THE ORIGIN AND CEREBRAL ORGANIZATION OF MAN'S CONSCIOUS ACTION

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1. The Problem

Several years ago two of the most outstanding psychologists of our day — B. F. Skinner and D. O. Hebb proposed to decode the well known abbreviation CNS as "Conceptual Nervous System".

At first this was a mere joke; now, however, we can earnestly accept it: The Human Brain not only recodes the sensory information, turning it into a system of concepts, but establishes Human Plans and Programs and forms a conscious control of human actions. It is really an Organ of freedom, and it would be unwise to ignore this basic feature by approaching the Human Brain with the same ideas and methods as the brain of the rat.

The following question now arises: Is it possible to find proper ways of understanding the basic qualities of the Human Brain neither following the old mentalistic approaches, nor repeating the mechanistic ideas which were popular a generation ago, but are unacceptable now? How can we come to a scientific solution of the old riddle of man's free activity and conscious behavior?

The answer to this question in no way lies in an analysis of the most intimate parts of the brain or in elaborate studies of single neurons.

To find a real solution of this problem one has to overstep the limits of the organism and to start analysing the concrete relations of the child with its immediate social environment.

Precisely this way was taken by the late L. S. Vygotski, the famous Soviet psychologist, and it is this way that we shall follow.

A newborn child starts its life with a series of innate self-regulating systems of a very elementary type — breathing and sucking, primitive orienting reflexes and a battery of early forms

of motor activity. These elementary forms of activity were thoroughly studied by a number of eminent scholars from Schelovanov in the USSR, Minkowski, Peiper and others in the Western countries t[illegible] recent brilliant investigations of my friend Jerome Bruner. But how far are these forms of behavior from the conscious and self-controlled forms of the conduct of a school child or of an adult!.

Where can we find the roots of these highest forms of voluntary, self-regulated forms of conscious behavior? This is really one of the basic questions of contemporary scientific psychology.

The newborn child starts its life in conditions of immediate social contact with the adults. The mother gives the child certain orders and repeatedly speaks to it. She shows an object, pointing to it and saying: "That's a doll", and the child turns its eyes towards the objects; she gives the command "Give me the doll" and the child tries to do it. The child's conscious action is originally *divided between two persons*: it starts with the mother's command and ends with the child's movement. But during the subsequent period of the child's development the structure of this action begins to change; the child starts using its own language; by saying "A doll!", it singles out the object named, turns its eyes to the doll and tries to grasp it. The child's own speach begins to serve as a command, and *the function, formerly divided between two persons, becomes now a new form of an inner, self-regulated psychological process.* This is the start of a new type of behavior, social by origin, verbally mediated by structure and self-controlled by the kind of its functioning.

Thus, we are approaching a new level of problems, and we shall try to trace the gradual development of the free and conscious form of human behavior.

2. Origin

The development of the highest forms of conscious, self-regulated behavior is by no means a simple process or a leap from a "field-reaction" to free behavior. The first acquisition of a command-controlled action is only a start of a long process of formation of the higher psychological functions, and a scholar must follow this process carefully.

Let us turn to some simple experiments and try to establish a basic model of the development of the child's self-controlled behavior.

It is well know that the adult's command may easily evoke an orienting reaction even in a child 6—8 months of age, and a simple motor action in a child 10—12 months old. If we name an object placed in the child's immediate environment, it will turn its eyes towards this object; if we say "lift your hands" the child will immediately do it.

It is clear that a verbal command can *start* the child's action, but it is not yet able to overcome the influences of the immediate environment; nor can it stop the action already started by the child or to construct a new program which could control the child's behavior.

Let us place a small plush rabbit in front of the child and allow to play with this toy. Let us then add a new toy, for example a rubber hen; now the command "give me the rabbit" fails: the child turns its eyes towards the rabbit, but they meet the attractive hen, and the child grasps this new toy; the child's behavior, controlled by the verbal command, is now blocked by an immediate orienting reaction to a novel stimulus.

The same can be seen if we try to use a verbal instruction to arrest an action already started by the child or to change it for another one.

Let us now place two objects — a rabbit and a hen close to a child 14—16 months of age and repeat several times the order "Give me the rabbit"; only then, without changing the intonation, let us command "Give me the hen". The inertia of the evoked action is at this stage so intense that we are often unable to change it and to overcome the previous stereotype; hearing the new order, the child continues to repeat its previous action (A. R. Luria and A. G. Polyakova, 1959).

The following experiment shows how gradually the verbal instruction assumes its controlling function. Two familiar objects are placed in front of the child: a wooden cup on its right and a wooden box on its left. The child sees that a penny is placed under the cup; then the instruction follows: "Give me the penny". A child of 1;6—1;10 easily fulfils this instruction. Some difficulties are observed if the fulfilment of the command is delayed for 20—30 seconds: in this case the verbal instruction may easily lose its directing role, and the child begins to examine both objects, grasping the object named only in 50% of all cases. The immediate orienting reaction suppresses the traces of the verbal order; and only at the next stage of development do the traces of the earlier perception and of the verbal order become stable and a selective action takes place (A. R. Luria and A. G. Polyakova, 1959).

The weakness of the directive role of the verbal instruction in small children can be seen even better in the last series of these experiments, when it loses its immediate perceptual base.

The same above-mentioned two objects are placed in front of the child, but this time the penny is put under one of the objects when the child's eyes are closed. Only then is the following verbal order given: "The penny is under the cup; give me the penny". Younger children at the age of 1;4—1;6 often ignore the verbal instructions and try to grasp both objects; a verbally-linked action is here replaced by an immediate orienting reflex. Older children at the age of 2;0—2;4 may start fulfilling the instruction; but when after 3—4 repetitions of the same order a new one is given, namely "The penny is under the box; give me the penny", the child ignores the verbal instruction and continues its previous action. These

mistakes begin to disappear only at the next step of development; only in children at the age of 2;8—3;0 does the verbal order become sufficiently stable and acquires its directive role independently of visual base.

It is clear that at these early stages of development the verbal command can *start* an action but is *unable to overcome the immediate influences or the inertia of already established stereotypes.*

3. Realization of verbally directed programs

The rule we mentioned may be easily illustrated by special experiments with a simple motor reaction.

Let us give a child of 1;8—2;2 a rubber balloon connected with a pneumatic recorder and ask him: "Press the ball". The result will not be as simple as it might be expected. If the plastic bulb itself does not evoke a grasping reflex, the child will start to press the balloon, but will be unable to stop the reaction; a series of successive pressures will be recorded during a considerable time period. All efforts to stop these uncontrolled movements will be futile, and if we order the child to press *only* when it is told to do so — we shall see that the child is unable to stop its movements; while hearing the command "Don't press any more", it often may even increase the pressures. The verbal command may *start* the action, but is yet unable to *arrest* it.

The weakness of the controlling function of the verbal instruction at this stage manifests itself even more distinctly in experiments with a *verbally conditioned motor reaction.*

The instruction: "When you see a light, you must press the bulb" seems to be extremely simple; but as a matter of fact, it includes a complex program of actions: a preliminary plan must be established; the immediate orienting reaction to the stimuli is to be blocked; the stimulus must acquire a conditional meaning, and programmed movement must be started only after the signal appears. The realization of this complex program proves to be impossible for a child of 2;0—2;6: after the words "When you see a light..." — it immediately begins to look for it, and stops the movements, but when it perceives the end of the instruction"... you must press the bulb" — it starts the motor reactions irrespective of the signal. Thus we come to a paradoxial result: when the light appears, the movements are blocked, but when the signal is absent — they start. In these cases the order "Press only when you see a light" is of no help; hearing this strict order, the child can neither increase its pressures nor fully stop its motor activity. The selective influence of the verbal instruction is not yet ripe, and no realization of a complex verbally formulated program is possible.

The same can be seen even in children of 2;8—3;0 if we make the instruction more complex and if we try to establish a complicated program of a conditional choice reaction.

Let us give the child the following command: "When you hear a sound, press twice", or "When you see a red light, press the lb; when you see a green light, don't do anything". In such cases .. child of 3;0 or even of 3;6 will easily retain the verbal instruction, but will still be unable to follow this program; in the first experiment it will respond to the sound with a series of uncontrolled pressures, and in the second it will press after it perceives both the positive and the negative signals. Only at the age of 3;6—4;0 does the child becomes able to fulfill this complicated program, blocking the immediate influence of the stimulus: but even a slight complication of the experiment results in a breakdown of this form of self-controlled, conscious behavior.

4. Development of a verbal control of actions

Now we come to the basic question: is it possible to speed up this process and to find means of improving the conscious control of the child's own actions even at early stages of its development?

All our attempts to improve the child's own control of its behavior at the age of 1;6—1;10 have failed. However, experiments with children of 2;6—2;8 produced some interesting results and opened up some ways for solving our problem.

At this stage of development we were still unable to assure the child's immediate control of its own behavior; however we could observe some positive results *when the child's motor reactions evoked a feed-back signal* which provided the child with information concerning the *result of its task*. If we instructed the child to press the bulb in order "to put out the light" — superfluous pressures disappeared. The same could be observed in older children when in the case of the command: "if you see the light — you will press twice" ...ery pressure resulted in a feed-back acoustic signal.

Thus, at this early stage of development a verbal program could be realized only if this realization was reinforced by a feed-back signal of the action fulfilled.

Now the following question arises: couldn't we replace this feed-back signal by the child's own controlling activity and use *the child's own speech, its own verbal commands, as means of control?*

Our first experiments with children of 2;4—2;8 gave negative results. A child of this age could easily respond to each stimulus with the simple verbal reaction "go!"; but if we instructed the child to accompany its own command by a motor reaction, by pressing the bulb, — we could see that the child's verbal command did not yet acquire a controlling function; giving itself the order "go!" the child either stopped the motor reaction or continued the superfluous pressures despite its own command.

Quite different results were obtained in children of 3;2—3;6: the introduction of the child's own commands "go!" had no success at the first stages of the experiments, but after some training

the child's motor reactions became co-ordinated with its verbal commands; starting to say "go!", "go!", the child began to produce organized motor pressures and to block the superfluous uncontrol movements; the cancellation of these verbal commands resulted in a re-appearance of the superfluous motor reactions.

The same was observed when we asked a group of somewhat older children to press twice in response to every signal and included in the realization of this program the child's own command "go!" "go!". In all these cases the child's verbal system, which was now based on more concentrated excitatory processes than the motor system, assumed controlling functions; we could observe the first manifestation of overt speech as the "highest regulator of human behavior".

However, it would be erroneous to suppose that at this stage of development the child's "Conceptual Nervous System" is ripe enough to control its conscious actions.

To prove it, we have only to make our experiments a little bit more complicated, and pass from simple motor reactions to a complex program of a *choice reaction*. Here the psychological pattern of the behavioral control changes: one positive signal (a green light) must evoke a motor reaction while another, negative signal (a red light) must block it. The psychophysiological role of the child's verbal commands undergo a fundamental change here as well: the positive command "go!" must start a motor reaction, while the negative command "no!" acquires a negative semantic meaning, but preserves its immediate excitatory influence: there is still an active voice reaction, and there still remains the question: which influence, i. e. the immediate excitatory influence or the semantic blocking will predominate. Experiments with children of 3;0—3;6 give a clear answer to this question: in many children of this age their own command "no!" not only does block the motor reaction, but e... disinhibits it; saying "no!", the child even increases the pressur...

The same can be seen in an even more grotesque form, in imbecile children of a much older age; in this case the verbal auto-command "no" results in a still stronger discharge of the motor reaction. This means that we can describe a stage when *the immediate discharging role of the child's own verbal command dominates over the semantic role of its speech*, and that further development is needed to make this semantic side of the child's speech a predominant one. This ultimate stage is reached only at the age of 4;0—4;6 years, when the child begins to form some inner programs of complex actions and when its own overt speech becomes a less decisive factor. Here the semantic programs based on the child's inner speech begin to acquire their controlling functions, and the child becomes able to fulfill the programs of simple choice reactions even without its own overt verbal reinforcement. This stage may be regarded as the first step towards the consolidation of the inner controlling mechanisms of the child's conscious actions, and, perhaps, as the first stage of the controlling functions of the "Conceptual Nervous System" mentioned at the beginning of this paper.

5. *Basic Principles Underlying the Functional Organisation of the Human Brain*

Let us now stop analysing the early development of the conscious control of actions and turn to the second problem of our discussion. What do we know about the cerebral processes that are responsible for the control of our behavior? Which structure of the Human Brain plays a decisive role in the establishment of plans and in the realization of programs of our behavior? Which basic systems of the brain ensure the selective attention and the permanent control of the highest forms of Man's purposive actions?

In our attempt to answer this question we by no means lose the sense of reality; we know very well, all we say is only the first approach to this problem. But as a result of nearly forty years of our work in the field of neuropsychological analysis of focal brain lesions we have obtained a series of basic data which can be used in our discussion, and we shall try only to bring them together rather than to speculate on an ultimate theory.

To say that the Human Brain operates as a whole means to make simultaneously a correct and an erroneous statement.

It is correct because the most complex forms of human actions require the participation of all brain systems; it is erroneous because we can hardly admit that the Human Brain — this highest point of Evolution — works as an undifferentiated whole and that the quality of its work depends exclusively on the active mass of its excited tissue. Modern data of brain morphology, physiology and neurology discard the idea of the brain as a homogenous unity, which was possible a generation ago but which is incompatible with modern knowledge. However, refuting the holistic approach to the brain, we in no way return to the old concepts of isolated nervous centres responsible for complicated psychological processes. The ideas of Gall and Kleist are as far from our approach as the ideas of Goltz and Lashley.

Today we have every reason to approach the Human Brain (including its cortex) — as *a complex functional system* which includes joint work of different levels and areas, each of which plays its own role. The concept of a "working constellation" advanced by the famous Russian physiologist A. A. Ukhtomsky, as well as the concepts of a "functional system", "dynamic localization of functions", or even Hebb's "cell assembly" has assumed in recent years a much more definite meaning than at the time when they were originated. We can only admire the modern research on the level of single neurons which has revealed a high specialization of these elementary brain units responsible for reactions to very special cues or for comparing signals. We have every reason to expect that this research

will soon come into accord with the facts of modern clinical neuropsychology.

Data obtained during the last decades give us all grounds ' single out at least *three basic blocks of the Human Brain*, ea making its own contribution to their common work.

The *first block* may be called ***block of Energy and Tone***; it includes the upper brain stem, the reticular formation and to a certain degree the oldest parts of the limbic cortex and hippocampus. This block is responsible for the stable tone of the cortex and for the state of vigilance which some psychiatrists erroneously call "consciousness". It would be unwise to discuss here the basic forms of activity of this block after the well known publications of Magoun and Moruzzi, Jasper and Penfield; their analysis of the changes in sleep and wakefulness, in arousal and drive may be regarded as the most significant contributions to our science. As shown by a group of outstanding scholars, this block includes a considerable amount of curious neurones which react to every change of the stimuli and which Jasper calls "attention units".

We had the opportunity to analyze the behavioral changes occuring in patients with lesions of the medial parts of the brain cortex and brain stem, and could observe in these patients marked disturbances in stable wakefulness, instability of memory traces and selective organization of thinking similar to those observed in dreamy states (cf. A. R. Luria, E. D. Homskaya, M. Critchley and oth., 1967; A. R. Luria, A. Ya. Podgornaya and A. N. Konovalov, 1969); but these lesions never resulted in any basic disturbances of the structure of concepts nor did they result in a primary loss of the simple programs which control the conscious action. In these cases a slight reinforcement increasing the lowered cortical tone may easily lead to a compensation of the defects and to a recovery of the deranged control of behavior (E. D. Homskaya, in print).

All this means that although the participation of the first block in the common work of the brain is of great significance for the higher forms of conscious activity, we have no grounds to consider it to be a mechanism which is specific for the realization of programmed actions.

The *second block* of the Brain includes the posterior parts of the hemispheres with the occipital, parietal and temporal regions as well as their underlying structures; it can be defined as a block of the *input, re-coding and storage of information* received from the external and proprioceptive world. It is well known that the systems of this block are highly modality-specific: the occipital lobe, being a central device for visual analysis, does not take part in the de-coding of acoustic signals, while the temporal lobe participates only in a limited and specific form in the organization of visual information.

It is also well known that each system entering this block has a hierarchical structure, and that the work of each primary (or extrinsic) zone is organized by a superimposed secondary (intrinsic) zone with highly developed upper levels of "associative" neurons. series of very important studies showed that only a small part the neurones of these zones are of the non-specific type of "attention units" while the greater part perform a highly specific function firing to isolated cues of different modalities. The specificity of these areas decreases with the transition to the "tertiary zones" of the cortex or to the "areas of overlapping" which include units reacting to different modalities and which provide a synthesis of serial influences to some simultaneous schemes. We had the opportunity to analyse the role of these areas in the elaboration of complex forms of spatial and conceptual structures (A. R. Luria, 1966 a, b), and we shall no longer dwell on the functions of these zones.

One basic feature is to be emphasised here: patients with lesions of the posterior parts of the brain may lose several important behavioral *operations*, but these lesions *never result in a general deterioration of their conscious conduct*: these patients retain their plans and their strategies; they are fully aware of their defects and very actively try to overcome them. They remain Human Beings in the full meaning of this word, and in spite of their tragic fate, they never lose their conscious forms of conduct.

We come to the conclusion that the second basic block of the Brain, no matter how important it may be, is in no way responsible for the regulation and control of Man's conscious behavior.

The *third block* of the Brain includes the *Frontal Lobes*, and it is of a particular interest for the basic problem of our discussion.

The frontal lobes of the brain are the last acquisition of the evolutionary process and occupy nearly one third of the Human hemispheres. They preserve a vertically organized structure typical of the motor zones (G. I. Polyakov, 1966) and their anterior parts possess some distinctive features of the most complicated "tertiary zones". They are intimately related to the reticular formation of the brain stem, being densely supplied with ascending and descending fibres, and their medio-basal parts may be regarded as an important cortical structure superimposed on the systems of the upper brain stem (French, 1958; Nauta, 1964, 1965 et al.). They have intimate connections with the motor cortex and with the structures of the second block, but in contradistinction to the latter, their work is not of a modality-specific type. As shown by a group of Russian scholars, their structures become mature only during the 4th—5th year of life, and their development makes a rapid leap during the period which is of decisive significance for the acquisition of the first forms of conscious control of behavior (E. P. Kononova, 1940; I. J. Glezer, 1959 et al.).

There are many reasons to suppose that this block of the brain plays an important role in the *realization of the plans and programs of human actions* and in the *regulation and the control of Human behavior*. We have considered this question in a series of publications

(Cf. A. R. Luria, 1966 a & b; A. R. Luria & E. D. Homskaya (eds) 1966 et al.) and here we shall only summarize our findings.

6. Frontal Lobes and Regulation of Conscious Actions. General data

Neurologists know very well the general kind of behavioral disturbances which are caused by severe lesions of the frontal lobes (limited lesions may be poor in symptoms because of certain equipotentiality of the foci of the prefrontal area, this "highest and least differentiated part of the human cortex", as formulated by Hughlings Jackson).

Patients with severe lesions of the prefrontal areas, as a rule, do not manifest any stable alterations of memory and orientation in the immediate environment which are typical of patients with lesions of the medial parts of the hemispheres. They don't suffer any defects in perception or movement, in speech or even logical operations. At first glance one may suppose that they preserve all the basic functions of the Human Brain.

But this is not the case. Attentive observation shows how deep are the disturbances in the regulation and control of the conscious behavior of these patients.

As a rule, only a limited part of the patients are able to create plans or to follow certain programs; nor do they preserve complicated motives of their conduct. No strategy can be observed in their behavior, and they do not try to find proper ways or means of fulfilling of a given task. Complex forms of behavior are, as a rule, replaced by primitive "field-actions", impulsive responses to immediate stimuli or by an inert reproduction of previously evoked stereotypes which at first were meaningful, but became totally senseless in new conditions.

The classical descriptions of the behavioral changes in animals after the destruction of their frontal lobes — beginning with the early publications of Bianchi and Jacobsen and ending with the latest findings of Anokhin and Pribram — have been enormously enriched by observations carried out on patients with massive lesions of the frontal lobes. We cannot forget one of our patients — a woman with a massive bilateral tumor of the frontal lobe — who at an early stage of her disease was seen to stir burning coal with a broom and to cook some of the bristles instead of noodles.

Nor can we forget a soldier with a massive bilateral gunshot wound of the frontal lobes who started to plane a plank, but could not stop and automatically continued this work until almost a half of the bench itself proved to be planed down.

It is easy to see that no defects of movements were responsible for such funny alterations of behavior, that massive derangements of the inner plans and programs predominated in these cases and that the purposeful forms of conscious behavior were replaced here by uncontrolled responses to immediate impressions or by automatic inert stereotypes.

The decisive role played by the Frontal lobes in the control of conscious behavior is beyond any doubt. But the problem still remains what are the mechanisms of these functions of the Frontal lobes?

7. *Frontal Lobes and Regulation of Vigilance*

Let us turn to some experimental data which could help us to answer this question.

To realize a complicated program one has to preserve a certain level of vigilance; it is well known that complex discursive activity can hardly be performed in a dreamy state.

But a general excitation of the cortex caused by impulses coming from the reticular formation is by no means sufficient in this case. The activity required for the realization of a complex program must be highly *selective*; it must be evoked by a definite goal or plan; the information which is related to the given plan is to be singled out and must become dominant while all outside impressions must be suppressed. It is obvious that such selective organization of the active state can be ensured only by a close participation of the highest cortical areas and their descending fibres.

The Frontal lobes, especially their medial parts, are exceptionally rich in descending and ascending fibres of the reticular formation; this was shown in a series of works by French (1955), Nauta (1964, 1968), Zager (1962) and others. We might therefore expect that the subject's strong intention can mobilize the apparatuses of the brain stem and, with the help of the activating system raise the activity of the frontal parts of the brain, and that lesions of the frontal lobes may result in a breakdown of these activating influences.

Both assumptions proved to be right.

The first was corroborated by a series of brillant experiments of W. Grey Walter in England and of M. Livanov in the USSR. It is well known from Grey Walter's studies that any expectation of a signal evokes a special kind of slow potentials which appear in the subject's frontal lobes and subsequently spread to the posterior parts of the cortex. Grey Walter (1963, 1966) called them "expectancy waves" and observed their intensification when the subject's activity increased, and their disapperance when the instruction was cancelled.

At the same time M. N. Livanov in Moscow, using a 50-channel amplifier, made an important observation: when the subject started solving a difficult intellectual task (such as multiplication of two two-digid numbers), a significant number of synchronously excited points appeared in his frontal lobes; they disappeared when the ploblem was solved or cancelled. The same could be observed in excited paranoid patients; the synchronously excited foci in the frontal cortex disappeared after the patients were treated with a tranquillizing drug.

These data make it very probable that *the frontal lobes of the human brain take an important part in the regulation of vigilance* required for the realization of complicated intellectual actions.

The facts we mentioned were obtained on normal subjects; but it is highly probable that in patients with severe lesions of the frontal lobes the regulation of the higher forms of vigilance may be markedly disturbed.

Precisly this problem has been carefully studied by Dr. E. D. Homskaya of our laboratory in a long series of experiments on patients with frontal lesions with the help of a battery of objective methods.

Let us review only some of her findings.

It is well known that the appearance of any stimulus evokes in a normal person a series of somatic reactions, which actually are symptoms of arousal or components of an *orienting reflex*, such as constriction of the vessels of the fingers, dilatation of the vessels of the head, galvanic skin reactions. These somatic reactions persist for a some time and are extinguished when the subject becomes habituated to the stimuli; they can be increased and prolonged if a special instruction is given, if the subject is asked to count the stimuli, to await some change in them, or to press a key when the stimulus appears, in other words when the stimulus assumes a "signalling meaning" (E. N. Sokolov, 1959; O. S. Vinogradova, 1959).

Such an increase and fixation of the vegetative components of the orienting reflex is observed in normal subjects and in patients with lesions of the posterior parts of the hemispheres; but it is not observed in patients with lesions of the frontal lobes and especially of its medial or basal parts. These patients may exhibit immediate vessele reactions to changes of the stimuli, but the verbal instruction we have mentioned doesn't evoke any stabilization of the vascular symptoms of the orienting reflex. This is of high diagnosti significance and often remains the only symptom of a frontal lobe lesion.

Similar data were obtained from experiments in which EEG components of the orienting reflex were recorded.

It is well known that any new and unexpected stimulus results in a depression of the alpha band of the EEG and especially of its high frequencies; it is likewise known that a verbal instruction imparting a special meaning to the signal makes this depression more pronounced and more stable.

The same is observed in patients with lesions of the posterior parts of the hemispheres; no such effect is seen in patients with lesions of the frontal lobes, especially of their mesial parts. The verbal instruction to count the stimuli or to await their changes does not increase the effect of desynchronization, and in some cases a slight depression of the lower frequencies or even a paradoxial exaggeration of the alpha diapason takes place.

During the last few years a new EEG-symptom of activation has been carefully studied and proved to be highly reliable. As shown by . A. Genkin (1962, 1963) and later by E. D. Homskaya and . Y. Artemieva (1966) a careful analysis of the structure of the alpha waves in a normal subject discloses a peculiar change in the asymmetry of the ascending and descending fronts of the alpha wave which bears a slow periodical character of 6—7 seconds. This regularity is observed in the quiet state of a normal subject and becomes violated when activation or intellectual arousal takes place.

The same can be observed in patients with lesions of the posterior parts of in brain; but no such breakdown of the regularity of the asymmetry index is observed in patients with lesions of the frontal lobes.

Perhaps of the greatest importance are data obtained from experiments with evoked potentials conducted by E. G. Simernitskaya on normal and brain lesioned subjects 1966).

It is known that each specific stimulus (visual or tactile) evokes specific potential changes in the occipital or sensorimotor parts of the cortex and that the expectation of such a stimulus results in an exaggeration of these evoked potentials.

The same effect, produced by the verbal instruction to await a signal, is seen in patients with lesions of the posterior parts of the hemishpere; but no such effect of a verbal command is seen in patients with lesions of the frontal or medio-frontal parts of the brain.

All these data obtained by E. D. Homskaya and her co-workers show that the *frontal lobes play a significant part in the regulation of the active states started by a verbal instruction.*

It is easy to see how important these data are for understanding the decisive role which the frontal lobes play in the control of the highest forms of human behavior.

8. Frontal Lobes and Realization of Programmed Actions

Disturbances in the regulation of vigilance observed in patients with severe lesions of the frontal lobes exert far reaching influences on the structure of Man's conscious actions. Being unable to sustain permanent selective attention, patients of this group become unable to fulfil complicated programs of actions.

Let us turn to a series of corresponding experiments.

Only patients with massive bilateral lesions of the frontal lobes and with a pronounced akinetic syndrome are unable to fulfill the simple instruction: "Lift your hand!"; the difficulties with which the fulfilment this command is connected increase when the patient's hands are under the bedsheet and when he has to execute a more complex program of successive movements: at first to free his hand, and only then to fulfill the instruction. In these cases he often answers: "Yes, I shall lift my hand..." but does not perform any movement at all.

As a rule, patients with severe lesions of the Frontal lobes can easily imitate simple movements performed by the psychologist, such as lifting a fist or a finger. But the picture completely changes if the given task is replaced by another one, i. e. when the verbal command comes in conflict with the visually presented pattern. Let us give the patient the following order: "When you see my fist, you will show me your finger!" In this case the realization of the program will be impossible, and although the patient retains the verbal instruction and repeats it, after 1—2 correct reactions the directing role of the verbal command breaks down and the required movement is replaced by an immediate imitative reaction. The same can be observed if we ask the patient to respond to every single knock with two knocks, and to every two knocks with a single one. The patient's inability to maintain a program organized by a verbal code and the reduction of his action to the level of immediate imitation are in both cases quite obvious.

The breakdown of an action controlled by a verbal program may assume a different form when the conscious action is replaced by an inert stereotype.

Let us for example, instruct the patient to lift his right hand in response to one knock and his left hand in response to two knocks. A patient with a less severe lesion of the frontal lobes is often able to fulfill this instruction. But if we break this stereotype (R—L—R—L—R—L—L), we find that the patient will preserve this stereotype order and will continue the alternation already started, irrespective of the given signals, even though he retains the verbal instruction. In cases of massive lesions of the frontal lobes this pathological inertia manifests itself even at the verbal level; if the patient is instructed to fulfil a simple program, for example, to produce one strong knock and two slight ones, and to accompany these actions by his own verbal commands: "Strong—slight—slight!", he often begins to change his commands: he adds perseverative repetitions of or of the links, and saying: "Strong—slight—slight... Strong—slight—slight — slight" and realizes this deformed program in his motor reactions.

It is obvious that in these cases the patient's own speech is unable to regulate his own behaviour. We could easily present a series of data, showing that the breakdown of the verbal control of behavior in patients with severe lesions of the frontal lobes brings about the same phenomena which we have already seen when discussing the early stages of development of the highest forms of conscious actions.

The breakdown of conscious actions and their replacement by inert stereotypes or primitive reactions to immediate impressions can be perfectly well analyzed in experiments with a graphic realization of given programs.

Any drawing of a figure actually presents an execution of a successive algorithm; in order to draw a cross, the subject has to draw a vertical line, and then switch his movement over to a horizontal one; in order to fulfill a more complex program — to draw circle and a cross he has to perform a series of movements: after drawing the circle he must move his hand to the next point of the sheet — and only then he can start drawing the cross. It can be easily seen that the fulfilment of this program requires that the previous movements, as well as all outside influences, be blocked.

In patients with severe lesions of the frontal lobes this complicated structure of the program may be violated, and its breakdown can be seen in every link of the alogorithm mentioned.

If the lesion is located in the deeper regions of the frontal lobe, the patient may start drawing, but the fulfilment of the program is violated by a motor perseveration. In the case of a severe damage of the prefrontal zone, the patient may be unable to fulfil the intermediate link of the program not mentioned in the instruction; the execution of the command "Drow a circle and a cross" does not shift his hand, and both figures prove to be superimposed. Sometimes the execution of the program is violated in some different link; the patient does not shift from one unit of the program to another, sticking at the first action and replacing the program of actions by an inert stereotype.

Finally, the realization of the program may be violated by uncontrolled outside influences or extraneous associations.

A patient with a traumatic cyst of the frontal lobes is instructed to draw a square. He begins to do it, but draws three quadrangles and then another big square following the borders of the sheet of paper.

The psychologist who conducts tre experiments whispers to his colleague: "Have you read that a pact was signed to-day?", — and the patient reacts to this immediately, writing in the middle of the uadrangle "...Act. N.". "What is the patient's name?" the psychologists asks his assistant; and the patient writes immediately "Yermolov". "Look, this is so similar to the behavior of lobectomized animals" whispers the psychologist, — and the patient adds to the already written word "Act" the words "on Animal breeding..." We can hardly find an example which could express better the breakdown of the patient's programmed action.

Here is another example of the same kind. A patient with a massive tumour of the left frontal lobe is asked to draw a triangle; he draws it at once, but adds a second one. Then he is asked to draw a minus; he draws an oblong, perseverating the closed form of the triangle. When he is asked to draw a circle, he does it, but additionally draws the same oblong in the middle of the circle and writes the words; "Entrance strictly forbidden!" Can you guess what the patient's former occupation was?...

The analysis of the basic types of breakdown of programs in patients with severe lesions of the frontal lobes opens up new vistas

in the Neuropsychology of the Conscious Action, its inner structure and its cerebral organisation.

9. Frontal Lobes and the Strategy of Plans

Up to now we have described disturbances in the realization of given programs in patients with severe lesions of the frontal lobes. It is obvious that even more massive defects may be observed in most complex forms of active behavior, when the patients have to develop their own strategies and to construct their own plans and programs. This can be easily seen in experiments where the patients have to elaborate some active operations to single out some decisive points of information.

Several years ago E. N. Sokolov (1958) proposed a special technique for analysing such perceptive strategies; this was followed by experiments of L. Arana (1961) on normal subjects and of O. K. Tikhomirov (1966) on patients with lesions of the frontal lobes.

A subject whose eyes are closed receives two sets of checkers having the forms of the letters H or E. He has to touch them successively with his finger and to recognize which letter is actually presented to him. At the first stages the subject's search for information is of an extended type: he touches all checkers; but very soon he develops a special strategy trying to single out only those points of information which are decisive for the discrimination of both letters. At the last stage only one trial is sufficient for fulfilling this task.

No such process of development of a strategy is observed in patients with lesions of the frontal lobes. As a rule, such patients touch all checkers, but they don't use the information they receive; nor do they shorten their search. The act of touching successive checkers is not used here for preliminary orientation to the given pattern, and the patients "conclusion" is a mere guess, but not normal process of a decision making.

A similar breakdown of complex strategies of perceptive search is observed in a series of most expressive experiments with active observation of thematic pictures and with simultaneous recording of the subject's eye movements.

Let us show to a normal subject a complex thematic picture, for example, a well known picture of the outstanding Russian painter Repin "The Unexpected Return". It presents a man who unexpectedly returned home after he had spent many years in tsarist prison. Let us fasten to the subject's sclera a little mirror which reflects a beam of light to a photosensitive paper recording the subject's eye movements. After recording the subject's free observation of the picture let us ask him some different questions, such as: "How old are the members of the family?" "How are they dressed?", "Is the family rich or poor?" or "How long was the man in prison?" Records of the eye movement made during 3 minutes show how complex is the exploratory activity of a normal subject and how profoundly the structure of his search changes depending on different instructions (Yarbuss, 1967).

No such complex structure of the search is observed in patients with severe lesions of the frontal lobes. These patients don't exhibit any strategy of their search behavior; they don't make any attempts to single out the decisive information by comparing separate details of the picture. They fix some points of the picture, sometimes chosen at random, and their eye movements bear a chaotic or perseverative character; no change of ocular movements manifests itself when different instructions are given. It becomes evident that no active strategy of search is applied by these patients, and that their perceptive behavior becomes profoundly changed.

May we assume that the structure of active forms of behavior is severely disturbed as a result of lesions of the frontal lobes?

We have had many occasions to prove the correctness of this assumption in a long series of experiments with different kinds of intellectual activities; in all cases we came to the conclusion that the Human frontal lobes are intimately involved in the realization of complex strategies of behavior and that severe injuries of these parts of the brain result in a breakdown of the basic structures of their intellectual activities (cf. A. R. Luria and E. D. Homskaya (eds. 1966; A. R. Luria and L. S. Tsvetkova, 1967).

10. Conclusions and Perspectives

This concludes the review of our basic data obtained during a long series of studies of the Origin and Cerebral Organization of Man's Conscious Action. Now we can pass to some general inferences.

We can fully agree with the assumption that the Human CNS is really a "Conceptual Nervous System" and that its basic task consists in elaborating some inner codes which result in the execution of certain plans and programs and in the regulation and control of Man's own behavior. This really makes the Human Brain an Organ of Freedom.

We likewise know that the origin of the highest form of self-regulating behavior doesn't lie in the depths of the organism, and in order to disclose its roots, we have to turn to the complex forms of a child's relations with its social environment and to its acquisition of language. We already know some features of the dramatic history of its development, and we possess some basic data concerning its cerebral organization. It is evident now what an important role the Frontal lobes of the Human Brain play in the organisation of the conscious control of behavior and what a profound breakdown of this highest forms of self-regulated activity is observed in severe lesions of this wonderful parts of the brain.

However, after long research work, we have to admit that we are only at the very beginning of our way and that the unsolved problems many times exceeds the scope of our actual knowledg

We don't yet know the neurophysiological mechanisms of the highest forms of conscious regulation of behavior; nor do we know the intimate physiological mechanisms of the work of our Frontal lobes. Our knowledge of the Frontal lobes is still too vague, and only during the last years have we began to acquire some data concerning their complex functional organization.

Thus, we are still very far from the solution of our basic problem — the Neuropsychological Organization of Man's Conscious Action, and we can only look forward with envy and hope to the work of the next generations of Psychologists who will one day take our place and bring to a successful end the work we have only started.

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