

THE FRONTAL LOBES
AND
THE REGULATION OF BEHAVIOR

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1.

In the course of many decades the problem of the function of the frontal lobes of the brain has remained unsolved. Stimulation of the prefrontal area of the brain cortex did not lead to sufficiently clear cut motor or sensory reactions, and destruction of this area did not lead to disorders in sensory, motor or verbal processes. However, psychiatrists have long ago pointed out that large scale destruction of the frontal lobes can lead to distinct disturbances in complicated form of rational behavior, a loss of initiative and goal-directed behavior, and disturbances in how a patient relates to his own defects. Such a state of affairs has emphasized the priority of discovering the sources of these disturbances: the role of the frontal lobes in the organization of complicated goal directed behavior must be expressed in terms accessible to psychophysiological analysis.

There is every reason to assume that functions of the frontal lobes, which could not be explained by the concept of the classical reflex arc, can be explained in terms of modern physiology which considers behavior as a complex self-regulating system. As is known, the frontal lobes are located above the central extremity of the "motor analyser" and retain intimate connections with the system of extero-

receptive analysis and synthesis, with formations transmitting interoceptive signalization, and with the reticular formation. According to all data received both from experiments with animals and from observations of patients with large-scale destruction of the frontal lobes, the frontal lobes play an active role in the formation of complicated and flexible programs for behavior, in the inhibition of reactions to irrelevant signals located outside the boundaries of this program, and in the collation of the results of behavior with initial intentions.

Thus mass destruction of the frontal lobes leads to a disintegration in the formation of complicated and flexible plans of action, to a disturbance in the inhibition of the orienting reflex, to irrelevant stimuli (not connected with the program), to a pathological perseveration of stereotypes once they have appeared, and to a disturbance in the ability to evaluate the correspondence between actions and initial intentions.

In man all these disturbances are most apparent in higher regulatory levels of psychological processes which are implemented by means of a system of verbal connections; thus disturbance of the signalizing and regulating function of speech is one of the most substantial indicators of the infliction of the frontal lobes.

A quarter century of research into the disturbance of the regulatory system of behavior in patients with inflictions of the frontal lobes has thrown more light upon the proposal made by V.M. Bekhterev at the beginning of this

century that the frontal lobes "have a psychoregulatory function", insuring the evaluation of the results of actions and directing movements and actions in conformity with the above mentioned evaluation" (V.M.Bekhterev, 1907; p.1964, 1968).

2.

The more complicated forms of regulating behavior, implemented by the participation of the verbal system, are formed during a child's first 4-5 years of life and progress in their development through a series of basic stages, as has been shown in various studies (L.S.Vigotski, 1956, 1960; A.R.Luria, 1956, 1958, 1963).

In the first stages of development the actions of the child can be induced (put into motion) by verbal instructions from an adult; however the verbal instructions of the adult cannot yet hold back actions already begun or switch them into other actions, cannot form a dominant behavior inhibiting orienting reactions to irrelevant (strong, novel, and interesting) stimuli, and cannot form a system of preparatory "pre-starting" connections, permanently defining a program of action.

During this period (2 - 2.5 years) the speech of the child is still insufficiently flexible and incapable of forming a sufficient number of complex programs for action; therefore the inclusion of personal verbal commands (even aloud) does not seem to be able to overcome the indirect action of irrelevant stimuli and insure the strict regulation of behavior.

Only in the next stage, once the speech of the child has

become sufficiently rich and flexible, does such speech (at first aloud and then internal) begin to acquire the necessary regulatory role. In the first phases (3 - 3.5 years), as repeated observations have shown, the external ("impulse") function of speech begins to play a prompting role, and in later phases (4 - 4.5 years) the regulatory role is already transferred to the complex semantic structure of a child's speech. During this period the child begins to become capable of forming a program of behavior with the help of speech and of fulfilling that program to some degree.

This process of forming complex verbal program to regulate the child's behavior continues to develop further, beginning to acquire more complicated forms in the 7 year old.

According to all available data, this process of forming verbal programs of behavior and developing the regulatory function of the verbal system in the child characteristically flows in parallel with the functional maturity of the frontal lobes whose connections, as is known, mature late, and whose development ends only at age 7-11 years.

All the above seems to imply that the frontal lobes of a grown adult are essential to insure more complicated forms of regulating behavior, and most of all those forms which are implemented by the close participation of the speech system.

The above also seems to indicate that destruction of the frontal lobes leads to the disturbance of this complicated regulation of psychological processes and directs the search for the symptoms of frontal lobe inflexion to the desubtugration of these forms of regulation.

3.

Research conducted over the last 25 years (A.R.Luria 1962, 1963; A.R.Luria and E.D.Homskaya (ed.), 1966) has shown that destruction of the frontal (prefrontal) areas of the brain interfere with the ability both to illicit a persistent state of activation in the cerebral cortex by means of verbal instructions and with the ability to insure the execution of a complicated program of action corresponding to those instructions.

Observation has shown that whereas in patients with inflections of the posterior (parietal, temporal, occipital) areas of the cerebral cortex verbal instructions can restore extinguished indicators of the orienting reflex and insure both a stable state of activation and a strong focus of dominant excitation in patients with inflections of the frontal lobes such an effect does not take place; and verbal instructions (giving certain stimuli signal functions) either do not in general restore extinguished GSR, vascular, or EEG components of the orienting reflex, or do not lead to a stable state of activation accompanied by a strong focus of dominant excitation (E.D.Homskaya, 1966; O.P.Baranovskaya, 1966; E.Ju.Artemyeva, 1966; and others).

This fact indicates that the frontal lobes participate in a process which permits the speech system in man to provide the stable background of activation necessary for the adequate organization of selective goal-directed behavior. Data collected by Grey Walter (1964, 1966) and M.N.Livanov et al. (1966) support this position.

On the other hand, research conducted over the past few years has shown that destruction of the frontal lobes interferes with the formation of a clear-cut program of behavior from verbal instructions and with the fulfilling of this program with adequate behavior. In all these cases the content of the verbal instructions may be remembered, but the instructions cease to inhibit the orienting reflex to irrelevant stimuli, cease to insure the smooth transfer from one action to another, and lose their regulatory role.

With more extensive destruction of the frontal lobes, even a direct verbal command will not produce the necessary effect. Although repeating the verbal instructions, the patient will not fulfill the program with the required actions. A similar disturbance appears in experiments with simple motor reactions to verbal instructions, where the patient retains the verbal instructions but does not react to the stated meaning of the signals. Attempts to assist the patient in the task by having him repeat the instructions aloud also do not yield the expected results in such cases (A.I. Mesheheryakov, 1966).

With less extensive destruction of the frontal lobes the signaling role of speech is preserved, but verbal instructions cannot yet form a program which can direct the further actions of the patient. Disturbance of choice reactions in patients with inflections of the frontal lobes serves as a good example. Here the patient retains the verbal formulation of the problem, but in practice does not organize his motor actions according to this formulation, and easily substitutes perseverative motor stereotypes for the required actions (M.P. Ivanova, 1966).

In patients with destruction of the frontal lobes, these destructions acquire an especially well defined character when the stated meaning of the signal, given to the patient in the verbal instructions, comes into conflict with the direct action of the stimulus. In these cases a patient with extensive destruction of the frontal lobes readily ceases to fulfill the stated actions required by the verbal instructions, and begins to follow the direct influence of the signal, exhibiting direct "echopraxis" reactions (E.D.Khomskaya, 1961; M.Marushevski, 1966; A.R.Luria, K.Pribram, E.D.Khomskaya 1964; and others).

Analysis has shown that the more complicated the program, the larger the number of interrelated subprograms it includes, and the more its fulfillment depends upon a hierarchical structure of memory traces, the more difficult it is for patients with afflictions of the frontal lobes to subject their behavior to such a program (V.V.Lebedinski, 1966).

If in patients with extensive destruction (most often bilateral) of the frontal lobes one often finds permanent disturbances in fulfilling programs prepared in verbal form, then patients with a less clearly defined "frontal lobe" syndrome show definite disturbances in all complicated forms of activity which are connected with the independent formulation of programs or complicated forms of "strategy". Observations have shown that the formulation of such programs on the basis of the probability of certain events ("probability prognosis") is clearly disturbed in such cases (O.K.Tikhomirov, 1966). Clearly observable disturbances also appear in the

formulation of certain "strategies" necessary for the solution of complex problems. As observations have pointed out, patients with influctions of the frontal lobes are unable to formulate complicated programs of constructive activity (S.G.Gadzhiev, 1966; L.S.Tsvetkova 1965, 1966) and the necessary strategy to solve complicated arithmetic problems (L.S.Tsvetkova 1966). In each of those cases, preliminary orientation to the problem, formulation of a plan for solution, and establishing a program of the sequential steps needed to solve the problem are all disturbed and are replaced by fragmentary impulsive actions or perseverative stereotypes, neither of which are appropriate to the correct solution of the problem. The disintegration of intellectual activities in patients with influctions of the frontal lobes consists of the disturbance of namely this kind of program for action (and not of the disintegration of categoric behavior).

All forms of disturbances of complicated activities in cases with the destruction of the frontal lobes are characterized by a parallel disturbance of the formulation and retention of complex programs for action along with a disintegration of the collation of the results of actions with their initial intentions and the consequent correction of mistakes. In short, along with disturbances in the regulation of activities there also appear disturbances in their control.

Both regulatie of the above mentioned defects are the basic components of the disturbance of complex forms of self-regulating activities that results from destruction of the frontal lobes.

4.

The disturbance of complex forms of regulation and control of psychological activities (most of all those which are realized with the help of a system of verbal connections) appear as one of the central indicators of the destruction of the frontal lobes and does not appear with destruction of the posterior areas of the cerebral cortex.

However, these disturbances do not appear in the same form and with the same clarity in all cases of destruction of the frontal lobes. There are two essential reasons for these differences.

First, the frontal lobes are not one uniform whole but include an entire series of separate systems, thus the localization of the infliction within the frontal lobes, may leave its imprint on the emerging disorder. Destruction of the posterior frontal areas of the brain, bordering on the premotor zone, can result in especially clear-cut disturbance of the complex organization of movements and actions in such cases the pathological perseveration of stereotypes (perseveration of sets) can on occasion frustrate the normal formation of a flexible plan for action and replace selective actions with perseverations. In cases with destruction of the posterior frontal region of the dominant (left) cerebral hemisphere, these disturbances are most clearly shown in the formation of a program of motor actions and speech activities, and appear in the well shown clinical phenomenon of inactive thought processes.

In cases of the destruction of the basal area of the frontal lobes, these disturbances may not produce pathological perseveration, but appear instead in a distinct disturbance of higher forms of inhibition and in an increase in impulsive behavior which interferes with the fulfillment of a complicated program.

In cases of destruction of the medial region of the frontal lobes, including the limbic region and formation in the mid-brain, the above mentioned disturbances may appear on a background of distinct memory disorders and lead to gross defects in the selectivity of complicated psychological processes.

The variations of the frontal lobe syndrome described above only point out the complex structure of the frontal lobes; but the physiological mechanisms lying at their base still need considerable thorough physiological study.

Secondly, the frontal lobes, being younger and less differentiated brain structures according to Hughlings Jackson possess a large degree of compensation of functions. Thus limited, early stage, and slowly developing afflictions which are not accompanied by general disturbances in the humoral or cerebrospinal fluid systems, can develop with hidden symptomatology.

It can be expected that the application of neuropsychological and psychophysiological methods to the study of frontal lobe functions in man should shed some light on the study of the functions of these highly complicated structures of the brain, and yield essential data for the analysis of the brain mechanisms behind higher forms of behavioral regulation in man.