4-51.
3 Dry

# THE ORIGIN and the Cerebral ORGANIZATION of the Man's Conscious Action.

by A. R. LURIA (MOSCOW)

—

An Evening Lecture
to the
XIX International Congress
of Psychology.

—

1969

# THE ORIGIN and ~~Brain~~ Cerebral Organization of the Man's Conscious Action

by A. R. LURIA (Moscow)

-

## 1. The PROBLEM.

Several years ago two of the most outstanding psychologists of our days - B.F. Skinner and D.O. Hebb proposed to de-code the well known term CNS as „Conceptual Nervous System"

That was firstly used as a joke; but we can earnestly accept it: the Human Brain does not only re-code the sensory information in a system of concepts; it ~~is responsible for~~ establishes Human Plans and Programs and for a conscious control of human actions. It really is an Organ of freedom, and it would be unwise to ignore this basic feature and to approach ~~to~~ the Human Brain with the same methods and ideas as the brain of a rat.

Now a question arises: how can we find propper ways to understanding the basic qualities of the Human Brain not following the old mentalistic approaches neither repeating the mechanistic ideas popular a generation ago but unacceptable now? How can we come to a scientific solution of the ~~problem~~ old riddle of the ~~free~~ man's free activity and conscious behavior?

The answer to this question doesn't lay ~~in the depths of our organism, or~~ in the most intimate parts of the Brain or in careful studies of single neurons.

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

That was the way used by the Late L.S. Vygotski, the famous Soviet Psychologist, and we shall follow this way.

A newborn ~~a~~ starts his life with a series of inborn ~~ch~~ self-regulating systems ~~x~~ of a very elementary type - breathing and sucking, primitive orienting reflexes and a battery of early ~~m~~ forms of motor activity. These elementary forms of activity were carefully studied by a series of eminent scholars from Schelovanov in the USSR, Minkowski, Peiper to the recent brillant studies of my friend Jerome Bruner. But how far are these formes of behavior from the ~~really~~ 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? That is really one of the basic questions of the contemporary [psychology] scientific.

The newborn starts his life in an immediate social contact with adults. The mother gives him orders and is permanently speaking to the child. She shows him an object, pointing to it and saying: „that's a doll", and the child turns its eyes towards the object; she gives him a command „give me the doll" and the child tries to do it. The childs conscious action is originally divided between two persons: it is started with the mothers command and it ends with the child's movement. Only in the next period of the childs development the structure of this action begins to change; the child starts to use its own language; saying „a doll" it singls out the object naming and tries to grasp it. The child's own speech begins to be used as a command, and the function, formerly divided between two persons, becomes now a new form of an inner self-regulated psychological process. That is the start of a new type of behavior — social by its origin, verbally-mediated by its structure and self-controlled by its kind of functionning.

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

## 2. The origin.

The development of the highest forms of conscious, self regulating behavior is not at all a simple process or a jump from „field reaction behavior" to free behavior. The first acquisition of command-controlled action is only a start of the long process of the formation of the Higher Psychological Functions, and a scholar has to follow carefully the steps of this dramatic history, starting by the earliest stages (as it was recently done by Jerome Bruner (1969) and following the further steps of the infant's development)

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

It is well known that the adult's verbal command can easily evoke an orienting reaction even in a child of 6-8 months and an simple motor action in a child of 10-12 month. Name an object placed in the childs immediate enviroment and it will turn its eyes towards the object; tell it „lift your hands!" and it will

immediately do it.

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

Let us place in front of the child a small plush rabbit and to allow him to play with this toy. ~~Now~~ Let us ~~then~~ then add a second toy - for example a ~~hen~~ bright rubber hen; ~~which is placed~~ now the old command „give me the rabbit" can fail: the ~~eyes~~ child's ~~turn eyes a~~ turns its eyes towards the rabbit, but they meet the new and attractive hen, and ~~he~~ it grasps this new toy; ~~(following his behavior is now submissed to the)~~ the child's behavior, controlled by the verbal command is ~~now substituted~~ now blocked by an immediate orienting reaction to a novel stimulus.

The same can be seen if we try to use the verbal instruction to arrest a child's action already started, and to change it to another one.

Let us now place close to the child of 14-16 month two objects - a rabbit and a hen ~~E~~ and give ~~him~~ it several times ~~an a command~~ an order: „give me the rabbit!"; then - without ~~a~~ changing the intonation let us ask it: „give me the hen!". The inertia of the evoked action is at that stage so intensive that we often are unable to change the child's action and to overcome the former stereotype, - and listening to the new order the child continues to repeat its former ~~action~~ action (A.R. Luria & A.G. Polyakova, 1959a).

The next experiment shows ~~how~~ ~~show the gradual step~~ how gradually the verbal instruction receives 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 observes that a penny is placed under the cup and we ~~give it an order~~ instruct it: „give me the penny!". A child of 1;6 - 1;10 easily carries out this order. Some difficulties are observed if ~~we~~ the fulfillment of the command is delayed by 20-30 seconds: here the verbal instruction can easily lose its ~~regu~~ directing role, and the child begins to observe both objects, grasping the named one only in a half of the cases ~~%~~. The immediate orienting reaction suppresses the traces of the verbal order, and only on ~~a~~ the next step of development the traces of the earlier perception and of the verbal order become stable and a selective action takes place (A.R. Luria & A.G. Polyakova, 1959-6)

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

The same two objects are placed in front of a child, but this time the penny is ~~the~~ hidden under one of the object when the child's eyes are closed. Only then the verbal order is given: „The penny is under the cup; give me the penny!" The younger children of 1;4-1;6 often ignore the verbal instruction and try to grasp both objects; a verbally-linked action is here replaced by an immediate orienting reflex. The older ~~group of the~~ children - of 2;0-2;4 can start by following the instruction, but when after 3-4 repetition of the same order a new command is given „The penny is under a box; give me the penny!" - the child ignores the verbal instruction and continues its former action. These failures begin to disappear only on the next step of development, and only in children of ~~3;0~~ 2;8-3;0 the verbal order becomes sufficiently stable and ~~a~~ acquires its directive role independent of its visual base.

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

3. The ~~acquisition~~ realization of verbally directed programs.

The rule we mentioned ~~can~~ could be easily shown by special experiments with the simple motor reaction.

Let us give a child of 1;8-2;2 a rubber ~~bulb~~ balloon connected with a pneumatic recorder and ask him: „Press the ~~bulb~~ ball!". The results we shall observe will be not as simple as we could expect. If the plastic bulb itself will not evoke ~~at~~ a grasping reflex, the child starts to press the balloon but will be unable to stop ~~th~~ the reactions, and a series of successive pressures will be recorded during a considerable time (Fig. 1). All efforts to stop these uncontrolled movements will be futile, and if we order the child to press only when he will be told, - ~~the chi~~ we shall ~~be~~ see that the child is unable to arrest its movements; listening to the command „don't press more!" it ~~even~~ often increases the pressures (Fig. 2). The verbal command can start the action, but is yet unable to arrest it.

Fig. 1.

Fig. 2

The weakness of the controlling function of the verbal instruction at that stage can be seen even more distinctly ~~with~~ in experiments with conditional motor reaction.

The instruction: „When you see a light - you will press the bulb" seems to be extreemly simple; but as a matter of fact it includes a complex

program of action: a ~~system of~~ preliminary plan has to be established; the immediate orienting reaction to the stimuli has to be blocked; the stimulus has to acquire a conditional meaning, and the programmed movement has to be started only after the signal appears. The realization of this complex program is impossible for a child of 2;0-2;6, and after it hears the words „When you see a eight..." — it immediately begins to look ~~at~~ to it, stopping the movements, and when ~~he~~ it hears the end of the instruction — „...you will press the bulb!" — it starts the motor reactions independent from the signals. So - we ~~recei~~ come to a paradoxial result: when the eight appears the movements are blocked, and when the signal is absent - they are started (Fig 3). In these cases the order „do press only when you see a eight" is of no help ~~and it results even if the child hears the the voice is~~ and the child ~~eight~~ listening to the ~~a severe voice~~ strict order ~~either~~ can either increase its pressures - or totally arrest its motor activity (Fig. 4)

Fig. 3.

Fig 4.

The selective influence of the verbal instruction is not yet ready, 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 ~~obtain a~~ establish a complicated program of a choice reaction conditionals.

Let us give to the child a command: „When you hear a sound - press twice!", or: „when you see a red eight - press the bulb; when you see a green one - don't do anything!" In such cases the child of 3;0 or even of 3;6 - will easily preserve the verbal instruction but will be still unable to follow this program, and in the first experiment will answer the sound with a series of uncontrolled pressures (Fig. 5), and in the second - will press ~~a~~ after it sees both - the positive and the negative signals (Fig 6)

Fig. 5.

Fig. 6.

Only by 3;6 - 4;0 the child becomes able to fulfill this complicated program, blocking the immediate influence of the stimuli, but even a slight complication of the experiment results in a breakdown of this form of self-controlled, conscious form of behavior.

## 4. The development of a verbal control of actions.

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

All attempts we made to improve the ~~immediate~~ child's own control of its behavior at the age of 1;6 - 1;10 failed. However experiments with children of 2;6 - 2;8 gave some interesting results and showed some ways for the solution of our problem.

At this stage of the developments we remained still unable to obtain the child's immediate control of its own behavior; but we could see some nice results if the child's motor reactions evoked a feed-back signal giving to the child an information of a result of its task.

Fig.7. If we instructed the child to press the bulb „to put out the light" - ~~additional~~ superfluous pressures disappeared (Fig. 7). The same could be seen in older children when ~~the~~ in a program „when you will see the light - you will press twice" - carry ~~a reaction to~~ pressure resulted in a feed back

Fig.8. acoustic signal (Fig. 8)

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

Now the question arises: couldn't we substitute this feed-back signal by a ~~higher and more speci~~ child's own controlling activity ~~of~~ and to turn to the child's own speech, using it's own verbal commands as controlling means?

Our first ~~attempts~~ experiments with children of 2;7-2;8 gave negative results. A child of this age could easily answer to each stimulus with a simple verbal reaction „go!"; but if we instructed the child to accompany ~~each his~~ its own command with a motor reaction, pressing the bulb, - we could see that the child's verbal commands did not yet acquired a controlling function, and giving itself an order „go!" it stopped the motor reactions or ~~the~~ continued the superfluous pressures despite of his own commands

Fig.9 (Fig. 9)

Different results were obtained in children of 3;2-3;6: introduction of the child's own commands „go!" didn't show ~~any~~ any success on the first stages of the experiments, but after some training it's motor reactions acquired a co-ordination with it's verbal commands, and starting to say „go!", „go!" the child begun to give organized motor pressures and to block ~~a~~ superfluous ~~unorg~~ uncontrolled movements; the elimination of ~~the~~ it's verbal

Fig.10. ~~auto~~-commands resulted in a re-appearence of the ~~a~~ superfluous motor reactions (Fig. 10)

The same was observed (~~if ~~by~~ we included the ch~~ ~~in slightly older children if we included~~) if we asked a group of slightly older children to

-Fig.11 press twice to every signal ~~and~~ including in the realization of this ~~ta~~ program ~~the~~ the child's own command „go! go!" (Fig. 11)

In all these cases the verbal system child's, which now was based on the more concentratat excitatory processes than the motor system, acquired it's controlling functions, and we could observe the first appearance of ~~what Pavlov called the~~ the ~~greatest~~ the overt speech as a „highest regulator of human behavior"

However it would be a mistake to suppose that at this stage of ~~the child's~~ development the child's „Conceptual Nervous System" is ripe to control its conscious actions.

To see that ~~it~~ we have only to make our experiments a little more complicated, and from simple motor reaction pass to a complex program of a reaction of choice. Here the psychological pattern of the behavioral control changes: one positive signal (red light) has to evoke a motor reaction while another - negative signal (green light) has to block it. The psychophysiological role of the ~~to~~ child's verbal commands ~~chan~~ undergo here a fundamental change as well: the positive command „go!" has to start a motor reaction, while the negative command „no!" acquires a negative semantic meaning but preserves an immediate excitatory influence: it still remains an active voice reaction, and it still remains a question, which influence - the blocking or excitatory will dominate. The experiments with the children of 3;0 - 3;6 give a clear answer to this question, and in many children of this age the child's own command „no!" does not block its motor reaction, but even disinhibits it, and saying „no!" the child even increases his pressure (Fig. 12).

Fig. 12.

The same can be seen even in a more grotesque form in imbecile children of ~~an older~~ a much older age, and the verbal auto-command „no" ~~of the elder~~ results in a stronger discharge of his motor reaction (Fig. 13).

Fig. 13

That means that we can single out a stage when an immediate discharging role of the child's own verbal command dominates over the semantic role of it's speech, and that a further way of development is needed to make this semantic side of the child's speech dominant.

This ultimate stage is reached only towards ~~3;6~~ 4;6 - 4.6 years, when the child begins to build some inner programs of complex actions and when its own overt speech becomes less decisive. Here the semantic programs based on the child's inner speech ~~become a~~ begin to acquire their controlling functions and the child becomes able to fulfill the programs of the ~~*~~ simple reactions of choice even without it's own overt verbal reinforcement. This stage may be regarded as a first step to the consolidation of the inner controlling mechanisms of the child's conscious actions, and perhaps - as the first stages of the controlling functions of the „Conceptual Nervous System" we mentioned at the beginning of this paper.

## 3.5. Some Basic ~~data on~~ principles of the Functional organisation of the Man's C N S.

Let us now stop our further analysis of 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, responsible for the control of our behavior? ~~What~~ Which structures of the human brain can play a decisive role ~~for these complex~~

~~mechanisms?~~ in establishing plans and realization of programs of our behavior? ~~which are the~~ which basic systems of the brain provide a selective attention and permanent control of the highest forms of Man's purposive behavior?

In our attempt to ~~this~~ answer this question we don't at all lose the sense of reality; we know all right - ~~we~~ all we say will be only a first approach to this problem, but nearly fourty years of our work in ~~an~~ a neuropsychological analysis of focal brain lesions gave us a series of ~~data~~ basic data we can use for our discussion, and we shall only try to bring them together rather than speculate on an ultimate theory.

To say that the Human Brain operates as a <u>whole</u> means to make at the same time a correct and an erroneous statement.

It is true because the most complex forms of human actions require ~~the acts~~ a participation of all systems of the brain; it is false because we hardly can suppose the Human Brain ~~works~~ - this highpoint of Evolution works as an undifferentiated whole and that the quality of its work depends only on the active mass of its excited tissue. Modern data of brain morphology, physiology and ~~clinical observ~~ neurology make impossible to preserve the idea of the brain as a homogenous unity, which was possible a generation ago but which is incompatable with our modern knowledge. But refusing ~~the ideas of~~ a ~~bra~~ holistic approach to the brain we don't in any sense return to the old concepts of isolated nervous centra responsible for complicated psychological processes. The ideas of Gall and Kleist are as far from our approach as the ideas of Goltz and Lashley.

Now we have all reasons to understand the Human Brain (including ~~to~~ its cortex) - as a <u>complex functional system</u> which includes a joint work of different levels and areas, each of them playing its own role. The concept of a „working constellation" of ~~A.A~~ the famous Russian physiologist A.A. Ukhtomsky or of a „functional mosaic" with a „dynamic localization of functions" or even of a „cell assembly" Hebb's, received in the latest years a much more definite meaning ~~We can~~ than it was at their origin. We can only admire the modern work on single neurons which showed a high ~~specialized kinds~~ ~~differentiation~~ specialization of these elementary ~~units~~ units of the brain situated in different parts of the brain providing reaction of very special cues or responsible for comparation of signals, and we have every right to expect that this work will soon come in a harmony with ~~our~~ ~~modern knowledge of the data~~ the facts of modern clinical neuropsychology.

Data collected during the last decades give us all grounds to single out at least <u>three basic blocks of the Human Brain</u>, each of them making its own contribution to its common work.

The first block may be called the block of Energy and Tone; it includes the formation of the upper brain stem, ~~and~~ the reticular formation and to a certain degree the oldest parts of the limbic cortex and hippocampus. This block is responsible for a stable tone of the cortex and ~~that~~ 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 Lindsley; their description of the changes of ~~the state~~ of sleep and wakefulness, ~~[illegible]~~ arousal and drive ~~can are well known are to~~ can be evaluated as the most significant contributions to our science. ~~[illegible]~~ As it was shown by a group of outstanding scholars this block includes a considerable amount of cerious neurones which react to every change of stimuli and which Jasper calls „attention units".

We had an opportunity to analyze the behavioral changes occurring in lesions ~~of deep parts~~ of the medial parts of the brain cortex and the brain stem, and we could observe in these patients marked disturbances of stable wakefulness, ~~proper selectivity~~ of memory traces and selective organization of thought processes (V) ~~we discussed elsewhere~~ (cf. A.R. Luria, E.D. Homskaya, Macdonald Critchley and S.M. Blinkov, 1967, A.R. Luria, A.Ya. Podygrnaya & A.N. Konovalov, 1969 ~~et~~); but these lesions never resulted in some basic disturbances of concepts the structure neither in ~~a loss of voluntary control of actions~~ primary loss of the simple programs controlling the conscious action. In these cases a slight reinforcement ~~re~~ which increases the lowered cortical tone - can easily result in a compensation of defects and in a restoration of deranged control of behavior (E.D. Homskaya, 1969).

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

The second block of the brain includes the posterior parts of the hemispheres with the occipital, parietal and temporal regions and their underlying structures; it can be defined as the block of the input, re-coding and storage of information received from the external and proprioceptive world. ~~That many~~ 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, and ~~only~~ the temporal lobe participates only in a limited and specific form in organization of acoustic information.

It is known as well that each system included in this block has a hierarchical structure, and that the work of every primary (or extrinsic) zone is organized by a superimposed ~~[illegible]~~ secondary (intrinsic) zone with a highly

V similar to those of the dreamy states,

developed upper levels of neurons „associative". A series of very important studies showed that only a minority of these neurones of these zones are of a non-specific type of the „attention units" while the major part have a highly specific function firing to isolated cues of different modality specific information. The specificity of these areas decreases with the transition to the „tertiary zones" of the cortex or to the „areas of overlapping" units which includes units reacting to different modalities and which provides a synthesis of serial influences to some simultaneous schemes. We had the opportunity to analyse the role of these areas in elaboration of the complex forms of spatial and conceptual structures (A.R. Luria, 1966 et al.), and we shall not dwell on the functions of these zones further.

One basic feature has to be mentioned here: patients with lesions of the posterior parts of the brain can lose several important behavioral operations, but these lesions never result in a general deterioration of their conscious activity: they retain their plans and preserve their strategy, they are fully aware of their defects and they very actively try to overcome their defects. They remain Human Beings in the full meaning of this term, and inspite of their tragical fate they never lose their conscious forms of conduct.

Thus we come to the conclusion that the second basic block of the Brain – as important as it is – is in no way responsible for the regulation and control of the man's conscious behavior.

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

The frontal lobes of the brain, occupy nearly one third of the Human hemispheres, are the last acquisition of Evolution and. There preserve a vertically organized structure typical for the motor zones (A.G.I. Polyakov, 1966) and their anterior parts bear some distinctive features of the most complicated „tertiary zones". They are intimately related to the reticular formation of the brain stem, having a dense supply of ascending and descending fibres and their medio-basal parts can be evaluated as an important cortical structure superimposed to the system of the upper brain stem (French, 1955, Nauta, 1964, 1965 et al.). They mature only during the first few years of the child. They have intimate connections with the motor cortex and the structures of the second block, but unlike it their work is no more of a modality specific type. As it was shown by a group of Russian scholars their structures become ready only during the 4th – 5th year of the childhood, and their development making a rapid leap during the period which is of a decisive significance of the formation of the first

acquisition of the first forms of the conscious control of behavior (E.P. Kononova, 1940 I.I. Glezer, 1959 et.ae.)

There are many reasons to suppose that this block of the brain plays an important role in the realization of plans and programs of human actions and in the regulation of control of human behavior.

We have discussed this in a series of publications (Cf. A.R. Luria, 1966 a & b, A.R. Luria & E.D. Homskaya, F (eds) & 1966 et.ae.) and in this discussion we have only to summarize our findings.

6. Frontal lobes and regulation of conscious actions. General data.

Neurologists know very well the general kind of behavioral disturbances following severe lesions of the frontal lobes. (Limited lesions can be poor in symptoms because of a kind of equipotentiality of the foci of the prefrontal area - this „highest and the least differentiated part of the human cortex", as Hughlings Jackson formulated it).

Patients with severe lesions of the ~~frontal lobes~~ prefrontal areas don't as a rule show stable alterations of the cortical tone, ~~motor~~ orientation in ~~space~~ the immediate environment and ~~time~~ time typical for patients with lesions of mental parts of the hemispheres. They don't suffer any defect in perception or movement, speech or even logical operations. At a first glance one can suppose that they preserve all basic functions of human brain.

But that is not the case, and an attentive ~~examination~~ observation can show how deep are the disturbances ~~they show~~ they show in regulation and control of ~~their~~ their conscious behavior. ~~of these patients~~.

As a rule - only a limited part of these patients are able to ~~cre~~ create plans or to follow programs of their behavior; neither do they preserve complicated motives ~~or higher~~ of their conduct. No strategy can be observed in their behavior and they do not try to find propper ways or means in realization of any task. Complex forms of behavior are as a rule ~~substituted~~ replaced by primitive „field-actions", impulsive responses to immediate stimuli or by inert reproduction of formerly evoked stereotypes which firstly were meaningful but became totally senseless in new conditions.

The classical descriptions of the behavioral changes of animals after destruction of their frontal lobes - from the early publications of Bianchi and Pavlov to the latest findings of Anokhin and Pribram - are many times enriched in observation with patients with massive lesions of the frontal lobes. We really cannot forget one of our patients - a woman with massive bilateral tumor of the frontal lobes who - at the ~~very beginning~~ early period of her disease ~~began to plane a plank~~ was caught while she steared the burning coals

with a broom and cooked a piece of blast instead of noodles.

We cannot forget a soldier with a massive bilateral gunshot wound of ~~the~~ the frontal lobes who ~~begu~~ started to plane a ~~plank~~ plank but could not stop his work and automatically continued it untill a half of the ~~[illegible]~~ joiner's ranch was planed.

It is easy to see that no ~~the~~ defects of movements were responsible in such ~~curious~~ funny alterations of behavior, that ~~I~~ a massive disturbances of inner plans and programs dominated in these cases and that the purposeful forms of conscious behavior were substituted here for uncontrolled answers to immediate impressions or for automatic, ~~realization of some~~ inert stereotypes.

The decisive role played by the Frontal lobes in the control of conscious behavior is out of question. But the problem remains: what are the mechanisms of such functions of the Frontal lobes.

## 7. Frontal lobes and the regulation of ~~active arousal~~ vigilance.

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

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

But a general excitation of the cortex provided by the impulses ~~coming~~ coming from the reticular formation is in no case sufficient for this purpose. The activity needed for a realization of a complex program has to be very selective; it has to be evoked by the goal or a plan; the information related to this plan has to be singled out and become dominant while ~~every~~ all outside impressions ~~distracting~~ have to be suppressed. It is obvious that such selective organization of the active states can be provided only by the close participation of the highest cortical areas and their descending fibres. ~~of the reticular formation. activating system.~~

The Frontal lobes - and especially their mesial parts - are exceptionally reach with descending fibres of the reticular formation; this was shown by a series of works of French (1957), Nauta (1964, 1969), Zager (1962) and others. That is why we can await that a strong intention of a subject can put in action the frontal parts of the brain, and that lesions of the frontal lobes accompanied by severe decrease of the active control of behavior can show a breakdown of these activating influences.

Both assumptions proved to be right.

The first one was supported by a series of brillant experiments of W. Grey Walter in England and of M. Livanov of the USSR. As it is well known in Grey Walter's studies any expectation of a signal evoked a special kind of slow potentials which appeared

in the subjects frontal lobes and afterwards spread to the posterior parts of the cortex. Grey Walter (1963, 1966) called them „expectancy waves" and could observe their intensification after the ~~ac~~ subject's activity increased and their disappearence after the instruction was removed.

At the same time M.N. Livanov in Moscow, using the technique of a 50-channel ~~amplifier~~ amplifier - made an important observation. When a subject ~~was given~~ started a difficult intellectual task (such as multiplication of two two-digit numbers) - a significant number of sinchronously excited points appeared in ~~the~~ his frontal lobes; they disappeared after the problem was solved or eliminated (Fig. 14). The same could be observed in excited paranoid patients, and the number of sinchronously excited foci in the frontal cortex disappeared after the patient was treated with a tranquillizing drug (Fig. 15).

Fig. 14.

Fig. 15

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

The facts we mentioned were obtained in normal subjects; but they make it very probable that in patients with severe lesions of the frontal lobes the regulation of ~~vigilance or arousal selec via~~ higher forms of vigilance can be markedly disturbed.

That ~~was the~~ was the problem ~~was carefully studied by~~ has carefully studied in a ~~in a series of~~ long series of experiments with patients with frontal lesions using a battery of objective methods.

Dr E.D. Konstaya of our laboratory

Let us review only ~~a few~~ some of her findings.

It is well known that an appearence of every stimulus evokes in a normal person a series of vegetative reactions (symptoms of arousal or) which really are components of an orienting reflex; constriction of the vessels of the finger and dilatation of the vessels of the head, galvanic skin reactions are among these components. These vegetative reactions remain for a period and are extinguished after the subject is habituated to the stimuli; they can be increased and prolonged if a special instruction is given, and if the subject is asked to count the stimuli, to await any change in them or ~~to~~ press a key when a stimulus appear, in other words - when a stimulus receives its „signalling meaning" (E.N. Sokolov, 1959, O.S. Vinogradova, 1959). (Fig. 16)

Fig. 16

Such ~~the~~ increase and fixation of the vegetative components of the orienting reflex is seen in normal ~~pa~~ subjects and in patients with lesions of the posterior parts of the hemispheres; but it is not observed in patients with lesion of the frontal lobes and especially of its mesial or basal parts (Fig. 17). This symptom is of a high-diagnostic significance and often remains as ~~an~~ the only symptom of a frontal lobe lesion.

Fig. 17

... instruction we mentioned doesn't evoke any stabilization of the vegetative symptoms of the orienting reflex.

Similar data were obtained in some experiments with recording of the EEG components of the orienting reflex.

It is well known that every new and unexpected stimulus results in a depression of the alpha diapason of the EEG and especially ~~in~~ of ~~the~~ its high frequencies; it is known as well that a verbal instruction giving a ~~sign~~ special meaning to the signal makes this depression more marked and more stable (Fig. 18)

Fig. 18

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 and especially of their mesial parts. A verbal instruction to count the stimuli or to await their changes does not increase the effect of de-~~pression~~ synchronization, and in some cases of even a paradoxial exa-geration of the alpha diapason ~~or~~ (a slight depression of the lower frequencies) finds place (Fig. 19)

Fig. 19.

During the last years a new EEG-symptom of activation was carefully studied and proved to be highly reliable. As it was shown by A.A. Genkin (1962, 1963) and then by E.D. Homskaya and E.Yu. Artemieva (1966), ~~1969~~ a careful analysis of the structure of the alpha waves in a normal subject shows a peculiar change in the ~~relations~~ asymmetry of the ascending and descending fronts of the alpha wave which ~~a~~ has a slow periodical character of 6-7 seconds. This regularity is observed in ~~a~~ quiet states of ~~the~~ a normal subject and ~~has~~ is broken when an activation or an intellectual arousal takes place (Fig. 20).

Fig. 20.

The same can be seen in patients with lesions of the posterior parts of the brain; but no such effect of the breakdown of the regularity of the asymmetry index is observed in patients with lesions of the frontal lobes (Fig. 21)

Fig. 21

Perhaps of the major importance are a series of data obtained in experiments with evoked potentials in normal and brain lesioned subjects conducted by E.G. Simernitskaya (1966, 1969)

It is known that each specific stimulus (visual or cutaneous) ~~evokes~~ evokes specific potential changes in occipital or sensori-motor parts of the cortex and that every expectation of such stimulus result in an exageration of these evoked potentials (Fig. 22).

Fig. 22

The same effect of a verbal instruction ~~asking a patient~~ to await a signal is seen in patients with lesions of the posterior parts of the hemisphere; but no such effect of verbal commands is seen in patients with lesions of the frontal or mesio-frontal parts of the brain (Fig. 23)

Fig. 23.

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

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

## 8. Frontal lobes and the realization of programmed actions.

Disturbances of the regulation of vigilance observed in patients with severe lesions of the frontal lobes have a far reaching influence on the structure of man's conscious actions. Being unable to sustain a permanent selective attention patients of this group ~~become unable lose the complicated~~ become unable to realize complicated programs of actions.

Let us turn to a series of experiments

Only patients with massive bilateral lesions of the frontal lobes and an expressed akinetic syndrome are unable to realize a simple instruction: „lift your hand!"; ~~the~~ difficulties to fulfill this command ~~could~~ increase when the patients hand are under the bed-sheet and he has to realize a more complex successive program of movements – firstly to set 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 do any movement at all. As a rule patients with severe lesions of the frontal lobes can easily imitate simple movements of the psychologist ~~pa~~ – lifting the fist or a finger. But the picture changes totally if we change the task to another one where the verbal command comes in a conflict with the visually presented pattern. Let us give to the patient an order: „When you see a fist – you will show me your finger!" In that case the realization of the program will be impossible, and although the patient retains the verbal instruction and repeats it – ~~take~~ but after 1-2 correct reactions ~~to~~ the directing role of the verbal command breaks down and the ~~patient's~~ needed ~~move~~ movement ~~begins to i~~ is replaced by ~~in~~ an immediate imitative reaction. The same can be observed if we ask the patient to answer every single knock with two knocks, and every two knocks with a single one. The inability to maintain the highest forms of behavior organized by a verbal code and the reduction of the action to the ~~low~~ level of an immediate imitation ~~in~~ both cases – is obvious.

The breakdown of ~~a verbally contro~~ an action controlled by a verbal program can take a different form ~~and~~ when the conscious action is replaced by an inert stereotype.

Let us 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 can often fulfill this instruction. But if we break this stereotype ~~order~~ (R-L-R-L-R-L-L) – we shall see that the patient will preserve this stereotype order and will continue the alternation he started ~~#~~ independently from the given signals, although ~~the~~ he retains the verbal instruction. In cases of ~~severe lesio~~ massive lesions of the frontal lobes this ~~inc~~ pathological inertia can be seen even in the verbal level, and if the patient is instructed to realize a simple program giving one strong knock and two

slight ones, ~~giv~~ accompanying his actions by his own verbal commands: „Strong-slight-slight!" – he often begins to change his commans adding ~~superflu~~ perseverative repetitions of one link ang saying „Strong-slight-slight... Strong-slight-slight-slight" etc. and realizing

Fig. 24 this ~~per~~ deformed program in his motor reactions (Fig. 24).

It is obvious that in these cases the ~~verbal~~ patient's own speech is unable to regulate his own behavior, and we could easily show a series of data, where the breakdown of the verbal control of # behavior in ~~severe pt~~ patients with severe lesions of the frontal lobes would repeat the ~~same~~ facts we have already seen when we discussed the early stages of the development of the highest forms of the conscious actions.

The breakdown of ~~realization~~ of conscious ~~programs~~ actions and their substitution by ~~primitive~~ inert stereotypes or primitive ~~fixed - imitative reach~~ reactions to immediate impressions can be excellently analyzed in experiments with graphic realization of ~~commar orders~~ given programs.

Every drawing of a figure is really an ~~fulfillment~~ execution of a successive algorythm; to draw a cross the subject has to draw a vertical line, and than switch his movement to a horizontal one; to fulfill a more complex program – to draw a circle and a cross – he has to realize a series of movements: to draw a circle – to move his hand to the next point of the sheet – ~~t~~ and than to start to draw the cross. It can be easily seen that the fulfilment of this program requires ~~a~~ blocking of former movements as well as ~~a~~ of all outside influences.

~~The breakdown of this complicated actions is just what we see in patients with severe lesions of the frontal lobes~~

In patients with severe lesions of the frontal lobes this complicated structure of the program can be broken, – and the breakdown can be seen in every link of the algorythm mentioned.

If the lesion is situated in deep regions of the frontal lobe – the patient can start ~~the~~ the drawing but its fulfillment is broken

Fig. 25. by ~~an~~ a motor perseveration (Fig. 25). If it is a case of severe damage of the prefrontal zone – he can be unable to fulfill the intermediate link of the program not mentioned in the instruction and execution the comand „draw a circle and a cross" –

Fig. 26 ~~draws both~~ does not ~~move~~ shift his hand and ~~draws~~ superimposes both figures at ~~the~~ (Fig. 26). ~~or~~ Sometimes the execution of the program is broken in a different link, and the patient does not shift from one

Fig. 27 unit of the program to another, sticking at the first action and ~~sugg~~ ~~cing subs~~ replacing the program of actions by an inert stereotype (Fig. 27)

Finally the realization of the program can be broken by uncontrolled influences of outside influences or extraneous associations.

Fig. 28 We are giving a nice exemple of such type of breakdown of a program in Fig. 28.

A patient with a traumatic cyst of the ~~prefro~~ frontal lobes is instructed to draw a quadrangle. He begins to do it but draws three quadrangles and then - a ~~large~~ big quadrangle following ~~the~~ the boards of the sheet. ~~The~~ When the psychologist leading the experiments whispers to his colleague: „Did you read - a pact was signet do-day", - and the patient reacts to this impression immediately, writing in the middle of the quadrangle „.. Act w..". „What is the patient's name?" asks the psychologist his assistent; and the patient writes immediately „Yermoev". „Look, that is so similar to the behavior of lobektomized animals" whispers the psychologist, - and the patien adds to the already written „Act" the words „on animae breeding..." We can hardly find an exemple which could better express the breakdown of the patients programmed action.

Another exemple is seen at the same figure. A patient with a massive tumor of the left ~~a~~ frontal lobe is asked to draw a triangle; at once he draws it and adds a second one. He is asked to draw a minus; he draws a ~~closed~~ ~~a~~ oblong, perseverating the closed form of the triangle. He is asked to draw a circle; he does it adding in the middle the same oblong and signing „Entrance strongly forbidden!." Can you guess what was the patients former occupation?..

The analysis of the basic types of the breakdown of the ~~conscious action~~ programs in patients with severe lesions of the frontal lobes opens ~~a~~ new vistas in the Neuropsychology of the conscious action, its inner structure and its cerebrae organisation

## 9. Frontal lobes and the strategy of plans.

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

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

A subject who's eyes are closed receives a pattern of checkers having the form of one of two letters - H or E. He has to touch them successively with one finger and to recognize which letter is actually given. At the first steps the search for information ~~has~~ is an extended ~~exa~~ type: the

subject touches all checkers; but very soon he develops a special strategy trying to ~~touch~~ single out only the points of decisive information ~~differing sufficient~~ for a discrimination of both letters. At the last stage - only one ~~no~~ trial is sufficent for that task (Fig. 29)

Fig. 29.

No such process of a development of a strategy is seen in patients with lesions of the frontal lobes. As a rule such patients to touch all checkers, but they don't use the information they receive, nor do they abbreviate their search. Touching of successive checkers is not used here for a preliminary orientation in the st pattern, and their „conclusion" is ~~more likely~~ a guess ~~the~~ but not as a normal process of a decision making (Fig. 30)

Fig. 30

The same kind of a breakdown of complex strategies of perceptive search can be observed in a series of the most expressive experiments dealing with active observation of thematic pictures, with a simultaneous ~~regis~~ recording of the subject eye-movements.

Let us ~~present~~ show to a normal subject a complex thematic picture - such as a well known picture of the outstanding Russian painter Repin „The Unexpected Return". Here is a prisoner who returned unexpectedly, returned home after he spent many ~~ear~~ years in a tsar's prison. Let us fasten to the subject's sclera a little mirror which reflects a beam of light to a photo-sensitive paper, recording the subject's eye movements. After a registration ~~f~~ a free observation of the picture by a normal subject 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 movements ~~of a normal subject~~ during 3 minutes ~~sch~~ show how complex are is ~~the~~ exploratory activity of a normal subject and how profoundly changes the structure of the search ~~a~~ in different instructions (Fig. 31) (Yarbuss, 1967)

Fig. 31.

No such complex structure of the search is seen in patients with severe lesions of the frontal lobes. These patients don't exhibit any strategy of their search behavior; ~~a~~ they don't make any attempts to single out the decisive information, comparing separate cues of the picture. They are fixing some points of the picture sometimes chosen by chance and their eye movement preserve a chaotic or persevera-tive type; no change of ocular movements is seen after different instructions were given (Fig. 32). It becomes evident that no active strategy of search ~~is~~ exists in these patients, and that their perceptive behavior is profoundly changed.

Fig. 32

Can we suppose that ~~the~~ the structure of the active forms of behavior

is ~~deeply~~ profoundly disturbed with lesions of the frontal lobes?
We had many occasions to prove that in a long series of experiments with different kinds of intellectual activities, and in all cases we could come to the conclusion that the frontal lobes human are intimately involved in realization of complex strategies of ~~to~~ behavior and that severe injuries result in a breakdown of the basic structures of their ~~intelle problem solving~~ intellectual activities (cf. A.R. Luria and E.D. Homskaya (eds), 1966; A.R. Luria & L.S. Tsvetkova, 1967) ~~et al.~~)

## 10. Conclusions and Perspectives.

We have finished the review of our basic data obtained during a long series of studies of the Origin and Cerebral Organization of the Man's Conscious Action, and we can turn now to some general conclusions.

We can fully agree with the assumption that the Human CNS is really a "Conceptual Nervous System" and that ~~its~~ its basic task is the elaboration of some inner codes resulting in execution of some plans and programs and in a regulation and control ~~to~~ of ~~the~~ Man's own behavior. That really makes the Human Brain an Organ of Freedom.
We know as well that the origin of this highest form of self-regulating behavior doesn't lay in the depths of the organism, and that we have to turn to the complex forms of ~~relation of~~ the child's relations to his social environment and to its acquisition of language to find its roots. We know now some ~~basic~~ features of the dramatic history of its development - and we have some basic data concerning its cerebral ~~Brain~~ organization. It is evident now what an important role play the Frontal Lobes of the Human Brain in the organisation of the conscious control of behavior and ~~how profou~~ what a breakdown of this ~~the~~ highest forms of the self-regulated activity is observed in ~~the~~ severe lesions of this wonderfue parts of the Brain.

However - after a long work - we have to admit that we are only at the very beginning of our way and that the amount of the unsolved problems is many times greater than the scope of our actual knowledge. We don't yet know the ~~intimate~~ neurophysiological mechanisms of the ~~controlling regula direction role of speech~~ highest forms of conscious regulation of behavior neither 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 we begun to acquire some data of their complex functional organization.

Thus - we are still very far from the solution of our basic problem - the Neuropsychological organization of the man's conscious Action, and at the end of our discussion we can only look forward - with envy and hope - to the work of the further generations of Psychologists who will once take place on this tribune and will ~~draw~~ lead to the end the work our generation has only started.

—

January - February
1969.