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COMPLEMENTARY DUALISM OR FUNCTIONAL LATERAL SPECIALIZATION?

1. Lateral Specialization in Ancient Tradition and Mythology

To speak of lateral specialization is to take up the old question found in myths and religions from the dawn of humanity. Gastaut has remarked that the prehistoric skulls he collected and examined presented a larger number of trepannings on the left than on the right. At the very begining, man's cranium was treated asymmetrically by the trepanners.

There is a fine distinction between the right and the left in the statuary and legends of ancient Egypt (but is there not also this distinction at the origin of the zodiac in which the cardinal points each have a well-specified role?) The legend of the struggle between Seth and Horus well reflects this subtlety of Egyptian thought. Seth personified evil and came to kill Osiris, the falcon-headed father of Horus. To avenge his father, Horus

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fought Seth and emasculated him, while Seth put out Horus' left eye. Thoth, the ibis-headed divinity of wisdom, intervened to give Horus back his fragmented eye. It was only when the left eye of Horus opened that the moon was resplendent, while the right eye closed and the sun set. Horus thus alternately presided over night and day, and, succeeding his father Osiris, he reigned over the world of gods and men.

It is perhaps this same current of thought we find later in the cabala, where the upper branches of the tree of the *Sephiroths* differ between the right and the left, between intelligence and wisdom, between severity and mercy.

However, it may be going too far to follow our comparison to India, which nevertheless was very concerned with marking the differences between the right and the left. In the psychophysiology of Hatha-Yoga, one of the traditional Indian philosophical systems, two principal channels are thought to convey the vital energy of man. They run parallel to each other and part from a third channel located in the center of the spinal column. At first sight, they could be similar to the two ganglion chains of the sympathetic nervous system that leave from the two upper cervical ganglions to join again at the level of the coccygeal ganglion, whose functions are still unclear. According to Indian tradition one of the channels, *Pingala*, goes from the right nostril to the right kidney. It is considered masculine and is connected with the sun (*Ha*). The other channel, *Ida*, going from the left nostril to the left kidney, is feminine and connected with the moon (*Tha*). The art and one of the ends of Hatha-Yoga is thus to regularize these right and left, masculine and feminine, solar and lunar, father and mother, energies. In India the concept of an androgynous being still exists: it is a divinity venerated under the name of *Ardhanarishvara*, the right half of whose body is masculine and the left feminine. May this not be the ancestor of the Greek hermaphrodite or of the *rebis* of the alchemists of the Middle Ages? This *rebis*, or " double thing, " is the hermetic androgyne, a two-headed creature symbolizing the union by Mercury of the masculine sun and the feminine moon.

As curiosities of natural history, such deformities may be called mosaic. They are often bisexual and laterally specialized.

Such are the gynandromorph butterflies, whose left half is female and whose right half is male.

II. Lateral Specialization in Biology and in Natural Science

Mother Nature, prodigal in eccentricities, has given birth to two-headed serpents, among other things. It is curious enough that serpents have two penises, only one of which is able to perform its function; but the *psammophis* is a sand snake with two heads. One of them lives until one head has swallowed the other. They are separated, the attacked snake then bites his aggressor, and the animal dies in this duel, according to the director of the Museum of Port Elizabeth. These enemy heads on the same body remind us of the Thomas Mann novel, *The Transposed Heads*, in which the heads finish by killing each other. We are also reminded of a neurological symptom called *mains diaboliques* that is sometimes observed in hemiplegics when they deny and more often totally ignore the paralysis of their left side. In this case, the left hand becomes an intruder, a stranger, and the right hand — become the hand of rectitude — may reject and fight it in a singular combat between the right and the left.

This also brings us to Siamese twins, with two heads or four arms; one head may sleep while the other remains awake. Here we are at the frontiers of sleep. In 1967 Michel and Roffwarg completely separated the two cerebral hemispheres of a cat and observed that one hemisphere could be asleep (at a slow frequency) while the other stayed awake, with alternations and a bilateral asynchrony. This question of sleep being linked to lateral specialization in the brain has been the subject of numerous studies, and we will take it up again with regard to man. Among primitive mammals, the kangaroos of the monotreme order do not have a *corpus callosa*, the commissure, the large band of nerve fibers that connects the neuronic cellular bodies of one hemisphere to another. In man also there is sometimes found at birth the absence or impotence of the *corpus callosa*. These cases, extremely rare, show practically no neurological and neuropsychophysiological deficit when they

undergo certain tests, such as those for split-brain epileptic patients by surgery on the *corpus callosa.*

Animals were long thought of as not laterally specialized. Recently it has been observed that cats do have this specialization, that is, an asymmetry in the motor functions between right and left with, for example, one preferred paw or one more rapid in capturing or gripping.

Are the spontaneous changes in the vigilance of mammals that pass from wakefulness to drowsiness before reaching the stage of semi-sleep (usually corresponding to a dream state in man) linked to variations in the functioning of the cerebral hemispheres? This question arises, for example, with cetaceans such as dolphins. From the fact that the dolphin must rise to the surface for air every sixteen or twenty minutes, it is possible to think of micro-sleeps, while he is resting immobile on the bottom of the ocean — or the observation pool. It also happens that he circles around on the surface at a regular pace: he could be sleeping. However, he often keeps one eye open toward the sky. Then, is he sleeping with one eye open, or is he only sleeping with one half of his brain, while the other is awake?

III. Lateral Specialization of the Body in Man

Let us now visualize the lateral specialization of the body in man. Using slices from the spinal column after post-mortem histological studies, Yakovlev has shown that the pyramidal tract that conveys the motor influxes of the cortical motor areas to the effector muscles was more significant on the right in right-handed cases. In other words, the right half of the body of a right-handed person will be stronger and more active, if not more rapid, than the left half. Now, the combined movement of transferral and rotation being helical, the right arm and leg will usually make helical movements toward the left. This may be observed in the universe of right-handers in which we live in the use of screwdrivers, scissors, corkscrews and so on. It is only recently that Sweden has introduced scissors for left-handed people into our " fascist " world of right-handers. In fact, it is not that simple, because there may be a directing or preferred foot, hand, eye or ear, each able to be right or left dominant.

Batteries of tests of lateral specialization of the body are currently in use by psychologists. A truly right-handed person is completely lateralized to the right, but there are many ambidextrous among the right-handed; true left-handers are rare (less than 9% of the population of France). In addition, there are important genetic factors. Individuals who are not well-specialized in right or left are " gauche " or awkward or slower in performing delicate tasks.

However, a true left-hander or a mixed right-hander is not at a disadvantage with respect to a true right-hander; it is almost the contrary. The functional localization of speech is in the left hemisphere, called dominant in a true right-hander, who would have severe disturbances in speech (aphasia), reading (alexia) and writing (agraphia) if he had a cerebral hemorrhage or a significant softening of the areas corresponding to these funcional areas. Contrarily, a true left-hander has a double representation, in both hemispheres, in areas connected to speech and, after cerebral lesion involving these structures, his chances of recovery are greater than those of a true right-hander.

Esthetics would be inconceivable without a certain asymmetry between the two sides of the body. This is particularly true of the face. Wolff, using photographs cut in half and artificially adjusted in the laboratory, reconstituted the left and right sides of the same subjects. Not only was the artificially-obtained symmetry unpleasant to look at but the right side of a right-handed subject appeared more square, more muscular and more decisive than the left half, which was more triangular and dreamy, and had a more introverted aspect than its right homologue. Although asymmetry in man is more noticeable on the exterior, it is nonetheless observable subcutaneously, particularly in the lower viscera.

Anatomically, the left hemisphere of the brain differs from the right hemisphere, if only because the area of speech at the level of the left fold is more developed than at the right, as Hecaen has recently observed. More especially, the lungs are not symmetrical; the heart and the aortal curve form a sort of oriented topological knot, as Weiss has noticed, that is opposed to the liver in its localization. The curve of the stomach and the unrolling of the intestines are also asymmetrical. The kidneys

and the two tracts of the sympathetic nervous system, as well as the genital organs, appear more symmetrical. It is not improbable that the left tract differs from the right, anatomically certainly, but perhaps also functionally. Tailors well know that there is an asymmetry in the testicles, the right being higher than the left; this has been the subject of a statistical study in biotypology. However, and this is more intriguing, viscera that are laterally specialized anatomically are apparently not specialized in the central nervous system. Such studies are difficult to carry out, because here it is a question of comparatively studying the physiology of cerebral structures that are not easily accessible. That is in the domain of the neurosurgeon specialized in the surgery of pain, epilepsy or abnormal movements, whose immediate clinical preoccupations are far from this problem of a possible functional visceral laterization.

IV. Cerebral Lateral Specialization

We are now going to visualize hemispheric lateral specialization in the cerebral hemispheres of man. Recent works have been written on this subject, and annual meetings of scientific experts are devoted to this topic of research that is making rapid progress.

Anatomo-pathological studies, those of localized cerebral lesions and those in particular of around fifteen split-brain cases, whose *corpus callosa* was completely dissected in Los Angeles by the neurosurgeon J. Bogen — working with Sperry and Gazzaniga — have considerably advanced our knowledge of compared physiology and the differences between the two hemispheres of the brain. Other split-brain cases have been studied in England by Glass and Butler, and at Dartmouth in the United States. These neurosurgeries are rare, because of the risk involved; they are usually performed only in cases of generalized epilepsy in which the complete resection of the *corpus callosa* permits that the propagation of discharges of an important epileptogenic center from one hemisphere to the other be avoided. These studies also benefit from research by psychologists and psycholinguists such as Gazzaniga in Los Angeles, Dimond in Cardiff, and W. D. Ten Houten.

Other research has been done in quantitative electro-encephalography that we will develop more fully in our discussion of what concerns the sleeping state, the action of psychoactive substances and of recent studies in psychiatry.

A global table of the different functions of the two cerebral hemispheres may be drawn up. It is implicit that in a normal subject these functions alternate in time in a complementarity of actions that contribute a complex cortical functioning, well-integrated and harmonious.

LEFT HEMISPHERE (*called dominant in right-handers*)	RIGHT HEMISPHERE (*called dominated in right-handers*)
Main centers of speech	Recognition of forms
Verbal activity	Recognition of faces
Mental calculation	Spatial activity
Reading	Recognition of musical sounds
Writing	Non-verbal ideation
Rhythm and time sequence	Recognition of basic terms
	Recognition of melodic sounds, creativity (?)

Sperry, apropos of attention, considers that the " dominant " left hemisphere is able to speak, to propose expression to the right hemisphere. Bogen, on the other hand, asks if the right hemisphere, being ceaselessly awake, does not alert the left hemisphere so that it can verbalize. For Bogen, the right hemisphere proposes and the left disposes:

LEFT HEMISPHERE	RIGHT HEMISPHERE
" I " in the world	The world in " me "

For Goldstein, the left hemisphere is hyper-rational and the right, emotional. A lesion on the left causes sadness, but the patient does not speak! A lesion on the right makes the patient indifferent or euphoric. However, this is still controversial.

In fact, numerous other adjectives have been proposed to differentiate between the complementary roles of the two cortical hemispheres in man. Why should functions linked to speech be located in the left hemisphere? Is it because the left hemisphere is dominant and capable of more complex functions than the more instinctive right hemisphere? Perhaps it is the opposite, speech only appearing late in human evolution. In the newborn infant, the right occipital area reacts to visual stimuli, contrary to the homologous left area. Speech could be considered as a specialized apprenticeship of the late-maturing phonatory muscles in the left hemisphere.

There are also differences linked to sex. Women are more favored at the level of speech, more dominant in the left hemisphere. Do they talk more than men, who seem more favored in visual-spatial tasks such as hunting?

Let us look at some experiments that have been done in several laboratories and support this dialectic of a functional hemispheric lateral specialization.

Electroencephalography is the gathering and registration in time of cerebral electric microcurrents, expressed in the form of spontaneous differences in potential. Electrodes placed on the scalp collect these currents that are amplified electronically and registered on a continuous paper tape at the time of registrations, called polygraphic. Several cerebral areas are registered simultaneously by the EEG, with eye movement, EKG, electromyogram of the chin muscles, electrodermogram, and so on. These biolectric signals may also be registered on magnetic tape and handled by a computer using diverse programs.

It is in this way that Ornstein and Galin in San Francisco studied the registrations of right and left temporal areas in normal subjects assigned different tasks. They used as control the relationship of medium amplitudes of the EEG between the right area and homologous left area. During a writing or linguistics task this relationship was 1.3, while it fell to 0.8 in a spatial or recognition of sound task. In other words, when a cerebral hemisphere is specifically activated, it corresponds to a lessening of the corresponding amplitudes of the registered EEG, often with the appearance of rapid frequencies (called Beta) proper to the cortical awareness.

Another example of the same type was given by Ingvar, who established a correlation between the blood flow to the cortex located at a precise spot, and the EEG. Now, we know that the right hand has nervous afferents and efferents, sense and motor conduits that all end or part from a very precise area situated to the left of the Rolando fissure.

Inversely, the left hand has cortical projections entirely lateralized to the right. When a patient studied by Ingvar made a fist with his right hand, the left area of cortical projection that was stimulated had a higher flow of blood, and at the same time an "activation" in terms of the EEG, which is characterized by a lessening in amplitudes and an increase in the frequencies of the corresponding EEG.

Another technique, called dichotic listening, has a subject listen to two different sounds or syllables through a stereophonic head-set. These are presented to him simultaneously. The subject is asked which sound or syllable he has recognized, and at the same time the EEG is registered and averaged, after the auditory presentation of the stimuli, in order to obtain the evoked potentials. This method permits the diagnosis of hearing problems connected with a loss of functioning in the right or left cortical auditive area.

J-F Joseph, in a recent thesis reporting on 100 righthanders, studied the EEG of the two hemispheres and after qualitative analysis obtained the following results:

1) frequencies were more stable and less varying on the right than on the left;
2) amplitudes were greater on the right than on the left in two-thirds of the voluntary subjects tested;
3) inter-hemispheric relationships were more important between the central parieto-occipital areas than between the more anterior or posterior areas;
4) between two electroencephalographic registrations done simultaneously, the EEG of the right hemisphere was in advance in time with regard to the EEG registered in the homologous area of the left hemisphere. This was true in two-thirds of the registered subjects and is in full agreement with Bogen's hypothesis that the right hemisphere proposes and "afterward" the dominant left disposes.

Let us now see if there are differences in this functional cerebral lateralization in the course of the various stages of sleep. It is indeed the case. In order to simplify Johnson considers two phases of wakefulness in man: the state of semi-wakefulness (associated with the state of falling asleep, called Stage 1) and the stage without semi-wakefulness (associated with Stage 2 and Stages 3 and 4 at slow frequencies). Now, Goldstein has shown that these two stages present EEG amplitudes whose distributions are not the same between the right and left hemispheres, in man as well as in cats and monkeys.

In 1968 Michel wrote: " Onirism must be located in the right hemisphere, the left hemisphere or in both hemispheres, and perhaps at different times. But in this latter case it must be admitted that two images may unfold independently... In some way, dreams unfold without our knowledge. "

This remains an open question. In fact, it is not easy to compare electrophysiological studies with the reports of dreams made *a posteriori* by the dreamer. The EEG does not contain, it seems, a cryptic description of a subjective dream state, and narration of a previous dream in a waking state is an interpretation in terms of speech, thus of the dominant left hemisphere! Moreover, such simplistic reasonings ignore the complementary roles that unite our two hemispheric confederates, who seem, at times humorously, to be in league to mystify the researcher.

Another chapter has just opened. Psychoactive substances, depressants of the central nervous system (hypnotism, tranquillizers, antihistamines or neuroleptics), and stimulants (amphetamines, hallucinogens, psychostimulants) have a specific action on cerebral lateral specialization. According to Goldstein, we may say that depressants preserve functional cerebral lateralization, proper to each subject, by blocking all variations of this lateralization, while stimulants do the opposite. This idea is interesting; however, tranquillizers acted preferentially on the right hemisphere, as we have shown in our work with Professor Deniker. In this way, perhaps a better integration of comprehension of the environment could be realized, without altering the structures proper to the personality that appear preferentially linked to the dominant left hemisphere, and thus to the major role of expression of the subject when faced with his

socio-cultural surroundings, that use all the resources of speech and writing. It goes without saying that these hypotheses remain to be verified in other experiments, with voluntary subjects as well as with patients.

Finally, we mention the latest research that is currently bringing under consideration that pathological variations in cerebral lateralization could intervene in mental pathology. These works have mainly been published by Goldstein in the United States, Perris in Sweden and Flor-Henry in Canada. In 1956 in France Girard submitted the hypothesis of a "dysphrenic," a malfunctioning between the two cerebral hemispheres perhaps being involved in schizophrenia. Using electroencephalograms registered at the right and left temporal areas in schizophrenics, Goldstein showed that the relationship of variance in amplitude between the right area and the left area was near O.5. This same relationship, registered by Perris in depressed patients, was on the contrary near 2. More simply, in schizophrenics the left hemisphere presented a malfunctioning that was manifested in a difficulty of the patient to fit into his environment, while the right hemisphere functioned normally. Inversely, depressed patients presented a malfunctioning of the right hemisphere that could appear in a personal inability to adjust to the environment so painfully felt that it could lead to an attempt at suicide. The most interesting fact here is that such quantitative indexes appear in relation to the improvement or aggravation of clinical symptoms evaluated on scales filled out by the clinicians. A meeting for comparison of the research done by different teams involved in these clinical evaluations was held in 1978 in Barcelona.

These pages have been intended only to illustrate some facets of multidisciplinary research concerned with lateral specialization in biology and in the science of man. We have not attempted the socio-cultural aspect in which, for some, the dominant and verbal right hemisphere is totalitarian in the West, especially in university circles, in opposition to the left hemisphere that is dominant in the Hopis, the Orient and in non-verbal archaic cultures. This socio-cultural aspect is no less interesting, however, because it touches on education. We have also failed to speak of the biological rhythms that may interfere with a functional dominance of the right or the left. As often happens, one

question brings up another. Profound cerebral structures such as the hippocampus or the thalamus all appear to be lateralized, and that may play a role in memory disturbances.

Regarding the problem with which we are concerned, we particularly stress that instead of a duality of opposition between the two cerebral hemispheres, there is rather a complementarity of indissociable functions, although they are specific in their nature. Would it not be well to become ambidextrous in the mind and realize the unity in diversity, a functional lateralization rather than a complementary dualism?

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