., and held the pencil or other instruments in the left hand. But, at the same time, all the pupils wrote with the right hand, and only one student from approximately 300, used the left hand for writing, because in Russia parents and teachers forced most of the children to use only the right hand for writing. Most of the pupils were not absolutely left-handed, but were ambidextrous. Thus, the full “non-right-handed” population contained approximately *30% of all children in my grades.* A large, positive correlation was found between total creative activity and “non-right-handedness.” A strong correlation has also been found between “non-right-handedness” and creative musical imagination (Gribov, 1987, 1988, 1989). Namely, these children displayed a rich and active imagination and an active world of fantasy (creativity was as natural as breathing to them). By contrast, right-handed pupils (approximately 70% of the total group) had no inclination to creativity; they tried, but were not successful. Corresponding data are shown in Table 1.

Table 1 (K–1) – correlation between “non-right-handedness” and total creative activity; (K–2) – correlation between “non-right-handedness” and creative musical imagination at different ages

Age (years)	7	8	9	10	11
K–1	0.70	0.76	0.64	0.66	0.35
K–2	0.78	0.72	0.75	0.75	0.74

All correlations are significant with $p<.01$.

The rating of “*non-right-handedness*” was obtained by a direct longitudinal observation of pupils during manual activities (this observation is most effective at the ages of 7–9). At this age activities involving construction using the left hand has not yet been blocked (children usually like to draw and sew etc., using the left hand). This observation was confirmed by parents.

“*Total creative activity*” is the sum of various voluntary acts of creativity performed by each pupil in the course of one year (during which there was the regular fostering of creativity). These data were obtained not with common measures of creativity, but via direct observations of creative activity in real life, when many natural mechanisms of motivation begin to work. Integral elements of activity (children’s creative and constructive activity using the right or the left hand) had the strongest correlation in this investigation.
The high correlations (Table 1) correspond to our theoretical hypothesis on the functional mixing paradigm (Gribov, 1987). We propose that it has a neuropsychological structural basis for the creative predisposition (see chap. 10.1).

The wide distribution of creative abilities (including creative musical imagination, chap. 8.2) in the "non-right-handed" children is explained by the breaking of the high functional separation, typical for right-handers, *by the mixing* placement of some polar hemispheric functions in the same hemispheric cortex, especially in the RH (Gribov, 1987). In the functional mixing case, the Global and the Local aspects of information are more collaborative, and they will periodically or simultaneously activate each other.

Relevant to this is Benbow's proposal about the *bihemispheric representation of cognitive functions*, as the basis for *extreme mathematical or verbal reasoning abilities* (Benbow, 1986), which could be associated with our functional mixing paradigm. The mixing could have different *organic* (e.g., hormonal) or *cultural causes* (e.g., C*hinese writing*, located in the non-verbal RH of the right-hander).

8.2 CREATIVE MUSICAL IMAGINATION AND HANDEDNESS

Creative musical imagination was measured by an individual, *introspective* questioning the pupils (Gribov, 1987, 1988). The questions were: "Do you sometimes hear music inside your head? Is it well-known music, or is it from your own imagination? What kind of music do you hear (instruments, voices, etc.)? When do you usually hear this?"

It was found that for "non-right-handed" children creative musical imagination is natural, and the melodies (they hear) do not repeat familiar melodies. They appear more often before sleeping, in a state of relaxation, and in peace and silence. Their musical experiences were varied and holistic ("I feel as if an orchestra is in my head"). This feeling is so natural for such children that they usually never tell anyone about it. Among 250 right-handed pupils, only 3 girls who were also able to hear music "inside" their head were found, but it is symptomatic that they heard only well-known fragments (from their reproductive musical imagination) connected to the music they learnt at musical school.

A beautiful description of the *creative musical imagination* gave *Wolfgang Amadeus Mozart* (as quoted in Hadamard, 1945, p. 16). Mozart stated: "When I feel well and in a good humor, or when I am taking a drive or walking after a good meal, or in the night when I cannot sleep, thoughts crowd into my mind as easily as you could wish. Whence and how do they come? I do not know and I have nothing to do with it. Those, which please me, I keep in my head and hum them; at least others have told me that I do so. Once I have my theme, another melody comes, linking itself with the first one, in accordance with the needs of the composition as a whole: the counterpoint, the part of each instrument and all the melodic fragments at last produce the complete work. Then my soul is on fire with inspiration. The work grows; I keep expanding it, conceiving it more and more clearly until I have the entire composition finished in my head though it may be long. Then my mind seizes it as a glance of my eye a beautiful picture or a handsome youth. It does not come to me successively, with various parts worked out in detail, as they will later on, but in its entirety that my imagination lets me hear it."

This spontaneously creative musical imagination, as described by Mozart, corresponds to introspection of the musical feelings experienced by the "non-right-handed pupils." Almost all of them could hear complete fragments of unknown "inside" music, usually in a state of relaxation, before sleep, or sometimes during walks or drives (maybe also after a "good meal").

8.3 CREATIVITY VERSUS ROUTINE – IN TRADITIONAL EDUCATION

Collective Hostility to Individual Creative Self-expression

Traditional (one-sided, reproductive) school education has been strongly criticized by many progressive pedagogues and psychologists (Cropley, 1988; Cropley, Mcleod and Dehn, 1991; Torrance, 1981). As mentioned before, a striking sociopsychological phenomenon was observed: a high level of *collective hostility to individual creative self-expression* (Gribov, 1987, 1988). It is symptomatic that this phenomenon was not confined to the first school grade. The hostility arose spontaneously and unconsciously. Its level was higher in older children. This phenomenon is invisible in traditional learning situations, and is a result of the one-sided (reproductive) stimulation of children's abilities at school. Being invisible and unconscious (also for teachers of traditional education), collective hostility (arising at school) could continue into adulthood, and establish a *sociopsychological mechanism for the repression of creative abilities, creativity, and innovations.* We assume that the traditional school (on the surface a source of new knowledge and sociocultural education) could be, at the same time, an "invisible" *contra-innovative instrument of socialization* for new generations.

Collective Protection of the Individual Creative Self-expression

After only 2 to 3 months of regularly fostering the creative self-expression of the pupils (only one hour per week), was it possible to eliminate this specific barrier and to change the collective hostility into a wide *collective protection of creative self-expression.* This shows that such protection may provide a new strong catalyst for creative development, and introduce a new element of socialization. This is not difficult to encourage, because creative activity is natural for children. Moreover, children are beginners in everything; they are not occupied by stereotypical thinking, and have a more artistic, more holistic manner of thinking and perception of the world (in contrast to adults). The intellectual and artistic fantasy of children is less inhibited with regard to time, and can spontaneously create basic elements of art and science etc., from the past, present, and future.

9. OUTSTANDING CREATIVITY – EMPIRICAL STUDY

Summary

These data are based on a study of the gestures of outstandingly creative persons, which was conducted at the University of Chicago.

It was assumed that, during conversation the group of outstandingly creative individuals *would gesture more with their left hand*, compared to the exclusive right-handers in the general population (as this would indicate a greater involvement of the RH in verbal communication). It was also further assumed that there would not be a significant difference in the right-hand/left-hand gesturing between outstanding creative individuals and the "non-right-handed" people in the general population.

It was found that outstandingly creative males and females show no significant differences when gesturing; but, a selected group in Chicago, which included 69% males and 31% females, and a subgroup, balanced by sex, showed significantly more left-handed and less right-handed gestures in comparison to the right-handers in the general population (balanced by sex).

The Chicago female (male) group was significantly leftward shifted compared to the right-handed females (males) and the subgroup, balanced by sex, showed *no significant differences between the left-handers and ambidextrous people*.

9.1 THE CONCEPT OF THIS EMPIRICAL STUDY

The idea was to extend the BFA data, obtained in other studies and in our research into creatively active school children (chap. 8 in this study), to test the BFA specific in the group of outstandingly creative individuals.

There are some difficulties to obtain the statistics relevant to this research, and to organize a full study with "handedness" tests, dichotic listening tests, and EEG data, etc., since this type of study requires extensive resources. Moreover, outstandingly eminent persons are extremely busy, and a researcher requires quite a few years to negotiate with them for permission to carry out such a study. Even when the University of Chicago was involved, a similar study (Csikszentmihalyi, 1996) lead by a very famous American psychologist, took approximately 5 years. This study was connected with the verbal interviewing of eminent creative individuals. But, the BFA aspect was not planned in the study of Csikszentmihalyi.

Because of these factors, we decided to proceed with a more limited *empirical study*, which could give an insight into the subject without making personal BFA tests.

The idea was to study the specifics of hand gestures as informative *indicators* of BFA (Kimura, 1973a, 1973b). This was not difficult to carry out, because such a large group of *outstandingly creative individuals* was investigated at the University of Chicago a few years ago and *archived in 91 videotapes*.

These video interviews were collected by M. Csikszentmihalyi and his team from 1990 to 1995 in an effort to *study the lives and thought processes* of *eminent creative individuals* (Csikszentmihalyi, 1996). The selection criteria were required that the person should be recognized by his or her peers and society as having made an *outstanding* contributions to his or her field.

Main Selection Conditions in the Chicago Study

Csikszentmihalyi (1996) wrote that there were *three main conditions for selecting participants*: "The person had to have made a difference to a major domain of culture – one of the sciences, the arts, business, government, or human well-being in general; he or she had to be still actively involved in that domain (or a different one); and he or she had to be at least 60-years old (in very few cases, when circumstances warranted, we interviewed respondents who were a bit younger)," (p. 13). "The selection process was slow and lengthy. I set out to interview equal numbers of men and women who met our criteria. A further desideratum was to get as wide a representation of cultural backgrounds as possible. With these conditions in mind, I began generating lists of people who met these attributes. In this task I availed myself of the best advice of colleagues and experts in different disciplines. After a while the graduate students involved in the project also suggested names, and other leads were provided by the respondents after each interview, producing what is sometimes called a 'snowball sample'" (p. 13). "Those who accepted included many individuals whose creativity had been widely recognized; there were fourteen Nobel prizes shared among the respondents (four in physics, four in chemistry, two in literature, two in physiology or medicine, and one each in peace and in economics). Most of the others' accomplishments were of the same order, even if they were not as widely recognized" (p. 14).

The biographic data of these persons, the kinds of questions asked, and answers given were analyzed in the volume "Creativity: Flow and the psychology of discovery and invention" (Csikszentmihalyi, 1996).

Handedness as an Indication of the Hemispheric Predominance

Handedness is generally assumed to be an indication of the predominance of one or the other cerebral hemisphere, with right-handers giving precedence to the left side of the brain which specializes in rational, quantitative mental processes, and left-handers using more of the holistic, integrative functions of the RH. Some studies, conducted mostly with *adults,* show a higher percentage of left-handers among *artists* and *architects* (Mebert & Michel, 1980; Peterson & Lansky, 1977), *chess masters* (Cranberg & Albert, 1988), *mathematicians* (Annett & Kilshaw, 1983), and *science students* (Coren, 1995; Coren & Porac, 1982; Kimura & D'Amico, 1989). Newland (1981) showed the predominance of left-handed adults in the Torrance creativity (figural) test. Benbow (1986) found that *mathematically precocious youths* (compared to moderately gifted groups) exhibit twice as much left-handedness (24%). Together with ambidex trous, or right-handers with left-handed family members, this was approximately 50% in the precocious group. Additional stimulus for this research was an earlier study involving the stimulation of children's creative activity in school, showing that creative activity strongly prevails among *non-right-handed children* (7–11-years old), compared to right-handed children (Gribov, 1987, 1988, 1992; Gribov & Maewsky, 1987).

Speech Presentation in Hemispheres and Handedness

We also remember the above-mentioned data of the speech presentation in hemispheres: the sodium amobarbital (Wada) test indicated that more than 95% of *right-handed* individuals have LH language. Even approximately *70% of left-handers are left lateralized for speech*, with the rest apparently having either bilateral (15%), or RH speech (Rasmussen & Milner, 1977). A recent similar study suggests that the incidence of pure RH speech may actually be much lower than was found above (Rasmussen & Milner, 1977), and *it is really bilateral speech in many cases* (Loring et al., 1990). The Dichotic listening test from Kimura showed *bilateral speech representation for ambidextrous persons* (Kimura, 1973b).

Neuroanatomical Features of Non-right-handedness

"Non-right-handed" adults have the following neuroanatomical features:

(a) Ambidextrous males have a 56% larger parieto-temporal callosal area than right-handers (Witelson, 1986, 1987, 1988). These parieto-temporal cortical regions contain *linguistic, spatial, and musical* skills usually represented asymmetrically in the cortex. Normally, males (right-handers) have a greater lateralization for both verbal and spatial skills than females (right-handed men accomplish spatial tasks better than women, but are worse at verbal tasks).
(b) Geschwind and Behan (1982) and Galaburda, Corsiglia, Rosen, and Sherman (1987) developed a hormonal theory related to handedness: if the male fetus is exposed to abnormally high levels of testosterone, it can modify the relative development of the two hemispheres. It can also increase some immune disorders (allergies, etc.), but it leads to a better development of the nondominant hemisphere (typically the RH, which also may lead to left-handedness). Exposing the female fetus of the mammalian to testosterone during critical stages of early maturation gives a masculinizing effect (Kelly, 1991).

Eminent Left-handed Adults in Human History

History has given us a rather impressive list of eminent adult left-handers (Smits, 1994):

Artists: Leonardo da Vinci, Michelangelo Buonarotti, Sebastiano del Piombo, Albrecht Dürer, Hans Holbein, Paul Klee, M.C. Escher, etc.

Politicians: Julius Caesar, Napoleon Bonaparte, Alexander Karl der Große, Winston Churchill, Bill Clinton, George Bush, Gerald Ford, Ronald Reagan, Nelson Rockefeller, H. Ross Perot, Harry S. Truman, etc.

Musicians and Composers: Ludwig van Beethoven, Benjamin Britten, Pablo Casals, Paul McCartney, Bob Dylan, Rudolf Kolisch, Sergej Prokofjew, etc.

Authors: Hans Christian Andersen, Lewis Carrol, Johann Wolfgang von Goethe, Heinrich Heine, etc.

Actors and Actresses: Charles Chaplin, Greta Garbo, Marcel Marceau; Marilyn Monroe, etc.

Scientists and Philosophers: Albert Einstein, Friedrich Nietzsche, Andrej D. Sacharov (the famous Russian physicist and political dissident was ambidextrous), Albert Schweitzer.

Sportsmen and Sportswomen: John Barnes, Bob Charles, Jimmy Connors, Sara Gomer, Goran Ivanisevic, Henri Leconte, Martina Navratilova, Pelé, etc.

One serious problem with the direct measure of the handedness of adults is that the percentage of "non-right-handers" appreciably decreases with age, since children's "non-right-handedness" is partially masked by the artificial shifting to right-handedness (fostered by a right-handed society). The study was intended to test, indirectly, the involvement of the RH or the LH of outstandingly creative individuals by comparing the frequency of their right- and left-handed gestures. Gesturing during speech is practically involuntary, and can be used as a simple indicator of cortical involvement of the different brain hemispheres in speech production and thinking.

9.2 METHOD AND HYPOTHESES

Method

The present study (Gribov and Csikszentmihalyi, 2001) investigated the gestures of the outstanding persons during the above-mentioned videotaped interviews. The data was compared with that collected during an investigation of the connection between hand gesturing and BFA in a normative sample (Kimura, 1973a, 1973b). Only 63 of the 91 videotapes (50 men and 13 women) were selected, because only in these were hand movements clearly visible.

Gestures were registered during a period of 10 minutes for each person. The same part of the interview was used for each person, involving the answer to the first question: "Of all the things you have done in life, of what are you most proud?" Gestures were classified and accounted for according to the method from Kimura (1973a, 1973b). The data were recorded in three columns: for the left hand (L), for the right hand (R) gestures made by a single hand, and a central column for simultaneous bimanual (B) gestures.

Kimura, *whose method was replicated*, differentiated between two types of hand movements accompanying speech dialogue:

(a) hand movements that involve touching one's body (e.g., scratching, pushing back hair, etc.). Kimura also excludes from the category of gestures manipulating a ring or a watch, and allocated such movements to a special category (all of these hand movements were excluded in this study).
(b) *free movements or true gestures* – hand movements which do not result in touching the body or returning the hand to a resting position. Free movements usually look like wavy hand movements, with the hand moving far from the body (all these hand movements were accounted as gestures in the Kimura study). *Only the second type of "true" gestures was accounted in our study.*

Three independent observers scored the 10-minute sections from 15 randomly selected videotaped records (from a total of 63 used in this study). They did not know the purpose of the research, and were trained to apply the above-mentioned method for coding gestures. For the comparison of observers' scores, the rank correlation method (Kendall, 1962) was used. Freedman's χ^2 -test gives $\chi^2 = 16.76$, $P<.001$, ($k=3$, $N=15$).

Hypotheses

(a) It was expected that the group of outstandingly creative individuals *would gesture more with their left hand* compared to the pure right-handers in the general population (as this would indicate greater accentuation of the right-brain activity especially in the case of artists, biologists, and natural scientists).
(b) At least hand *gesturing will be balanced* that could indicate greater integration of left- and right-brain functional systems in the Chicago group, than in pure right-handers in the general population. This hypothesis derives from the fact that, in many areas, (e.g., business, science, theoretical physics, verbal fields such as literature and journalism) outstandingly creative achievements depend on a good level of cooperation and balancing between the activity of the verbal and nonverbal functional systems. Right-handed subjects in the general population, on the contrary, gesture about three times as much with the right hand, than with the left hand ($p<.001$, Kimura, 1973a).
(c) There is no difference between the Chicago group gesturing and *left-handers* and the *ambidextrous* in the general population (in the distribution of the left-handed, bimanual, and right-handed groups, average gestures are scored in %).

9.3 SEX DIFFERENCES IN THE CHICAGO GROUP

The results of gesturing for the complex Chicago group of eminent creative persons, including sex differences, are presented below (Table 1 and Table 2).

Table 1 Average hand gesture scores (L-left, R-right, B-bimanual) during a 10-minute dialogue and standard deviations (SD) for the full Chicago group of 63 eminent persons (13 females, 50 males), (one tailed t-test).

	Left/(SD)	Bimanual/(SD)	Right/(SD)	F(LvsR)	F(BvsR)	F(LvsB)
Average gestures	**43.17**	**48.17**	**31.22**	**3.65**	**9.50**	**0.44**
/df1=1, df2=62/	(40.59)	(40.79)	(34.46)	**p<0.1**	**p<.01**	**-**

The direct analysis of variance (for *dependent samples* of the left-handed, bilateral, right-handed gesturing) showed a significant difference (p<.01) only between the right-hand gestures and bimanual gestures. For the total Chicago group there was a significantly higher bimanual gesturing, F(**BvsR**) =9.50**,** df =1; 62).

There is no significant difference between Left- and Right-handed, (LvsR); Bimanual and Left-handed (BvsL) gesturing: F(LvsR) =3.65 (p<0.1), df =1; 62; F(**BvsL**) =0.44, df =1; 62.

Table 2 Comparison of average gesture scores during a 10 minute dialogue with the Chicago male and female subgroups, made by left-/L/, right-hand /R/, and bimanually /B/, and a comparison of their average ratios R-L / R+ L, and standard deviations (SD); (one tailed t-test).

	Left hand (SD)	**Bimanual** (SD)	**Right hand** (SD)	**R-L/R+L** (SD)
Females, (N = 13)	**44.15** (34.24)	**43.46** (50.04)	**19.31** (18.41)	**- 0.38** (0.49)
Males, (N = 50)	**43.50** (42.40)	**49.4** (38.10)	**32.60** (35.10)	**- 0.11** (0.56)
df = 61,	**t = 0.06**	**t = 0.47**	**t = 1.31 (p<0.1)**	**t = 1.60 (p <0.1)**

Table 2 shows the *absence of significant differences* in average gesture scores between females and males for each column and also between two ratios, R–L / R+ L for 50 males and 13 females in the Chicago group.

9.4 THE CHICAGO GROUP AND RIGHT-HANDERS

In the Chicago subgroup (*balanced by sex*), females and males are compared to the corresponding samples of right-handers, as studied by Kimura (1973a, 1973b, 1986) and Sousa-Roza (1979).

Chicago Subgroup balanced by Sex and Right-handers

Table 3 shows the comparison, balanced by sex, of the Chicago subgroup of 26 persons with the right-handers from Sousa-Roza (1979), during a 10-minute dialogue.

Table 3 **Comparison of average gesture scores by the Chicago subgroup *(balanced by sex)* during a 10 minute dialogue, with the data from Sousa-Roza (1979) for right-handers, and standard deviations (SD), (in %); (one-tailed t-test).**

		Left-hand (SD)	Bimanual (SD)	Right-hand (SD)
(1)- Right-handers (Sousa-Roza, 1979)	**N = 32**	**25.60** (21.50)	**32.00** (?...)	**42.40** (27.10)
(2)- All Chicago group,	**N = 63**	**35.86** (33.68)	**39.60** (33.53)	**25.54** (27.09)
(3)- Chicago 13m.+13f.	**N = 26**	**45.41** (42.05)	**32.41** (31.44)	**22.17** (20.56)
(1) vs. (2) comparison	**df = 93,**	**t(1vs2)=1.80 (p<.05)**	**-------**	**t(1vs2)=2.87 (p<.005)**
(1) vs. (3) comparison	**df = 56,**	**t(1vs3)=3.43 (p<.005)**	**------**	**t(1vs3)=3.19(p<.005)**

Table 3 also shows a significant increase of left-handed gesturing and, simultaneously, a decrease of right-handed gesturing in the Chicago group compared to the right-handers from the Sousa-Roza sample data. Balanced by sex, within the Chicago subgroup are 13 males and 13 females. Selected randomly were 13 males from all groups of 50 males from the Chicago group.

Chicago Females and Right-handed Females

Chicago females (males) group is compared with the right-handed females (males) studied by Kimura (1987), (Tables 4a, 4b).

Table 4a **A comparison of the Chicago females average gesture scores during a 10 minute dialogue, with the data from Kimura (1987) for right-handers (as ratio R-L / R+L, and standard deviations (SD)); (one-tailed t-test).**

		R-L / R+L (SD)	t	p
Chicago females group	**N = 13**	**- 0.38** (0.49)	**df = 21**	
Right-handed females	**N = 10**	**(neutral task) + 0.226** (0.476),	**t=3.03,**	**p<.005**
(Kimura, 1987)		**(verbal task) + 0.272** (0.547),	**t=2.96,**	**p<.005**
		(spatial task) + 0.216 (0.359),	**t=3.24,**	**p<.005**

In all cases a *significant difference* was found between the Chicago and Kimura's right-handed female groups.

Chicago Males and Right-handed Males

Table 4b **A comparison of the Chicago males (average gesture scores during a 10 minute dialogue) with the data from Kimura (1987) for right-handers and standard deviations (SD), (as in the Table 4a); (one tailed t-test).**

		R-L / R+L (SD)	t	p
Chicago group, males N = 50		**- 0.11** (0.63)	**(df = 57)**	
Right-handers, males N = 9 (Kimura, 1987)	**(neutral task)**	**+ 0.373** (0.780)	**t=2.01,**	**p<.025**
	(verbal task)	**+ 0.267** (0.793)	**t=1.58,**	**p<0.1**
	(spatial task)	**+ 0.413** (0.509)	**t=2.37,**	**p<.025**
	(overall)	**+ 0.351** (0.690)	**t=1.98,**	**p<.05**

Differences between the Chicago and Kimura right-handed males are significant in relation to the neutral and spatial ($p<.025$) tasks; the differences are significant not only in relation to the verbal task ($p < 0.1$), but they are also significant in relation to the overall data of Kimura ($p<.05$).

9.5 THE CHICAGO GROUP VERSUS LEFT-HANDERS AND THE AMBIDEXTROUS

Unfortunately, in the case of the left-handers and the ambidextrous, Kimura did not study bimanual gestures, but only gestures produced by the left hand and the right hand (Kimura, 1973, 1973b). She presented the main statistical data without standard deviations (SDs), a necessity for the t-test. But, it is still possible (without knowing the SDs) to test correctly *the absence of a significant difference* between the Chicago group and the left-handers and the ambidextrous in Kimura's study, as is proposed above in the third hypothesis.

For the t-test, the well-known expression is used:

$$t=(A_1-A_2):\sqrt{[(N_1-1)(SD_1)^2+(N_2-1)(SD_2)^2]}\ \sqrt{(1/N_1 + 1/N_2)}, \qquad (1)$$

where A_i is the statistical average score (with the corresponding SD_i),
N_i is the number of persons in the i-group.

In the Table 4b above, we have (A_1, SD_1, N_1), but Kimura has only (A_2,-?-, N_2). The border value for $t=t_{max}$ is for $SD_2=0$. While $SD_2 > 0$, the real t will be always less than t_{max} (as it shows the t- expression for the t-test). If even $t=t_{max}$ is not large enough for a significant difference between A_1 and A_2, it means that there will never be significant differences between them. Table 5 presents the corresponding comparisons.

In all cases (Table 5), there are *no significant differences* between the left-handers, the ambidextrous, and the Chicago subgroup, balanced by sex.

Table 5 **A comparison of average gesture scores during a 10 minute dialogue with the Chicago subgroup (balanced by sex) (in %), with the data from Kimura for left-handers and the ambidextrous and standard deviations (SD), (in %); (one tailed t-test)**

		Left hand (SD)	Right hand (SD)
Chicago (13males+13females)	**N= 26**	**67.19** (62.21)	**32.81** (30.42)
Left-handers (RE >), Kimura	**N= 17, df=41,**	**53.3 /t<0.92/**	**46.7, /t<1.89, t≈1.3/**
Left-handers (LE >), Kimura	**N= 8, df=32**	**74.1 /t<0.31/**	**25.9 /t<0.63/**
Left-handers , Kimura	**N= 18, df=42**	**60.4 /t<0.46/**	**39.6 /t<0.93/**
Ambidextrous, Kimura	**N= 9, df=33**	**58.4 /t<0.42/**	**41.6 /t<0.85/**

(RE >) – data for people with higher right-ear scores and (LE >) – data for people with higher left-ear scores, as found in the dichotic listening test (Kimura, 1973, 1973b).

9.6 DIFFERENT PROFESSIONAL CHICAGO SUBGROUPS

The Chicago group contained eminent people with very different professional orientations. They could have specific differences in gesturing (i.e., in the different left-brain/right-brain functional accentuation). Some professional fields were selected: male “natural science” (including Nobel Prize winners); male “natural science” excluding Nobel Prize winners; male via “biology”; male “artists”; male “Nobel prize winners” (mostly “theorists”); female “natural science”; male “business”; male “verbal fields” (such as authors, journalists, poets, etc.); female “verbal fields.”

Table 6 shows the average scores for left-hand, right-hand, and bimanual gestures, and statistical differences between these gestures inside each subgroup (for depended variables).

Table 6 Chicago subgroups with different professional orientations (average number of gestures during a 10 minute dialogue and standard deviations (SD)).

	N	Left (SD)	Biman.(SD)	Right (SD)	F(LvsR);	F(B vsR)	df
(g1)-Males	**19**	**50.37**	**45.55**	**22.58**	**6.55 (p<.05)**	**5.17(p<.05)**	**1;18**
(all natural science)		(37.78)	(37.68)	(23.63)	Δ=+27.79	Δ=+22.97	
(g2)-Males (natural	**11**	**49.45**	**63.09**	**17.55**	**10.65 (p<.01)**	**8.83 (p<.05)**	**1;10**
science, excl. NP)		(32.10)	(41.65)	(15.35)	Δ=+31.9	Δ=+45.54	
(g3)-Males	**7**	**63.20**	**36.00**	**11.71**	**13.1 (p<.05)**	**5.59 (p<.05)**	**1; 6**
(biology)		(33.47)	(21.73)	(8.71)	Δ=+52.49	Δ=+ 24.29	
(g4)-Males	**6**	**65.67**	**51.50**	**28.67**	**9.08 (p<.05)**	**0.72(n.s.d.)**	**1; 5**
(artists)		(71.96)	(50.95)	(28.70)	Δ=+ 37.00		
(g5)-Males	**8**	**32.88**	**40.19**	**29.50**	**0.93 (n.s.d.)**	**0.26 (n.s.d.)**	**1; 7**
(Nobel Prize winners)		(24.25)	(46.06)	(31.73)			
(g6)-Females	**7**	**47.00**	**39.43**	**11.29**	**4.05 (n.s.d.)**	**0.29 (n.s.d.)**	**1; 6**
(natural science)		(53.28)	(19.28)	(9.89)			
(g7)-Males	**7**	**45.86**	**53.43**	**45.14**	**0.00 (n.s.d.)**	**0.11(n.s.d.)**	**1; 6**
(business)		(43.06)	(36.59)	(36.80)			
(g8)-Males	**18**	**29.67**	**38.11**	**38.67**	**0.30 (n.s.d.)**	**0.00 (n.s.d.)**	**1;17**
(verbal fields)		(33.62)	(25.94)	(46.17)			
(g9)-Females	**4**	**62.00**	**53.25**	**41.75**	**0..27 (n.s.d.)**	**0.14 (n.s.d.)**	**1; 3**
(verbal fields)		(53.88)	(58.87)	(12.09)			

N – number of persons in each professional group; “L” – left-handed, “B” – bimanual, “R” – right-handed average gesture scores; (....) – their standard deviations (SD) – no significant differences (n.s.d.).

Table 6 also presents the data of the direct analysis of variance for dependent groups (between the left-handed, bilateral, and right-handed gestures in each presented Chicago subgroup).

Right-brain Activity Accentuation – Table 6

Significant differences between the (LvsR) and (BvsR) average gesture scores are only for *male* subgroups, having the strongest left-handed gesturing accentuation:

(1) male – “natural sciences,” F(**LvsR**)=6.55; F(**BvsR**)=5.17;(df=1;18), (p<.05);

(2) male – “natural science group excluding Nobel Prize winners” shows even more significant differences in gesturing: $F_{(LvsR)}=10.65$, ($p<.01$); $F_{(BvsR)}=8.83$, ($p<.05$), (df=1;10), is possible to anticipate because almost all Nobel Prize winners in the studied group are theorists, working with very complicated abstract mathematical tools;

(3) males in the fields via “biology” also have significant differences in gesturing: (L>R) and (B>R) with $p<.05$;

(4) male “artists” have significantly more left-handed than right-handed gestures: (L>R), $F_{(LvsR)}=9.08$, ($p<.05$), df=1;18;

Balanced Left-brain/Right-brain Activity (Table 6)

For groups of males – “Nobel Prize winners”; males – “verbal fields”; males – “business”; females – “natural science”; females – “verbal fields” – there are no significant differences in all cases between left-handed and right-handed gestures, and between bimanual and right-handed gestures. This means that these subgroups have relatively more balanced left-brain and right-brain activity than groups with the left-brain accent. Note, that there is no Chicago subgroup with a significant right-handed gesturing accent.

Table 7 sets out a comparison of the subgroups.

Table 7 **Comparison of the left-handed (LvsL), right-handed (RvsR), bimanual (BvsB) average gesture scores, during a 10 minute dialogue, for some of the professional Chicago subgroups, as presented in Table 6 (one tailed t-test).**

	t (LvsL)	**t (RvsR)**	**t (BvsB)**	**df**
19 males “science” vs. 18 males “verbal”	**1.75 (p<.05)**	**1.34 (p<0.1)**	**(n.s.d.)**	**35**
7 females “science” vs. 4 females “verbal”	**0.49 (n.s.d.)**	**4.55 (p<.005)**	**0.59 (n.s.d.)**	**9**
7 females “science” vs19 males “science”	**0.18 (n.s.d.)**	**1.22 (n.s.d.)**	**(n.s.d.)**	**24**
7 females “science” vs18 males “verbal”	**1.06 (p<0.1)**	**1.56 (p<0.1)**	**(n.s.d.)**	**23**
7 females “science” vs. 7 males “business”	**(n.s.d.)**	**2.35 (p<.025)**	**(n.s.d.)**	**12**
6 males “art” vs. 18 males “verbal”	**1.69 (p<0.1)**	**0.5 (n.s.d.)**	**(n.s.d.)**	**22**
6 males “art” vs. 7 males “business”	**0.61 (n.s.d.)**	**(n.s.d.)**	**(n.s.d.)**	**11**
6 males “art” vs. 19 males “science”	**0.69 (n.s.d.)**	**(n.s.d.)**	**(n.s.d.)**	**23**

Table 7 shows that the males – “science” use their left hand significantly more for gesturing than males with “verbal” accentuation (t=1.75, $p<.05$, df=35). At the same time, (see Table 6) males – “science” use significantly more (≈twice more) left-handed ($p<.05$) and bimanual gestures ($p<.05$) compared to the right-handed gestures in their subgroup; (n.s.d.)– no significant differences.

Females – “science” use significantly less right-handed gestures than females – “verbal” (t=4.55, $p<.005$, df=9); yet for the left-handed and bimanual gesturing there are no significant differences between these subgroups.

Females – “science” have significantly less active right-handed gestures than males – “business” (t=2.35, $p<.025$, df=12).
Presented in the “verbal” subgroup (Table 6) is, more or less, equal left-handed and right-handed gesturing activity (there is no significant difference between left-handed and right-handed gesturing activity).

10. HIERARCHICAL MODEL OF CREATIVE ABILITIES

Summary

The *functional RH/LH mixing* is supposed to be a neuropsychological basis for any type and level of creative predisposition. Usually, it decreases the LH dominance and increases the activation of the RH. This *mixing* could have different *organic causes*, or even be *culturally provoked.*

The *organic cause* of the functional mixing is relevant for outstanding creativity and is connected to prenatal hormonal exposure, which induces better RH development and provokes functional mixing within it.

The *cultural cause* of the functional mixing could be interesting for general moderate creativity and is connected, for example, with C*hinese writing-signs,* which are located in the nonverbal RH of the right-handed person.

It is proposed that *the neuropsychological basis for outstanding creativity* consists of:

(a) *two large, valuable, temporal plana*, which are well developed in both hemispheres (it is a vast neuronal space for linguistic, spatial, and musical skills);
(b) *LH/RH functional mixing* in the RH, including *two-sided verbality* with complete conservation of the *salient RH spatial functions*;
(c) *additional corpus callosum fibers*, connecting these enlarged (a)-fields;
(d) *larger, special cortical zones,* which determine individually the strong sides of outstandingly creative predisposition (specific to some professions).

The two-sided verbal (speech or writing) factor provides exceptionally flexible RH/LH functional cooperation and competence, resulting in *creative dialogic thinking* connected to the *creative process of cognition*. This explains the unusual, contradictory features of outstandingly creative persons (for example: maturity/childishness; parallel logic/intuition; autism/openness and emotionality; laconic verbal style; revolutionary/conservatism; double science/art focus with bright, nonverbal thought equipment, etc.).

The "Vertical" creativity cluster ("natural science", "biology" and "artists" in the Chicago study) has the RH activity accentuation with corresponding "artistic" features, which easily create new paradigms and new fields (Leonardo da Vinci, Goethe, Einstein, Planck, Prigogine).

The "Horizontal" creativity cluster has a balanced RH/LH dominance with slightly more dominance in the LH ("Nobel Prize winners", "verbal fields", "business", and female – "natural science" in the Chicago study, that is, physicist John Bardeen and others). In both cases, RH verbal minds can easily prepare short drafts of novel categorization schemes, looking like half-finished products for further LH cultivation.

Thus, the coexistence of the RH/LH verbal minds provides, in usually very stable structures of logical thinking determinants, kinds of quantum mechanical "*tunneling effects,*" facilitating their adequate spontaneous transformations.

10.1 FUNCTIONAL MIXING PARADIGM – AS THE BASIS FOR CREATIVE ABILITIES

The wide distribution of creative abilities in the leftward dominated and ambidextrous children is connected to the breaking of the total functional separation, typical for right-handers, that is, the *mixing* placement of polar hemispheric functions in the same hemisphere, especially in the RH (Gribov, 1987). It decreases the LH dominance and creates a general condition for the permanent, soft, or intensive neuronal activation of creative associative flows in the RH (against the background of the LH analytical activity). The proposal of Benbow (1986) is that the bihemispheric representation of cognitive functions is connected with extreme mathematical, or verbal reasoning abilities, and could be associated with the above mentioned functional mixing paradigm.

This *mixing* could have different neuronal variations and different causes: it could be speech, writing, or it could be part of other important, specific LH motoric or perceptual functions in the RH and/or in the LH. There could be different *organic reasons causing the mixing* – from prenatal, hormonal exposure, to early traumatic effects.

An early one-sided *cortical trauma* can provoke the development of loose, functional, neuronal space in the opposite hemisphere, with a corresponding "crowding" cortical effect that could reduce the functional possibilities in this hemisphere (Levy, 1969).

Culturally provoked mixing as, for example, early bimanual training, or "archaic" *Chinese writing stereotypes,* located in the *right* (nonverbal) temporal plana of right-handers, could operate as a "bridge" between abstract and concrete worlds (Gribov & Maewsky, 1987). It could provide and preserve a better *neuronal inter-functional balance*, and could stimulate additional RH activity in the *majority* of the right-handed population, having normally well-separated functions.

One *negative side* of the mixing (in the RH of the *right-handers*) could be the "theft" of neuronal space in the RH (normally prepared for RH functions) and this could reduce the RH functional potential (e.g., spatial abilities) which is important for *outstanding creativity*.

10.2 HIGHEST LEVEL OF CREATIVITY – PARADIGM OF THE CREATIVE DIALOGIC MIND

Levy and Gur (1980) suggested that high levels of fetal sex hormones may promote the maturation rate and *cognitive development* of the RH more than the LH. Later, Benbow (1986) and O'Boyle et. al. (1995) proposed that prenatal exposure to testosterone is a decisive factor for *extreme intellectual precocity.*

This factor could also be decisive in the case of *creative ability,* but it is necessary to:

(a) switch emphasis from the traditional vectors of *intellectual precocity,* or *early cognitive development* to the specific *creative abilities vector.* These vectors, in some cases, could be orthogonal to each other, as mentioned above, for example, for IQ and figural creativity tests (Torrance, 1967);
(b) consider a *multilevel – "spectral" approach* to creative abilities because creative abilities are much more widely distributed in the human population than extreme intellectual precocity, and are present in childhood at least in most left-handed and ambidextrous children (approximately 30% of all age groups), including *creative musical imagination* connected with these children (Gribov, 1987, 1988, 1992).

We repeat our proposal that prenatal exposure to testosterone (which enhances RH development and provokes, in many cases, non-right-handedness) may build the following *neuropsychological bases* for outstanding *creativity:*

(a) *two large, valuable, temporal plana*, (vast neuronal space for linguistic, spatial, and musical skills) which are well-developed in both hemispheres;
(b) *LH/RH functional mixing* in the RH: *two-sided verbality* and some other functions (without the "theft" of neuronal space, and with the conservation of the *salient RH functions*);
(c) *additional corpus callosum fibers* connecting these additional fields;
(d) *larger, special cortical zones* (possibly similar to the visual cortical zone in great artists).

The Two-sided Verbal Factor – with Compensated RH-visuospatial Zones

It appears to be especially intriguing because it provokes flexible, *creative, dialogic thinking*, performing more or less equal dialogue of two different, possibly opposite, cognitive styles. This could be a necessary pre-condition for the most effective and the highest levels of creative functional cooperation and competence between the brain hemispheres.

Indeed, the study from Sperry (1974) showed that in split-brain patients, "Each hemisphere … has its own … private sensations, perceptions, thought, and ideas, all of which are cut off from the corresponding experiences in the opposite hemisphere. Each left and right hemisphere has its own private chain of memories and learning experiences that are inaccessible to recall by the either hemisphere. In many respects each disconnected hemisphere appears to have a separate "mind of its own."" (p. 29).

For almost 150 years, it has been known that the capacity for speech resides primarily in the LH. The sodium amobarbital (Wada) test, which is performed by totally blocking the activity of the LH or the RH, indicated that more than 95% of *right-handed* individuals have LH language. However, only approximately 70% of *left-handers* are left lateralized for speech, with the rest apparently having either bilateral (15%) or RH (15%) speech (Rasmussen & Milner, 1977). A similar study carried out recently suggests that the incidence of pure RH speech may actually be much lower than it was found above (Rasmussen & Milner, 1977) and it is, in reality, bilateral speech in many cases (Loring, et al., 1990). In most cases, injuries on the left side of the brain cause speech damage, while right-brain injuries leave speech intact.

Note: ***The Functionally compensated two-sided speech factor*** explains the unusual creative ability of the "non-right-handed." At the same time, a relatively small number of right-handers (approximately 5%) with an additional speech center in the RH (with *compensated* – preserved and rich visuospatial RH functions) could have a similar mechanism providing creative abilities. This means that the two-sided, *compensated,* verbal consciousness is the most important factor for creative predisposition.

"Non-right handedness" is one of the most important visible factors which show the LH/RH hemispheric functional mixing within the same hemisphere. However, this mixing could also exist for some *right-handed* people, who have some mixing cortical areas (*not necessary for the motoric function*). The most important pre-condition for the production of highly creative abilities could be the two polar speech centers with well-compensated visuospatial functions found in the RH. This additional proposal could explain why some outstandingly creative persons in the Chicago group reacted (in gestures) like right-handers.

Unfortunately, in our empirical Chicago study we could not perform dichotic listening tests for the group and could not perform tests of handedness because we only used the archival tapes from the study of Csikszentmihalyi (1966), mentioned above.

Julius Caesar could dictate two different letters simultaneously (mentioned by Plutarch).

Andrej Sacharov

The concept of two-sided verbality originated 10 years ago as a result of my few meetings with one of the most creative persons of the 20th century – the famous Russian nuclear physicist and dissident Andrej Sacharov. He demonstrated (as a joke) his excellent left-handed writing in the normal and *in the mirror position*, as Leonardo da Vinci had done before. If people asked his opinion, he could answer: "I have two opinions at once…, but it is not easy to decide which one is my real one". People around him were often confused by such "strange" answers.

The recollections of Sacharov's colleagues highlight the paradoxical nature of some of his personal features, including his [original] bi-cameral verbality (Keldish, et al., 1996). One of his colleagues, B. Smagin, wrote that he found in Sacharov a "surprising, attractive, naiveté in union with a delicate mind and slyless (artless), unprotected frankness" (p. 566). I. Shklovsky described him as follows: "the union of an unbending steadfastness with a kind of a childish ingenuousness, kindness, and even naiveté were distinctive features of his character" (p. 776). M. Perelman remembers his "childish laugh" (p. 490). *As natural effects of childishness, RH and adult-LH verbal subminds coexist (I. Gribov).*

J. Smirnov repeats the memories of the physicist T. Kusnezova (who worked together with the young Sacharov) who depicted him at the age of 32 as a man who "slightly stammered and his speech was rather troubled. Later this feature was strongly reduced…He usually drew on a board with his left hand" (p. 597). E. Feinberg remembers Sacharov often talking to him while clearly working simultaneously on a different thought but this did not affect his ability to carry out a conversation (p.702)]. *As a parallel activity of two relatively independent verbal minds (I. Gribov).*

L. Keldish remembers that Sacharov had "concrete imagery thinking even in the most abstract fields and it was reflected often in his strange drawings. His way of thoughts was very unusual and often even not clear…it was very difficult to follow his logic – it was inconsequent. The complete picture of the event always aroused in his head, but he could not right away explain it wholly. …Many people noted also that he spoke with difficulties of choosing words" (p.317). *Holistic, imagery, intuitive, inconsequent RH- thinking style with a non-fluent speech of youth (I. Gribov).*

I. Tamm noted once that Sacharov viewed each problem as if he had, in front of him, a clean sheet of paper, and then made amazing discoveries. *RH-mind with a fresh view of the beginner (I. Gribov).*

V. Ginsburg remarked on the pronounced "apartness," and *autism* of Sacharov (p. 246) – as A. Pais also noted in A. Einstein. I. Perelman wrote that Sacharov was a self-absorbed man and could be lost in his thoughts. *This is because psychologically he was "not alone" with nonstop thoughts going on in him inside the RH-LH verbal dialog (I. Gribov).*

E. Feinberg stated that "his "apartness" was combined inscrutably with his emotionality and a force of feeling for other people" (p. 702). M. Pripstein stated that "he had a constant tendency to something new and an ability [of] wonder." *This is because of a strong contribution of the RH emotional verbal mind (I. Gribov).*

I. Perelman commented "the poet S. Marshak noted that each man has two ages – passport age and that of a kid, which did not disappear in him… by that

– the second age of Sacharov would have been 12 years" (p. 490). *This could be the age of his RH-verbal consciousness (I. Gribov).*

V. Zuckerman stated that "Sacharov was a talented physicist and inventor of a wide profile, he was a generator of ideas with wonderfully developed intuition" (p. 747). A. Jaglom wrote that Sacharov told him that: "he cannot write long articles" (p. 780); "he also had no love for long logically unstained proofs of theorems and to fat detailed books." I. Perelman commented further that he could manage with the simplest mathematical methods. V. Zuckerman stated that "He had miracle physical intuition, he could predict results arising through very complicated formulas" (p. 748). *The cognitive power of the RH-verbal mind is based on the nonverbal RH processes and it requires only laconic verbalization and condensed, local forms of logical proofs (I. Gribov).*

M. Levin remembers his peculiar ability of "rapprochement of distant ideas" and his good ability to draw (p. 350). *The first ability is connected with imagery associative-cognitive RH mechanisms; the second is natural for the RH tissue of thinking (I. Gribov).*

Leonardo da Vinci

The similarity between the above mentioned psychological features of the physicist Sacharov and the left-handed Leonardo da Vinci is amazing. Leonardo da Vinci also preferred to draw and write using the left hand. He also mentioned, about himself, that he often had not enough phrases to express his own thoughts, and it was difficult for him to learn Latin well. He wrote many pages with notes, made by mirror writing with his left hand (from the right to the left). He was a great inventor, scientist, and painter, but also a very good singer and gifted musician (as were A. Einstein and M. Planck). Leonardo da Vinci was a very *self-absorbed* man, similar to Sacharov. At the same time, Leonardo da Vinci surprised people by his interest in festivals and different artistic effects for fiestas. It shows the *childish side* of his soul. His biographer, Vasari, was very surprised that Leonardo da Vinci was often so occupied by the "construction of these trifles" (Neumayer, 1995).

Wolfgang Amadeus Mozart and Vincent van Gogh

Mozart was also known for behaving in a childish way all his life (Neumayer, 1995). The same characteristic was given to van Gogh by his close friend P. Gorlitz who wrote about him that: "He was the man who could be differentiated from the usual type of persons by being an absolute child" (Neumayer, 1995).

Albert Einstein

A study of his biographies shows that Einstein also had distinct elements of duality in his character: He was a wise man with all-knowing eyes. At the same time, within him was something childish – he retained forever the wonder of a 5-year old boy, which sees a compass for the first time. He was on the one hand sociable, but on the other hand disposed to solitude from his childhood.

A clear mind paradoxically combined in him with a belief in the aesthetic scientific feeling, as mentioned by J. Holton who wrote the "psychological biography" of Einstein (Luk, 1978, p. 98). Einstein proposed many ideas, many of which often had an aesthetic, but not a logical nature. He preferred deep and laconic theoretical postulates inspired by his aesthetic intuition. He was revolutionary in many fields, but conservative in perception of the modern quantum physics, because this was against his aesthetic norms of physical theory. All his life he developed concepts of united physical theory, he was one of a few pioneers (*M. Planck, L. de Broglie, E. Schrödinger*) who established quantum physics. Einstein (1953) attempted to build his uniform field theory partially in connection with the assumption that relativistic field theory, probably, could give a key to the more perfect quantum theory. He was convinced that the statistical quantum theory is too superficial, and it is necessary to build it on the basis of the general relativity theory (Einstein, 1949). Only now is it clear that his intuition was try. It is not so unexpected that, namely, his dual (and contradictory) mind could propose and carry out very strange, logically paradoxical, dual physical phenomena connected with the famous *wave-particle dualism.* His outstanding intuition suggested to him that the corpuscular-wave dualism required something unheard of before in physics (Einstein, 1942), and much later this was verified in corresponding physical theories containing *additional space dimensions.*

Naive and Childish Features in the Adult Creator

Many psychological as well as neuro-biological studies show a decline of creative functioning in adult age, perhaps already in the twenties (Smith, 1999). Smith raised the question: "does this mean that creative elderly people have preserved a childish nucleus?" (p. 352). He further noted that very specific psychical states of "so-called oceanic experiences are most typical of highly creative people – and of children and these experiences imply, among other things, that the individual self merges with something beyond its narrow boundaries" (p. 354).

The American psychologists Runco and Charles (1997) noted that childish *naiveté* is one of the most interesting personal characteristics connected to creative people. They wrote that naiveté "is not indicative of a lack of experience, but rather a way of describing how creative individuals resemble children" (p. 134). Solomon, Powell, and Gardner (1999) wrote about the childlike abilities in creative adults, such as disregarding convention and pushing questions and inquiries to their limits. These authors noted that a creative person's childish insight, feelings, and experiences are joined productively with the most advanced understanding and skills achieved in a domain.

We propose that the observed childish naiveté in highly creative adult personalities and, at the same time, adult understanding and skills could be naturally explained by the above mentioned *functionally, compensated, bicameral verbality*. The RH simultaneously carries, for example, excellent visuospatial functions and has also enough well developed (probably, in children up to the age of approximately 10–12 years) verbal abilities that realize the childish, naive (autonomous) side of the creative personality's consciousness, where

RH-imagery, RH-associative ability, high RH-emotional involvement, and RH-holistic informational processes play a major role. At the same time, the LH accumulates intellectual abstract thinking typical in adults and sensory-motoric skills, that is, libraries of different algorithms and stereotypes necessary for culturally convenient and significant creative achievements (Gribov, 1987, 1988, 1992). A similar situation (RH – as mentioned above) is typical for the young human brain, when abstract thinking mechanisms in the LH are not so strongly developed, and the RH-cognitive and behavioral involvement plays a much stronger role in the consciousness than it would later in adulthood.

Creative Dialogic Consciousness in Adults

This has the *independent*, naive, and creative "RH verbal voice" of a *child or teenager*. It advocates for more competent RH functional involvement, collaborating or competing with the opposite – *adult consciousness* of the LH – it is more bureaucratic, abstract, analytical, and verbal. Instead of normal leftward "bureaucratic autocracy" (as in people with separated functions) it leads to some kind of "functional democracy," for example, in the left-handed, the ambidextrous, and some right-handed people with bicameral verbal centers. This "functional democracy," realizing in the same brain will stimulate powerful, inexhaustible *creativity flow production* (as it could in a child), but with much more effective selection, analysis, comparison, routine structural development, and implantation of new ideas in existing professional domains, reflecting this *most complete creative cognition*. It could also explain the surprising combination of opposite personal features, found in the outstandingly creative person, such as, for example, openness versus the ability to form a good Gestalt; acceptance of the unconscious into the conscious; distanced attitude versus being strongly engaged; a critical, questioning attitude versus constructive problem solving; egocenteredness versus altruism and empathy; self-criticism and self doubt versus self-confidence; relaxedness versus concentration (Csikszentmihalyi, 1996).

Bi-cameral consciousness in creative persons could also explain the paradoxical mixing of stereotypical male and female characteristics: creative persons cross the boundaries of gender stereotypes. This is often typical for female inspiration, sensitivity, responsibility, but also for elaboration, autonomy, and a positive self-image, which is typical for males (Fromm, 1980).

Note: The prevalence of males, amongst the most creative achievers (e.g., in science), could be explained by the more developed RH-*spatial abilities* in males, and their better [compensation] inside the larger cortical temporal plana in the RH containing the RH-speech center (especially for "non-right-handed" males, as was mentioned above).

"Bi-cameral" verbal activity will not easily break fully operational, nonverbal, functional activity in the RH (necessary for creating new sensory reality). Instead, it will always diffuse into the valuable RH-neuronal space and activate it. [On the contrary,] a break in the fulfillment participation of RH-activity (in decision making processes) could be normal for a brain with strictly divided functions with only the left-sided verbal center that could be typical for the majority of right-handers.

The proposed *two-sided verbal paradigm* is supported by the data from dichotic listening and EEG measurements, connected with *mathematically gifted adolescents.* These teenagers recognized (well, by each hemisphere) significantly more syllables than the *average adolescents.* The gifted group had no asymmetry at all: the LH was only slightly better with recognition than the RH (only in the most extreme cases did they have RH advantage). Authors note that such *dichotic listening* is even *better* correlated with intellectual ability than hand preference per se (O'Boyle & Benbow 1995).

10.3 "VERTICAL" AND "HORIZONTAL" TYPES OF CREATIVITY

The RH-functional Activity Accentuation in Creative Personality

This is significant for males – "natural sciences" (using nearly twice as much left- and bimanual gesturing than only with the left hand); males – "natural science" group excluding Nobel Prize winners; males in the fields via "biology"; and male "artists" (Table 6).

This ***"Vertical" creativity cluster,*** having the right brain activity accentuation, could have two valuable "two-sided" verbal-centers with the speech and spatial functions slightly *better developed, or dominating in the RH*. In other words, we propose that creative people from this *cluster* have a more *"artistic" creative cognitive profile*, and are more effective in *"vertical" creativity* – in the creation of new paradigms and new fields. This is not unexpected for the "natural science" (without a strong mathematical background), for the "biology," and especially for the "artists" subgroups. Remember, that in hand gesturing, the males – "natural science" also use significantly more left-handed gestures than males with "verbal" accentuation. Typical examples are the left-handed Albert Einstein (who was also a good violinist and inventor, and had extraordinary creative physical intuition, but his mathematical tools were not the best), or leftward gesturing Ilya Prigogine, who, looking more like an artist than a scientist, created a new field – nonequilibrium thermodynamics.

Balanced LH/RH Functional Accentuation in Creative Personality

This is significant for male – "Nobel Prize winners"; male and female – "verbal fields"; male – "business"; female – "natural science." These subgroups have no significant differences between left-handed and right-handed gestures, and also between bimanual and right-handed gestures (Table 6).

The "Horizontal" creativity cluster intends to have two valuable "two-sided" verbal centers, but with a slight dominance in the LH. The "Nobel Prize winners" subgroup includes mostly theorists (theoretical physicists), using intensely complicated, abstract mathematical tools. This could explain why this falls into the cluster of the functionally balanced subgroups. These persons could be more effective in the *"horizontal" creativity* – in the frames of exist ing paradigms as, for example, double Nobel Prize winner physicist John Bardeen, who successfully applied the quantum theory.

If we look into the history of quantum physics, we see that the pioneers of the new paradigms, even in the abstract field of theoretical physics, were normally most [synthetic], even artistic persons (it is well known, for example that A. Einstein [a violinist] and M. Planck [a pianist] liked to play music, to improvise musically and even performed at a semi-professional level. Moreover, as one of the greatest physicists of the 20th century, A. Einstein was a left-hander. Such people have a clear holistic panoramic vision of their subject, [are able to establish new domains, and they are able to change directions and propose a new picture of the world in their *scientific domain*.]

Another type of creative scientist is characterized by a relatively more abstract, formal, analytical ability, and a less synthetic, artistic one, compared to Leonardo da Vinci, A. Einstein, and M. Planck. The more analytical type effectively develops new formalisms on the basis of paradigms produced by pioneers – such as Leonardo da Vinci, A. Einstein, M. Planck, or Prigogine. This more analytical type is successful at a less revolutionary, longitudinal, "*local problem solving*" process. Evidently, the majority of Nobel Prize winners in physics are connected with a variety of scientific achievements, corresponding to the "horizontal" type of creativity. It appears that the horizontal/vertical differentiation could be important for future research, connected with the neuropsychological, personal creativity profile of scientific pioneers.

10.4 CREATIVITY – SCIENCE VERSUS ART

Hadamard (1945) attempted to answer the question: "Where lies the physics of the mind?" The famous physicist Penrose wrote: "It seems to me that the importance of aesthetic criteria applies not only to the instantaneous judgments of inspiration, but also to the much more frequent judgments that we make all the time in mathematical (or scientific) work. Rigorous argument is usually the last step! Before that, one has to make many guesses, and for these, aesthetic convictions are enormously important – always constrained by logical argument and known facts…It is these judgments that I consider to be the hallmark of conscious thinking. My guess is that even with the sudden flash of insight, apparently produced ready-made by the unconscious mind, it is consciousness that is the arbiter, and the idea would be quickly rejected and forgotten if it did not 'ring true'" (p. 422).

He combines simultaneously two different processes in the paradoxical equilibrium combination of intuitive, nonverbal (mainly), and conscious attention.

Note: How is this possible? This could be easy for people with "bicameral," verbal consciousness, when verbal, critical, control attention cannot destroy the nonverbal mental modeling processes – flow of imagery associations and polymodal nonverbal feelings. This paradoxical, equilibrium combination has been achieved by people such as Einstein, Goethe, and Prigogine.

10.5 CREATIVITY – INTUITION VERSUS LOGIC

Penrose (1991) was reminded of the notion of Poincare: "I did not verify the idea; I should not have had time" (p. 423), which briefly characterizes his intuitive style of mathematical thinking. In [the discussion on] the "nonverbality of thought" Penrose wrote: "One of the major points that Hadamard makes in his study of creative thinking is an impressive refutation of the thesis, so often yet expressed, that verbalization is necessary for thought. One could hardly do better than repeat a quotation from a letter he received from Albert Einstein: The words or the language, as they are written or spoken, do not seem to play any role in my mechanism of thought. The psychical entities, which seem to serve as elements of thought are certain signs and more or less images, which can be "voluntarily" reproduced and combined. The above-mentioned elements are, in my case, of visual and some muscular type. Conventional words or other signs have to be sought for laboriously only in a second stage, when the mentioned associative play is sufficiently established and can be reproduced at will" (p. 424).

Hadamard (1945) also wrote about himself "words are totally absent" from his mind when he "really thinks." He fully agreed with Schopenhauer when he wrote, "thoughts die the moment they are embodied by words."

Penrose (1991) said about himself: "Almost all my mathematical thinking is done visually and in terms of non-verbal concepts, although the thoughts are quite often accompanied by inane and almost useless verbal commentary, such as 'that thing goes with that thing and that thing goes with that thing,' (I might use words sometimes for simple logical inferences)" (p. 424). "…I had noticed, on occasion, that if I have been concentrating hard for some while on mathematics and someone would engage me suddenly in conversation, then I would find myself almost unable to speak for several seconds. This is not to say that I do not sometimes think in words, it is just that I find words almost useless for *mathematical* thinking" (p. 424). He concludes, in accordance with P. Torrance, that "the main polarity in mathematical thinking seems to be analytical/geometrical" and as himself, Penrose is "very much on the geometrical end of things but the spectrum among mathematicians generally is a very broad one. Whereas analytical thinking seems to be mainly the province of the left side of the brain, geometrical thinking is often argued to be the right side's, so it is a very reasonable guess that a good deal of conscious mathematical activity actually does take place on the right!" (Penrose, 1991, p. 425).

Note: This means that RH nonverbal, modeling mechanisms play an exclusive role also in the thinking process of *outstanding mathematicians*, and it appears to be correct to connect the above mentioned data from Benbow (1986), concerning precocious mathematical giftedness, with our study on *outstanding creativity*.

IV. DISCUSSION AND CONCLUSION

Summary

European civilization is reflected in the contradictory, creative personality as the universe is in a drop of water. It has also childish-creative and maturity-conservative sides. One example of the latter is traditional education, which tends to ignore the dimension of creative development in childhood. This tradition could be characterized by some components of the conservative past, namely: (a) *The monological, sociocultural paradigm;* (b) *The paradigm of ignoring children's creative potential; and* (c) *The verbal intellectual paradigm.*

At the beginning of the 20th century, European education had a good chance to *implant creativity*. Pioneers of progressive education such as Kulman and Kerschensteiner in Germany, Bakushinsky and Lev Tolstoy in Russia, Pablo Picasso in France, John Devey in USA, etc., aimed to change the conservative paradigms radically. These important innovative efforts were, however, abandoned during the course of two deeply regressive dictatorships in the thirties and, after the Second World War, were easily forgotten (at least until today) in a Europe destroyed by conflicts.

The *ideal of the creative personality,* and the critical view of traditional education, were *reborn* in the USA after the "Russian sputnik shock." Now, the subject of creativity has been included in many University studies and experimental, educational programs concerned with fostering creativity at school. It is now a solid base of knowledge – and the richest scientific infrastructure – for the successful, *creative transformation* of the American education system. Thus, the USA now has a strongest leading position in this field, which extremely important for development of the *modern innovative culture* in the 21st century. In Germany and in Europe, this very important process is still only in the beginnings. This gap can rapidly increase the economical price, which relatively less innovative Europe will pay in the future.

11.1 CREATIVE POTENTIAL AND TRADITIONAL EDUCATION

The Conservative, Monological, Sociocultural Paradigm

This paradigm came, historically, from the traditional, authoritarian forms of interaction between people found in rigid conservative cultures (namely from the traditionally authoritarian style of behavior between parents and children, teachers and pupils). A widespread democratization of these relationships could provide a key to the creative potential of society. Modern education could accelerate the emergence of a new multi-logical paradigm (cross-historical, cross-cultural, and cross-ages in family and at school etc.).

For example, a cross-historical view of the different school subjects at school could give the panorama of a *paradigmatic evolution* in human knowledge, presenting different, sometimes dramatically opposite, models of reality (e.g., light is the wave – light is the particle). Such meta-knowledge and evolutionary vision will protect the personality from dogmatic positions, and it will provide a *psychological readiness* to participate in creativity and cultural innovation. Now we have much more innovative civilization than existed previously (when paradigms of the traditional education were established). However, modern culture has dramatically accelerated evolution and this calls for a more flexible, creative personality, which can adjust to this evolutionary dynamic.

An example of education in the context of the cooperative project – "a dialogue of cultures" was developed in Russia by the teachers V. F. Litovsky, V. A. Jampolsky, and S. J. Kurganov (Kurganov, 1989), and by the philosopher Bibler (Bibler, 1975). One aspect of their teaching method was to get the pupils to use different thinking paradigms existing in culture and science. The pupils learned *to experience* different paradigms, such as the personalities of the corresponding epoch, and were also encouraged to create new paradigmatic concepts.

The Paradigm of Ignoring Children's Creative Potential

This paradigm appears to be a characteristic of traditional, conservative, mass education and, thus, could strongly contribute to a stagnation of society. Traditionally, verbal intelligence was fostered through education, for example, even up to the level of University students in the USA. Important differences between intelligence and creative productivity were discovered in the 60^{th}. Study of Chambers (1969), showing that a certain level of intellectual ability is essential for creative productivity, but beyond a given "floor," which varies in different fields, *there is no relationship between measured intelligence and creativity*. MacKinnon (1961) also found, that in a group of creative architects, the correlation between intelligence and creativity was found to be *nonsignificant* (–0.08). Barron (1961) obtained correlations approximately +0.4 between the two variables over the total range of intelligence, but that *beyond an IQ level of 120, intelligence is a negligible factor in creativity* (creative architects and authors, who had won national recognition were investigated in this study).

In Europe, a positive attitude to children's creative potential was connected to the *revision of traditional, academic visual art*. An increasing number of progressive artists realized that naive and "primitive" art has a deep aesthetic quality, and some of them recognized the *creative and artistic abilities of children* (Renoir, Cezanne, Gauguin, Matisse, Picasso, Deren). This revision influenced art education, connected to the famous German art pedagogues Kulman, Kirschensteiner, and also the Russian art pedagogue and art critic Bakushinsky (Bakushinsky, 1981). The great Russian author L. Tolstoy also discovered the outstanding aesthetic quality of *children's poetic speech and writing* (verbal art field) when he encouraged them to create stories in his private village school.

Unfortunately, as mentioned above, this European innovative drive has been lost in *Europe*. An important task for education and psychology today is to reanimate this and develop it as fast as possible. It is also important not to ignore the subject, even if somebody believes that the concept of "creativity" *is not a scientific category.*

Verbal Intellectual Paradigm

The verbal intellectual paradigm has been the core of traditional education, psychology, and cybernetics for a long time. It accepts, as self-sufficient, the role of abstract signs, formal logical structures in thinking, and plays down the significance of the object-sensitive base of thinking (the most important for creativity). First of all, it is associated with an abstract alphabetical system: this strong and broad cultural "background," or cultural "magnet," leads to a stronger verbalization of the human psychosphere. It is necessary to find effective cultural balances against this. One of them is art, in which "unusual intensity, force, and perfection of the first period of children's artistic creativity" is amazing (Bakushinsky, 1981). The unique significance of art is the awakening of the creative consciousness in early childhood. But, such an influence must be continuous to ensure that creativity and aesthetics become an important part of the child's personal life. This habit could be developed, initially, by the family and at school.

As was mentioned above, the concepts of educational reform, connected to the creative personality ideal (which arose at the beginning of the 20th century in Europe) were *revived* only after the Second World War in the USA. Psychologist E. Paul Torrance made a significant contribution to the creative learning revolution in America. His latest study shows the results of his extensive experience in this field (Torrance, 1981). He wrote: "Frontier-thinking educators throughout the world are searching for ways of removing some of the unnecessary restriction on learning and thinking and moving to a "no limits to learning" concept of education. In his article, Torrance predicted a large role for computers in the future of creative education.

However, this vision of the modern "one-linear" computer in education is too optimistic, because the thinking processes of the human being are connected with the "parallel, quasi-continual, informational processes," which are no longer possible in the typical "one-linear" computer structure (Gribov, 1981). However, in general, his vision of education in the future is progressive.

Torrance stated: "A major obstacle to a "no limits to learning" type of education is the antiquate concept of the nature of the human mind…, the knowledge teachers, educational policy makers, and college of education facilities lags far behind actual developments" (Torrance, 1981).

11.2 THE TORRANCE CONCEPT OF THE NATURE OF THE HUMAN MIND

Torrance (1981) wrote that only a few scientists have progressed in their understanding of the human mind beyond the rather superficial knowledge of the mental functioning reflected in intelligence tests: Bloom's taxonomy of educational objectives (Bloom, 1956), Piaget's developmental theories (Piaget, 1969), and Guilford's Structure of Intellect Model (Guilford, 1967). They have made some differences to the ways children are taught at home and in school, but these theories deal only with local aspects of the human mind and "are preoccupied with a *rational view of learning and thinking*." Torrance continues that this one-sided position "reflects in the 1961 report of the Educational Policies Commission, which recommended that the 'ten rational processes' become the central objectives of American education" as the "highest capabilities of the human mind." He goes on to write that: "This view represents an age-long bias of Western culture. Many of the Eastern cultures would maintain that the rational processes are important and essential, but man's highest capabilities are in the realms of intuition and creativity, the supra-rational." Torrance wrote "all leading models of creative thinking call for both patterns of information processing." He shows examples of such bipolar vision in the theory of education and intelligence:

(a) Osborn (1952, 1967) – this is "critical" and "creative" intelligence which he realized in his famous training methods;
(b) Edwards de Bono (1970) – this is "lateral" and "vertical" thinking;
(c) Rollo May (1975) – this is "rational" and "supra-rational";
(d) Gordon (1961) – this is "intellectual," "irrational," and "emotional";
(e) Torrance (1963) – this is the concept of "learning creatively" versus "learning by authority, by being told."

12. WESTERN CIVILIZATION AND THE FAR-EASTERN CULTURAL WORLD

Summary

The European and Chinese cultural worlds (China, Japan, Korea) have very different writing (alphabetic – European, located in the LH and hieroglyphic – Chinese, located in the RH). This opposing cortical location creates a distinction between Far-Eastern and Western human thinking: alphabetic writing *divides* hemispheres, where as hieroglyphic writing *cooperates by mixing basic functions,* thereby, playing the role of a "bridge" between two cognitive poles (abstract and concrete, verbal and figurative, discursive and simultaneous in thinking and in language).

The Far-Eastern world developed simple and effective *psychotechniques, changing BFA processes* into more RH activation: for example, repetitive *"vocal mantras,"* blocking the internal LH motoric speech and facilitating opposite RH functions. In the Far-Eastern culture were developed *"manual mantras,"* blocking internal right-handed, thin finger manipulations, and working as a "sleeping draught" for the LH motoric, stereotype centers, facilitates meditative states; were developed also *paradoxical verbal "Koans",* which are sharp, paradoxical, verbal statements called verbal LH shock that also increases RH activation; it is, for example, a *hermit's life* – a very long verbal isolation, developing spiritual imagination.

It is possible that the "alphabetic" Western civilization will soon be seriously challenged by the Far-Eastern "hieroglyphic mind," which is more aesthetic, plastic, and creative.

12.1 DIFFERENCES BETWEEN THE FAR-EASTERN / WESTERN CULTURES

In the context of BFA, the Far-Eastern civilization of the Chinese cultural world is one of great interest. Here, the abstract and concrete, the verbal and figurative, and the discursive and simultaneous are associated within the structure of their writing signs – hieroglyphs. This type of sign is closer to the pole of the concrete and figurative, etc., than a letter or a word of any European language. The deep penetration of text and pictures, and the internal coupling of painting and calligraphy in China, Japan, and Korea show that the gap between the hemispheric functions is not so deep, and that the verbal hemisphere (LH for most people) is not so dominant as in European civilizations (Gribov & Majewsky, 1987; Gribov, 1988).

This is also well known in the high aesthetic quality of Far-Eastern *improvising folk art* that was almost absolutely lost in postindustrial Europe and in the good aesthetic education of children (in calligraphy, ikebana, poetry of traditional forms, home made music etc.).

In Far-Eastern countries, simple, effective, and very old psychotechniques of stimulating the imagination have a wide application (Suzuki, 1959). Evidently, they are connected to the reduced dominance of the rational LH and activation of the nonverbal RH.

Educational Routine and "Creative Criminals"

There is one interesting detail against the background of the economical success in Japan – the crime rate was the lowest in the world, and the capturing of criminals was the highest (Seward, 1977). We propose (on the basis of our experience in fostering creativity in some "difficult" adults at school) that, *namely, fostering creativity* could positively change these "difficult" and potentially antisocial, but very creative teenagers. Their creative potential was suppressed by educational routine. Usually, these boys were from families without fathers, and they had no intellectual support at home. At a young age they lost the motivation to study, and had bad "school grades," corresponding to a low level of self-estimation. "Crime," for these teenagers, could be seen as some kind of *social strike* and escape into antisocial behavior.

Such explanations could certainly correspond to the data showing a higher incidence of delinquency and criminality among left-handers and mixed-handers (Ellis, 1987).

Far-Eastern Psychotechniques and BFA

The following Far-Eastern psychotechniques, closely connected to the BFA phenomena, are analyzed (Gribov, 1988):

The vocal mantras

This ancient *verbal psychotechnique* uses spiritually significant, simple sounds with a minimum of syllables, repeated methodically many times. The meditative effect can be explained by the way that such a monotonous repetition, at the same time, blocks any other *verbal* conscious activity of the LH, that is, yielding an excellent, simple, "*periodic verbal blocker*" that reduces verbal functional dominance, and facilitates any opposite nonverbal activity (imagination, etc.).

The manual "mantras"

This ancient *manual, finger, psychotechnique* is typical for Far-Eastern traditions. It is a fine cyclical finger motoric movement, repeated methodically many times (usually people use small stones on a string, which look like beads). The meditative effect can be explained as the "*manual blocking effect,*" in this case the *blocking of the motoric stereotype cortex,* related to the fine hand-movement stereotypes, including writing stereotypes. It can also facilitate activation of opposite cortical functional structures.

Note: The manual, motoric psychotechnique may be associated with the cyclic shading in the drawing process when right-handers draw with the right hand, (e.g., such drawing techniques were typical to Vincent van Gogh).

A hermit's life

A hermit's life is another conscious *"verbal deprivation psychotechnique,"* following the Middle East and Far-East tradition. A hermit rejects any contact with other people (it can be a very long isolation, e.g., approximately 7 years. The isolated person lives in a small closed place. People can give him food, but he has no verbal or visual contact.

Buddhism describes the goal of this isolation – namely, that the hermit's life deepens spiritual imagination (Suzuki, 1959). Indeed, the corresponding verbal isolation leads to a decrease in normal verbal cortex activity, that is, verbal (LH) dominance, and facilitates the compensatory RH activity (leading to the very rich, bright imagination, comparable with hallucinations).

Koans

Koans are paradoxical statements, which challenge the verbal, logical competence. This type of illogical statement such as "a dead cat is the most beautiful picture in the world!" provocatively blocks the verbal reasoning system, that is, such psychotechniques work as some kind of *"logical shock"* method. This verbal shock activates the RH-compensatory activity.

These psychotechniques help to switch functional dominants, and facilitate an easier entry into a psychic state of meditation, connected to a stronger activity of the nonverbal hemisphere.

The verbal koans may be associated, for example, with the unusual task of figure drawing in the unusual turnover position (e.g., by a vertical position, as does the German artist Baseliz, and as it is proposed in the method of B. Edwards (chap. 4.2).

At the same time, the state of meditation can change outside space-perception, and produces a feeling of the aesthetization (harmony, peace, beauty) of visible reality. It is not accidental that the high aesthetic quality of visual folk art, the good, aesthetic education of children, and their participation in folk art activity (in calligraphy, ikebana, poetry of traditional forms, home made music, etc.) is very popular in Japan.

Western civilizations could assimilate the above-mentioned psychotechniques and/or develop other, very simple application methods, useful for the modern European culture.

12.2 SOME PROPOSALS RELATED TO THE "ECOLOGY OF CREATIVITY"

In our study, we propose ways to reduce the so-called leftward (rational) functional dominance observed in Western civilization. This dominance could cause a serious block to creativity, because it is typical for the major right-handed part of the Western population (Gribov, 1988, 1994). This has been suggested by:

– *human movements,* making the left hand more active alongside the right hand (e.g., using both hands to draw, construct, play certain sports, design tools, dance etc.).
– *communication,* combining the simultaneous and the discourse codes in any statement, actively including other types of intermediaries between the abstract and the concrete (as with hieroglyphs) alongside the alphabetical written language. More use of emotional coloring of the statements and use of metaphors, etc.
– *artistic culture,* reviving, in everyday life, the improvisatory, mass artistic creative activity, an activity with deep traditions which are, in many cases, almost lost (the Russian chastooshka, the Japanese haiku and ikebana, the American spirituals, such as jazz etc.).
– *pedagogic,* (with due account to the above system of means) to synthesize the reproductive method, which has monopolized education, with the creative one. It is necessary to develop individual and collective creative self-consciousness through dialogue, cooperation, and the co-creative work between children and teachers.

12.3 THE CYBERNETIC REVOLUTION AS A BASIS FOR THE LIBERATION OF THE HUMAN CREATIVE POTENTIAL

The humanization of our civilization and its qualitative transformation is connected to the modern cybernetics revolution, predicted by Wiener (1948). He predicted that progress in cybernetics will depreciate all kinds of routine human activities including *routine intellectual abilities*, but will preserve *creative abilities* as irreplaceable.

Today, it is not difficult to propose that this (dramatically accelerating) information revolution will *radically reduce the working hours of more people,* and (for the first time in the history of human civilization) it will lead to an *epoch of free time* with creative freedom, where a "paradise for creative self-expression and creative cooperation" will be realized. It appears that our 21st *cybernetic century* has a real chance to open a new epoch of human progress where the generic conception of "Homo-Sapiens" connects to the biblical "Homo-Creative." It is important for Europe not to lose (for a second time) this historical chance, and *not to miss* the development of a new, innovative educational system, corresponding to the "Homo-creative" (where cognitive processes will support creativity, and the traditional passive way of studying will be transformed into *creative cognition*, modeling the essence of human existence and human dignity.

REFERENCES

Adolphs, K., Damasio, H., Teanei, D., Damasio, A. R. (1996). Cortical systems for the recognition of emotion in facial expressions. J. Neurosci., 16: 7678-7687.

Alpatov, M. W. (1963). Matisse. Moscow, Art, (Rus.).

Ananjev, B. G. (1960). Psychology of affective cognition. PN RSFSR, Moscow, (Rus.).

Annett, M., Kilshaw, D. (1983). Mathematical ability and lateral asymmetry. Cortex, 18: 547-568.

Arnheim, R. (1966). Toward a psychology of art. Univ. of California Press, Berkeley and Los Angeles.

Bakushinsky, A. B. (1981). Art creativity and education. Moscow, Art, (Rus.).

Basar, E. (1980). EEG-brain dynamics: relation between EEG and brain evoked potentials. Elsevier, Amsterdam, North Holland.

Basar, E., Rosen, B., Basar-Eroglu, C., Greitschus, F. (1987). The associations between 40 Hz - EEG and the middle latency response of the auditory evoked potential. Int. J. Neurosci., 33: 103-117.

Basar, E., Basar-Eroglu, C., Röschke, J., Schütt, A. (1989). The EEG is a quasi-deterministic signal anticipating sensory-cognitive tasks. In: E. Basar and T.H. Bullock (Eds.), Brain Dynamics, Progress and Perspectives, Springer-Verlag, Berlin, 43-71.

Basar-Erogly, C., Strüber, D., Stadler, M., Kruse, P., Greitschus, F. (1995). Slow positive potential in the EEG during multistable visual perception. In: P. Kruse and M. Stadler (Eds.), Ambiguity in Mind and Nature. Springer-Verlag, Berlin Heidelberg, 389-405.

Basar, E., Demiralp, T. (1995). Fast rhythms in the hippocampus are a part of the diffuse gamma response system. Hippocampus, 5: 240-241.

Basar, E., Basar-Eroglu, C., Demiralp, T., and Schürmann, M. (1995). Time and frequency analysis of the brain's distributed gamma band system. IEEE Engineer. Med. Biol., 14: 400-410.

Basar-Eroglu, C., Strüber, D., Kruse, P., Basar, E., Stadler, M. (1996a). Frontal gamma-band enhancement during multistable visual perception. Int. J. of Psychophysiol., 24: 113-125.

Basar-Eroglu, C., Strüber, D., Schürmann, M., Stadler, M., Basar, E. (1996b). Gamma-band responses in the brain: a short review of psychophysiological correlates and functional significance. Int. J. of Psychophysiol., 24: 101-112.

Barron, F. (1961). Creative vision and expression in writing and painting. In: D. W. MacKinnon (Ed.). The creative person. Berkeley: Institute of Personality Assessment Research, University of California, 237-251.

Bellak, L. (1958). Creativity: some random notes to a systematic consideration. J. of Projective Techn., 4: 363-380.

Bellugi, O., Poizner, H., Klima, E. S. (1983). Brain organization for languages: clues from sign aphasia. Human Neurobiol., 2: 155-170.

Benbow, C. P. (1986). Physiological correlates of extreme intellectual precocity. Neuropsychol., 24: 719-725.

Benton, A. L. (1968). Differential behavioral effects of frontal lobe disease. Neurophsychol., 6: 53-60.

Berger, H. (1930). Über das Elektrenkephalogramm des Menschen, II. J. Psychol. Neurol. 40: 160-179.

Bernstein, N. A. (1967). The coordination and regulation of movements. Pergamon, New York.

Bibler, C. S. (1975). Thinking as creativity. Prosveschenie, Moscow.

Bizzi, E., Accornero, N., Chapple, W., Hogan, N. (1984). Posture control and trajectory formation during arm movement. J. Neurosci., 4: 2738-2744.

Bizzi, E., Hogan, N., Mussa-Ivaldi, F. A., Giszter, S. (1992). Does the nervous system use equilibrium-point control to guide single and multiple joint movements? Behav. Brain Sci., 15: 603-613.

Bizzi, E., Mussa-Ivaldi, F. A., Giszter, S. F. (1991). Computations underlying the execution of movement: a biological perspective. Science, 253: 287-291.

Bizzi, E., Mussa-Ivaldi, F. A. (2000). Toward a neurobiology of coordinate transformations. In: M. Gazzaniga (Ed.), Cog. Neurosci.,. MIT Press, 489-500.

Bizzi, E., Polit, A., Morasso, P. (1976). Mechanisms underlying achievement of final head position. J. Neurophysiol. 39: 435-444.

Black, F. W., Strub, R. L. (1976). Constructional apraxia in patients with discrete missile wounds of the brain. Cortex, 12: 212-220.

Bloom, B. S. (Ed.). (1956). Taxonomy of educational objectives. Handbook I: Cognitive Domain. Longman, Green, New York.

Bowers, D., Bauer, K. M., Coslett, H. B., Heilman, K. M. (1985). Processing of faces by patients with unilateral hemisphere lesions. I. Dissociation between judgment of facial affect and facial identity. Brain and Cognit., 4: 258-272.

Braitenberg, V. (1978). Cell assemblies in the cerebral cortex. In: R. Heim and G. Palm, (Eds.). Architectonics of the Cerebral Cortex. Lecture Notes in Biomathematics, Theoretical Approaches in Complex Systems, Springer-Verlag, Berlin, 171-188.

Buracas, G., Zador, A., Deweese, M., Albrtght, T. (l998). Efficient discrimination of temporal patterns by motion-sensitive neurons in primate visual cortex. Neuron, 20: 959 969.

de Bono E. (1970). Lateral thinking. Harper and Row, New York.

Brady, M., Hollerbach, J. M., Johnson, I. L., Lozano-Perez, I., Mason, M. T. (1982). Robot motion: planning and control. MIT Press, Cambridge, MA.

Broadbent, D. E. (1977). The hidden preattentive process. Amer. Psychologist, 32: 109-118.

Caminiti, R., Johnson, P. B., Urbano, A. (1990). Making arm movements within different parts of space: Dynamic aspects in the primate motor cortex. J. Neurosci., 10: 2039-2058.

Carr, C. E. (1993). Processing of temporal information in the brain. Annu. Rev. Neurosci., 16: 223-243.

Chambers, J. (1969). A multidimensional theory of creativity. Psychol. Reports, 25: 779-799.

Chatrtan, G. E., Petersen, M. C., Lazarete, J. A. (1959). The blocking of the rolandic wicket rhythm and some central changes related to movement. Electroencephalogr. Clin. Neurophysiol., 11: 497-510.

Chiselin, B. (1955). The creative process. Mentor, New York.

Christman, S., Kitterle, F., Hellige, J. (1991). Hemispheric asymmetry in the processing of absolute versus relative spatial frequency. Brain Cognit., 16: 62-73.

Cooper, R., Winter, A. L., Crow, H. J., Grey, W. (1965). Comparison of subcortical, cortical and scalp activity using chronically indwelling electrodes in man. Electroencephalogr. Clin. Neurophysiol., 18: 217-228.

Coren, S., Porac, C. (1982). Lateral preference and cognitive skills: An indirect test. Percept. and Motor Skills, 54: 787-792.

Coren, S. (1995). Differences in divergent thinking as a function of handedness and sex. Amer. J. of Psychol., 108: 311-325.

Costa, L. D., Vaughan, H. G. (1962). Performance of patients with lateralized cerebral lesions. J. of Nervous and Mental Disorders, 134: 162-168.

Cranberg, L., Albert, M. (1988). The chess mind. In: L. Obler and D. Fein (Eds.), The exceptional brain. Guilford Press, New York, 204-222.

Cropley, A. (1991). Unterricht ohne Schablone, Wege zur Kreativität. Ehrenwirth, München.

Cropley, A., McLeod, J., Dehl, D. (1988). Begabung und Begabungsförderung. Entfaltungschancen für alle Kinder! Roland Asanger Verlag, Heidelberg.

Csikzentmihalyi, M. (1996). Creativity. (Flow and the psychology of discovery and invention). HarperCollins Publischers, New York.

Davidson, K. J. (1992). Anterior cerebral asymmetry and the nature of emotion. Brain and Cognit., 20: 125-151.

Delis, D. C., Robertson, L. C., Efron, R. (1986). Hemispheric specialization of memory for visual hierarchical stimuli. Neuropsychol., 24: 205-214.

Diesmann, M., Gewaltig, M. O., Aertsen, A. (1996).
Characterization of synfire activity by propagating 'pulse packets'. In: J. Bower, (Ed.). Computational Neuroscience: Trends in Research. Academic Press, San Diego, 59-64.

Dick, D. E., Vaughn, A. O. (1970). Mathematical description and computer detection of alpha waves. Math. Biosci., 7: 81-95.

Donoghue, J. P., Sanes, J. N. (1994). Motor areas of the cerebral cortex. J. Clin. Neurophysiol., 11: 382-396.

Duhrssen, A. (1957). Discussant in the Arden House conference on motivating the creative process. Harriman, New York.

Duda, P. D., Brown, J. (1984). Lateral asymmetry of positive and negative emotions. Cortex, 20: 253-261.

Duncker, D. (1945). On problem solving. Psychol. Monographs, 58, No 270.

Edelman, G. M. (1987). Neural darwinism: the theory of neuronal group selection. Basic Books, New York.

Edwards, B. (1979). Drawing on the right side of the brain. J.P. Tarcher, inc., Los Angeles.

Einstein, A. (1953). Louis de Broglie, physician et penseur. Michel, Paris, Vol. 3.

Einstein, A. (1942). Letter to M. Besso; august 1942 // EB, 336.

Einstein, A. (1949). Letter to M. Besso; august 16, 1949 // EB, 409.

Eisenstein, S. M. (1980). Psychology of art. In: B. S. Meilah, N. A. Hrenov, (Eds.). Psychology processes of artistic creativity. Nauka, Petersburg, 173-203.

Elbert, T., Hommel, J., Lutzenberger, W. (1985) The perception of Necker Cube reversal interactions with the Beitschaftspotential. Int. J. Psychophysiol., 3: 5-12.

Ellis, H. (1987). Neurohormonal bases of varying tendencies to learn delinquent and criminal behavior. C. J. Braukmann and E. K. Morris (Eds.), Behavioral Approaches to Crime and Delinquency: Application, Research and Theory. Plenum, New York, 499-518.

Ellis, A. W., Young, A. W., Andersen, C. (1988). Modes of word recognition in the left and right cerebral hemispheres. Brain and Lang., 35, 254-277.

Engel, A. K., Roelfsema, P. R., Fries, P., Breght, M., Singer, W. (1997). Role of the temporal domain for response selection and perceptual binding. Cerebral Cortex, 7: 571-582.

Farber, D. A. Beteleva T. G. (1985). Interhemispheric differences in mechanisms of visual perception in ontogenesis. Sensorial systems: Sensorial processes and asymmetry of hemispheres. Petersburg., 127-135.

Feldman, A. G. (1974). Change of muscle length due to shift of the equilibrium point of the muscle-load system. Biofizika, 19: 534-538.

Fink, C., Halligan, P., Marshall, J., Prith, C., Frackowiak, R., Dolan. R. (1996). Where in the brain does visual attention select the forest and the trees? Nature 15: 626-628.

Fiorentini, A., Berardi, N. (1984). Right-hemisphere superiority in the discrimination of spatial phase. Perception, 13: 695-708.

Flash, T., Gurevich, I. (1992). Arm movement and stiffness adaptation to external loads. In: Proceedings of the annual conference in IEEE Engineering in Medicine and Biology Society. IEEE Publishing Services, New York, 885-886.

Franco, L., Sperry, R. W. (1977). Hemisphere lateralization for cognitive processing of geometry. Neuropsychol., 15: 107-114.

Freeman, W. J. (1975). Mass action in the nervous system. Academic Press, New York.

Freeman, W. J. (1979). Nonlinear dynamics of paleocortex manifested in the olfactory EEC. Biol. Cybernet. 35: 21-37.

Freeman, W. J., Skarda C. A. (1985). Spatial EEC patterns non linear dynamics and perception the neo Sheringtonian view. Brain Res. Rev. 10: 147-175.

Fromm, E. (1980). Greatness and limitations of Freud's thought. New American Library, New York.

Gafni, H., Zeevi, Y. Y. (1977). A model for separation of spatial and temporal information in the visual system. Biol. Cybern., 28: 73-82.

Gainotti, G., Tiacci, C. (1972). Patterns of drawing disability in right and left hemispheric patients. Neuropsychol., 8: 379-384.

Galaburda, A. M., Corsiglia, C., Rosen. C., Sherman, C. (1987). Planum temporale asymmetry reappraisal since Geschwind and Levitsky. Neuropsychol., 25: 853-868.

Gazzaniga, M. S., Sperry, R. W. (1967). Language after section of the cerebral commissures. Brain, 90: 131-138.

Gazzaniga, M. S. (1970). The bisected brain. Appleton, New York.

Gazzaniga, M. S., Hillyard, S. A. (1971). Language and speech capacity of the right hemisphere. Neuropsychol., 9: 273-280.

Gazzaniga, M. S., Ledoux, J. E., Wilson, D. H. (1977). Language praxis and the right hemisphere: clues to some mechanisms of consciousness. Neurology 27: 1144-1147.

Gazzaniga, M. S., LeDoux J. E. (1978). The integrated mind. Plenum Press, New York.

Gazzaniga, M. S. (1985). The social brain: discovering the networks of the mind. Basic Books, New York.

Gazzaniga, M. S. (1998). The mind's past. University of California Press, Berkeley.

Gastaut, H. (1952). Etude electrocorticographique de la reactivite des rhythmes rolandiques. Rev. Neurol., 87: 176-182.

Georgopoulous, A. P., Kettner, R. E., Schwartz, A. B. (1988a). Primate motor cortex and free arm movements to visual targets in three-dimensional space: I. Coding of the direction of movement by a neuronal population. J. Neurosci., 8: 2913-2927

Georgopoulous, A. P., Kettner, R. E., Schwartz, A. B. (1988b). Primate motor cortex and free arm movements to visual targets in three-dimensional space: II. Coding of the direction of movement by a neuronal population. J. Neurosci., 8: 2928-2937.

Gerstein, G. L., Gochin, P. M. (1992). Neuronal population coding and the elephant. In: A. Aertsen and V. Braitenberg, (Eds.). Information Processing in the Cortex: Experiments and Theory. Springer-Verlag, Berlin, 139-173.

Geschwind, N., Behan. P. (1982). Left-handedness: Association with immune disease, migraine and developmental leaning disorder. Proceedings of the Natl. Acad. Sci. (USA), 79: 5097-5100.

Gisztter, S. F., Mussa-Ivaldi, F. A. and Bizzi, E. (1993). Convergent force fields organized in the frog's spinal cord.. J. Neurosci., 13: 467-491.

Glezer, V. D. (1985). Vision and thinking. Nauka, Petersburg.

Glezer, V. D., Ivanoff, V. A., Tscherbach, T. A. (1973). Investigation of complex and hypercomplex receptive fields of visual cortex of the cat as spatial frequency filters. Vision Res., 13: 1875-1904.

Gordon, H. (1978). Left hemisphere dominance for rhythmic elements in dichotomically presented melodies. Cortex, 14: 58-70.

Gordon , W. J. J. (1961). Synectics. Harper and Row, New York.

Gray, C. M., Singer, W. (1987). Stimulus specific neuronal oscillations in the cat visual cortex: a cortical function unit. Soc. Neurosci., 404: 3.

Cray, C. M., Singer, W. (1989). Stimulus-specific neuronal oscillations in orientation columns of cat visual cortex. Froc. Natl. Acad. Sci., USA, 86: 1698-1702.

Gribov, I. A. (1977a). The microstructure of human movements. In: Material of the conference of young scientists, March, 29, 1977, Medicine, Moscow, 113-115.

Gribov, I. A. (1977b). The functional role of EEG-rhythms in the context of the microstructure of human movements. In: Material from the conference of young scientists, March, 29, 1977, Medicine, Moscow, 116-119.

Gribov, I. A. (1980). The influence of hemispherical functional asymmetry on the picture character (portrait of another man). In: Personality in the system of collective relations. Kursk, 65-66.

Gribov, I. A. (1981). Quasicontinual simultaneity as a basic principle of human intellect and some perspectives on the development artificial intellect. Materials from the 9th National Symposium of Cybernetics (10-15 November, 1981) in Suchumi, Vol. 3: 162-165.

Gribov, I. A. (1987). The artistic self-expression of children as a factor in the activation of their creative potential. Man-Creativity-Computer, Moscow, Vol. 1: 124-126.

Gribov, I. A., Majewsky, J. V. (1987). Optimization of the communication structure of signs for stimulation of creative thinking. Operating with diffuse categories. ELM, Baku, 37-38.

Gribov, I. A. (1988). Schöpferische Activität- Wesen and Voraussetzung vor dem Hintergrund der sowjetischen Hirnhemisphärenforschung. Dynamische psychiatrie, 106/107: 378-395.

Gribov, I. A. (1989). Psychological and educational conditions to develop the creative self-expression of students and teachers. Voprosy – Psikhologii, Moscow, 2: 75-82. (Rus.).

Gribov, I. A. (1992). Creativity and brain hemispheres: educational implications. European J. For High Ability, 3: 6-14.

Gribov, I. A. (1994). Defence and development of creative and humanistic potential (as the problem of psycho-ecology). In: Creative potential exploring and development. April 6-9, Pavia, Italy. University of Pavia, European Council for High Ability, 75-76.

Gribov, I., Csikszentmihalyi, M. (2001). Creativity and brain functional asymmetry (as measured by conversational gestures). (Creativity Research Journal), (in publ.).

Goldberg, E., Costa, L. D. (1981). Hemisphere differences in the acquisition and use of descriptive systems. Brain and Lang., 14: 144-173.

Guilford, J. P. (1959). Intellectual resources and their value as seen by creative scientists. In: C. W. Taylor (Ed.). The third (1959) University of Utah research conference on the identification of creative scientific talent.. University of Utah Press, Salt Lake City, 128 –149.

Guilford, J. P. (1967). The nature of human intelligence. McGraw-Hill, NY.

Hadamard, J. (1945). The psychology of invention in the mathematical field. University Press, Princeton.

Haken, H. (1983). Synergetics. An introduction (3rd ed.). Springer, Berlin.

Hari, R., Salmelin, K., Mäkelä, J. P., Salenius, S., Helle, M. (1997). Magnetoencephalographic cortical rhythms. Int. J. of Psychol., 26: 51-62.

Harmon, L. R. (1955). Social and technological determiners of creativity In: C. W. Taylor (Ed.). The 1955 University of Utah research conference on the identification of creative scientific talent. University of Utah Press, Salt Lake City, 42- 52.

Hebb, D. O. (1949). The organization of behavior: a neuropsychological theory. Wiley, New York.

Hellige, J. B. (1980). Effects of perceptual quality and visual field of probe stimulus presentation on memory search for letters. J. of Experim. Psychol.: Human Perception and Performance, 6: 639-65l.

Hellige, J. B., Longstreth, L. E. (1981). Effects of concurrent hemisphere-specific activity on unimanual tapping rate. Neuropsychologia, 19: 395-405.

Hellige, J. B., Wong, T. M. (1983). Hemispheric specific interference in dichotic listening: Task variables and individual differences. J. of Experim. Psychol.: General., 112: 2l8-239.

Hellige, J. B., Mitchimata, C. (1989). Categorization versus distance: hemispheric differences for processing spatial information. Memory and Cognit., 17: 770-776.

Hellige, J. B., Kee, D. W. (1991). Asymmetric manual interference as an indicator of lateralized brain function. In: G. R. Hammond (Ed.). Advances in psychology: Cerebral control of speech and limb movements. North Holland, Amsterdam, XX-XX.

Hellige, J. B. (1990). Hemispheric asymmetry. In: M. Rosenzweig and L. Porter (Eds.). Annual rev. of psychol. Annual Rev., Inc., Palo Alto, 41: 55-80.

Hellige, J. B. (1993). Hemispheric asymmetry. Harvard University Press, Cambridge, MA.

Hines, D., Glista, G., Byres B. (1985). Perceptual interference and hemispheric specialization. Brain and Cognit., 4: 76-89.

Hinton G. E., Andersen J. A., (Eds.). (1989). Parallel models of associative memory. Lawrence Erlbaum associates, Ink., Hillsdale, NJ.

Hogan, N. (1984). An organizing principle for a class of voluntary movement control. J. Neurosci., 4: 2745-2754.

Hogan, Bizzi, N., E. Mussa-Ivaldi, F. A., Flash, I. (1987). Controlling multijoint motor behavior. In: K. B. Pandolf, (Ed.). Exercise and sport sci. rev., Macmillan, New York, 15: 153-190.

Hollerbach, J. M., Atkeson, C. G. (1987). Deducing planning variables from experimental arm trajectories: Pitfalls and possibilities. Biol. Cybern., 56: 279-292.

Hoppe, K. D. (1977). Split brain and psychoanalysis. Psychoanalytical Quarterly, XLVI: 220-242.

Hubel D. H., Wiesel T. N. (1979). Brain mechanisms in vision. In: The brain. A scientific American book, 84-97.

Huber, P. J., Kleiner, B., Gasser, T., Dumermuth, C. (1971). Statistical methods for investigating phase relations in stationary stochastic processes. IEEE Trans. Audio Electroacous., 19: 78-86.

Ivry, R., Robertson, L. C. (1998). The two sides of perception. MIT Press, Cambridge, MA.

Jahnsen, **H., Linas, R.** (1984a). Electrophysiological properties of guinea-pig thalamic neurons an in vitro study. J. Physiol. (London), 349: 205-226.

Jahnsen, **H., Linas, R.** (1984b). Ionic basis for the electroresponsiveness and oscillatory properties of guinea-pig thalamic neurons in vitro. J. Physiol. (London), 349: 227-247.

Keep, O. A. (1957). Discussant in the Arden House conference on motivating the creative process. Harriman, New York.

Kalaska, J. F., Cohen, D. A. D., Hyde, M. L., Prudhomme, M. (1989). A comparison of movement direction related versus load direction-related activity in primate motor cortex, using a two-dimensional reaching task. J. Neurosci., 9: 2080-2102.

Kaufman, **L., Locker, Y.** (1970). Sensory modulation of the EEG. Proc. Am. Psychol. Assoc., 179-180.

Keldish L. V. (chairman Ed.), (1995). He lived between us. Memories about Sakharov. Keldish, L. V., Altshuler, B. L., Bolototovsky, B. M., Dremin, I. M., Feinberg, V. A. (Eds.). Practika. Moscow.

Kelly, D. D. (1991). Sexual differentiation of the nervous system. In: E. R. Kandel. J. H. Schwartz, and T. M. Jessell (Eds.). Principles of neural science. Appleton, Lange, Norwalk, CT, 959-973.

Kendall, M. S. (1962). Rank correlation method. London: Institute of personnel management, occasional Paper N3.

Kimchi, R., Palmer, S. (1982). Form and texture in hierarchically constructed patterns. J. of Experim. Psychol. : Human Percept. and Perform., 8: 525-535.

Kimura, D. (1973,a). Manual activity during speaking - I. Right-handers. Neuropsychol., II: 45-50.

Kimura, D. (1973,b). Manual activity during speaking - II. Left-handers. Neuropsychol., II, 51-56.

Kimura, D., D'Amico, C. (1989). Evidence for subgroups of adextrals based on speech lateralization and cognitive patterns. Neuropsychol., 27: 977-986.

Kitterle, F., Christman, S., Hellige, J. (1990). Hemispheric differences are found in the identification, but not the detection, of low versus high spatial frequencies. Percept. Psychophysics, 48: 297-306.

Kinsbourne, M. (1970). The cerebral basis of lateral asymmetries in attention. Acta Psychol., 33: 193-201.

Kinsbourne, M. (1972). Eye and head turning indicates cerebral lateralization. Science, 176: 539-541.

Kinsbourne, M., Hiscock, M. (1983). Asymmetries of dual task performance. In: J. B. Hellige (Ed.). 1. Cerebral hemisphere asymmetry: Method, theory and application. Praeger, New York, 255-334.

Kinchla, R. A., Wolfe, J. (1979). The order of visual processing: ,,Top-down," ,,bottom-up," or ,middle-out." Percept. and Psychophysics, 33: 1-10.

Klimesch, W., Pfurtscheller, G., Mohl, W. (1988). Mapping and long term memory. The temporal and topographical pattern of cortical activation. In: G. Pfurtscheller and F. H. Lopes Da Silva (Eds.), Functional Brain Imaging, Hans Huber Publishers, Toronto, 131-142.

Klimesch, W., Schimke, H., Ladurner, C., Pfurtscheller, C. (1990). Alpha frequency and memory performance. J. Psychophysiol., 4: 391-390.

Klimesch, W., Schimke, H., Pfurtscheller, C. (1993). Alpha frequency, cognitive bad and memory performance. Brain Topogr., 5: 1-11.

Klimesch, W. (1999). “Paradoxical” alpha synchronization in a memory task. Cog. Brain Res. 7: 493-501.

Klintman, H. (1984). Original thinking and ambiguous figure reversal rates. Bulletin of the Psychonomic Society, 22: 129-131.

Knox, C., Kimura, D. (1970). Cerebral processing of nonverbal sounds in boys and girls. Neuropsychol., 8: 227-237.

Koffka, K. (1935). Principles of Gestalt psychology. Harcourt Brace, New York.

Köhler, W. (1920). Die physischen Gestalten in ruhe und im stationären zustand. Vieweg, Braunschweig.

Köhler, W. (1940). Dynamics in psychology. Liveright, New York.

König, P., Engel, A. K., Singer W. (1996). Integrator or coincidence detector? The role of the cortical neuron revisited. Trends Neurosci., 19: 130-137.

Krech, D., Calvin, A. (1953). Levels of perceptual organization and cognition. J. of Abnormal and Social Psychol., 48: 396-400.

Krechevsky, I. (1938). An experimental investigation of the principle of proximity in the visual perception of the rat. J. of Experim. Psychol., 22: 497-523.

Kruger, L., Henry, Ch. (1957). Electrical activity of rolandic region in unanesthetized monkey. Neurology, 7: 490.

Kruse, P., Stadler, M. (1990). Stability and instability in cognitive systems: multistability, suggestion, and psychosomatic interaction. In: H. Haken and M. Stadler (Eds.). Synergetic of Cognition, 201-215.

Kruse, P., Stadler, M., Pavlekovic, B., Gheorghui, V. (1992): Instability and cognitive order formation: Self-organization principles, psychological experiments, and psychotherapeutic interventions. In: W. Tschacher, G. Schiepek and E. J. Brunner (Eds.). Self-Organization and Clinical Psychology. Springer, Berlin, 102 - 117.

Kruse, P., Strüber, D., Stadler, M. (1995). The significance of perceptual multistability for research on cognitive self-organization. In: P. Kruse and M. Stadler (Eds.). Ambiguity in mind and nature. Springer-Verlag, Berlin Heidelberg, 69-84.

Kuhn, T. S. (1962). The structure of scientific revolutions. University of Chicago Press, Chicago, IL.

Kurganov, S. J. (1989). Children and adult in the teaching dialog. Prosveschenie, Moscow.

Lamb, M. R., Robertson, L. C. (1987). The effect of acute alcohol on attention and the processing of hierarchical patterns. Alcoholism: Clin. and Experim. Res., 11: 240-248.

Lange, G. C. (1957). Discussant in the Arden House conference on motivating the creative process. Harriman, New York.

Lashley, K. S. (1960). Persistent problems in the evolution of mind. In: Beach, F. A., Nissen, N. W. and Boring, E. G. (Eds.). The Neuropsychology of Lashley. New York, 455-477.

Lee, W. J. (1957). Discussant in the Arden House conference on motivating the creative process. Harriman, New York.

Levy, J. (1969). Possible basis for the evolution of lateral specialization of the human brain. Nature, 224: 614-615.

Levy, J., Trevarthen, C. (1976). Metacontrol of hemispheric function in human split-brain patients. In: Experimental psychology: Human percept. and perform. 2: 299-312.

Levy, J., Cur, R. C. (1980). Individual differences in psychoneurological organization. In: J. Herron (Ed.), Neuropsychology of left-handedness. Academic, New York., 142-152.

Levy, J., Heller, W., Banich, M., Burton, L. (1983). Perceptual asymmetry in free-viewing of chimeric faces. Brain and Cognit., 2: 404-419.

Levy, J., Reid, M. (1976). Variations in cerebral organization as a function of handedness, handwriting posture and sex. J. of Experim. Psychol.: Ceneral. 107: 191-144.

Ley, K. C., Bryden, M. P. (1979). Hemispheric differences in processing emotions and faces. Brain Lang., 7: 127-138.

Lebedev A. N. (1976). Neurophysiological basis of quantitative regularities in psychology. In: H. G. Geissle and Y. M. Zabrodin (Eds.). Advances in Psychophysics, Berlin.

Livanov, M. N. (1940). About rhythmical irritations and intercorrelations of fields in the brain cortex. Physiol. J., USSR, 28, output 2-3.

Lopes da Silva, F. H. (1991) Neural mechanisms underlying brain waves: from neural membranes to networks. Electroencephalogr. Clin. Neurophysiol., 79: 81-93.

Loring, D. W., Meador, K., Lee, G., Murro, A., Smith, J., Vlanigin, H., Gallagber, B., King, D. (1990). Cerebral language lateralization: evidence from intracarotid amobarbitol testing. Neuropsychol., 28: 831-838.

Losanov, G. (1971). Suggestology. Science and art, Sophia.

Lubinski, D. A., Benbow, C. P. (1992). Gender differences in abilities and preferences among the gifted: implications for the math-science pipeline. Current Directions in Psychol. Sci., 1: 61-66.

Luk, A. N. (1978). Psychology of creativity. Nauka. Moscow.

Maccoby, E., Jacklin, C. (1974). The psychology of sex differences. Stanford University Press, Palo Alto. CA.

MacKinnon, D. W. (1961). Creativity in architects. In: D. W. MacKinnon (Ed.), The creative person. Berkeley: Institute of Personality Assessment Research, University of California, 291-320.

Macmillan, M. A., Kaplan, H. L., Creelman, C. D. (1977). The psychophysics of categorical perception. Psychol. Rev., 84: 452-471.

Maffei, L., Fiorentini, A. (1977). Spatial frequency rows in the striate visual cortex. Vision Res., 17: 257-264.

Mainen, Z. F., Sejnowski, T. J. (1995). Reliability of spike timing in neocortical neurons. Science, 268:1503-1505.

Martinez, A. P., Moses, F. L., Blaettler, D., Stiles, J., Wong, E., Buxton, R. (1996). Lateralized differences in spatial processing: evidence from RT and IMRI. Paper presented at the Second International Conference in Functional Mapping of the Human Brain, Boston.

May, R. (1975). The courage to create. Norton, New York.

McGlone, J., Davidson, W. (1973). The relation between cerebral laterality and spatial ability with special reference to sex and hand preference. Neuropsychol., 11, 105-113.

McGlone, J. (1980). Sex differences in human brain activity: a critical review. The Behav. and Brain Sci., 3: 215-263.

McFie, J., Piercy, M. E., Zangwill, O. L. (1950). Visual-spatial agnosia associated with lesions of the right cerebral hemisphere. Brain, 73: 167-190.

McFie, J., Zangwill, O. L. (1960). Visual-constructive disabilities associated with lesions of the left cerebral hemisphere. Brain, 83: 248-260.

Mebert, C. J., Michel, G. F. (1980). Handedness in artists. In: J. Herron (Ed.), Neuropsychology of left-handedness. Academic Press, New York, 275- 278.

Miller, R. (1999). Unifying cell assembly theory with observations of brain dynamics. In: Behav. and brain sci., 22: 297-298.

Morasso, P. (1981). Spatial control of arm movements. Exp. Brain Res. 42: 223-227.

Moretti, M. M., Charlton, S., Taylor, S. (1996). Effects of hemispheric asymmetries and depression on the perception of emotion. Brain and Cognit., 32: 77-82.

Moscovitch, M., Scullion. D., Christie, D. (1976). Early versus late stages of processing and their relation to functional hemispheric asymmetries in face recognition. J. of Experim. Psychol.: Human Perception and Performance, 2. 401-416.

Mussa-Ivaldi, F. A. (1997). Nonlinear force fields: A distributed system of control primitives for representing and learning movements. In: Proceedings of the 1997 IEEE International symposium on Computational Intelligence in Robotics and Automation. IEEE Press, New York, 84-90.

Mussa-Ivaldi, F. A., and Giszter, S. F. (1992). Vector field approximation: A computational paradigm for motor control and learning. Biol. Cybern., 67:491-500.

Mussa-Ivaldi, F. A., Giszter, S. F., and Bizzi, F. (1994). Linear combinations of primitives in vertebrate motor control. Proc. Natl. Acad. Sci., USA. 91:7534-7538.

Nalcaci, E., Basar-Eroglu, C., Stadler, M. (1999). Visual evoked potential interhemispheric transfer time in different frequency bands. Clinical Neurophysiology, 110. 71-81.

Navon, D. (1977). Forest before the trees: The precedence of global features in visual perception. Cog. Psychol., 9: 353-393**.**

Necker, L. A. (1832). Observation on some remarkable phenomenon which occurs on viewing a figure of a crystal or geometrical solid. The London and Edinburgh Philosophical Magazine and J. of Sci., 3: 329-337.

Neumayer, A. (1995). Künstler im Spiegel der Medizin. Pichler Verlag Gmbh, Vienna.

Nevskaja, A. A., Leushina, L. I. (1990). Hemispheres asymmetry and visual images recognition. Leningrad. Nauka.

Newland, G. A. (1981). Differences between left- and right handers on a measure of creativity. Percept. and Motor Skills, 53: 787-792.

Nikolaenko, N. N. (1982). Figural activity of the right and the left hemisphere. In: Relationships of the brain hemispheres. Materials of the Conference. Tbilisi.

Nikolaides, K. (1941). The natural way of draw. Boston.

O'Boyle, M. W. (1985). Hemispheric asymmetry in memory search for four-letter names and human faces. Brain and Cognit., 4: 104-132.

O'Boyle, M. W., Alexander, J. E., Benbow, C. P. (1991). Enhanced RH activation in the mathematically precocious: A preliminary EEG investigation. Brain and Cognit., 17: 138-153.

O'Boyle, M. W., Benbow, C. P. (1990a). Enhanced right hemisphere involvement during cognitive processing may relate to intellectual precocity. Neuropsychol., 28: 211-216.

O'Boyle, W., Benbow, C. P. (1990b). Handedness and its relationship to ability and talent. In: S. Coren (Ed.), Left-handedness: Behavioral implications and anomalies. North Holland, Amsterdam, 343-372.

O'Boyle, M. W., Gill, H. S., Benbow, C. P., Alexander, J. E. (1994). Concurrent finger-tapping in mathematically gifted males: Evidence for enhanced right hemisphere involvement during linguistic processing. Cortex, 30: 519-526.

O'Boyle, M. W., Hellige, J. B. (1982). Hemispheric asymmetry, early visual processes and serial memory comparison. Brain and Cognit., 1: 224-243.

O'Boyle, M., Hellige, J. B. (1989). Cerebral hemisphere asymmetry and individual differences in cognition. Learning and Individ. Differ., 1: 7-35.

O'Boyle, M. W., Benbow, C. P., Alexander, J. E. (1995). Sex differences, hemispheric laterality, and associated brain activity in the intellectually gifted. Developmental Neuropsychol., 11: 415 - 443

Obrzut, J. E., Boliek, C. A., Obrzut, A. (1986). The effect of stimulus type and directed attention an dichotic listening with children. J. of Experim. Child Psychol., 198-209.

Obrzut, J. E. (1995). Dynamic versus structural -processing differences characterize laterality patterns of learning disabled children. Developmental Psychol., 11, XX-XX.

Ornstein, R., Herron, J., Johnstone, J., Swencionis, C. (1979). Differential right hemisphere involvement in two reading tasks. Psychophysiol., 16: 398-401.

Osborn, A. F. (1952). How to become more creative. Scribners, New York.

Osborn, A. F. (1967). Applied imagination (3rd Rev. Ed.). Scribners, New York.

Pais, A. (1982). The science and the life of Albert Einstein. Oxford Univ. Press, New York.

Palm, G. (1990). Cell assemblies as a guideline for brain research. Concepts Neurosci., 1: 133-147.

Pantev, C., Elbert, T., Lütkenhöner, B. (1994). Oscillatory event-related brain dynamics. Plenum Press, London, New York.

Parking, A. J., Williamson, P. (1987). Cerebral lateralization at different stages of facial processing. Cortex, 23: 99-110, 723-731.

Penrose, R. (1991). The emperior's new mind. Penguin Books, New York.

Perlman, A. L. (1972). Fourier transforms and the human visual process. Junior thesis. Berkeley.: U.C.

Petche, H. (1996). Approaches to verbal, visual and musical creativity by EEG coherence analysis. Int. J. Psychophysiol., 24: 145-159.

Peterson, J. M., Lansky, L. (1977). Left-handedness among architects. Percept. and Motor Skills, 45: 1216-1218.

Pfurtscheller, G., Aranibar, A. (1977). Event related cortical desynchronization detected by power measurements of scalp EEG. Electroencephalogr. Clin. Neurophysiol. 42: 817-826.

Pfurtscheller, G., Klimesch, W. (1992). Functional topography during a visuoverbal judgment task studied with event- related desynchronization mapping. J. Clin. Neurophysiol., 9: 120-131.

Pfurtscheller, G., Stancäk, Jr. A., Neuper C. (1996). Event-related synchronization (ERS) in the alpha band an electrophysiological correlate of cortical idling: a review. Int. J. of Psychophysiol., 24: 39-46.

Phillips, M. L., Young, A. W., Senior, C., Brammer, M., Andrew, C., Calder, A. J., Bullmore, E. T., Perrett, D. I., Rowland, D. I. D., Williams, S. C., Gray, J. A., David, A. S. (1997). A specific neural substrate for perceiving facial expression of disgust. Nature, 389: 495-498.

Piaget, J. (1969). The origins of intelligence in children. International Universities Press, New York.

Piercy, M., Hacaen, H., de Ajuriaguerra, I. (1960). Constructional apraxia associated with unilateral cerebral lesions: Left and right sided cases compared. Brain, 83: 225-242.

Piercy, M., Smyth, V. O. G. (1962). Right hemisphere dominance for certain nonverbal intellectual skills. Brain, 85: 775-790.

Pitts, W. H., McCulloch, W. S. (1947). Bull. Math. Biophys., 9: 127-147.

Polich, J. M. (1982). Hemispheric differences for visual search: Serial vs. parallel processing revisited. Neuropsychologia, 20: 297-307.

Pribram, K. (1975). Toward a holonomic theory of perception. In: S. Ertel, L. Kemmler, M. Stadler, (Eds.). Gestalttheorie in der modernen Psychologie. 161-184.

Rager, G., Singer, W. (1998). The response of cat visual cortex to flicker stimuli of variable frequency. Fur. J. Neurosci., 10: 1856-1877.

Rasmussen, T., Milner, B. (1977). The role of early left-brain injury in determining lateralization of cerebral speech functions. Annals of the New York Acad. of Sci., 299: 355-369.

Robertson, L. C. (1986). From Gestalt to neo-Gestalt. In: T. J. Knapp and L. C. Robertson (Eds.), Approaches to cognition: Contrasts and controversies. Lawrence Erlbaum Associates, Hillsdale, N.J.

Robertson, L. C., Lamb, M. R. (1991). Neuropsychological contributions to theories of part/whole organization. Cogn. Psychol., 23: 299-330.

Rolls, D. T., Tovee, M. J. (1994). Processing speed in the cerebral cortex and the neurophysiology of visual masking. Proc. R. Soc. Lond. B257: 9-15.

Rotenberg, V. S. (1993). Richness against freedom: two hemisphere functions and the problem of creativity. European J. For High Ability, 4: 11-19.

Rotenberg, V. S., Arshavskij V. V. (1984). Search activity and adaptation. Nauka, Moscow.

Rotenstreich, N. (1983). Man and his dignity. The magnes Press. The Hebrew Univ. Jerusalem.

Reynolds, C. R., Kaufman, A. S. (1978). Lateral eye movement behavior in children. Paper presented to the annual meeting of the Southeastern Psychological Association, Atlanta.

Rostovzew, N. N. (1980). Method of art teaching. Prosveshenie, Moscow.

Runco, M. A., Charles, R. E. (1997). In: M. A. Runco, (Ed.). Creative potential and performance. In: Creativity research handbook. Hampton Press, Inc., Vol. 1: 115-155**.**

Sackheim, A., Gur, R. C. (1978). Lateral asymmetry in the intensity of emotional expression. Neuropsychologia, 16: 473-481.

Salmelin, R., Hari, R. (1994). Characterization of spontaneous MEG rhythms in healthy adults. Electroencephalogr. Clin. Neurophysiol. 91: 237-248.

Satiel, P., Tresh, M., Bizzi, E. (1998). Spinal cord modular organization and rhythm generation: An NMDA iontophoretic study in the frog. J. Neurophysiol., 80: 2323-2339.

Sergent, J. (1982). The cerebral balance of power: confrontation or cooperation? J. Exp. Psychol.: Hum. Percept. Perform, 8: 253-272.

Seward, J. (1977). The Japanese. (7th. Ed.). Lotus Press, Tokyo.

Shadlen, M. N., Newsome, W. T. (1994). Noise, neural codes and cortical organization. Curr. Opin. Neurobiol. 4: 569-579.

Shadlen, M. N., Newsome W. T. (1998). The variable discharge of cortical neurons: implications for connectivity, computation, and information coding. J. Neurosci., 18: 3870-3896.

Singer, W. (2000). Response synchronization: a universal coding strategy for the definition of relations. In: M. Gazzaniga, (Ed.). Cog. Neurosci.,. MIT Press, 325-338.

Singer, W., Gray, C. M. (1995). Visual feature integration and the temporal correlation hypothesis. Annu. Rev. Neurosci., 18: 555-586.

Shevelev, I. A., Kamenkovich, V. M. (1997). Scanning hypothesis: visual perception synchronized with alpha activity. Int. J. of psychophysiol., 25: 28-29.

Slatter, K. H. (1960). Alpha rhythm and mental imagery. Electroencephalogr. Clin. Neurophysiol. 12: 851-895.

Smith, G. J. W. (1999). Perceptogenesis. In: M. A. Runco, S. R. Pritzker., (Eds.). Encyclopedia of creativity. Academic Press. 347-354.

Smits, R. 1994. Alles mit linken Hand. Rowohlt. Berlin.

Solomon, B., Powell, K., Gardner, H. (1999). Multiple intelligences. In: M. A. Runco, S. R. Pritzker, (Eds.). Encyclopedia of creativity. Academic Press. Vol. 2: 273-283.

Soloveitchik, J. B. (1978). Redemption, prayer, Talmud Torah. Tradition, New York.

Softky, W. R., Koch, C. (1993). The highly irregular firing of cortical cells is inconsistent with temporal integration of random EPSPs. J. Neurosci., 13: 334-350.

Softky, W. R. (1995). Simple codes versus efficient codes. Curr. Opin. Neurobiol., 5: 239-247.

Sousa-Roza, J. F., Rohberg, R., Mercure, A. (1979). Effects of type of information (abstract-concrete) and field dependence on asymmetry of hand movements during speech. Percept. and Motor Skills, 48: 1323-1330.

Sperry, R. W. (1964). The great cerebral commissure. Scientific Amer., January, 44-52.

Sperry, R. W. (1974). Lateral specialization in the surgically separated hemispheres," In: , F. O. Schmitt and F. C. Worden ,(Eds.). The neurosciences third study program. Mit Press, Cambrige, MA.

Sperry, R. W., Gazzaniga, M., Bogen, I. (1969). Interhemispheric relationships: the neocortical commissures, syndromes of hemisphere disconnection. Handbook of clinical neurology, Amsterdam. 273-290.

Sperry, R. W. (1985). Consciousness, personal identity and the divided brain. In: D. F. Benson, E. Zaidel, (Eds.). The dual Brain. Guilford Press, New York.

Springer, S. P., Deutsch, G. (1998). Left brain right brain: perspectives from cognitive neuroscience. (5-th ed.). W. H. Freeman and Company, New York.

Stadler, M., Kruse, P. (1990). The self-organization perspective in cognitive research: historical remarks and new experimental approaches. In: H. Haken and M. Stadler (Eds.), Synergetics of Cognition. Springer, Berlin. 32-52.

Stadler, M., Richter, P. H., Pfaff, S., Kruse, P. (1991). Attractors and perceptual field dynamics of homogeneous stimulus areas. Psychological Research, 53: 102-112.

Stadler, M., Vogt, S., Kruse, P. (1991). Synchronization of rhythm in motor actions. In: H. Haken and H. P. Koepchen (Eds.), Rhythms in Physiological Systems. Berlin: Springer., 215-231.

Stadler, M., Kruse, P. (1995). The function of meaning in cognitive order formation. In: P. Kruse and M. Stadler (Eds.), Ambiguity in mind and nature. Springer-Verlag, Berlin Heidelberg, 5-21.

Stalans, L., Wedding, D. (1985). Superiority of the left hemisphere in the recognition of emotional faces. J. of Neurosci., 25: 219-223.

Stein, M. I. (1953). Creativity and culture. J. of Psychol., 36: 311-322.

Steriade, M., Lunas, R. R. (1988) The functional states of the thalamus and the associated neuronal interplay. Physiol. Rev., 68: 481-508.

Steriade, M., Obor, P., Lunas, R. R., Lopes da Silva, F. H., Tiihonen, J., Kajola, M., Hari, R. (1989). Magnetic μ-rhythm in man. Neurosci., 32: 793-800.

Sternberg, R. J. (1986). A triarchic theory of intellectual giftedness. In: R. J. Sternberg and J. E. Davidson (Eds.), Conceptions of giftedness. Cambridge University Press, New York, 223-243.

Stevens, C. F., Zador, A. M. (1998). Input synchrony and the irregular firing of cortical neurons. Nature Neurosci., 1: 210-217.

Suzuki, D. T. (1959). An introduction to Zen Buddhism. Arrow books, London.

Tadd, L. (1903). New way for the art education. Petersburg (Rus.).

Tadd, L. (1899). New methods in education. Orange Judd Company-London, Sampson, Low, Marston Co., New York.

Tadd, L. (1900). Neue Wege zur Künstlerischen Erziehung der Jugend. Volgtländer Verlag, Leipzig.

Taylor, C. W. (1988). Approaches to and definitions of creativity. In: R. J. Sternberg, (Ed)., The nature of creativity. Cambridge University Press, New York.

Torrance, E. P. (I981). Implications of whole-brained theories of learning and thinking for computer-based instruction. J. of Computer-Based Instruction, 7: 99-105.

Torrance, E. P. (1963). What research rays to the teacher: creativity in the classroom. National Educational Association, Washington, D.C.

Torrance, E. P. (1967). The Minnesota studies of creative behavior: national and international extensions. J. of Creative Behav., 1: 137-154.

Torrance, E. P. (1974). Norms-technical manual: Torrance Tests of Creative Thinking. Scholastic Testing Service, Bensenville, IL.

Thorpe, S., Fize, D., Marlot, C. (l996). Speed of processing in the human visual system. Nature, 38: 520-522.

Toth, N. (1985). Archeological evidence for preferential right-handedness in the lower and middle Pleistocene, and its possible implications. J. of Human Evolution, 14: 607-614.

Tuhonen, J., Kajola, M., Han, R. (1989). Magnetic μ-rhythm in man. Neurosci., 32: 793-800.

Van Winsum, W., Sergeant, J., Geuze, R. (1984).The functional significance of event-related desynchronization of alpha rhythm in attentional and activating tasks. Electroencephalogr. Clin. Neurophysiol., 48: 519-524.

Vogt, S., Stadler, M., Kruse, P. (1988). Self-organization aspects in the temporal formation of movement gestalts. Human Movement Science, 7: 365-406.

Wapner, W., Hamby, S., Gardner, H. (1981). The role of the right hemisphere in the apprehension of complex linguistic material. Brain and Lang., 14: 15-33.

Wedding, D., Cyrus, P. (1986). Recognition of emotion in hemifaces presented to the left and right visual fields. J. Neurosci., 30: 161-164.

Wertheimer, M. (1938). The general theoretical situation. In: W. D. Ellis (Ed.). A source book of Gestalt psychology. Kegan Paul, Trench, Trubner, London.

Wertheimer, M. (1945). Productive thinking. Harper, New York.

Wiener, N. (1948). Cybernetics (or control and communication in the animal and machine, MIT Press, Cambridge, MA.

Williamson, S. J., Wang, J. Z., Ilmoniemi, R. J. (1989). Method for locating sources of human alpha activity. In: S. J. Williamson, M. Hoke, G. Stroink and M. Kotani (Eds.). Advances in Biomagnetism. Plenum, New York, 257-260.

Williamson, S. J., Kaufman, L., Lu, Z. L., Wang, J. Z., Karron, D. (1997). Study of human occipital alpha rhythm: the alphon hypothesis and alpha suppression. Int. J. of Psychophysiol., 26: 63-76.

Winner, E., Gardner, H. (1977). The comprehension of metaphor in brain-damaged patients. Brain, 100: 717-729.

Witelson, S. F. (1985). The corpus callosum is larger in Left-handers. Science, 229: 665-668.

Witelson, S. F. (1986). Wires of the mind: Anatomical variations in the corpus callosum in relation to hemispheric specialization and integration. Neurol. and Neurobiol., 17: 117-138.

Witelson, S. F. (1987). Hand preference and sex differences in the isthmus of the corpus callosum. Society for Neurosci., Abstracts, 13: 48.

Witelson, S. F. (1988). Neuroanatomical sex differences: of no consequence for cognition? Behav. and Brain Sci., 11: 215-217.

Woodward, S. H. (1988). An anatomical model of hemispheric asymmetry. J. of Clin. and Experim. Neuropsychol., 10: 68.

Zenkov, L. R. (1978). Some aspects of semiological structure and functional organization of the "right-hemispheric thinking". The unconscious. Vol. 1. Metsniereba, Tbilisi, 740-750.

Zhukova, G. N. (1974). Optimization of one-joint periodic movement control. Automatics and Telemechanics. Acad. of Sci. USSR, Moscow, 4: 143-150.

Zurif, E. (1974). Auditory lateralization: Prosodic and syntactic factors. Brain and Lang., 1: 391-404.