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SELF-REGULATION OF HIGHER NERVOUS ACTIVITY

by

A. A. Krauklis

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ABSTRACT: The behavior of animals and man is first and foremost an active equilibration between the individual and the changing conditions of the environment.

At the same time, physiological and psychological observations on experimental animals and human beings, as well as medical practice and daily human experience, indicate that all effector individual activity connected with behavior (including intellectual-emotional motivation, speech, respiratory and many visceral reactions) is organized by the nervous system not only with a view toward ensuring the basic, primary adaptive effect -- the individual-environmental system -- but also a secondary adaptive effect -- the balanced functioning of the nervous system itself.

Thus, carrying out any effector act, as a rule, is accompanied by the appearance of secondary neural and humoral effects which act as "feedback" to the nervous system. So, as a result of the reproduction of corresponding effector acts, the nervous system is able to carry out self-regulation of its activities.

Self-regulation of the nervous system by means of conditioned reflex reproduction of effector reactions "advantageous" for ~~these goals~~ (so-called compensatory reactions) guarantees the conservation of an optimal regimen and adequate level of integration of higher nervous system activity in animals and, in particular, in man.

The adequacy and economy of these mechanisms in most connections depends on the adaptive effectiveness of all psychic human activities. Therefore, the problem of improving and stabilizing the self-regulation of higher nervous activity is the basic physiological content of human psycho-hygiene and psychoprophylaxis.

In the present work the possible physiological mechanisms for the self-regulation of higher nervous activity are examined in animals and in man, as well as the significance of disturbances of these mechanisms in the function of internal organs.

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The self-regulation of the nervous system is still very little studied. Therefore, our attempt to characterize certain basic systems of its mechanisms of necessity involves the statement of a number of controversial and hypothetical postulates. It should be noted that our aspiration to elucidate the problem of self-regulation of higher brain function as far as possible in a broader context will, now and then, not permit us to dwell upon data of separate experiments and observations in greater detail.

There need be no doubt that as physiology, psychology and neurocybernetics concerned with self-regulation of nervous activity develop, all will obtain a greater degree of mathematical expression. However, the presently existing methods possible for quantitative analysis of the phenomena under study (for example, behavioral acts of the individual) are still too imperfect for use in attempts to express the results of observations and the postulated mechanisms for self-regulation of higher nervous activity in mathematical form.

In this connection, we have used descriptive methods for stating the experimental date and the theoretical generalizations, ~~hopting~~ hoping that the material presented here will challenge the interest of physiologist, psychologists and physicians in the problem of self-regulation of higher nervous activity as well as in the development of methods which will permit mathematical analysis of the phenomena of self-regulation which are under investigation.

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CHAPTER I

THE PROBLEM OF SELF REGULATION OF HIGHER NERVOUS ACTIVITY

THE BRAIN AS A SELF REGULATING SYSTEM

§1. Contemporary biology regards the animal and human organism as a self-regulating, self-improving and self-reproducing system, the functioning of which is aimed toward the securing of constancy of vitally important physico-chemical parameters and structural integrity of the organism by continual equilibration of all elements in the system, as well as of the system as a whole with the surrounding environment (i.e., by simultaneous stabilization of the "organism" systems and the higher order systems of "organism-environment".

I. P. Pavlov and his school have proved that equilibration of the organism in higher animals and in man in relation to the changing conditions of existence in the external world is secured mainly by the brain, with the aid of conditioned reflex mechanisms.

In physiology it has been firmly established that the brain, by neurohumoral mechanisms, also regulates the function of the internal organs, providing homeostasis in the internal milieu of the organism.

It has been shown by Soviet physiologists (Bykov, 1947; Kurtsin, 1952, 1954: Ayrapstyants, 1952, 1959: Usiyevich, 1953, 1957: Bykov, Kurtsin, 1960: and others) that neurohumoral regulation of the internal milieu is controlled by conditioned reflex mechanisms which exert both an initiating and a correcting effect on organ and tissue function.

It may be considered as proven that, with the aid of conditioned reflex mechanisms, the brain integrates all aspects of activity within the organism — the vegetative, behavioral and psychic — by providing integrity and stability for both the "organism" system and the "organ-environment" system.

The brain is capable of fulfilling the most complex integrating functions only when the level and conditions of its work are stably sustained at optimum or nearly so. In this connection the question arises: by which physiological mechanisms is the regulation of function of neural structures in the brain, including higher nervous activity, maintained?

It is known that any viological system and its components, i.e., organs, are regulated on the one hand by the influence of the external world and, on the other hand, by influences produced by the functioning of the organs themselves and by "feedback" to those organs. The second mechanism, that is, the mechanism of self-regulation by feedback, is a basic function of any self-sustaining system and its parts.

Of course, the nervous system and the brain are also regulated both by external influences and by the internal milieu (the latter is "external" in relation to the brain) and by secondary influences which originate as the result of the activity of the brain itself.

In the present work they are examined on the basis of those functions of the brain which control higher nervous activity.

Does self-regulation of higher nervous activity exist? Everyday experience, laboratory observations and scientific analysis prove that it does. Any effector activity of animals or man (psychic, behavioral and visceral) is continuously being controlled, sustained, corrected or reorganized by changes which arise from the environment and from within the organism during the effector activity itself.

It is known that the results of the functioning of any self-regulatory system through "feedback connections" control both the function of separate component systems and the program of the system as a whole. It is the same in the nervous system.

The program and the level of integration of higher nervous activity necessary for solving concrete tasks (see §7) are regulated by variations from the optimal which arise in the functional state of neural structures during the process of intense cerebral work and which mobilize compensatory mechanisms of self-regulation; these permit the establishment of an optimal program, and adequate standard of integration of higher nervous activity for a concrete situation.

It is known, for example, that the development of intellectual-emotional stress in man at a time of decision (or during preparation for decision) concerning a more or less difficult mental task is usually accompanied by compensatory increases in isometric contraction of the skeletal musculature and heightening of the inspiratory tone, by which is produced an increase in proprioceptor influx, permitting activation of tonic influences on the reticular formation in the brainstem which go to the cerebral hemispheres.

CONDITIONED REFLEX REGULATION OF THE FUNCTIONAL STATE OF THE CEREBRAL HEMISPHERES IN ANIMALS BY USING EXPERIMENTAL STIMULI

§2. In the physiology of higher nervous activity, the conditions for the formation of conditioned and unconditioned response reactions to stimuli in the environment and internal milieu which are created by the experimentor during the experiment, according to the investigative plan, have been studied in detail. This has established that conditioned and unconditioned stimuli have both an initiating and a tonic effect on brain activity, i.e. they produce a reorganization both in the immediate conditioned and unconditioned effector activity of the subject and in the functional state of the brain.

Much less studied is the role of those secondary neural and humoral influences (on brain activity) which arise during the carrying out of conditioned and unconditioned responses and during changes in the functional state of the brain, and which act by "feeding back" to the functioning of the brain itself.

In the laboratory of I.P. Pavlov and his successors, it has been shown that not only may external (in terms of the brain) stimuli assume signal importance, but so may any functional state of the neural elements in the cerebral cortex. However, this most important postulate was used in general only for explaining phenomena related to conditioned reflex readings in time, i.e., in explaining the origin of conditioned reflexes as traces of stimuli (reflexes per time, followed and delayed). It was not used for explaining the self-regulation of cerebral activity where a change in the functional state of neural structures for the worse may produce as conditioned signals the simultaneous activation of one or another component of the regulatory mechanisms which restore the optimal functioning state of the brain.

Thus, attention in the physiology of higher nervous activity has mainly been directed toward the study of the program of formation of conditioned reflexes, behavioral and visceral, that occurs in response to stimuli primarily evoked by the experimentor in the experimental situation (including the internal milieu of the experimental animal), whereas the regimen of continuous modification and reorganization of conditioned-reflex activity produced by stimuli which arise secondarily during the execution of conditioned reactions, behavioral and visceral, remains insuffiently studied.

In this connection, in surveys of the problems of self-regulation of cerebral activity, in particular the self-regulation of conditioned reflex activity, main consideration is usually given to the problem of the elaboration of a conditioned reflex setting of the functional state or functional constellation in the brain in response to the stimulus produced by the experimentor.

It should be noted that authors who study higher nervous activity frequently speak of the regulation (or setting) of a nonfunctional state of the brain and the cerebral cortex, emphasizing all the while the leading role of the cortex in executing higher nervous activity. It is known that conditioned connections are restricted to certain levels of the cerebrum. However, the school of I. P. Pavlov, as well as the newest neurophysiological data, have shown that the cerebral cortex is a higher integrator of conditioned reflexes which organizes and controls complex functional systems of conditioned reflexes at different levels in the brain.

The main experimental material which proves the existence of conditioned reflex regulation of cortical activity has been obtained by Soviet physiologists using the Pavlovian method of elaborating conditioned reflexes.

First, in the laboratories of I. P. Pavlov data were obtained which testified to the existence of neural mechanisms which regulate the functional state of the cerebral cortex by means of previously elaborated conditioned connections (Fol'berg 1912; Speranskiy, 1925; Ivanov-Smolenskiy, 1927; Rikman, 1928, Pavlov, Petrova, 1932; Kupalov, Denisov, 1933).

In recent years, conditioned reflex regulation of cortical activity in animals has been described by many authors (Shchitov, 1937, 1939; Asratyan, 1941, 1953, 1955, 1958; Abuladze, 1949; Beritov, 1947; Batsuro, 1947; 1949; Kupalov, Yaroslavtseva, 1949; V. V. Yakovleva, 1949: Alekxeyeva, 1949; Kostenetskaya, 1949, 1953; 1958, 1960; Kolesnikov, 1949; Anokhin, 1949, 1958; Laptev, 1949; 1952; Kupalov, 1952, 1954, 1957, 1960; Murav'yeva, 1953, 1954; Struchkov, 1956; Lomonos, 1953; Danilov, 1955; Chzhe Tszy-tsyao, 1958; Sakhiulina, Mukhamedova, 1958; Zubkov, 1960 and others).

The conditioned reflex regulation of the excitability of the visual analyzer in animals has been described by many authors (Bogoslovskiy, 1936; Makarov, 1940, 1956; Snyakin, 1953, Gavrilova, 1957, 1960; and others).

Depending on the purpose of the experiments, investigators stress different aspects of the conditioned reflex regulation of nervous activity. Thus is described, for example, the conditioned reflex regulation of cortical tone (Kupalov and coworkers), the conditioned reflex switching of dominent nervous activity from one functional system of conditioned reflexes to another (Asratyan et al), the conditioned reflex "preparedness" of the organism to subsequent external reflex activity (Vatsuro), the adjusting effect of external surroundings on the cortex with the aid of conditioned-reflex activation of subcortical formations (Beritov, Anokhin), the conditioned reflex origin of different biological dominants at a subcortical level (Anokhin, Kubkov), the regulation of the visual analyzer by a constructed conditioned reflex (Makarov, Gavrilova).

In the work by the above-mentioned investigators, it has been proven that stimuli produced and controlled by the experimentor, appearing as conditioned signals, are capable of establishing the tone and type of activity in the higher areas of the cerebrum which carry out conditioned reflex activity.

Such conditioned reflex regulation of the functional state of the brain, of course, is not sufficiento to secure an optimal program of higher nervous activity, because this requires that any divergence in the program of higher nervous activity away from optimal (for example, the origin of too much tension between facilitory and inhibitory systems of brain activity) may act as a signal which brings into play compensatory neural mechanisms which correct the program toward optimum. Moreover, it is necessary that all stimuli which signal the possible origin of imminent dangerous divergences from optimum conditions might, by the conditioned reflex pathway, simultaneously mobilize compensatory mechanisms capable of averting or decreasing these deviations.

Thus, the maintenance of optimal conditions and a high level of higher nervous activity is possible only in the presence of effective conditioned reflex self-regulation of the function of cerebral structures. The latter, however, remains extremely poorly studied by physiologists.

THE IDEAS OF AMERICAN PSYCHOPHYSIOLOGISTS CONCERNING THE MAINTENANCE OF NEURAL HOMEOSTASIS

§3. Experience in everyday human life, psychological and clinical observations convincingly indicate that there exists an autoregulation of higher nervous activity by means of which every intellectual-emotional, behavioral and visceral reaction of the organism, produced in the process of performing secondary neural and humoral effects, acts in turn on the cerebrum and corrects its work.

Participation of the effector (somatic and visceral) reactions in the regulation of the functional state of the brain, in particular, the level of higher nervous activity, has been extremely scantily studied by physiologists. At the same time, the observation has been repeatedly made in man by physicians and psychologists that such be avioral acts and even visceral reactions occur quite frequently; the adaptive value of these consists only in the "feedback" via peripheral effectors of excessively strong emotional stimuli, or in the "generalization" of these by increasing muscular activity and respiratory excursions as the result of supplementary afferent influences which can modify psychic activity in the brain (Rösel, 1928; Cannon, 1929, 1937, 1939; Saul, 1939, 1944; Young, 1939; Alexander, 1939, 1941, 1950; Freeman, 1948 a, b; Lang, 1950; Smirnov, 1960; Myasishchev, 1960).

In the works of Soviet and foreign physiologists who are studying the higher nervous activity of animals and man, one repeatedly encounters factual material which supports the existence of conditioned-reflex mediated self-regulation of nervous activity. However, this material usually is not utilized for the study of self-regulation and the question of self-regulation of nervous activity is not even raised.

Many foreign physician-psychologists, as well as physiologists, particularly the Americans, in trying to relate empirical observations on human behavior with the anatomical and functional structure of the nervous system, put forward the interpretation that neural equilibrium or homeostasis (Cannon, 1937) is maintained by increases or decreases in the amount of nervous energy which goes out from the brain to peripheral effectors or arrives at the brain from neural receptors. These hypotheses are summarized in the work of the American psychophysiologist, Freeman/ Freeman, 1949a, b/.

According to Freeman, the most important means of ensuring neural homeostasis in man is, on the one hand, by a rapid and effective discharge of excess nervous energy through effector channels, i.e., verbal (speech), ideomotor, motor and visceral reactions of the individual, and, on the other hand, by the supplementary generation of nervous energy and heightening of stimulation to nerve centers with the aid of local or generalized tension in the skeletal musculature.

As characteristics of neurohumoral or behavioral homeostasis, Freeman recommends the following in dices:

1) the arousal index, which characterizes the amount of energy mobilized within the organism in response to different stimulus;

2) the discharge index, which characterizes the amount of energy "freely discharged" by the organism during the skeletomotor reaction;

3) the recovery quotient -- the ratio between the above-mentioned indices -- which characterizes the rate of equilibration of the changes in the function of the organism provoked by the different stimulus.

A low recovery quotient means slow equilibration and protracted internal stimulation, i.e., the presence of significant, self-sustaining tension within the individual. A high quotient means the reverse state.

Freeman's concept is interesting in that it stresses the importance of neural or neuromuscular homeostasis as a more economical state of the nervous system, the maintenance of which is the biological goal of nervous activity. Therefore, the most important criterion of the effectiveness of the latter is the speed of recovery of functional equilibrium in an organism disturbed from equilibrium by previous stimuli.

For us, Freeman's view is of greatest interest in that maintenance of neuromuscular homeostasis occurs with the aid of effector, mainly behavioral, reactions which permit a measured "discharge" or even generate a greater or lesser amount of nervous energy.

It should be noted that Freeman, like many other foreign psychologists, oversimplifies the regulation of neural homeostasis by limiting its processes to the discharge or generation of nervous energy. He ignores the capability of the human brain extremely effectively to control the intra-central coordination of neural structures and the afferent input and effector flow of neural activity within the limits of the brain, as well as the capacity of the brain to hold back and equalize the great number of nerve impulses in the intra-central restricted systems of neural connections.

In emphasizing the importance of free discharge of nervous energy, Freeman did not sufficiently evaluate the fact that the known optimal delay of neural activity within the brain is a necessary condition for the functioning of neural structures within the cerebrum, especially the condition for setting a high level of afferent and efferent integration of higher nervous activity (see Ch. 2, §§2,7).

By emphasizing the role of contraction and tension in the skeletal musculature in the regulation of the functional state of the nervous system, Freeman underestimated the role of skeletal muscle relaxation. He likewise ignored the participation of the respiratory apparatus, i.e. the respiratory rhythm, in the regulation of neural activity.

The understanding of the dynamics of nervous activity presented by Freeman is extremely schematic and, in many connections, does not answer present day concepts. According to Freeman, the stimuli which act on the nervous system evoke in it a certain amount of nervous energy which is distributed to the cerebral cortex where it is refined and then discharged through one or another effector channel. If one channel is blocked, a corresponding amount of energy is discharged through other channels, etc.

It is clear that such a concept is not only extremely simple but also misinterprets the factual dynamics of nervous activity (See Ch.2, §1).

According to Freeman, it is accepted that, with urgent discharge of excessively strong nervous energy produced by a biologically strong stimulus, there occurs a "drainage" of the "superfluous" nervous energy from the nervous system. However, this postulate does not correspond to neurophysiological data, which show that the energy freed in neural tissues by the action of stimuli on neural receptors is used for the regeneration of some manifestations of neural activity, including the spread of impulse activity; however, the energy itself is not shifted from one area to another within the nervous system and does not leave the nervous system for peripheral effectors (see Ch. 2, §1).

Freeman quite inadequately takes into account the rules of higher nervous activity established by the I. P. Pavlov school, even ignoring the role of conditioned reflex mechanisms in the formation and reproduction of those motor and postural sonic stereotypes which are used by animals and man to ensure neuromuscular homeostasis. Thus, Freeman deprives himself of any possibility of understanding the physiological mechanisms of homeostasis.

Freeman does not emphasize the special importance which homeostasis of psychic activity acquires in man.

Like the majority of psychologists and psychophysiologists in capitalistic nations, Freeman does not squarely face the basic fact that, in man, neural homeostasis (including psychic activity) is maintained not only by biological and psychological activities but, first and foremost, by the social activities of man,i.e. with the aid of creative work activity in the same broad sense, with the aid of the most adequate reflection and creative transformation of the conditions of his existence in the environment -- nature and society.

NEUROPHYSIOLOGICAL DATA ON THE EXISTENCE OF SELF REGULATION OF CORTICAL ACTIVITY

§5. Data from contemporary neurophysiology demonstrate the existence of autoregulation of activity in the higher regions of the brain -- the cerebral cortex -- by means of double feedback connections between the cortex and subcortical formations that allow execution of corticofugal control over centripetal conduction of afferent impulses to the brain, as well as control of intracentral coordination, including control of subcortical influences on the cortex (Magoun, 1950, 1958; Jasper, Ajmone-Marsan, Stall, 1952; Bremer, Terzuolo, 1952, 1953, 1954; Hugelin, Bonvallet, Dell, 1953; and many others).

The influence of the attention process and the psychic (emotional) set of the animal over conduction of afferent impulses along the brain stem has been demonstrated. Hernandez-Peon and others /1956/, for example, observed that electric potentials evoked in the coclear nucleus of the conscious cat by repeated sound stimuli became weaker if the animal's attention was caught by showing it mice or blowing the odor of fish into the chamber. These same investigators (Hernandez-Peon et al., 1956, 1957/ observed depression of visual potentials registered along the visual pathway when the cat paid attention to auditory or olfactory stimuli. Similar results, in essence, were obtained in observations on people/Dawson, 1958; Heck, Zetterström, 1958; Garcia-Austt, Bogacz, Vanzulli, 1959; Larsson, 1959; Samson, Samson-Dolius, Rinshon, 1959; and others).

All these data are concerned with the presence of conditioned reflex control of afferent flow.

As a result of work done by many authors (Bremer, 1937, 1949, 1953; Rheinberger,Jasper, 1937; Rhines, Magoun, 1946; Moruzzi, Magoun, 1949; and many others) the extreme importance of the ascending systems of the reticular formation in the brainstem and midbrain for regulation of the level of activity and work-capacity has become clarified, as has its importance in the reorganization of spatial types of activation and inhibition (Jasper, 1962) of the cerebral cortex.

The importance of the paleocortex, the so-called limbicsystem, in the generation of emotional tone and the reactions of emotional arousal has been well established (see Ch. 7, §4).

It has been made clear that the cerebral cortex, the reticular formation, the thalamus, hypothalamus, limbic system and other parts of the brain are all functionally connected by cyclical bonds. As a result, the brain structures which implement higher nervous activity, function as an integral closed system.

It must be admitted that the mechanism for self-regulation of cortical activity by double feedback and the cyclic neural connections: cortex-subcortical formation-cortex is an essential, constituent part of the self-regulation of higher nervous activity.

According to the viewpoint of Kupalov (1960) and Kostenetska (1960) two mechanisms may be put forward for the conditioned signal: one toning up mechanism, which regulates the level of the stimulatory and inhibitory processes, the other, which formulates and puts into action one or another response reaction. The toning mechanism may arise primarily in the lower regions of the brain via the reticular formation and secondarily also via the cortex, i.e., via the influence of the cortex on the reticular formation. The activating effect of the reticular formation on the cortex may be both diffuse and localized; this is supported by the physiological facts of higher nervous activity and by data first presented by Morutstsa.

There is a basis for suggesting that all forms of conditioned reflex setting of cortical tone or the type of cortical activity described by Soviet authors and presented above (see §2) are implemented by the participation of corticofugal control over the afferent flow and subcortical-cortical influences, i.e., by the participation of cortical self-regulatory mechanisms.

As a conditioned signal which produces activation of certain corticofugal influences, i.e., activation of the corresponding cortico-subcortical and subcortical-cortical neural connections, serves the stimulus applied by the experimentor, including the experimental conditions. The unconditioned stimulus used in the experiment acts as an intensifier, i.e., the change in the function of the brain structures evoked by these stimuli.

It follows from this, that a conditioned reflex setting of some functional state of the brain, despite the mechanisms of cortical self-regulatory activity participating in it, still does not appear as self-regulation of higher nervous activity (see §1 and 2).

Although rich experimental material concerning the functional structure of the brain, gathered by physiologists and morphologists over the last 50-60 years, confirms and physiologically explains the life experience of man (including clinical observations by psychologists and physicians), concerning the existence of self-regulation of human psychic activity or the question of self-regulation of higher nervous activity in animals and man, physiologists have still not begun to move.

An attempt to characterize some aspects of this problem was made in our previous publications (Krauklis, 1957, 1958, 1959z,b, 1960 a, b, 1962, 1963), in particular, in the monograph "Conditioned reflex regulation of nervous activity" (Riga, 1960). On the basis of our own observations, and the data from sources in the literature (mainly the work of Kupalov), we brought forth in 1959-60 the concept of conditioned reflex self-regulation of nervous activity.

OUR CONCEPT OF SELF-REGULATION OF HIGHER NERVOUS ACTIVITY

PRIMARY AND SECONDARY ADAPTIVE SIGNIFICANCE OF EFFECTOR REACTIONS

§6. According to our data, there may be evoked by a conditioned reflex pathway through the neural structures of the brain both intracentral efferent activity and behavioral and visceral (and in man, also, intellectual-emotional and verbal) reactions, during the performance of which neural and humoral effects arise secondarily and modify or reorganize the afferent flow and the effector flow with the goal of sustaining an adequate level of higher nervous activity in a concrete situation and for an optimal program of higher nervous activity (Krauklis, 1960a, 1962, 1964).

For the conditioned signal which mobilizes the above-mentioned reactions (which correct brain activity), all stimuli to the nervous system which signal what is occurring at a given moment (actual) or is expected in the immediate future (probable) serve to change the program of higher nervous activity away from the optimum.

Restoration of an optimal program of higher nervous activity or the approach of the program to normal serves as the reinforcement for attaining the desired corrective effect.

The above-mentioned efferent, i.e., effector reactions, if evoked for the purpose of carrying out secondary, biologically useful effects, act as compensatory reactions which render the functioning of the brain optimal.

It is clear that secondary effects capable of mobilizing brain function arise not only with efferent reactions specially evoked for such goals, but also with any other effector reaction evoked, for example, to influence the environment. It must be stressed that any somatic or visceral reaction simultaneously sets into action several adaptive effects which can be divided into two groups according to their biological importance and the conditions of their origin.

1. The primary adaptive effect is the direct equilibration of the organism with the actual or probable changes in the conditions of existence in the environment (for example, setting analyzers on the stimulus side, the acquiring of food, the avoidance of noxious stimuli, the increase in pulmonary ventilation, etc.).

2. The secondary adaptive effect is the adaptation of the functional state of neural structures in the brain to the demands

of the ongoing or expected situation, i.e., ensuring an adequate primary adaptive effect with simultaneous maintenance of an optimum program of cerebral work, first of all, of higher nervous activity.

The secondary adaptive effect arises as a result of:

1) changes in the correlation between delayed, i.e. nervous activity circuiting within the brain, and activity which moves out from the brain to peripheral effectors;

2) changes in neural activity entering the brain.

A relative increase in the number of impulses exiting from the brain leads to a decrease in the number of impulses which circuit within the brain as well as a decrease in the tension between facilitory functional systems and equilibratory or inhibitory systems of brain activity. An increase in the number of circulating impulses (as a result of inhibition of the switching of impulses to effector pathways) leads to an increase in the tension of higher nervous activity (see Ch. 2, §4).

Changes in the flow of afferent impulses to the brain and in biologically active substances in the blood (by increase or decrease in somatic or visceral reactions) alter intracentral coordination, having phasic and tonic effects on higher brain areas (see Ch. 3) and acting as conditioned stimuli which signal the beginning of subsequent links in the evoked stereotypes and consequent functional changes in the brain (see Ch. 4).

Conditioned and unconditioned effector reactions in the organism, which carry out various primary adaptive effects, i.e., which directly adapt the organism to the changing conditions of the environment are primarily adequate.

Conditioned reactions evoked only to sustain the optimal program of higher nervous activity, which have no primary adaptive importance, may appear secondarily adequate, but only if they favor the establishment of an optimal functional state of the neural structures needed to carry out the effector reactions which possess primary adaptive value, and if they be themselves as accessory effects do not alter the implementation of the latter.

In cases in which conditioned reactions evoked to ensure a secondary effect not only do not have any primary adaptive value but even alter the implementation of the latter by means of other effector reactions, they will become inadequate (see Ch. 7,§1).

The adaptive efficacy of higher nervous activity is greater, the more the reactions evoked to ensure the primary adaptive effect simultaneously carry out a desired secondary effect.

Conditioned reactions evoked for regulation of the functional state of the nervous system (called, for the sake of brevity, "reactions of secondary significance") are constituent parts of conditioned reflex self-regulation of higher nervous activity.

Depending on whether or not reactions of secondary significance favor the reorganization of the chiefly efferent flow, or even the afferent flow of nervous activity, one may distinguish two main groups of mechanisms, or two types of self-regulation of higher nervous activity.

FIRST TYPE. Self-regulation of higher nervous activity by means of setting a program of effector flow — i.e., that brain activity which exits to the effectors.

As an example, we may take the decrease in tension of higher nervous activity evoked by strong intellectual-emotional experience, such as the result of frank conversation with friends and the adequate behavioral reaction.

SECOND TYPE. Self-regulation of higher nervous activity by means of setting a program of afferent flow, i.e., nervous activity entering the brain.

An example of this might be the elevation of cortical tone and, in relation to this, the work-capacity of a man for mental work by increasing the interoceptor flow, in particular proprioceptive flow to the brain as a result of performing effective physical exercises.

The second type of self-regulation includes two variants: a) conditioned reflex generation (by means of effector reactions) primarily of unconditioned stimuli and b) conditioned reflex generation mainly of conditioned stimuli. Since the second variant has exceptionally greater significance in the self-regulation of higher nervous activity in man, it is expedient to separate it into another (third) type of self-regulation.

THIRD TYPE. Self-regulation of higher nervous activity by means of setting a program of conditioned signals which act on the nervous system.

For example, there is the increase in cortical tone and, connected with this, an increase in industry and work capacity as the result of the creation of a friendly atmosphere at work and at home and the removal of misunderstandings and other sources of ill humor, etc.

In such an instance, setting up a program for the flow of impulses, mainly unconditioned in origin, belongs to the second type of self-regulation.

All three types of self-regulation of higher nervous activity are reciprocally conditioned; one begets another, strengthens it or weakens the secondary adaptive effect (see Ch. 5).

In the case of optimal interaction, they ensure a more or less stable maintenance of the optimal regimen and a level of higher nervous activity adequate for the concrete situation.

REGIMEN, LEVEL AND ADAPTIVE EFFICACY OF HIGHER NERVOUS ACTIVITY

§7. By regimen of higher nervous activity we understand a means of functional combination and unification of neural structures, receptors and effectors which participate implementation of higher nervous activity. In other words, the regimen is the program of spatial and temporal organization of the arrival, processing and exit of information (coded as impulses of neural activity adequate for a given situation (and thus an adequate primary adaptive effect) upon the expenditure of a minimal amount of neural energy and minimal loss of functional capabilities at higher levels in the brain (in particular, the cerebral cortex).

By the level of higher nervous activity we mean the level of integration of information arriving at the brain and exiting from the brain, i.e., the level of afferent and efferent integration. In other words, the level of higher nervous activity is the degree to which the brain adequately reflects the changing conditions in the environment, including the effector activity directed toward the most effective equilibration between organism and environment.

The more differentiated and complete the analysis and synthesis of incoming information, the more completely and effectively the cumulative experience of the individual is used in processing the information, while the more precise the information put out, the higher the level of activity in the brain, i.e., the effector activity of the individual corresponds to the actual situation and its probable changes in the immediate future.

Thus, a case in which a person, encountering difficulty and even temporary failure in serious creative work, mobilizes his volitional and intellectual resources, learns, works and overcomes difficulties, is an example of human mobilization of a high level of higher nervous activity.

If the same man in a similar situation is intimidated by his initial failure, does not want to learn, struggle, or find a creative solution and drops the work begun, seeking something easier -- this is an example of a low level of higher nervous activity.

When the experimental dog in the experimental situation precisely distinguishes the biological meaning of stimuli applied: he responds to the electric stimulus (or to the conditioned signal which s nifies the former) with his paw and a local, specialized motor reaction -- by flexing the corresponding extremity -- and does not respond to the differentiated signals and conditioned stimuli, this indicates the presence of a relatively high level of integration of neural stimuli.

If another dog, in a similar experimental situation, instead of responding with a stable and differentiated behavior to conditioned stimuli and the signals used by the experimentor responds with a wild, generalized defense reaction or even inert freezing into a position of passive waiting with lowered head, shivering, sharp increase in respiratory rate, yelping, etc., in the absence of a low level of higher nervous activity.

It follows from this that "in general" there is no optimal program of higher nervous activity, only an optimal regimen for carrying out some level of integration of higher nervous activity.

The adaptive task of self-regulatory mechanisms of higher nervous activity consists in the capacity to establish and maintain an optimal program for possibly higher and, in this connection, more adequate levels of higher nervous activity in the actual situation.

In other words, the problem of self-regulation is to ensure adequacy and economy, i.e., a high, adaptive efficacy of higher nervous activity.

It must be stressed that the economy of neural activity is expressed not only in saving of expenditures, i.e., in the effective utilization of the energy resources of neural tissue in the active situation, but also in securing sufficient supplies of energy and the functional capabilities of the brain for the future. Therefore the degree of adequacy and economy, i.e. the degree of adaptive efficacy of neural activity is determined not only by the actual (primary and secondary) adaptive effect but also by the potential, expected (probable) future effect.

Both aspects of the adaptive efficacy of the work of the brain -- that adequate for the reaction situation (primary adaptive effect) and the economical program of cerebral work)secondary effect) are closely interconnected. On surveying the mechanisms of self-regulation of neural activity from the viewpoint of purely physiological regulation, both aspects presented above are equally important for ensuring stable functioning of the nervous system. Examining the same self-regulatory mechanisms from the biological point of view, and in man also in terms of social regulation, preference must be given to the primary adaptive effect.

Depending on the situation, self-regulation of the nervous activity of an individual may be directed in the first place to the setting of an optimal program; then a high level of integration is possible.

In the succeeding chapters will be examined such important characteristics of the regimen of neural activity as the quantitative correlation between incoming retained and outgoing impulses as well as between the dominant "competing" systems of neural connections. This, in the final account, determines the strength, mobility, equilibration and tension of neural processes. The postulate is made that the program of higher nervous activity is characterized by the intensity of expenditure of energy and the functional resources in the brain necessary for maintenance of a certain correlation between incoming and outgoing impulses, as well as a definite level of equilibrium (and "tension") between "competing" dominants.

CHAPTER 2

SELF-REGULATION OF HIGHER NERVOUS ACTIVITY BY MEANS OF SETTING A REGIMEN OF EFFECTOR FLOW

(FIRST TYPE OF SELF-REGULATION)

REGULATION OF THE INTENSITY OF EFFECTOR SWITCHING AND ITS ROLE IN SETTING AN OPTIMAL RATIO BETWEEN IMPULSES CIRCULATING WITHIN THE BRAIN AND THOSE EXITING FROM IT

§1. Afferent impulses of neural activity which are produced by stimulation of receptors and which enter the brain, modify or reorganize the existing cyclic activity of the nerve network of the brain circuits by increasing the activity of certain functioning systems of neural connections and decreasing the activity of others.

The increase in brain activity, i.e., the increase in the number of impulses which circulate along restricted systems of neurons, having reached a certain level, promotes the spread of impulses to other systems of neural connections or even to efferent neurons. By spreading along restricted systems of neural connection, i.e., by being retained within the brain, the impulses continue to circulate within brain structures, altering the functional state of these structures and functionally uniting them, until the impulse activity is exhausted. By being spread to efferent neurons and increasing their activity, the impulses permit effector impulses to arise, i.e., effector flow, and thus originate the effector response reactions of the organism to the stimulation of receptors.

At any moment in time the nervous system must maintain a ratio, optimal for the actual situation (including the actual functional resources of the brain), between the number of impulses entering the brain, the number of impulses retained within the brain and the number of impulses which leave the brain for peripheral effectors, by ensuring that the distribution of impulses which circulate along different restricted systems and which exit to effector pathways is adequate for the situation.

Depending on how precisely and stably the above-mentioned optimal ratio is maintained by the nervous system (i.e., the regimen of brain function), the adaptive efficacy of cerebral work varies from higher to lower.

It should be noted that if we are concerned with the incoming and outgoing impulses of neural activity, their circulation and spread through the nervous system, etc., then we imply by this the spatial and temporal dynamics of rhythmic impulse activity in neural tissues. A wave of activity, starting as the result of freeing a sufficient amount of energy from some portion of neural tissue, provokes the origin of corresponding physicochemical alterations and the liberation of energy as well from nearby portions of the nervous tissue, by maintaining the same distribution of the wave of activity.

The distribution of waves of neural activity in the brain and in the nervous system as a whole occurs in relatively restricted functional systems and neural circuits which connect all brain structures by cyclic and feedback connections as well as connections between the brain and the periphery, and which have numerous open channels for the input and outflow to and from the systems and circuits of neural activity.

As mentioned earlier (see Chapter 1, §6), the program of incoming, circulating and outgoing impulses and its conditioned reflex regulation determines, in many respects, the efficacy, i.e., the adequacy and economy, of higher nervous activity.

In this work, we are interested not in the neural mechanisms which directly provide the primary adaptive effect of higher nervous activity but in the neural mechanisms which first provide the secondary effect, i.e., the maintenance of an optimal regimen and a high level of integration of higher nervous activity. In this chapter, we will examine the question of regulation within the nervous system of the program for switching nervous activity from the brain to effectors.

The ratio between delayed, i.e., that circuiting within the brain, activity and the activity which emerges from the brain determines the functional state and work regimen of the brain in two ways.

Firstly, by this ratio we determine the number of impulses circuiting within restricted systems and the rate of function and interaction of these, which are competing among themselves, i.e., those impulses which inhibit one another and which mutually equilibrate, the restricted systems of neural connections in the brain (i.e., the intensity of stress on brain activity, and, in particular, on higher nervous activity).

Secondly, by the same ratio is determined the number of impulses exiting to effectors and, in connection with this, the intensity of effector reactions in the organism.

If the ratio mentioned earlier deviates from optimum toward a redominance of outgoing impulses, then, firstly, the tension of higher nervous activity (i.e., activity of competing and mutually equilibrating functional systems of cond tioned connections) is decreased and, secondly, the activity of somatic and visceral effectors is increased, and while consequently so is the flow of afferent impulses and humoral agents to the brain which arises during the maintenance of effector reactions and which secondarily alters the functional state of the brain (see Chapter 3).

If the ratio between the activity retained in the brain and that emerging therefrom deviates towards a prevalence of impulses being retained in the brain, the tension of higher nervous activity is increased and the activity of the effectors is relatively decreased.

§2. Cyclic neural activity, i.e., circulation of impulses along restricted, self stimulating systems within the brain, create the conditions for the carrying out of all basic cerebral functions. It functionally unites neural structures of different functional specificity at all levels in the brain: it conditions sequential phenomena and unites traces from preceding stimuli with changes in activity which arise during present stimulation. In other words, cyclic activity unifies the functions of the brain in space and in time by providing timed sampling and the formation of shortlived or operative memory (Forbes, 1922; Ranson, 1930; Lorente de No, 1933, 1934, 1935, 1938, 1943, 1947; Gasser, 1937; Rashevsky, 1938; Jung, 1938; Hillgard, Marquis, 1940; Kennard et al., 1941; Dempsey, Morrison, 1943; Kupalov, 1947, 1949; Beritov, 1948, 1953, 1961; Konorski, 1948; 1959; Hebb, 1949; Mak Kallok, Kossa, 1958; Gerard, 1949; Burns, 1950, 1951, 1953; Fessar, 1954; Braz'ya, 1955; Smirnov, 1956; Viner, 1958).

Cyclic activity, i.e., impulses which circulate along the neural networks and circuits and which evoke repeated activity in the same neural elements and connections, favors the occurrence of permanent physicochemical and microstructural changes in neural elements and, thus, the formation of long term or ermanent memory (Viner, 1958; Konorski, 1959).

The nerve elements of the neocortex are functionally united by cyclic and double feedback connections which perform highly differentiated analysis and synthesis of the sensory input from subcortical structures that summate and accumulate neural activity evoked by the sensory input and by biologically active substances, and that have energy-supplying and tonic effects on the neocortex and on the structures of the archeocortex which generates the reactions of emotional awakening and emotional tone.

Thus, intracentral neural activity circulating, i.e., being retained, in the brain is the functional basis for maintenance of continuity in the psychic activity of animals and man.

In the case of excessive intensification and stressing of intracentral activity, for example, during strongly expressed reactions of emotional awakening, regulatory mechanisms (i.e., mechanisms for self-regulation of nervous activity) are mobilized which reorganize the program of the distribution of brain activity between closed intracentral systems and the effector pathways. As the result of strengthening the switching over of impulses to efferent neurons and effector organs adequate for the actual situation, emotional awakening takes on the potential for the "discharge" in external manifestations, i.e., in effector reactions (speech, mimicry, motor, locomotor, respiratory, cardiocirculatory, etc.).

Consequently, the tension of intracentral activity is lessened.

In the case of an excessive decrease in the intensity of intracentral activity, regulatory mechanisms are mobilized which switch impulses to effector, or, more precisely, which permit the switching of impulses only to those efferent neurons which organize effector reactions capable of secondarily generating a large number of afferent impulses and which activate the brain via humoral agents (for example, the postural tonic contraction and tension of skeletal musculature, the increase in secretion of thyroxin and adrenergic substances, and so forth).

It is evident from the above that not only is the maintenance of an optimal quantitative ratio between circulating and outgoing impulses important, but so also is the distribution of the latter by different effector channels, i.e., the actual qualitative effector integration of impulses. Switching of the same number of impulses from the closed systems of the brain to peripheral effectors may have extremely different consequences for the functional state of the brain, depending on which effector pathway the impulses go to, i.e., depending on what – in qualitative and quantitative terms – will be the secondary input of afferent impulses and humoral agents (via the blood) evoked by the effector reactions (see Chapters 3, 4 and 5).

It follows that the brain must possess finely differentiated and mobile regulatory mechanisms, in order not only to establish in any situation the optimal quantitative ratio between the activity retained in the brain and that emerging from it, but also to ensure a distribution of outgoing activity to effectors which promotes an optimal regimen.

It is clear that this is possible only in the case where regulatory mechanisms function on the basis of previously selected and elaborated stereotypes of conditioned connections.

The task of the present chapter is to characterize certain aspects of conditioned reflex regulation of the switching of brain activity to effectors, or, more briefly, of effector switching.

A METHOD FOR STUDYING EFFECTOR INTEGRATION OF OUTGOING IMPULSES

§3. In order to characterize the dynamics of incoming, retained, and outgoing impulses quantitatively and precisely, it is necessary to have instruments which permit the quantitative measurement of the total afferent inflow and effector outflow. Present day apparatus for recording bioelectric potentials, which reflect impulse activity in nerve fibers, i.e. cells, cannot perform such measurements in the intact experimental animal under chronic experimental conditions. Ordinary electroencephalography is not suited in principle to this goal.

Therefore, it was decided to relinquish the attempt to use a method of recording bioelectric potentials of nerve activity in our observations (which were directed toward studying the conditioned reflex regulation of afferent influx and efferent outflow).

We considered it advisable to limit ourselves to an objective recording of effector reactions and careful visual observation of the behavior of the experimental animal or subject.

For this we considered: 1) The original level of effector activity; 2) the adaptive characteristics of the situational stimuli as well as the short term conditioned and unconditioned stimuli; 3) the dynamics of the response reaction of the organism to these stimuli both during the application of the stimulus and during the intervals between; 4) the reactions of after effect and the process of returning the effector activity of the organism to its original level; 5) the conditioned origin, dynamics, and functional structure of the effector reactions of secondary significance (see Chapter 1).

In studying the questions we have proposed, we have relied on the Pavlovian method of forming conditioned reflexes in experimental animals (dogs and white rats) and in humans, which has permitted us to ascertain the main regularities of higher nervous activity, including the self-regulation of the latter by means of effector reactions, using as an "indicator" the dynamics of effector activity in the individual.

By comparing information introduced into the brain of the experimental animal or man during an observation session with the information emerging from the brain, we could establish certain main schemata (of course, not of a material nature) concerning the functioning of neural mechanisms which maintain an optimal program of the transformation of information into the brain.

The task of a physiologist in such a situation of observation consists in organizing the introduction of the information corresponding to the aims of the investigation into the brain of the experimental subject and in recording insofar as possible all information issuing from the brain (i.e., all effector reactions of the organism which arise as the result of the transferral of incoming information into the brain.

Unfortunately, simultaneous objective recording of many components of the response reaction of the organism is technically extremely difficult. Thus, it is practically impossible, using the existing methods for the physiological study of higher nervous activity, to determine, without crudely breaking the elementary rules of observation, the dynamics of multiple humoral changes in the experimental subject as well as many visceral, motor and sensory reactions.

In this connection, we have limited ourselves to an objective record only of certain main somatic and visceral components of the effector activity being studied in animals or man.

Considering our previous experience in studying conditioned reflex effector integration (efferent synthesis) of neural activity (Krauklis, 1960, pp. 140-152) we used an optical polygraph on a photokymogram to record, simultaneously, the following groups of components of the effector activity:

1) Specialized components — the elaborated, local, motor reflex (for example, the flexing of an extremity in the dog after elaboration of the corresponding defensive motor reflex);

2) motor components of the orienting and general readiness reaction of the organism, i.e., the alarm reaction (for example, turning, lowering or lifting the head, postural tonic contraction and tension of skeletal muscles and changing of position);

3) motor components of the general defense reaction in the experimental animal or its equivalent (for example, motor reactions of all four limbs in a dog held in an experimental support, motion of the lower jaw in the dog with barking, biting a strap, etc.);

4) local motor reactions which appear as so-called "self-reactions" and also inadequate motor reactions which have no primary adaptive value for the experimental situation (e.g., blinking and swallowing movements, licking movements in dog, etc.);

5) the main visceral components of the general readiness or even general defense reaction or equivalent consequences (e.g., respiratory excursions of the chest and abdomen, pulse, regional vascular reactions, systemic arterial pressure, gastric motility, secretion of saliva).

In white rates, mainly visceral observations were performed. In the human subjects, the verbal response of the subject about how he was feeling and the subjective evaluation of stimuli presented in the session were considered.

The portions of photokymograms presented in this work were recorded in observations on experimental animal and human subjects by coworkers in our laboratory, Yu. Briyedis, L. Rotsen, I. Rotsen-Krauklis, D. Liyepa and others.

PARTICIPATION OF CONDITIONED REFLEX MECHANISMS IN MAINTENANCE OF OPTIMAL REGIMEN OF EFFECTOR SWITCHING. PROPHYLACTIC AND COMPENSATORY SWITCHING OF ACTIVITY IN THE BRAIN TO PERIPHERAL EFFECTORS.

§4. Any deviation of the regimen of higher nervous activity from optimal involves the mobilization of self-regulatory mechanisms directed toward restoration of the optimal regimen.

One of the basic mechanisms of self-regulation of higher nervous activity is that of the maintenance of a ratio, optimal for a given situation, between the number of retained impulses, i.e., those circulating within the brain, and the number of impulses of nerve activity emerging from the brain.

The leading factor in maintaining this ratio is the conditioned reflex facilitation or inhibition of the switching of brain activity to peripheral effectors.

The number of impulses switched over to the periphery is regulated by conditioned reflexes.

Also, the distribution of impulses emerging from the brain by different effector pathways is regulated by conditioned reflexes, i.e., the effector integration of impulses or, in other words, it is the qualitative characteristic of effector switching.

Let us first examine the quantitative side of effector switching.

In cases in which the brain and, in particular, the neural structures which carry out higher nervous activity, are capable of retaining and equilibrating practically any number of impulses which evoke afferent flow, such a regimen of efferent switching may be established in principle, when only a known number of impulses necessary to maintain sensory, behavioral and visceral activity of the organism adequate for the situation may be switched to peripheral effectors.

If as a result of a decrease in the supply of energy and functional potential of the brain, in particular of the cerebral cortex, the maintenance and equilibration of a large number of impulses in the brain is rendered impossible or difficult, a regimen of effector switching becomes established such that more impulses than necessary to ensure the flow of effector activity are switched to peripheral effectors.

The additional effector switching is exceedingly rarely the result of a complete inability of the brain of animals or man to sustain and equalize impulses which are arriving at the brain or are being generated therein. More frequently, the additional effector switching is mobilized by conditioned reflex pathways in response to primary, more or less serious disturbances in the equilibrium of brain function.

In essence, additional effector switching is mobilized in order not to allow excessively sharp deviations from optimum to arise in the work of the brain. It acts as a prophylactic measure which ensures that sufficient supplies of neural energy and functional potential are preserved in the brain.

The prophylactic nature of supplementary effector switching is shown by the circumstance that in the majority of instance man is capable by voluntary effort either to prevent or to decrease supplementary effector switching arising as the result of overexertion and fatigue of the nervous system.

In cases where, as a result of sudden and very strong stimulation to the human brain there arises such a powerful type of activity which cannot be momentarily equilibrated within the closed systems of the brain and therefore begins rapidly to be switched over to effector pathways, there are mobilized by conditioned reflexes, within the first seconds after the beginning of the stimulation, dominant systems of activity of a high order which have an inhibitory and controlling effect on the efferent nerve pathways and which limit effector switching.

If such conditioned reflex inhibitory effects are organized even before the advent of sudden and strong stimuli, as occurs, for example, in the opportune preparation of a person for powerful, anticipated stimuli, then frequently the supplementary effector switching of extremely strong cerebral activity produced by the stimuli may be limited at the very start and be brought to a minimum.

Thus, for example, a sudden painful or sharp sound stimulus, markedly disturbing and stimulating a person, is a new event and may produce a more or less involuntary, stormy motor reaction: flinching, jumping up, shrieking, sharp gesticulation or mimicking reaction, etc.

Warning the same man about the forthcoming differential stimulus often prevents or markedly diminishes the stormy supplementary effector switching as the response to the stimulus. At the same time, as a result of the preliminary preparation of the human nervous system for the anticipated stimulus, there sometimes occurs, via the conditioned reflexes, an insufficiently strong fright reaction and emotional awakening which is accompanied by a sharp increase in the activity of the corresponding cerebral structures. As a result, the supplementary, i.e., prophylactic, switching of inadequately strong cerebral activity to peripheral effectors may still approach the expected differential stimulus.

The intensity of the prophylactic effector switching (inadequately strong) of brain activity evoked by conditioned signals, by which the nervous system prepares for a forthcoming differential stimulus, may be regulated at will by man to a significantly greater degree than the intensity of effector switching of activity evoked by unexpected differential stimuli.

The intensity of compensatory effector switching of nervous activity is also regulated arbitrarily, i.e., by conditioned reflex, in the after effect period, i.e., in the subsequent seconds after stopping the conditioned or unconditioned stimulus, and also other manifestations of compensatory effector switching (see §5).

As a graphic illustration of the above, we will use sections of kymograph tracings made in laboratory studies of the regimen of effector switching in human subjects (children from 8 to 14 and adults from 18 to 35 years old).

During the observation session, verbal and physical stimuli are used on the subjects: the sound of a loud bell or pistol shot, electric and cold stimulation. In some cases the subject was told at the beginning of the session that during the session unpleasant, but absolutely harmless, stimuli would be applied and the reactivity of the nervous system and function of the cardiovascular system and other organs would be investigated. In other instances, the subject was forewarned immediately before application of the stimulus, and sometimes the stimulus was given without warning (Fig. 1-4).

The observations show that conditioned reflex regulation of

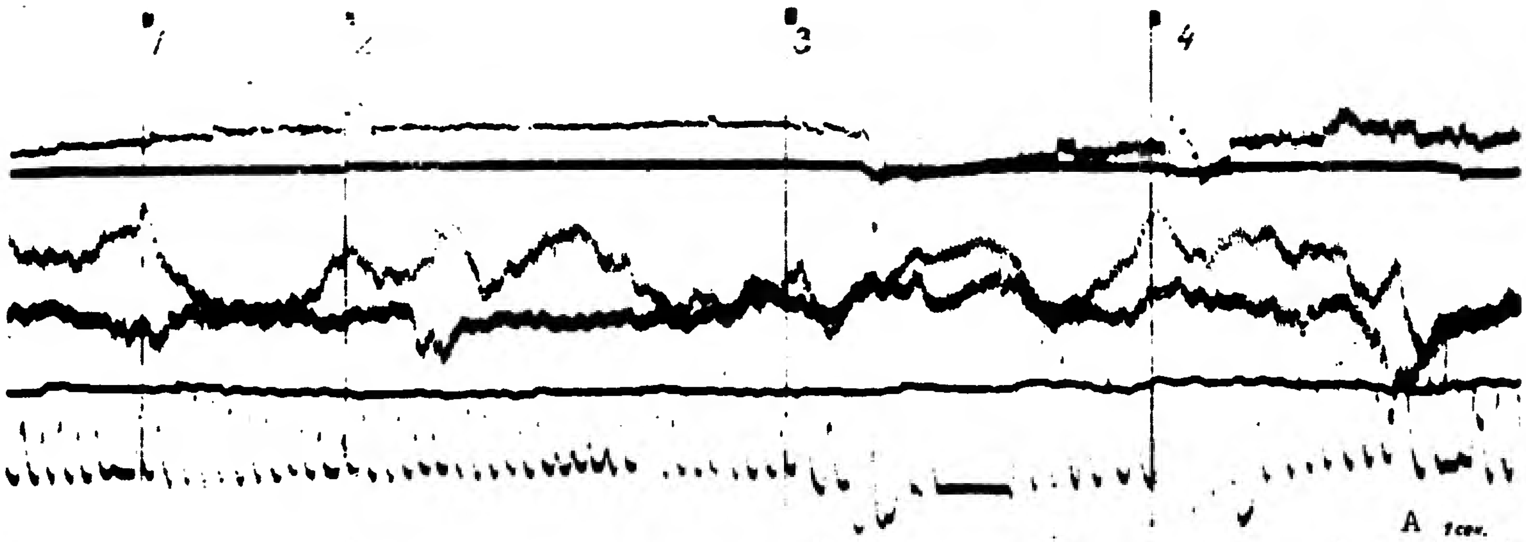

Fig. 1. Changes in the reaction of the subject to the sound of a pistol shot in relation to the nature of the preliminary level of nervous activity (subject N.N., strong and equilibrated type of nervous system). 1) Verbal instruction: "Repress any motor or respiratory reactions in response to the following shot;" 2) shot; 3) instruction: "The next shot will follow without warning;" 4) shot. From top to bottom: Blinking, movement of lower jaw, plethysmogram of thumb and sphygmogram of radial artery in left arm; muscle contraction of knee flexors; pneumogram; time marker (in subsequent figures these designations will not be indicated). A) 1 sec.

of the quantitative aspect of effector switching takes place with the formation, activation and inhibition of dominant functional systems of a high order, which have mainly inhibitory and control-

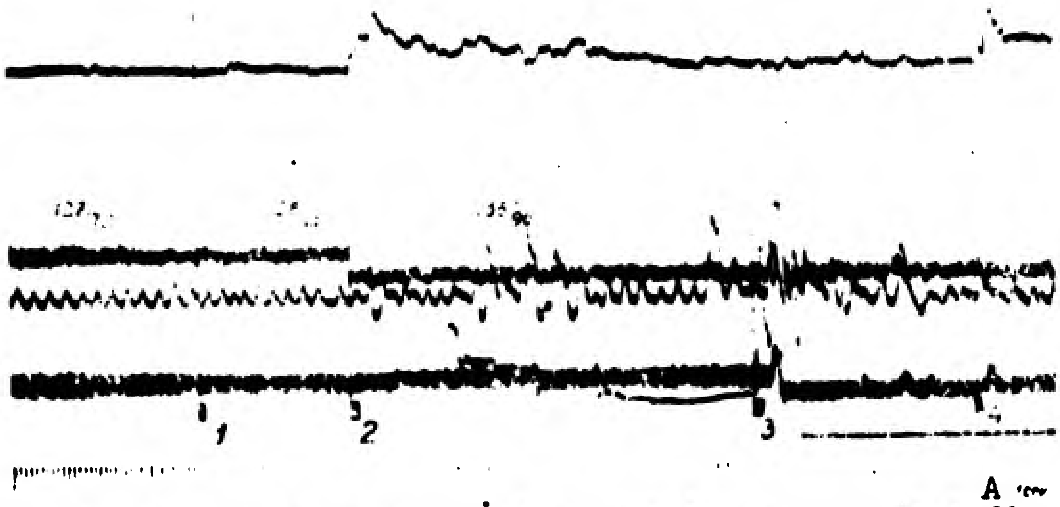

Fig. 2. Changes in the general preparedness reaction depending on the nature of preliminary setting of nervous activity in subject Zh. B. before a pistol shot. 1) Verbal instruction, "Attention, a loud sound stimulus will be given (subject did not know that a pistol shot would follow); 2) shot; 3) instruction: "Attention, a shot will follow!". Top to bottom: Blinking, sphygmogram of radial artery (numbers signify Korotkov pressure); pneumogram; contraction of extensor and flexor muscles of the knee. A) 1 sec.

ling influences on neural structures that mediate switching of brain activity over to effector neurons. Conditioned reflex lessening of this inhibitory effect involves the intensification of effector switching and vice versa.

The arbitrary slackening of the intensity of prophylactic effector switching by activation and maintenance of effective inhibitory influences of a high order through a second signal system has its limits — sometimes broader, sometimes extremely narrow — depending on the energy and functional reserves of the brain. If the limits are ignored and one tries at will to give rise to all the forms of prophylactic switching activity over to somatic effectors when higher nervous activity is already nearly overstrained, then one may only provoke overstrain. Furthermore, instead of emerging to somatic effectors, excessive brain activity may, in compensation, gain a free exit to visceral effectors and thus disorganize the functioning of internal organs (see §5, and also Chapter 7, §5).

Therefore, prophylactic effector switching which arises against a background of a definite decrease (actual or imminently expected) in the energy and functional supply of activity in the higher regions of the brain (in particular, the cerebral cortex) may have extremely useful secondary adaptive significance if,

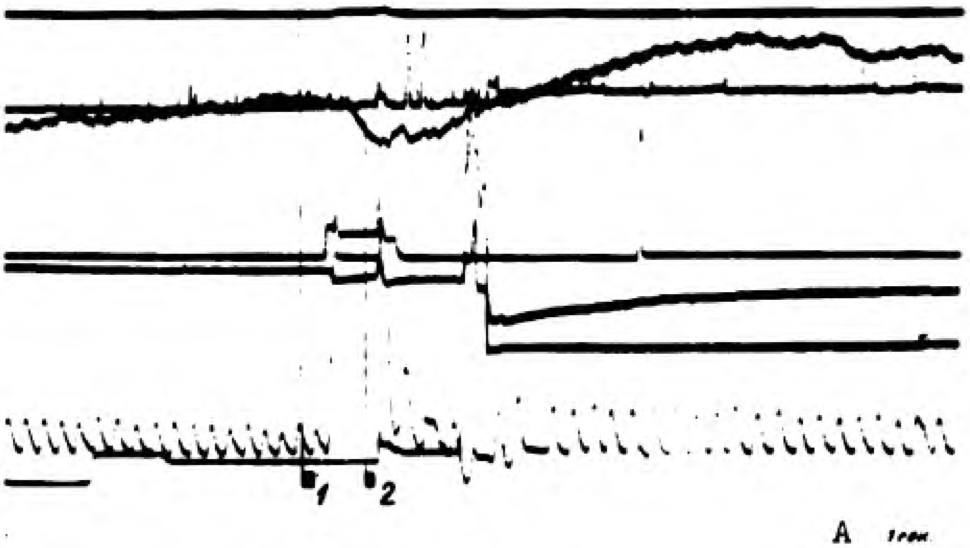

Fig. 3. Reaction of subject I.P. to the sound of a pistol shot while holding his breath in deep inspiration (shot is fired without warning). Reaction begins only after spontaneous exhalation. 1) Instruction: "Breathe in as deeply as possible and hold your breath;" 2) shot. Top to bottom: Contraction of flexors and extensors of the right thumb; blinking; plethysmogram of left thumb; movement of lower jaw; contraction of knee flexors; pneumogram; contraction of knee extensors. A) 1 sec.

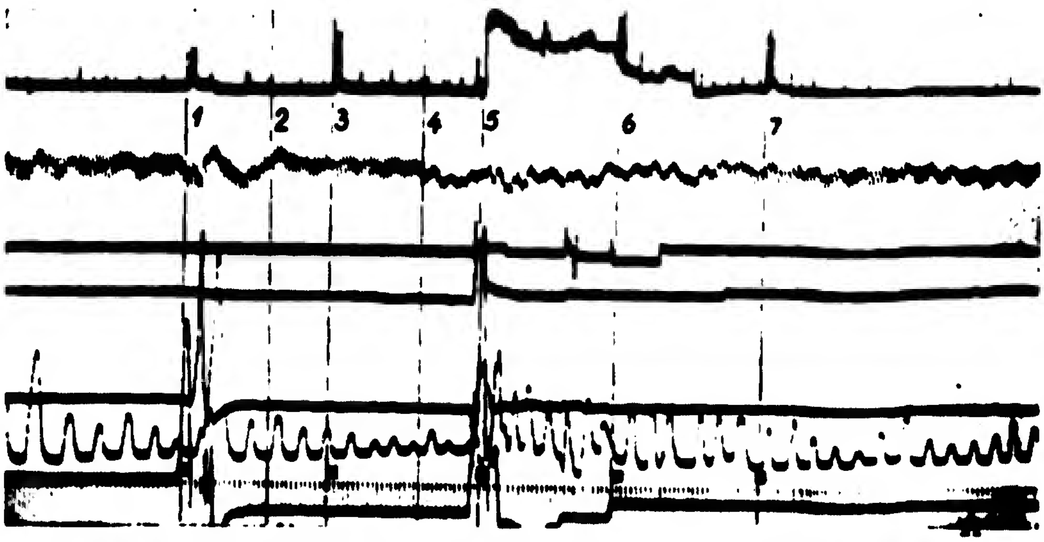

Fig. 4. Changes in intensity and form of blinking and general readiness reactions in subject I.P. (with standard triple stimulation of the cornea by a stream of air) as dependent upon the nature of the preliminary set of nervous activity. 1) Stimulus to cornea without preparatory instruction; 2) instruction: "There will be a stimulus to the cornea;" 3) stimulus to cornea; 4) instruction: "Attention, there will be a strong stimulus to the cornea;" 5) stimulus to cornea (same intensity as all remaining stimuli;" 6) stimulus to cornea; 7) stimulus to cornea. Top to bottom: Blinking; sphygmogram of left radial artery; movement of lower jaw; contraction of flexors or extensors of right thumb; contraction of flexors of knee; pneumogram; contraction of knee extensors. A) 1 sec.

and this stands to reason, the effector reactions of secondary significance evoked are not inadequate for the situation, do not prevent the realization of the reactions which have primary adaptive effect and do not evoke secondary effectors which deepen the disorder of the functional state of the brain (see Chapter 5, §2).

§5. It is known that any stimulus which acts on the nervous system and evokes an increase in the activity of restricted, self-stimulating systems within the brain causes a more or less marked aftereffect, because increased activity of closed neural circuits is continued for some time after the stimulus ceases. With sufficient intensity of trace activity in the closed systems and under conditions that facilitate the exit of impulses from the closed circuits to effector neurons, effector switching occurs. The latter, if sufficiently intense, produces an effector reaction from the aftereffect, (Krauklis, 1960a, pp. 81-98).

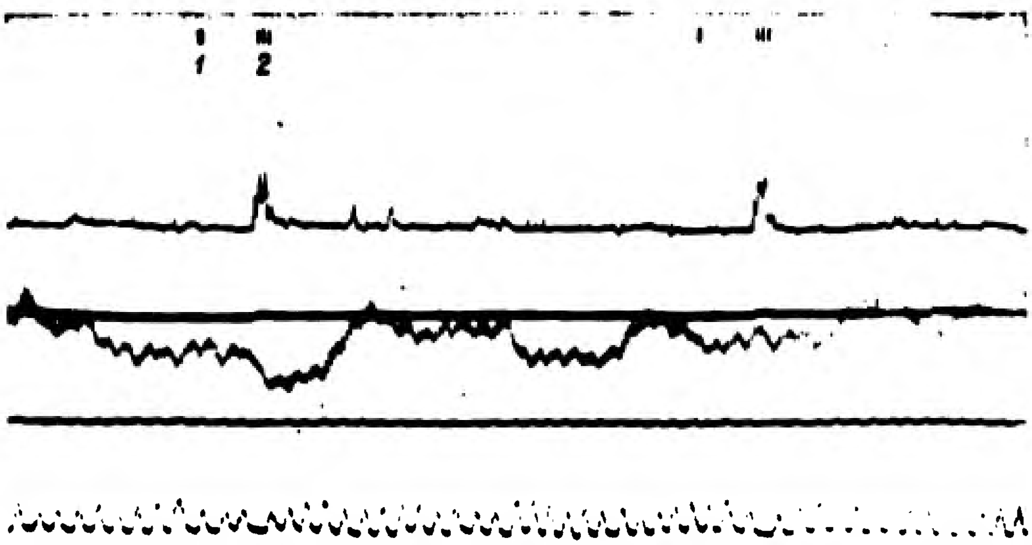

Fig. 5. Absence of expressed compensatory reactions, including aftereffect reactions, during formation of the blinking reaction in subject A.K. 1) Conditioned signal; 2) thrice repeated warning stream of air to cornea. From top to bottom: blinking motion; motion of lower jaw; plethysmogram of thumb; contraction of extensors to knee; pneumogram.

In cases where the increase in brain activity produced by verbal or by nonverbal stimulation is relatively great, while the outflow of activity to effector neurons as the result of stimulation is relatively slowed down, but the slowing is abolished immediately after the stimulus ceases, the conditions are set for the production, to a greater or lesser degree, of a marked aftereffect reaction. By its secondary significance, the aftereffect reaction is a compensatory reaction which arises as a result of the compensatory switching at the time of inadequately strong activity from the brain to effectors.

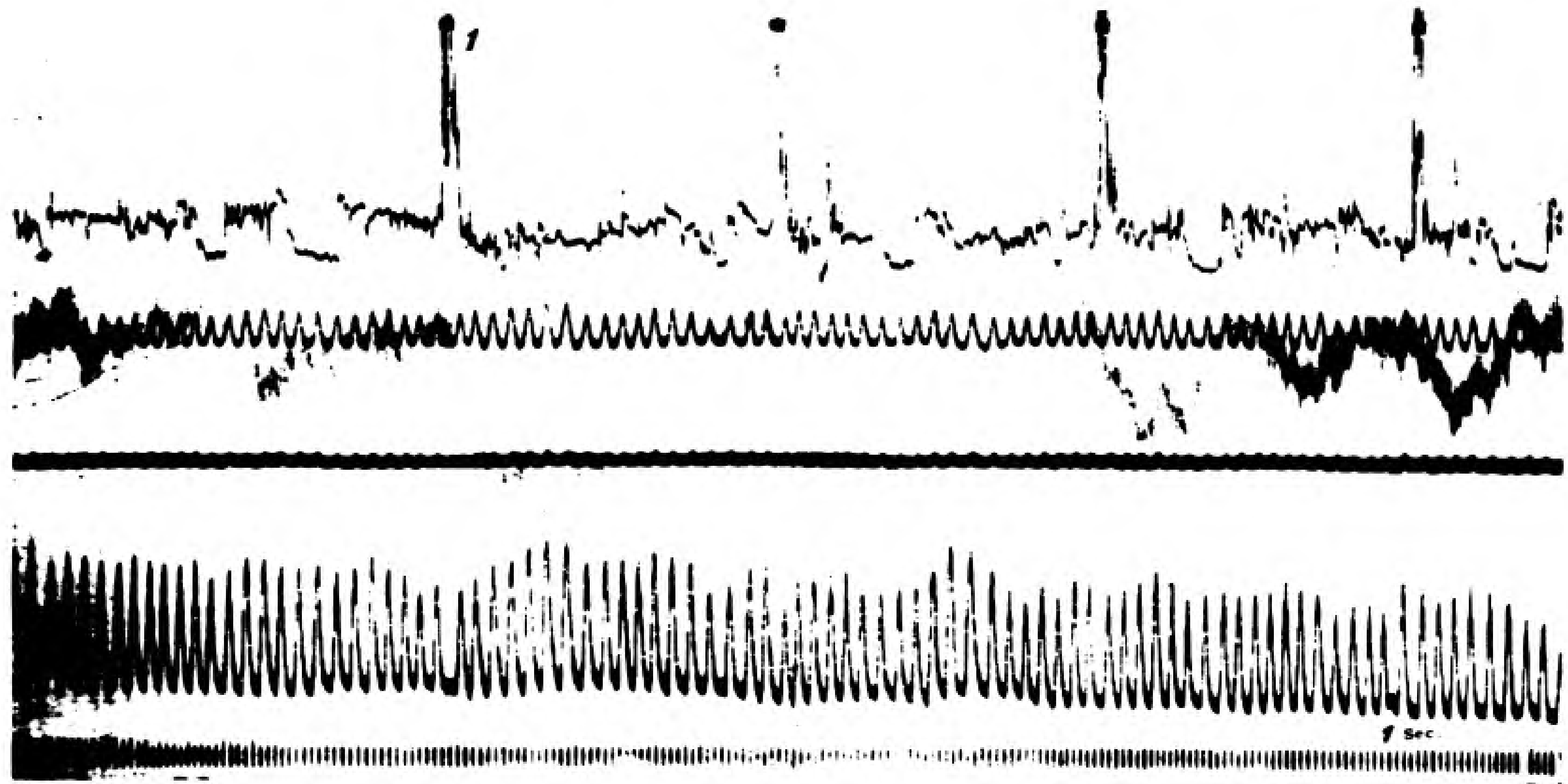

Fig. 6. Compensatory switching of nerve activity of the brain through identical time intervals (cycles) to effector pathways for specialized (i.e., blinking) react-ons and to vasomotor centers in the after effect period and also in the intervals between stimuli (beginning stages of formation of conditioned reaction over time in subject P.O.). 1) Triple stimulation of cornea by stream of air. Top to bottom: Blinking reaction; contraction of knee extensors; plethysmogram of thumb; contraction of knee flexors; pneumogram.

As an illustration of compensatory effector switching which arises as an after effect, we may use the figures presented above (see Fig. 1-4) as well as figures that show sections of kymograms recorded during laboratory study of the dynamics of effector switching and effector integration of brain activity in human subjects and experimental animals (Fig. 5-15).

In instances when there occurs, on the one hand, a marked increase in brain activity which arises against the background of limited functional possibility for equalizing the activity within closed systems while, on the other hand, there is noted a slowing down of those neural pathways through which a large number of impulses of cerebral activity might have been prophylactically switched to adequate efferent neurons, impulses are compensatorily switched through any pre-efferent nerve paths which are free from inhibition.

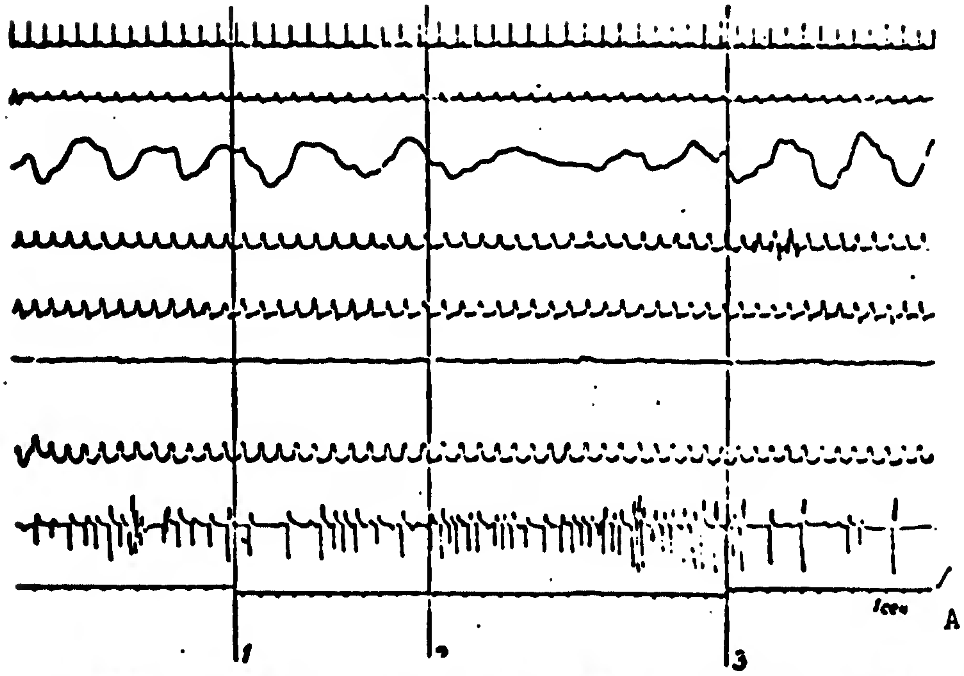

Fig. 7. Compensatory switching of nerve activity provoked by session situation to nonspecific effector path of the blinking reaction, increase in blinking motion during respiratory blockade (by means of a special mask) and a decrease in blinking motion after blockade (subject N.K.) (experiment of A.Krauklis and Ya. Skard). 1) Verbal signal: "Attention, cornea stimulation will occur;" 2,3) Beginning and end of partial respiratory blockade. Top to bottom: Electrocardiogram (Lead 1); electromyogram of quadriceps muscle; pneumogram; piezosphygmogram of crural artery, carotid and temporal arteries; piezogram of blinking motion. A) 1 sec.

Compensatory effector switching of brain activity arises and is, by virtue of its secondary adaptive significance, an expression of prophylactic effector switching.

Supplementary effector switching which occurs as an after-effect, represents compensatory switching in a temporal sense. The supplementary effector switching via any channels that are free from inhibition and that arise during the action of the stimulus, is compensatory switching in a spatial sense.

If the prophylactic effector switching is inadequately strong, cerebral activity may be implemented through efferent neurons and effectors which are adequate for a given situation; then the necessity for mobilization of compensatory pathways of switching does not arise. If the number of impulses which are urgently switched to the periphery is too large to be switched through adequate effector pathways, or if the latter are slowed down, then a larger or smaller number of impulses goes out compensatorily to other, less adequate or inadequate effector pathways. As a result, effector reactions arise which are not adequate for the situation.

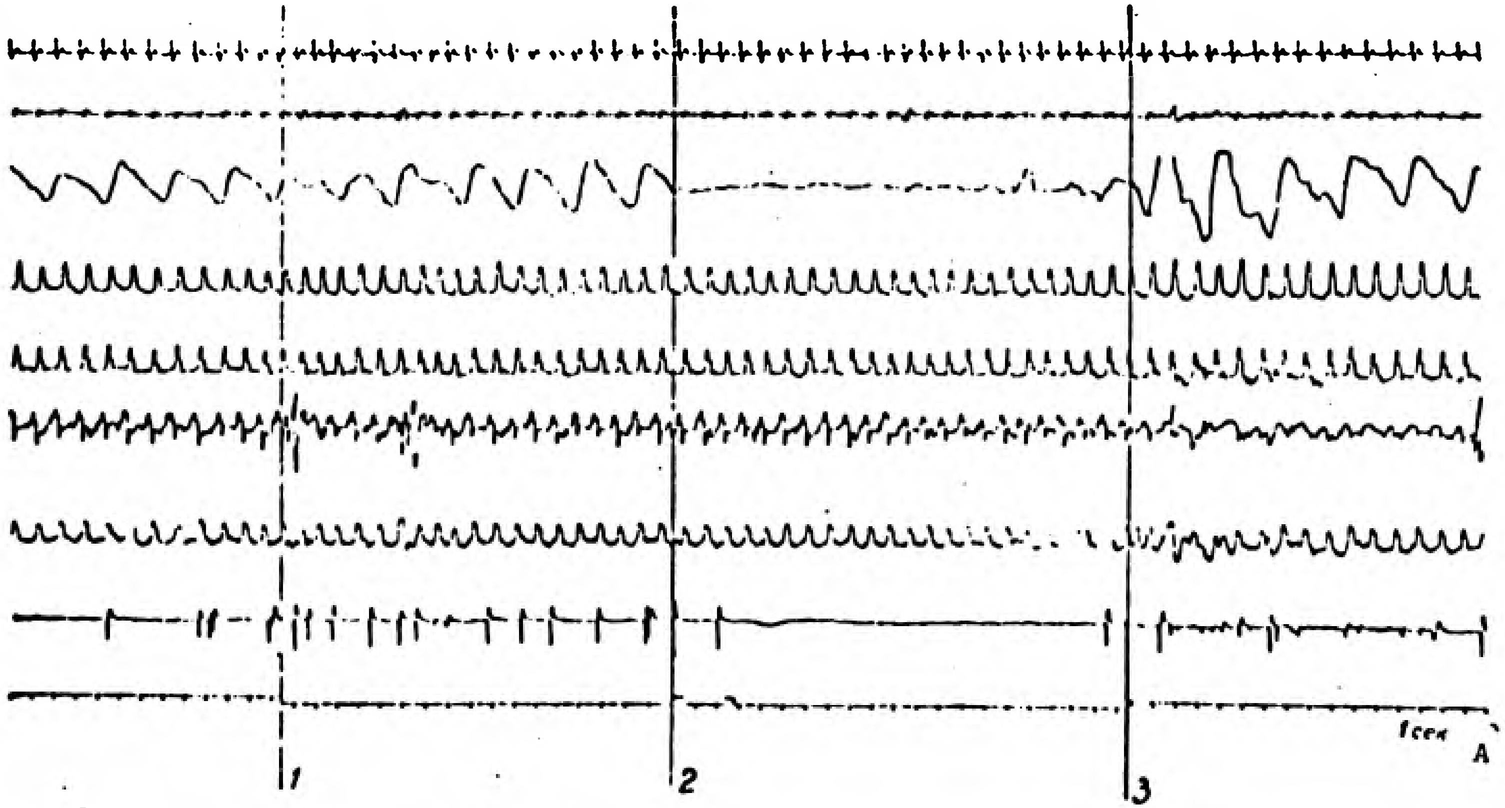

Fig. 8. Inhibition of nonspecific conditioned blinking motions during respiratory blockade (by closing ventilation mask) and their compensatory increase after the end of blockage (subject L.L.). Key is the same as in Fig. 7. Separate irregular variations on piezokymogram of carotid artery are related to the act of swallowing (high oscillations) or to the tension of neck muscles (see aftereffect after cessation of respiratory blockage). A) 1 sec.

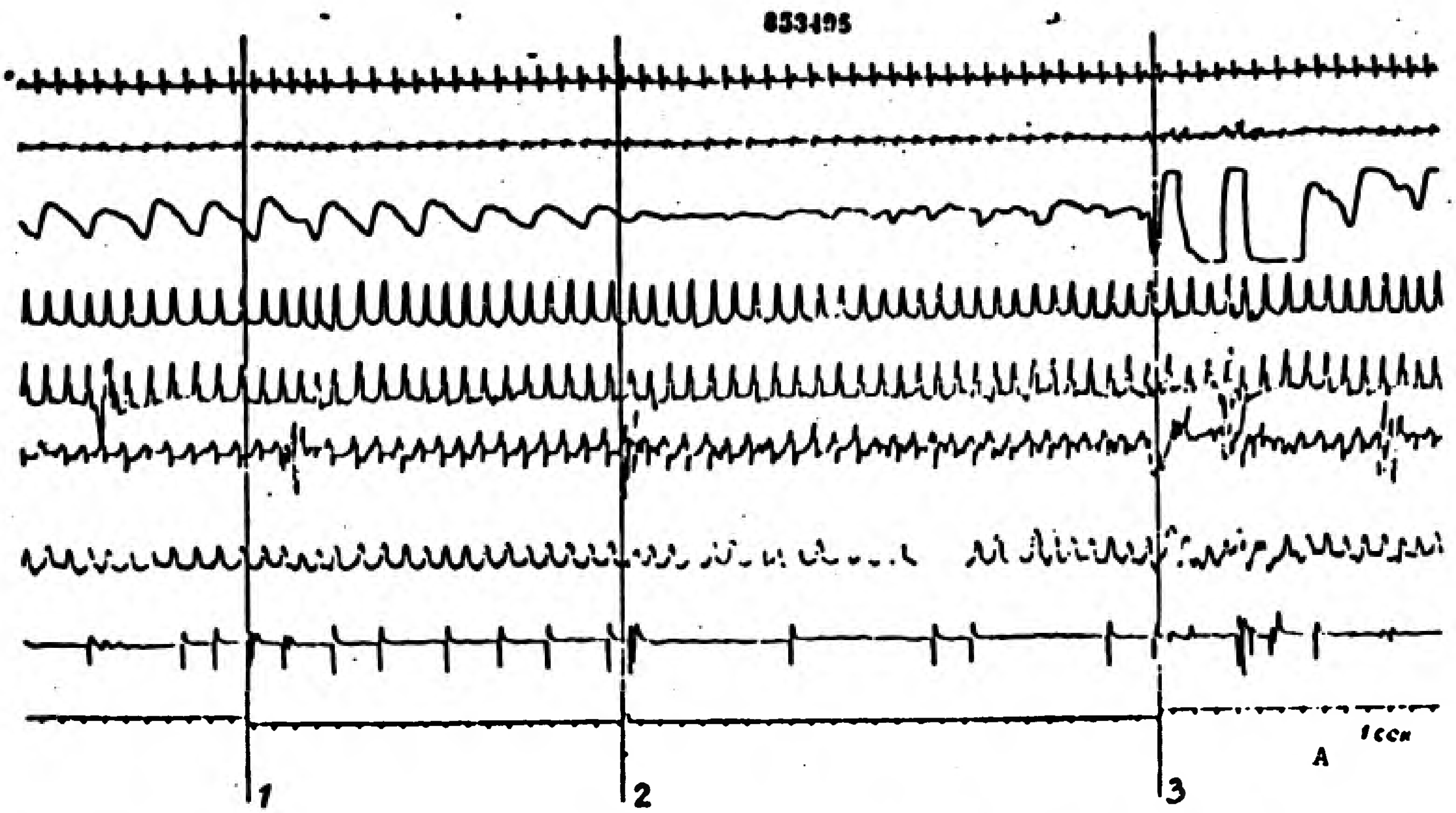

Fig. 9. Inhibition of conditioned blinking movements during respiratory blockage and compensatory strengthening of these reactions (and compensatory contraction of thigh muscles, appearing of swallowing motions, deepening of respiratory excursions, etc.) after cessation of blockage (subject A.G.) Legend same as in Fig. 7. A) 1 sec.

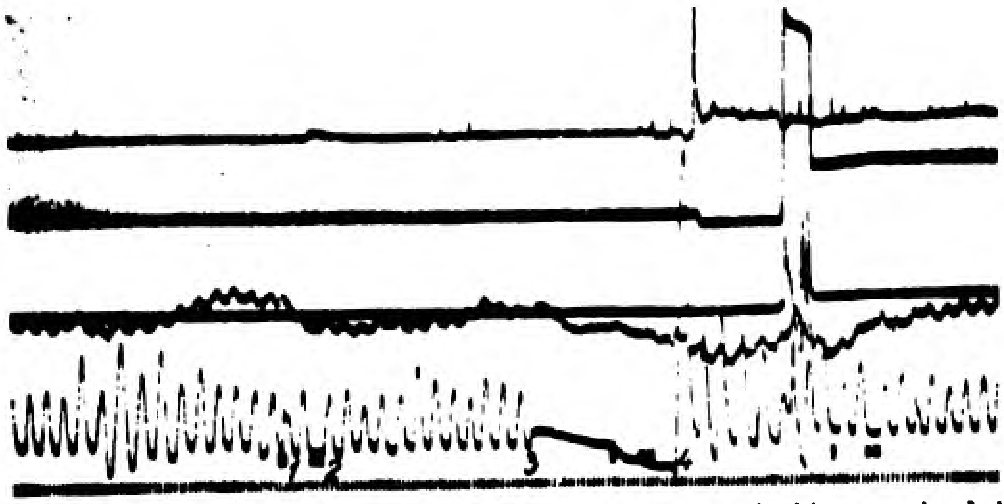

Fig. 10. Compensatory switching of neural activity evoked by respiratory blockade, specific and nonspecific effectors after cessation of blockage (subject N.N.). 1) Conditioned signal; 2) Fourfold stimulation of cornea by stream of air; 3,4) beginning and end of respiratory blockade. Top to bottom: Blinking motion, contraction of flexors and extensors of knee, plethysmogram of thumb, pneumogram.

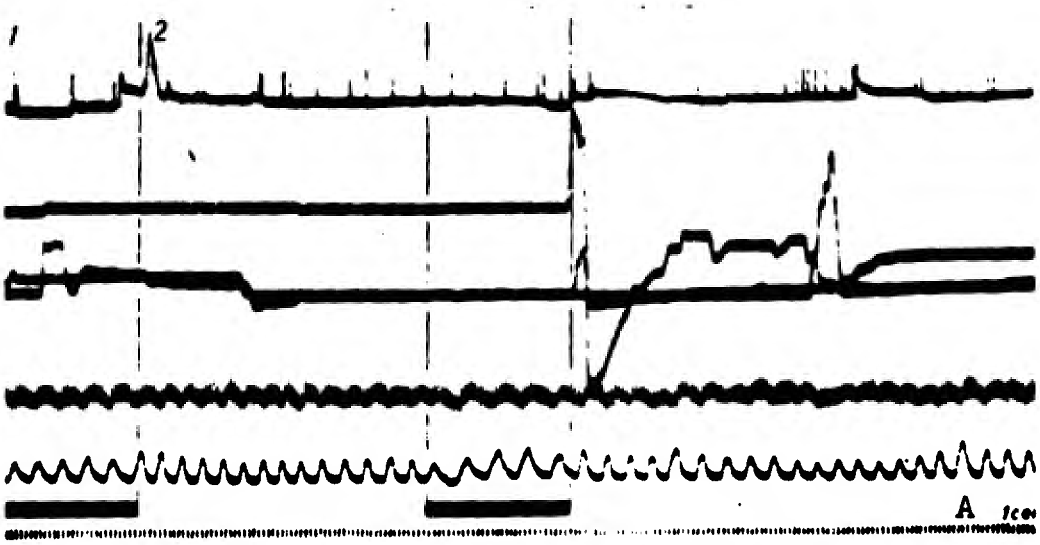

Fig. 11. Compensatory switching of neural activity produced by artificial increase in resistance to breathing to nonspecific somatic effectors after stopping the resistance (subject G.Ya.). 1 and 2) Beginning and end of increased resistance to breathing. Top to bottom: Blinking motion; contraction of extensor and flexors of the knee; motion of lower jaw; plethysmogram of thumb; pneumogram. A) 1 sec.

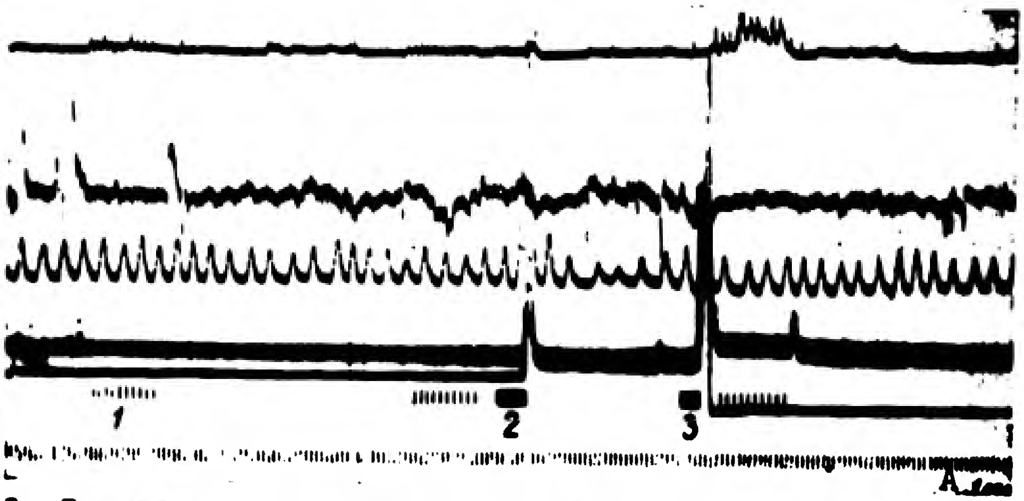

Fig. 12. Increase in the unconditioned blinking reaction against a background of after-reactions following cessation of static load (lifting a weight of 5 kg to a certain height) applied to the flexor muscles of the 2nd, 3rd and 4th fingers of the right hand (subject A.V.). 1) Tenfold stimulation of cornea with a stream of air; 2,3) start and end of static muscle load. From top to bottom: contraction of flexors of right 2nd, 3rd and 4th fingers; blinking motion; plethysmogram of fingers of left hand; pneumogram; contraction of flexors and extensors of the knee. A) 1 sec.

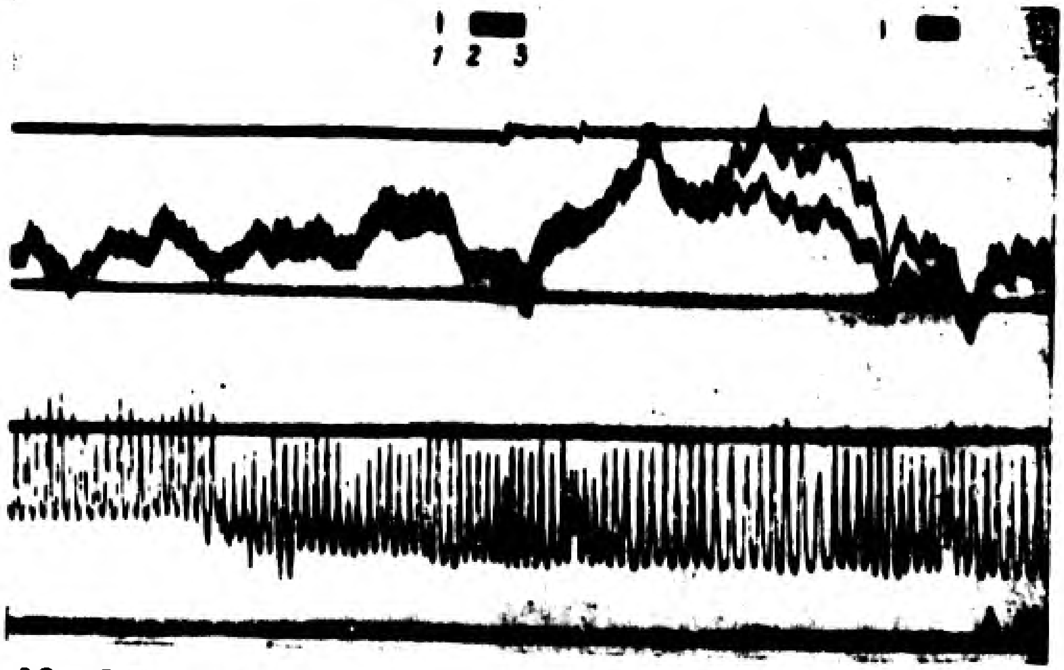

Fig. 13. Compensatory switching of nerve activity mainly to vasomotor centers after first application of electrical stimulation to subject E.A. against a background of voluntary decrease in motor and respiratory reactions. 1) Conditioned signal; 2,3) beginning and end of electrical stimulation. Top to bottom: motion of knee, plethysmogram of right and left thumbs; contraction of flexors and extensors of the knee; pneumogram. A) 1 sec.

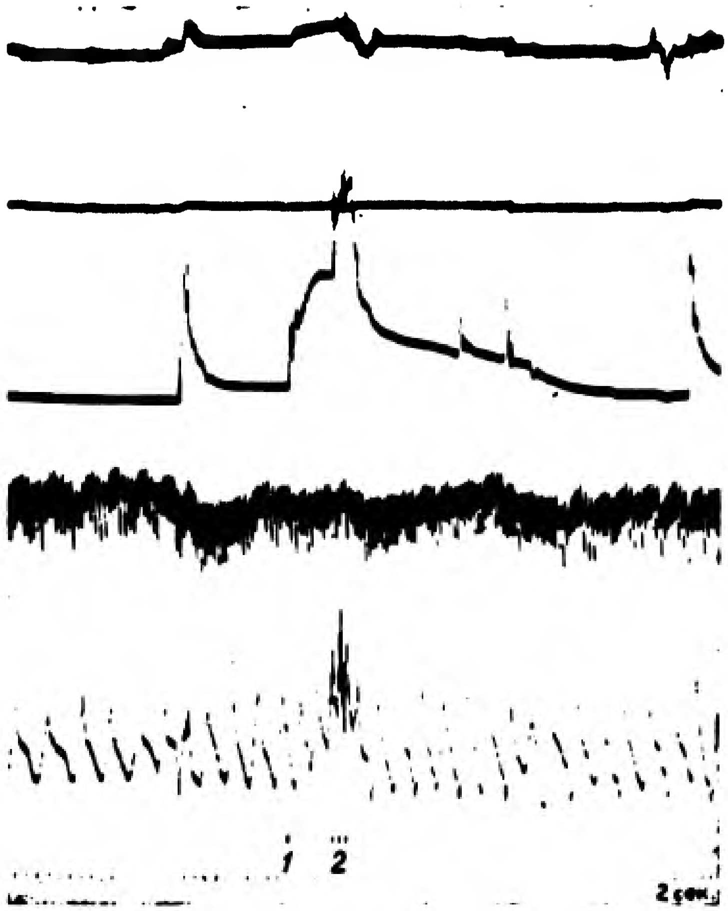

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Fig. 14. Compensatory switching of neural activity to effectors by elaborated conditioned motor reactions during the period of after-effect in the formation of the defensive motor conditioned reactions in the dog, Moris (experiment of Dzh. Liyepa). 1) Conditioned signal; 2) triple stimulation of the right hindleg. Top to bottom: movement of head; movement of forelegs; movement of right hindleg; sphygmogram of carotid artery; pneumogram. A) 2 sec.

If the pathways for switching to somatic effectors are slowed down (for example, in man by a voluntary decrease in the external manifestations of strong emotional arousal), all prophylactic switching of brain activity to the periphery may make a compensatory exit to visceral effectors, providing visceral reactions which are inadequately strong or inadequate in physiological effect.

Human daily life is full of graphic examples which reaffirm the presence of prophylactic and compensatory switching of excessively strong activity from higher regions of the brain to certain effectors and, in this connection confirm the presence of ideomotor, behavioral and visceral reactions in man which are quantitatively inadequate for the actual situation.

Fig. 15. Compensatory switching of neural activity mainly to the respiratory apparatus and cardiovascular system in the aftereffect period with formation of defensive motor conditioned reactions (in the stage of alteration of signal meaning of conditioned signals) in the dog, Shalis (2 sections from a kymogram from experiments by Dzh. Liyepa). 1) Positive conditioned signal; 2) electrodermal reinforcement; 3) differential signal. Top to bottom: head movement, neck movement, movement of forelegs movement of right hindleg, sphygmogram of carotid artery; pneumogram. A) 2 sec.

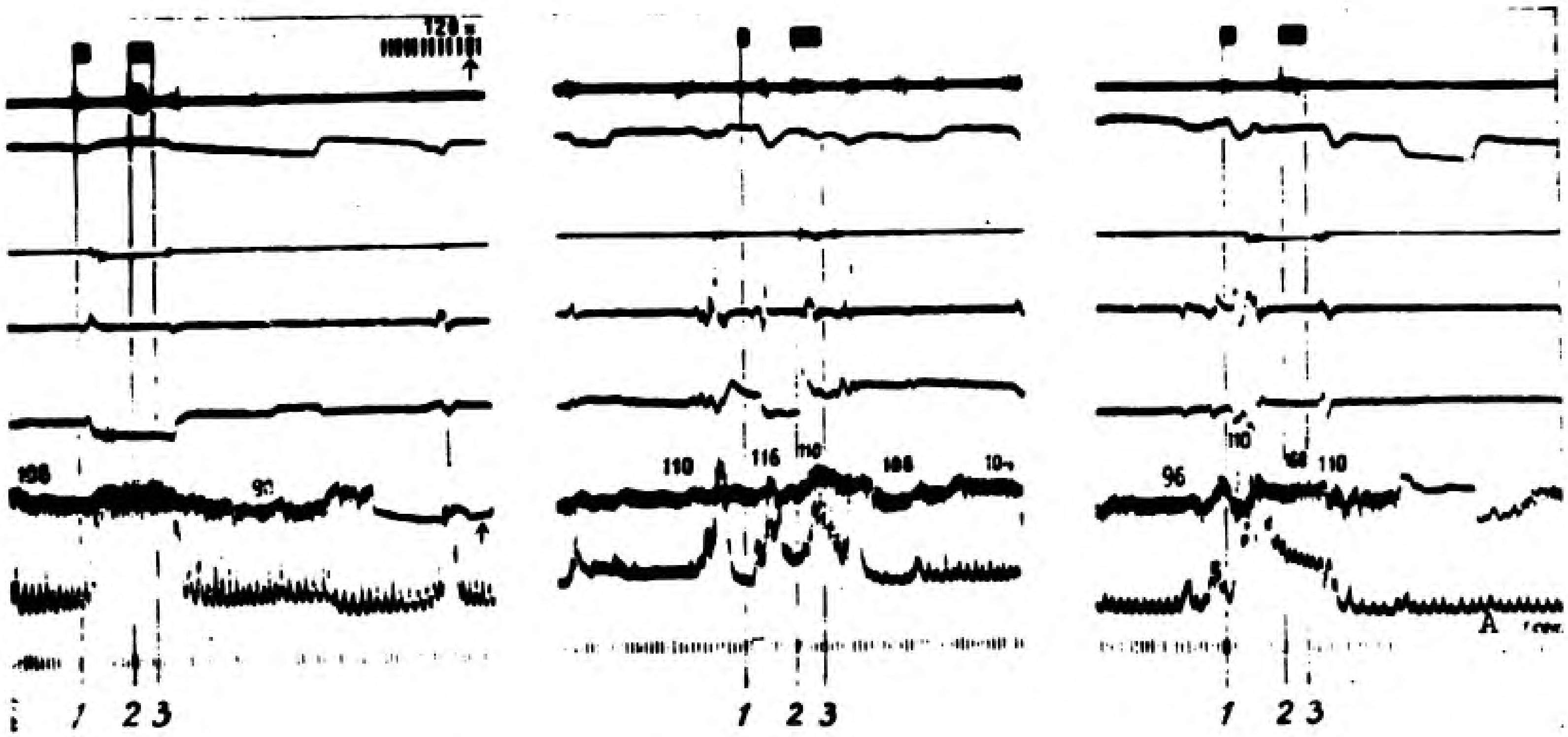


Fig. 16. Compensatory switching of neural activity to forelegs and to left hindleg with loading of right hindleg (i.e.,stimulation) with a 2 kg weight (vis three ergographs) and the process of formation of the defensive motor conditioned reactions by the method of Petropavlovskiy in the dog, Dzhulis (3 sections of kymogram from experiments of Yu. Briyedis). First section – prior to load; second, during load; third, from 3 min after removing load (see reproduction of compensatory reaction of the forelegs and left hindleg). 1) Conditioned signal; 2,3) start and end of electrodermal reinforcement of right hindleg. Top to bottom: markers for end-systolic arterial pressure (each marker is 5 mm Hg, readings are marked by a cross, true pressure by an arrow); movement of jaw; movement of head; movement of right hindleg; movement of forelegs, movement of left hindleg, sphygmogram of carotid artery (numbers indicate pulse rate); pneumogram. A) 1 sec.

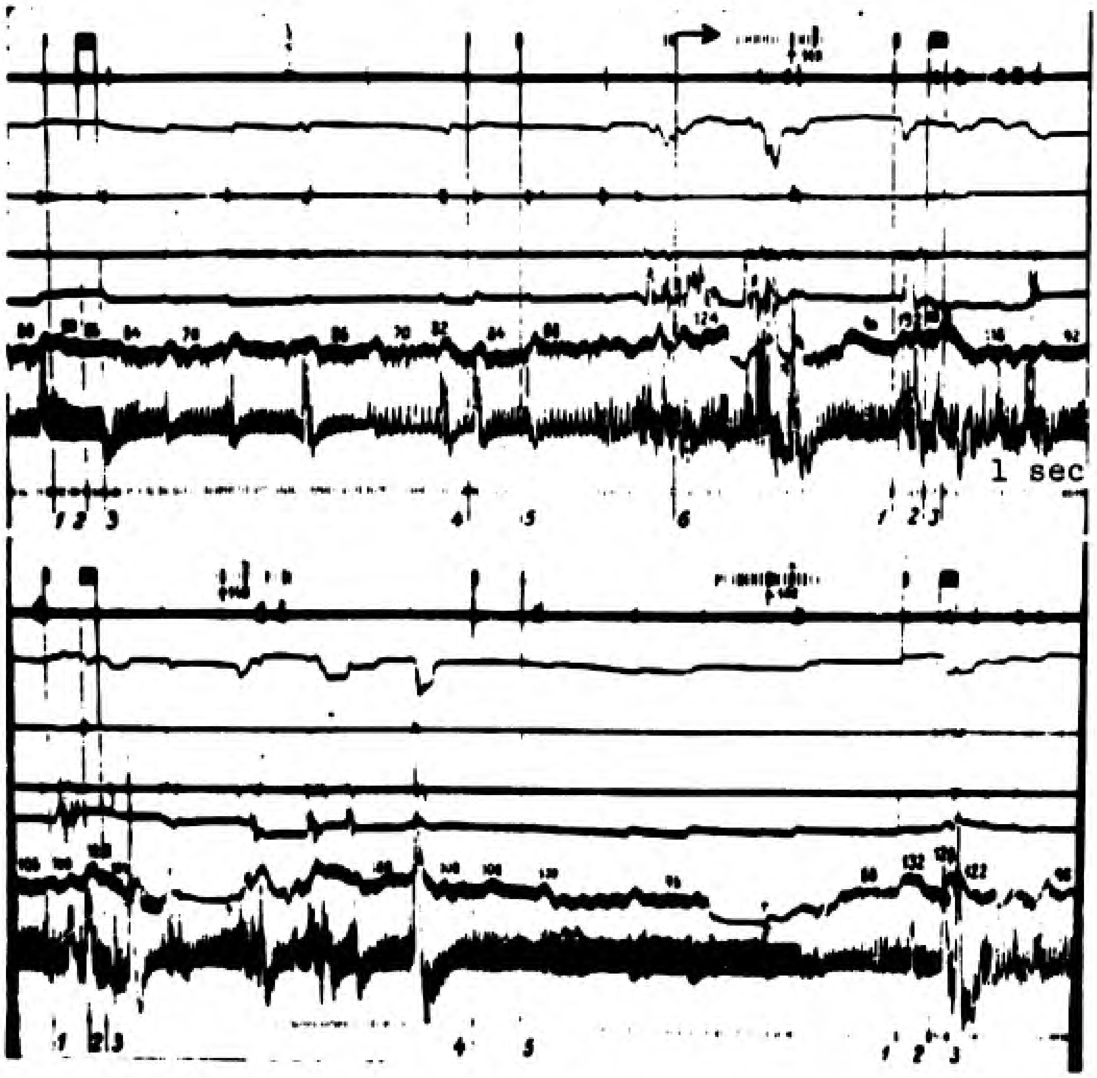
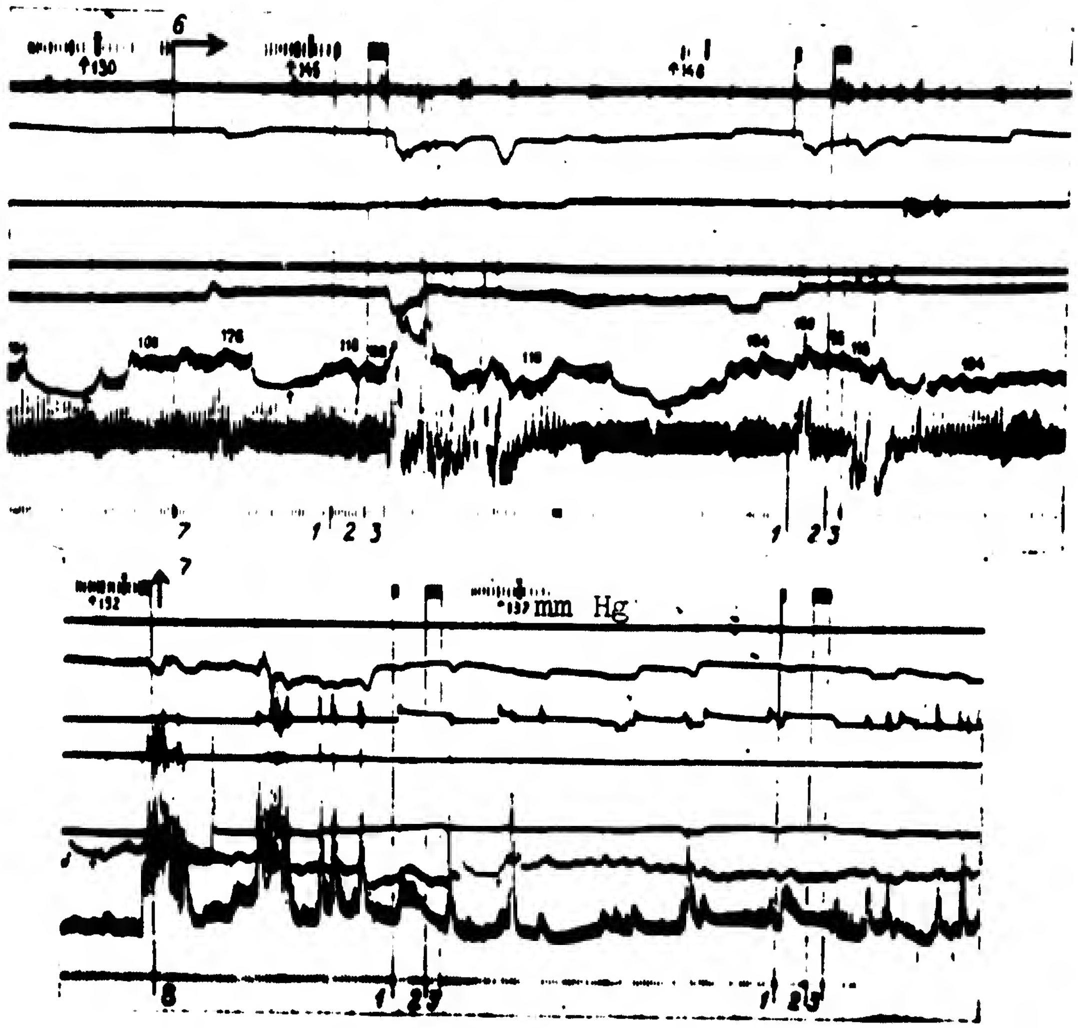


Fig. 17. Compensatory switching of neural activity during load and mechanical blockade, as well as deblockade of movement of the extremities during the process of forming the defensive motor reaction according to the method of Petropavlovskiy in the dog Dzhulis (4 sections of Kymogram, experiments of Yu. Briyedis). 1) Conditioned signal; 2,3) beginning and end of electrodermal reinforcement; 4,5) beginning and end of differential signal; 6) beginning of load (2 kg weight) on right hindleg; 7) beginning of blockade to motion of left hindleg; 8) end of load to right hindleg and blockade of left hindleg. The decrease in initial somatic compensatory reactions (produced by load and blockade) in the second and third sections is accompanied by a compensatory increase in respiratory and cardiovascular reactions. Wild compensatory reactions in the aftereffect period following deblockade testify to the significant increase in activity of the corresponding effector neurons as the result of the massive output of latent (circulating) neural activity to peripheral effectors. Top to bottom: markers of arterial pressure (see Fig. 16); movement of jaw, head, right hindleg, forelegs and left hindleg, sphygmogram of carotid artery (numbers indicate pulse rate), pneumogram.

Fig. 17 Continued



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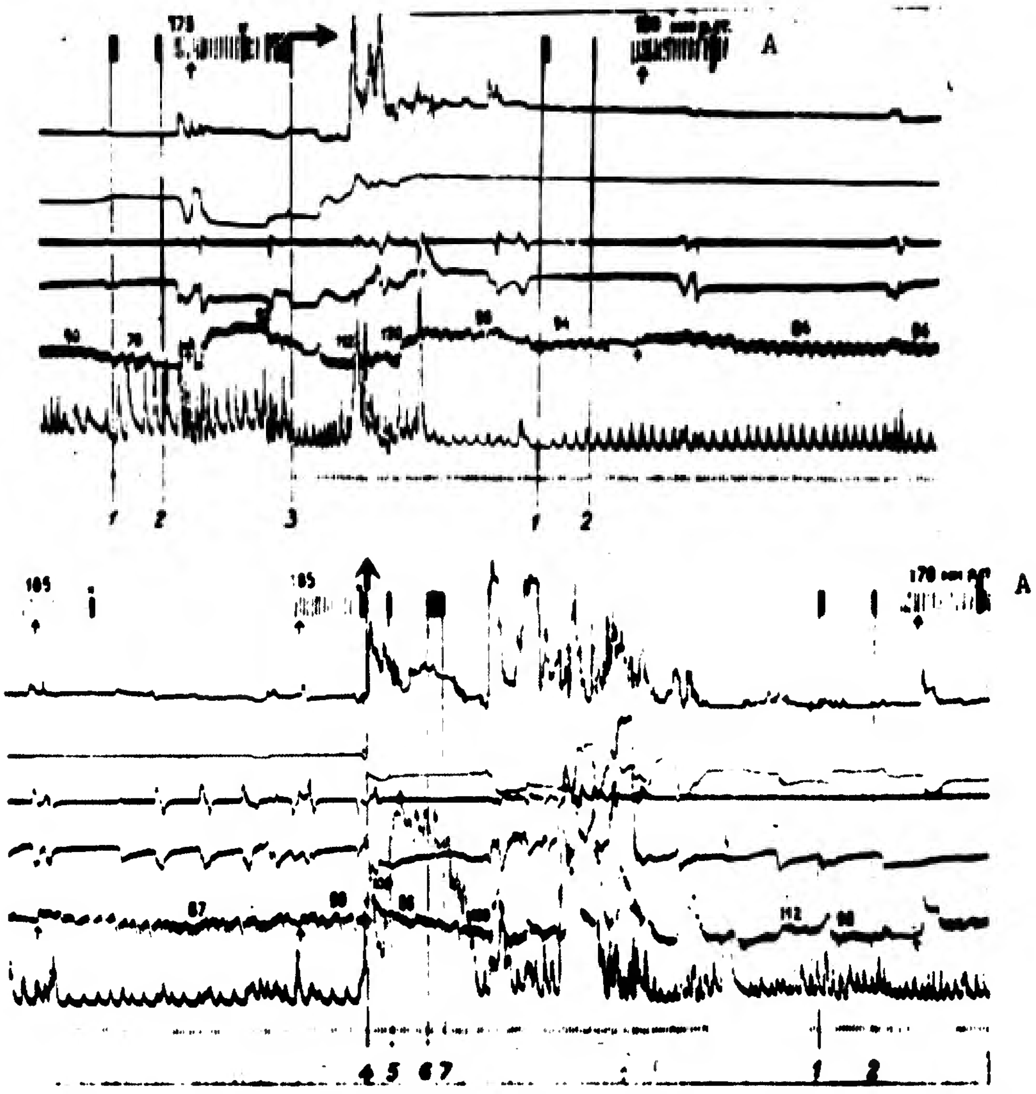

Fig. 18. Compensatory switching of neural activity under mechanical blockade, in particular under deblockade of head movement during the formation of the defensive motor conditioned reactions on the basis of electric stimulation of salivation in the dog Dzhulis (2 sections of kymogram from experiments by Yu. Briyedis). The animal rapidly becomes externally quiet after the start of the blockade and subsequently leg movements are unimpeded. 1,2) Beginning and end of differential signal; 3) start of blockade to movement of head; 4) cessation of blockade; 5) conditioned signal; 6,7) start and end of stimulation of salivation by induction current. Top to bottom: markers for arterial pressure (see Fig. 16); motion of jaw, head and sum of all four extremities; postural tonic contraction of hip muscles; sphygmogram of carotid artery; pneumogram. A) mm Hg.

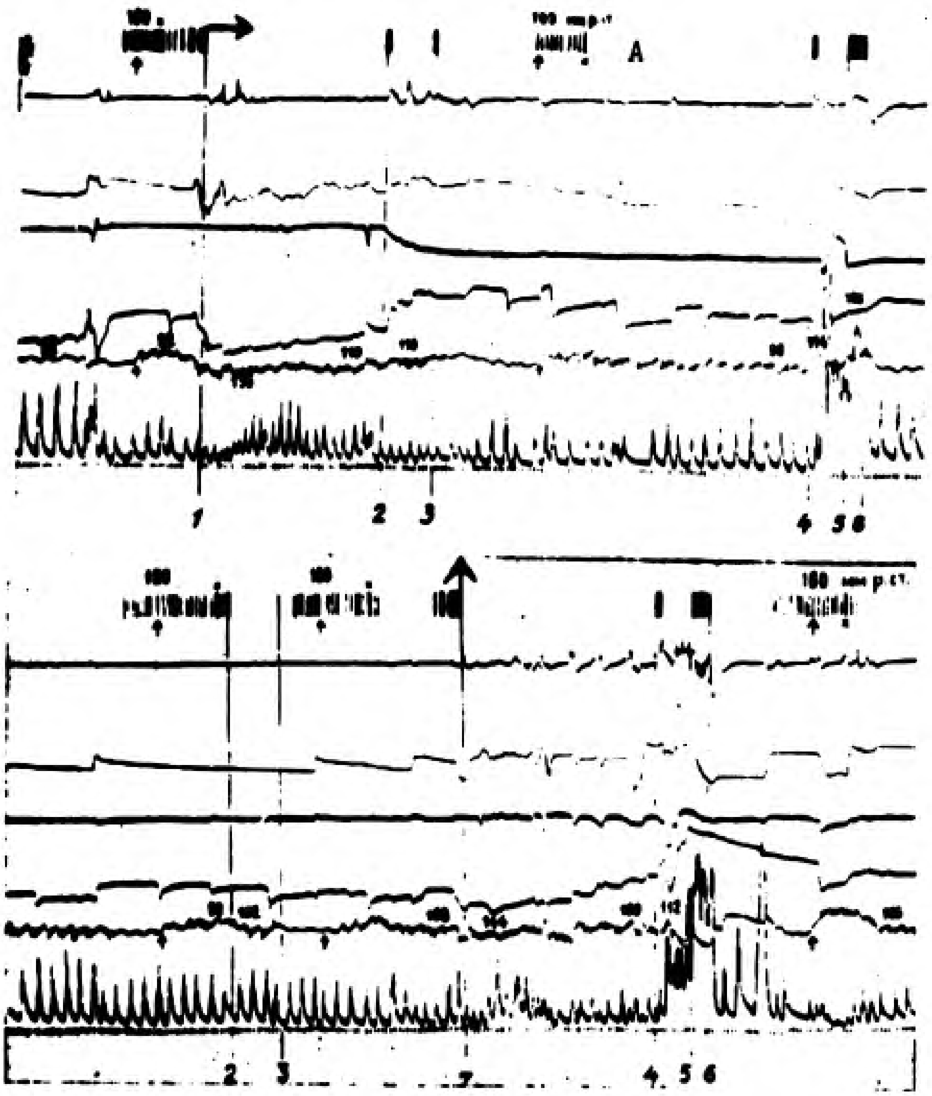

Fig. 19. Compensatory switching of activity under mechanical blockade in particular during deblockade of movement in the lower jaw during formation of the defensive motor conditioned reactions on the basis of electrical stimulation of salivation in the dog Dzhulis (2 sections of kymogram from experiments by Yu. Briyedis). 1) Start of blockade to movement of lower jaw; 2,3) start and finish of differential signal; 4) conditioned signal; 5,6) start and finish of stimulation to salivation by induction current; 7) end of blockade. Top to bottom: markers for arterial pressure (see Fig. 16); movement of lower jaw, head and sum of all extremities; postural tonic contraction of hip muscles; sphygmogram of carotid artery (numbers indicate pulse rate); pneumogram. A) 100 mm Hg.

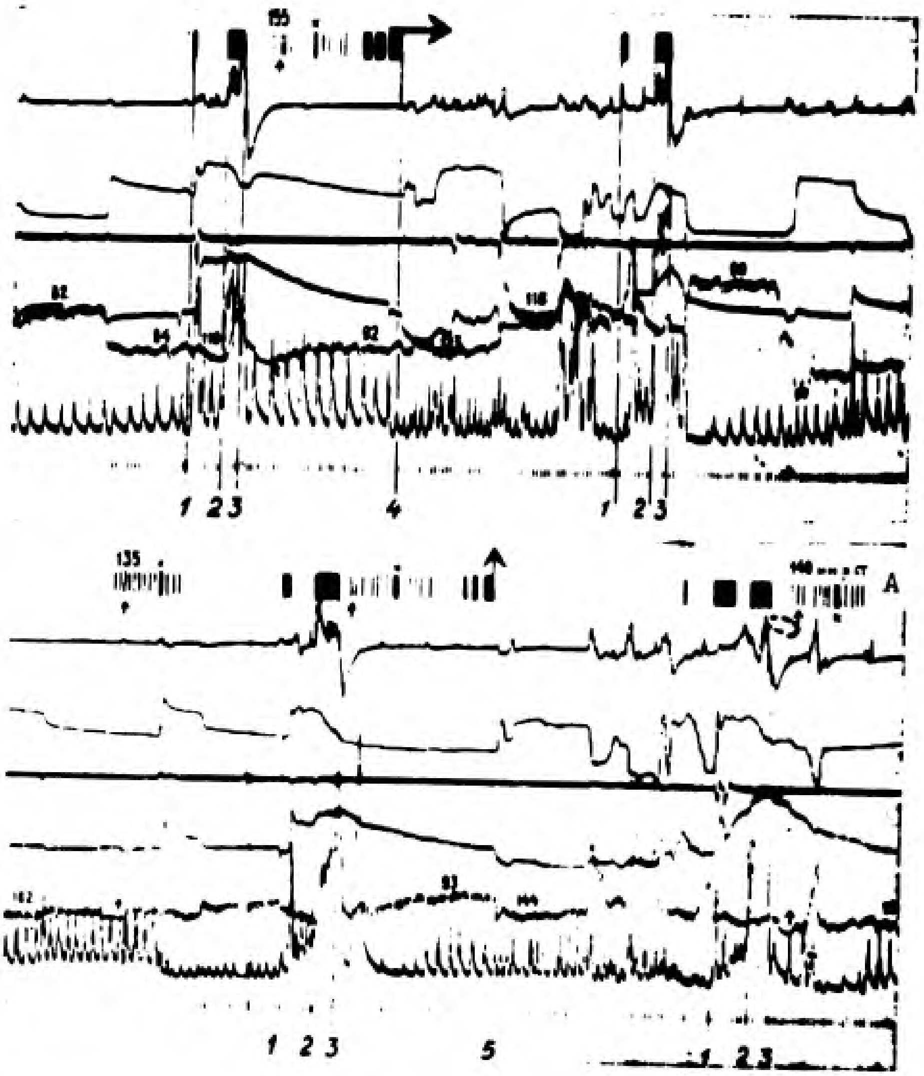

Fig. 20. Compensatory switching of neural activity under mechanical blockade and deblockade to movement of nonspecific effectors – all four extremities – during formation of the defensive motor conditioned reaction by electrical stimulation of salivation in the dog Dzhulis (2 sections of kymogram from experiments by Yu. Briyedis). 1) Conditioned signal; 2,3) beginning and end of stimulation to salivation by induction current; 4,5) start and end of blockade to motion of all limbs. Remaining legend is the same as in Fig. 19. A) 140 mm Hg.

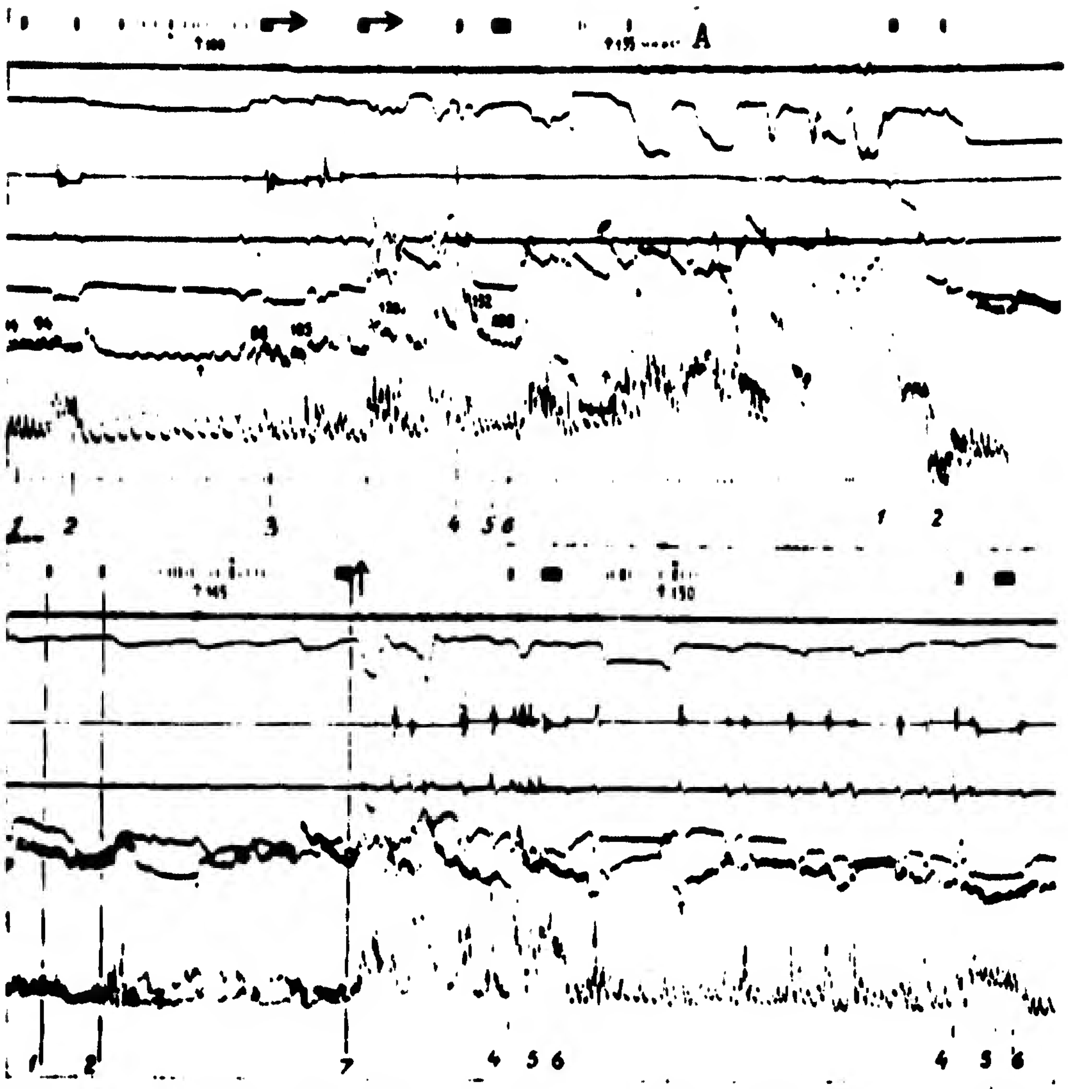

Fig. 21. Compensatory switching of neural activity in the dog Dzhul'bar (2 sections of kymogram from experiments by Yu. Briyedis) under mechanical blockade and deblockade to motion of both hindlegs during formation of the defensive motor conditioned reaction according to the method of Petropavlovskiy. 1,2) Start and end of differential signal; 3) start of blockade to motion of hindlegs; 4) conditioned signal; 5,6) electrodermal reinforcement of right hindlegs; 7) end of blockade. Top to bottom: markers for arterial pressure (see Fig. 16); motion of lower jaw, head, right hindleg and left hindleg; postural tonic contraction of hip joint musculature; sphygmogram of carotid artery (with numbers for pulse rate); pneumogram. A) mm Hg.

The exerpts from laboratory experiments are presented above (performed on human subjects and experimental animals) illustrating the course of the compensatory distribution of effector impulses produced by conditioned and unconditioned stimuli which emanate from the brain (Figs. 16-21).

CHARACTERISTICS OF THE "COMPENSATORY REACTIONS" IN THE PHYSIOLOGICAL LITERATURE

§6. In the laboratories of I.P. Pavlov were established the diverse motor reactions arising in experimental animals during formation of salivatory conditioned reflexes and different types of internal inhibition; however, not having a direct relationship with the conditioned reflexes elaborated. Thus, for example, Parfenov (1905) observed that with extinction of the simple salivatory conditioned reflex general stimulation of the animal occurs. In the intervals between stimuli a strong, generalized motor reaction is noted; the dog was breathless.

In the literature were found similar reactions called "Parfenovskiy" reactions. Subsequently they have been described by many authors (Fol'bort, 1912; Vasil'yev, 1924; Petrova, 1946 and others).

From our point of view, all similar motor reactions which usually arise against a background of overexertion of higher nervous activity during the formation of internal inhibition, represent compensatory reactions that result from prophylactic and compensatory switching of inadequately strong cerebral activity to other peripheral effectors. Compensatory reactions are also different forms of "self reactions" which arise in animals under strong stress to higher nervous activity (Krauklis, 1952, 1955, 1960, 1962: Norkina, 1955, 1961). Evidently, in greater or lesser degree, the various biologically unfavorable motor reaction, reactions "to the environmental setting," reactions "of substitution," etc., are also related to compensatory effector switching, as has been noted in animals by many investigators (Anokhin, 1949, 1958; Pavlova, 1949; Protopopov, 1950; Norkina, 1955, 1961; Alekseyeva, 1957; Ye. A. Yakovleva, 1957; Kupalov and Khananinshvili, 1958 and many others — see Krauklis, 1960, p. 190).

Compensatory reactions, in essence, are those motor reactions which arise in man with intensified emotional stress, as described by American authors (Peak, 1931; Luria, 1932; Sherrington, 1948; Hollingworth, 1939; Freeman, 1940, 1942, 1948a, b; Arnold, 1942, Oldroyd, 1942, and others).

The term "compensatory reactions" was first used in the Soviet physiological literature by Kryazhev (1952) for designating various motor reactions which arise in the monkey during elaboration of internal inhibition but which do not have a direct connection with the elaborated conditioned reflex. Kryazhev observed that these motor reactions, as it were, substitute for an extinguishing or extinguished positive conditioned reflex. He notes that in the overexertion of cortical processes in the dog during formation of feeding conditioned reflexes often leads to the development of supramaximal inhibition and sleep, while in the monkey, under the same conditions, vigorous stimulation, expressed in various behavioral reactions of a compensatory nature, is usually produced.

Bukov and Kurtsin (1960), in analyzing data obtained by Kryazhev, conclude that with overexertion of nervous activity, evidently, the compensatory complex generally described by the school of I.P. Pavlov does not always develop, i.e., protective inhibition. Under certain conditions, a compensatory complex of another type – protective stimulation – occurs, in which stimulation is switched from certain cortical complexes to others which protect the former. The authors assume that such a principle of switching cortical complexes occur in the daily life of man as well.

Such a proposal by Bykov and Kurtsin is close to our own view that compensatory switch ("discharge") of conditioned stimulation participates in the mechanisms of cortical self-regulation, i.e., in higher nervous activity (Krauklis, 1957, 1958, 1959a, b, 1960a, b, 1962). Unfortunately, Bykov and Kurtsin, while elaborating a theory of corticovisceral pathology, in fact did not consider the importance of compensatory switching of inadequately strong activity from cerebral neural structures in the origin of disturbances of the internal organs.

Norkina (1955, 1961), in a visual study of motor conditioned reflexes in dogs and monkeys based on much material, distinguishes the following forms of compensatory reactions: 1) Unfavorable reactions or reactions opposite thereto, which are elaborated during experiments; 2) reactions to the environmental setting in the form of aggressive or orienting-investigative reactions; 3) self-reactions in the form of scratching, biting, searching, etc. In addition, motor reactions elaborated during ontogenesis are considered compensatory reactions.

Norkina considers that substitution of an elaborated conditioned reflex by other, different reactions takes place according to the principle of stimulus outflow over a pathway free from inhibition. The direction of stimulation is conditioned by the preparedness of nerve cells and reflex pathways for stimulation, in particular, by functional interconnections among cortical points (Norkina, 1961).

It must be mentioned that Norkina, like other authors who have described reactions of compensatory origin, does not attempt to expose the possible adaptive importance of the compensatory reactions. She does not raise the question of the possible elective conditioned reflex strengthening and consequent reproduction of the compensatory reactions which are advantageous for the correction of the regimen and level of nervous activity of the compensatory reactions. At the same time, experiments on animals show that compensatory reactions, if they repeatedly had exerted in the past a useful influence on the functioning of the brain, might be strengthened and reproduced by conditioned reflex in situations which are familiar in certain characteristics even when the functional state of the brain does not require prophylactic and compensatory switching of brain activity to effectors (see §8 and §9).

Kryazhev, Norkina and other authors who have described motor reactions of compensatory origin, have only considered somatic compensatory reactions. However, human life experience, clinical observation and experimental data (Krauklis, 1960a, b, and also the present work, Chapter 2, §5; Chapter 5, §5; Chapter 6, §4 and Chapter 7, §5) show that in man and in experimental animals there arise other, very often visceral, compensatory reactions (see §8).

PROBLEM OF THE FORMS OF PROPHYLACTIC AND COMPENSATORY EFFECTOR SWITCHING WHICH ENSURE THE MOST OPTIMAL REGIMEN OF NERVOUS ACTIVITY

§7. As already noted, the intensity of effector switching of brain activity is regulated by conditioned reflex intensification (in man, also voluntarily) or weakening of inhibitory controlling influences of a higher (for example, cortical) order over subcortical switching relays which determine the output of impulses to effector pathways.

However, in order for prophylactic switching to have a useful regulatory effect upon the regimen of nervous activity, it is necessary for conditioned reflexes to regulate not only the number of impulses switched but also the qualitative side of switching – the distribution of impulses along different somatic and visceral efferent pathways

Conditioned reflex regulation of effector integration of impulses, compensatorily switched to the periphery, must provide the following conditions for switching. Firstly, the result of prophylactic and compensatory switching, i.e., the corresponding effector reactions, must be adequate for the given situation in which the individual finds himself. If these themselves do not have a direct primary adaptive significance, then they must favor, or, at least, not hinder implementation of reactions which have primary significance.

Secondly, the reactions produced as the result of prophylactic switching must, in the process of fulfillment, generate also secondary conditioned and unconditioned stimuli which, by "feedback" to the brain, may promote intensification of those positive changes in the functional state of the brain that call forth prophylactic effector switching. This means that secondary stimulation (including secondary humoral effects) must favor an increase in the tone of higher cerebral regions, decrease of excessive stress to higher nervous activity, optimalization of the regimen and increase in the level of integration of the latter. If, on the contrary, the secondary influences which arise during the performance of the compensatory reactions produce even greater stress to higher nervous activity and further deviation of the regimen of nervous activity from optimum by requiring further strengthening of prophylactic switching of inadequate brain activity to the periphery and forming a "vicious circle;" then the conditioned reflex regulation of effector integration is inadequate and must be urgently reorganized by conditioned reflex regulatory influences of a higher order.

The pathways of impulse switching to different efferent neurons are determined by previously elaborated conditioned and unconditioned connections or by those currently elaborated by functional systems (stereotypes). Activation or inhibition of different stereotypes of neural connections (at different brain levels) is regulated by a functional system of higher order which dominates in the given situation, is localized in the cerebral cortex and integrates efferent and pre-efferent structures of different subcortical formations. The level of integration of effector impulses, i.e., the level of adaptive effectiveness which is conditioned by the latter, depends on the original functional state of the nervous system (in particular, on the tone of the cerebral cortex), on the life experience, education and habits of the individual, and also on the adaptive significance of the stimulus which acts on the nervous system and produces an excessive increase in brain activity and functional stress, and which must be removed by prophylactic and compensatory strengthening of impulses leaving the brain.

Below are presented examples from laboratory observations which illustrate the dependence of the qualitative nature of prophylactic effector switching on the above enumerated factors (Figs. 22-24, also Figs. 1-6, 14, 15, 19, 21).

§8. In the preceding section, we discussed the principal criteria which characterize adaptive effectiveness of prophylactic and compensatory effector switching. In this section will be presented data that exemplify these criteria.

First we present certain data and views by American authors who have studied the effect that discharging excessive neural energy through effector channels has on the psychic functions of man.

According to data from several authors, the most effective is discharge of marked neural tension via specific channels. Thus, for example, observations were made on persons who wished to advance at college who had to answer a number of questions concerned with their personalities. It appeared that those persons who gave precise, direct and open replies and, according to instructions, then pressed upon a contact lever, attained behavioral equilibrium factor than persons who tried to evade direct, open answers and who discharged their nervous energy into inadequate motor acts such as shivering, making a fist, sudden generalized motor reactions and so forth (Luria, 1932).

Arnold (1942) performed observations on typists who were improving their work under conditions of gradually increasing load. He established the interesting phenomenon: those persons who hit the keys of the machines more rapidly and harder fulfilled the task more effectively and tired less than those who "discharged" increasing stimulation through unnecessary movements of the feet, multiplying turning of the body, conversation, etc.

However, in certain cases, it might also be useful to discharge increasing stimulation through nonspecific effector channels. Thus, for example, different motor automatisms: involuntary contraction of muscles, leg movement, chewing of chewing gum, and so forth, promoted the carrying out of optimal, specific response reactions by the subject during application of electric stimulation by "discharging" excessively strong stimulation and, by this, promoted the general equilibration of the person during taking exams or during continued intellectual load (Hollingworth, 1939; Freeman, 1940; Freeman, Pathman, 1942).

Freeman notes that in instances where compensatory nonspecific reactions become too powerful, they begin to hinder the performance of specific reactions. Thus, for example, singing to oneself may favor the completion of intellectual work; however, if the person pays too much attention to this, then the quality of the work done may suffer.

With "discharge" of an increasing psychic stimulus one must preserve a "golden mean" by considering that, with too weak a discharge, a strong stimulus will persist undischarged, while too strong a discharge will favor the production of a still greater stimulus, i.e., self-stimulation of the nervous system.

Thus, Oldroyd (1942) showed that under conditions which require from the subject a very great mobilization of nervous energy, there arose in all subjects nonspecific, generalized emotional reactions; while under conditions which demand arousal reactions of moderate intensity, generalized emotional reactions are observed only in such subjects who "discharge" emotional tension either very weakly or very strongly.

The types of "discharge" in different people are different in nervous tension. In some, "discharge" takes place mainly through motor acts; in others, through verbal ones, i.e., the act of speaking; in still others, through ideomotor or even visceral reactions. Which of these types is most effective?

According to the data of Freeman (1948b), the majority of investigators consider that the most effective means of "discharge" and equilibration is the discharge of nervous energy through motor and verbal acts. If the latter are blocked, then "discharge" is accomplished via ideomotor reactions.

Sherrington (1938) considered that "discharge" through verbal acts lies in between musculoskeletal acts of behavior and thinking. Speech is the expression of partial inhibition of motor acts of behavior. Human activity in the outside world provides the greatest calm and rest, thought and fantasy the least. At the same time, the uncontrolled motor activity of man involves the greatest danger for him in the outside world and the least spiritual tension. Speech stands midway between external and spiritual activities in man.

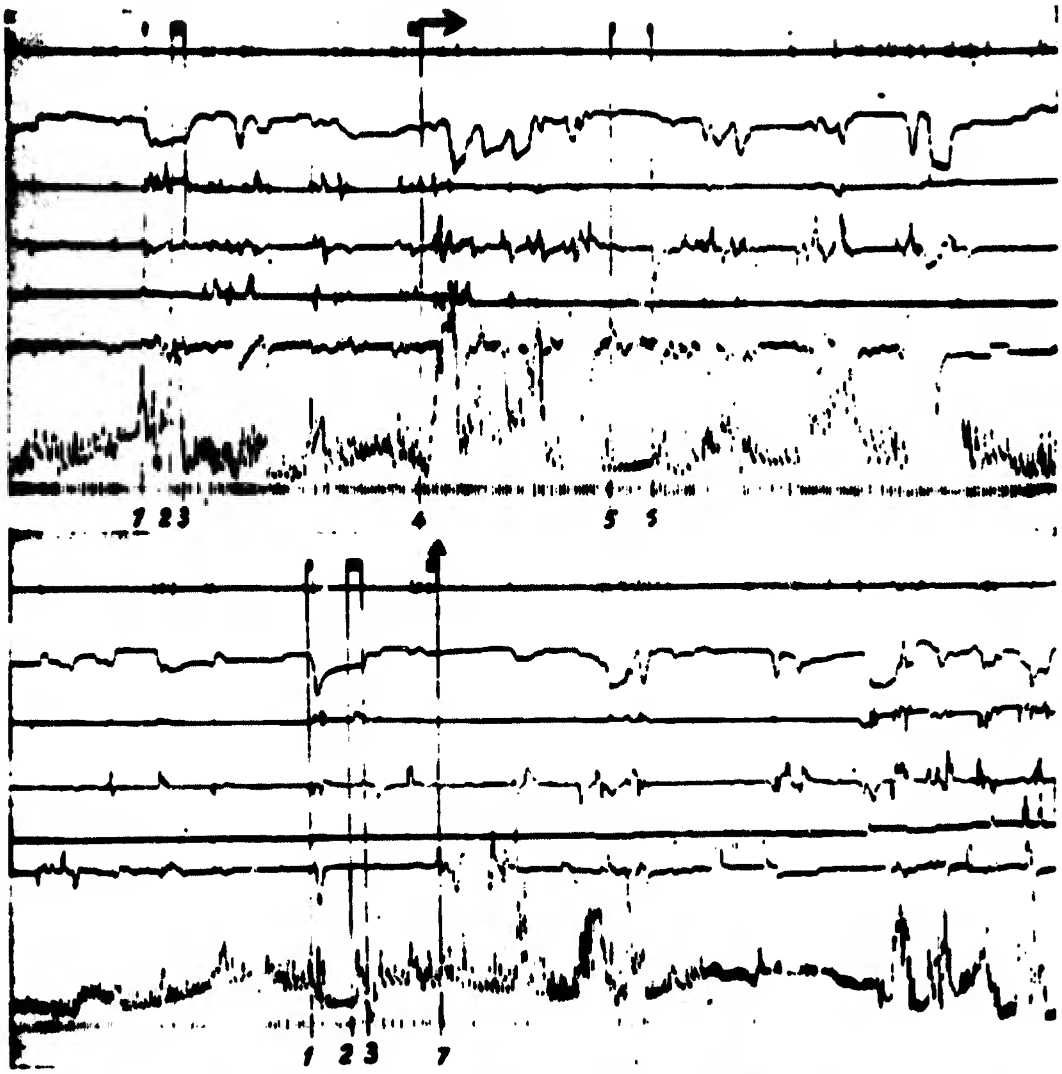

Fig. 22. Lack of usual markeu compensatory reactions under mechanical blockade to movement of hindlegs against a background of intramuscular adrenalin (3 ml 0.1%) injected into the dog Dzhul'bars. During blockade, motor and respiratory reactions, which are extremely vigorous in the original setting, are decreased, the animal, is as it were, externally quiet, however, the arterial pressure is raised. After deblockade the legs show increased motor irritability and respiration is significantly deeper and more rapid. 1) Conditioned signal; 2,3) electrodermal reinforcement of right hindleg (in dogs the defensive motor reactions are elaborated by the method of Bekhterev-Protopopov); 4) beginning of blockade to hindlegs; 5,6) beginning and end of differential signal; 7) cessation of blockade. Top to bottom: movement of lower jaw, head, right hindleg, sum of both forelegs and left hindleg; sphygmogram of carotid artery (which reflects a contraction of the neck muscles at the same time) with sharp drop in the amplitude during blockade and aftereffect; pneumogram.

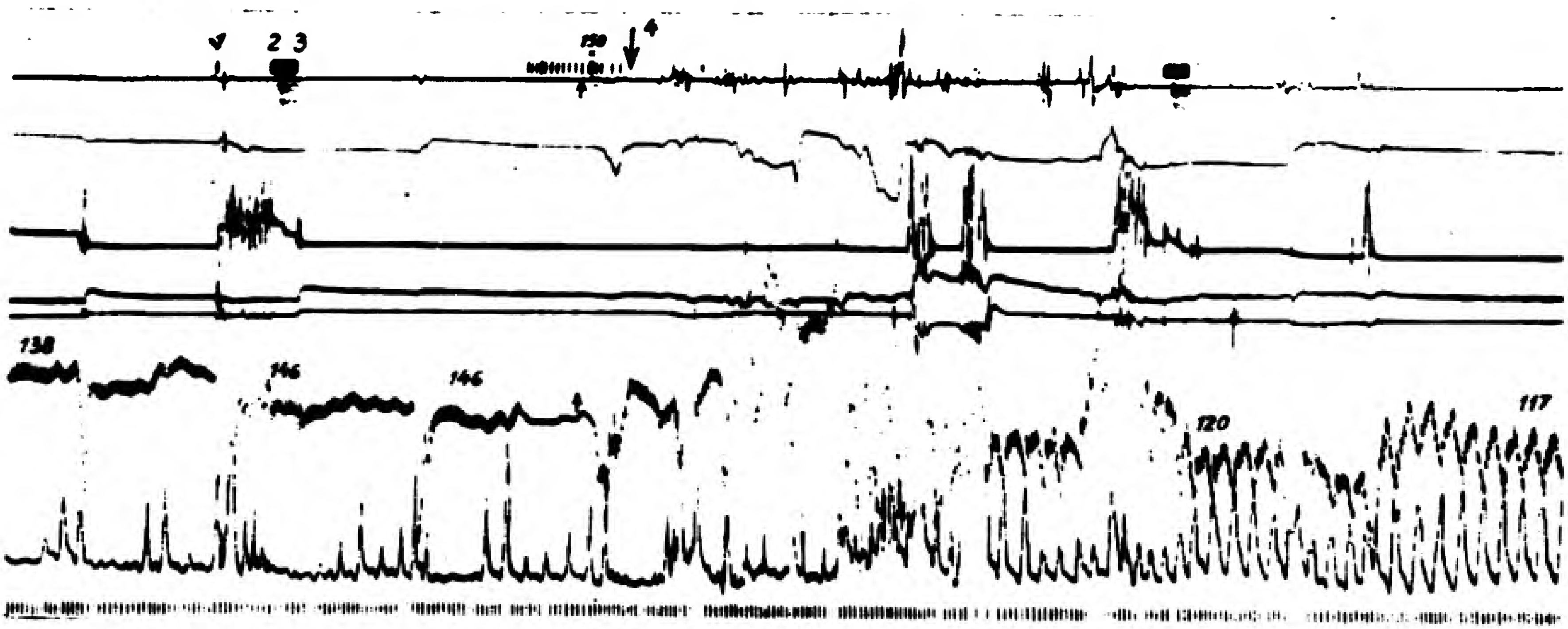

Fig. 23. Compensatory reactions at the start of an experimental increase in resistance to breathing (by decreasing the diameter of the aperture in a tube placed into the trachea of a tracheotomized animal) and the disappearance of compensatory reactions after accustoming the animal to a new respiratory regimen. Change in the respiratory regimen takes place against a background of general stimulation with the formation of the defensive motor conditioned reaction according to the method of Bachterev-Protopopov in the dog Pumna (experiment of Yu. Briyedis). 1) Conditioned signal; 2,3) electrodermal stimulation of the right hindleg; 4) start of increase in resistance to breathing. Top to bottom: markers for arterial pressure (see Fig. 16); movement of lower jaw and head, right hindleg, left hindleg and sum of forelegs; sphygmogram of carotid artery; pneumogram.

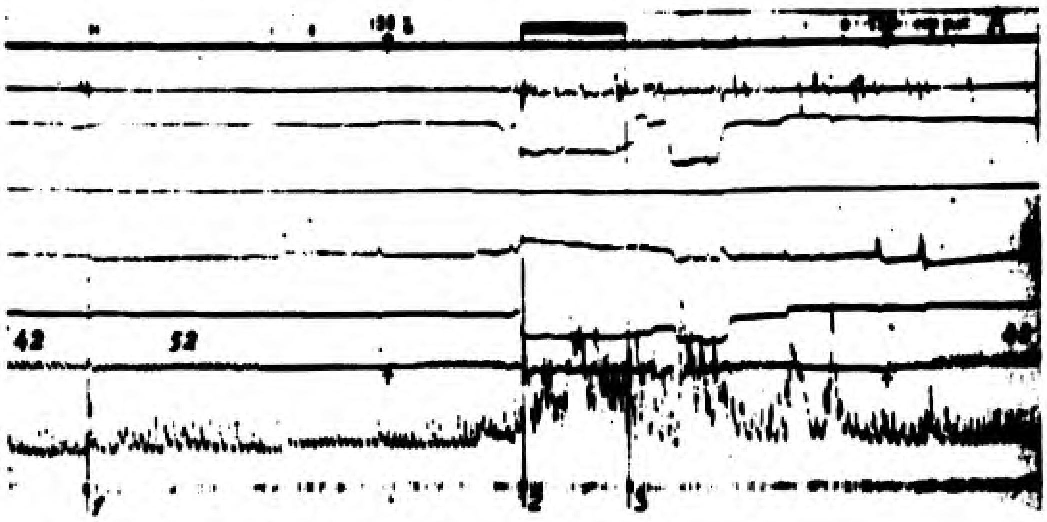

Fig. 24. Characteristics of compensatory reactions at the time when the conditioned signal is applied — demonstration of food in feeding trough — and during the period of aftereffect (following the eating of food and closing of the trough) during the formation of feeding motor conditioned reactions in the dog Dzhek (experiment of Yu. Briyedis and L. Rotsen). 1) Start of conditioned signa ; 2,3) feeding at trough and eating of food. Top to bottom: markers of arterial pressure (see Fig. 16); secretion of saliva; movement of lower jaw, head, forelegs and hindlegs; postural tonic contraction of hip joint muscles; sphygmogram of carotid artery; pneumogram. A) 150 mm Hg.

Freeman (1948a) summarizing his own observations, as well as the observations of other American authors, who have studied the behavior of human subjects by using psychophysiological testing, stresses the circumstance that the discharge of nervous energy in man by means of certain behavioral acts is subordinated to conscious control and may be, to a greater or lesser degree, completely slowed down. Limited discharge of nervous energy is manifested in specific behavioral acts and unlimited discharge in extensive, nonspecific acts. Both with excessive discharge and with its inhibition, there arises in man a marked contraction and tension in the skeletal musculature. Control over discharge of nervous energy, in the opinion of Freeman, plays an extremely important role in the maintenance of neuromuscular homeostasis of the individual both normally and in pathology.

On the basis of data from our observations, we consider that prophylactic and compensatory switching of inadequately strong brain activity to the periphery (and the compensatory reactions which arise therefrom) have adaptive significance in those instances when it firstly, in fact decreases the actual or imminently expected tension of neural activity and thus favors the organization of effector activity by the individual suitable to the occasion, and secondly, its external manifestation (as a compensatory reaction) does not contradict the actual or anticipated situationand does not impede the performance of such effector reactions which have been produced with the aim of ensuring the primary adaptive effect.

Examples of compensatory reactions which arise during laboratory observations on experimental animals and human subjects were given in the preceding sections of this chapter. Here we will present an example from daily life.

Let us imagine that in a certain business a production meeting is taking place that is notable for the number of heated arguments among those attending, so many that these quarrels produce in some of them, for example in N., an extremely strong intellectuo-emotional stress. The urgent prophylactic switching of cerebral activity to the periphery which is mobilized by N.'s nervous system in order to decrease the stress may have extremely varied results, depending on the actual form of expression of the prophylactic switching.

The most useful adaptive effects (secondary and primary) evidently will be attained when the prophylactic effector switching is manifested in vigorous, outspoken and, possibly, extremely spirited but sufficiently businesslike and tactful approaches to N's comrades, to elucidate and defend his point of view in the questions being argued.

Less effective would be another variant of "discharging" excessive stimulation. Let us suppose, for example, that N., not being capable of "repressing" the rising emotional tension, and at the same time not possessing the courage to address the meeting openly, leaves the meeting and tries to "discharge" the "stagnant" stimulation either by taking a walk in the fresh air or by physical exercise at work or sports, etc. Such a means of prophylactic and compensatory effector switching will be effective (relative to equilibration of nervous activity) only if the individual manages to depress and extinguish effectively that dominant system of nervous activity formed during the stormy conference and if he continues to sustain and generate totally new biologically and physically negative emotional stimulation. If N. cannot manage to extinguish this negative dominant and to substitute another positive dominant for it, all attempts at self deliverance from unpleasant nervous tension or overstrain by "escape" from a nociceptive situation or by physical exercise may be ineffective and N. can only be advised to return to his comrades at the production meeting and attempt to "discharge" his excess and inert stimulation by more adequate means.

Even less effective is the variant of prophylactic switching in which a person tries to "discharge" his emotions in fantasy consciously, whereas the emotional tension rising all during the meeting goes in compensation to the skeletal musculature and internal organs, producing in lieu of adequate behavioral and verbal reactions, a continued muscular and, possibly, arterial hypertension, increase in inspiratory tone, weakening of respiratory excursion, quickening of pulse, etc. The result of such inadequate compensatory switching of excessively strong cerebral activity may be extremely bad: a subsequent increase in general stimulation and nervous tension, further increase in the unfavorable variants of effector switching, still greater increase in general stimulation (as the result of excessively strong flow to the brain of afferent impulses inadequate in quantity and origin and of stimulatory humoral agents, etc.), i.e., the formation of a "vicious circle."

There is another variant of inadequate prophylactic switching of excessive emotional stimulation, as when the individual N., attempting as much as possible to "discharge" the stimulation faster and more effectively, begins to shout, swear, threaten and accuse those present, etc. As the result of such antisocial behavior, even greater tension pervades the psychological atmosphere, further "increasing the furor" among those present, which may promote to an even greater degree the nervous tension in N. and create the conditions for much unpleasantness in the future. However, the most serious consequence of such not only tactless but also antisocial behavior in N. is further building of tension of nervous acitivity in the other persons, "compensatory switching" of his unpleasant stimulation and tension to the people around him.

It should be noted that some questions related to the factors under consideration which determine the adequacy and adaptive efficacy of prophylactic and compensatory effector switching will be clarified in the subsequent chapters of this book.

SUGGESTED NEURAL MECHANISMS OF CONDITIONED REFLEX CONSOLIDATION AND REPRODUCTION OF COMPENSATORY REACTIONS

§9. Frequently, in similar situations and with similar deviations of the regimen of higher nervous activity away from optimum there arise more or less similar compensatory reactions. The latter represent the reproduction of previously elaborated stereotypes of effector reactions in the organism.

The question is: by which neural mechanisms is determined the disinhibition of different stereotypes of effector reactions in a given situation?

Based on our observations and by studying the rich experimental material from the I.P. Pavlov school, in particular, data obtained in the laboratory of Kupalov (Krauklis, 1960a), we propose the existence of the following mechanism for the origin of compensatory reactions.

If one starts from the premise that any more or less intense effector reaction is connected with a decrease in the intensity and stress of nervous activity within the functional systems of the brain that organize these reactions, then it must be recognized that any effector reaction is capable of being accompanied by a biologically useful secondary effect if it is accomplished against the background of inadequately strong stress of cerebral function.

In the brain different stereotypes of conditioned connections which reflect stereotypes of temporally coincident or sequential stimulation of the nervous system are continually being formed and extinguished. The formation within the brain of a stereotype of conditioned connections which reflect the sequence and temporal coincidence of the following events in the external or internal milieu of the organism, including the events taking place in the brain, should be assumed: 1) stopping the stimulation; 2) stimulation or functional changes which provide inadequately strong stress to brain function; 3) stimulation or changes arising in effector reactions; 4) stimulation or changes which cause a decrease in the tension of cerebral function as the result of increased effector switching of brain activity to effectors.

Since the latter, the final link in the stereotype, has a useful effect on the functional state of the brain, it acquires the importance of reinforcing in relation to the subsequent links (kupalov, 1947, 1949, 1952, 1955). As a result the first two links in the stereotype may reproduce by a conditioned reflex pathway the effector reactions, i.e., effector switching which accompanies the decrease in tension of the corresponding functional systems in the brain.

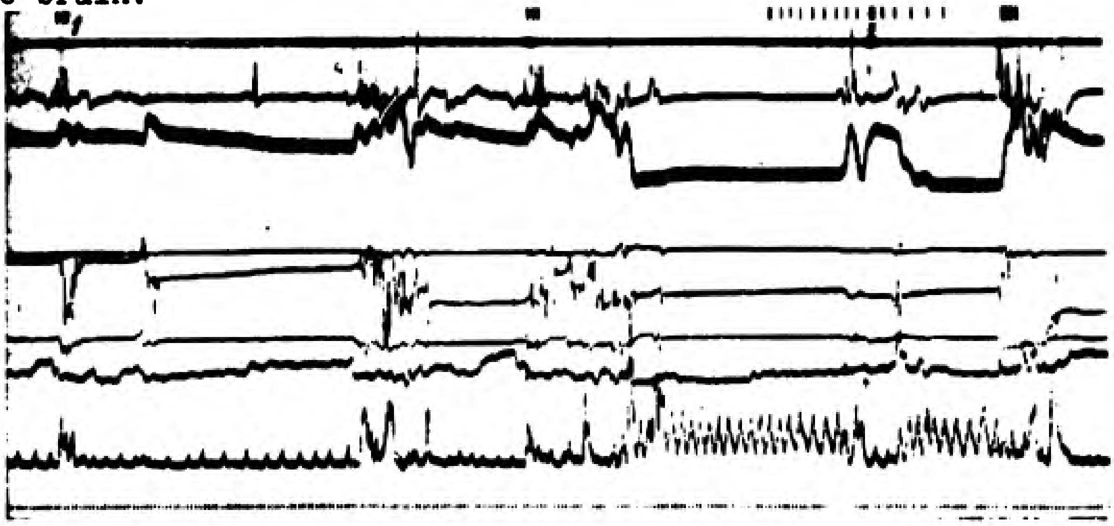

Fig. 25. Origin of compensatory reactions as aftereffects, reactions to a situation (see increase in the second half of the Figure), and reactions over time (in the last third of the interval between stimuli) in the process of forming defensive motor conditioned reactions per time in the dog Bonza. 1) Application of electrodermal stimulus to right hindleg at 2-minute intervals. Top to bottom: salivation; movement of lower jaw, head, sum of forelegs,right hindleg and sum of both hindlegs; sphygmogram of carotid artery, pneumogram.

It is known that with preparation of the animal or human subject to perform some motor act, there arises a conditioned reflex preliminary activation of such effector pathways and effectors which will implement this motor act (Freeman, 1939; Mourer et al., 1940; Shaw, 1940; Bassin, 1946; Yusevich, 1954; Kratin, 1955; Bassin, Serkova, 1956; Bassin, Beyin, 1957; Krychowa, Steinhart, 1960).

In the same way, effector pathways and effectors may be activated by conditioned reflexes and prepared for performance of probable subsequent prophylactic switching of inadequately strong cerebral activity to the periphery. This takes place in situations where the situational stimulus signals the probable evocation of an inadequate increase in the intensity and stress of brain activity in the immediate future, by providing coincident preparation of effector pathways for the forthcoming massive prophylactic switching.

As cerebral activity increases under the influence of available, biologically strong conditioned and nonconditioned stimuli, the actual switching of brain activity along previously prepared effector pathways is initiated and intensified (Figs. 25-27, also Fig. 17).

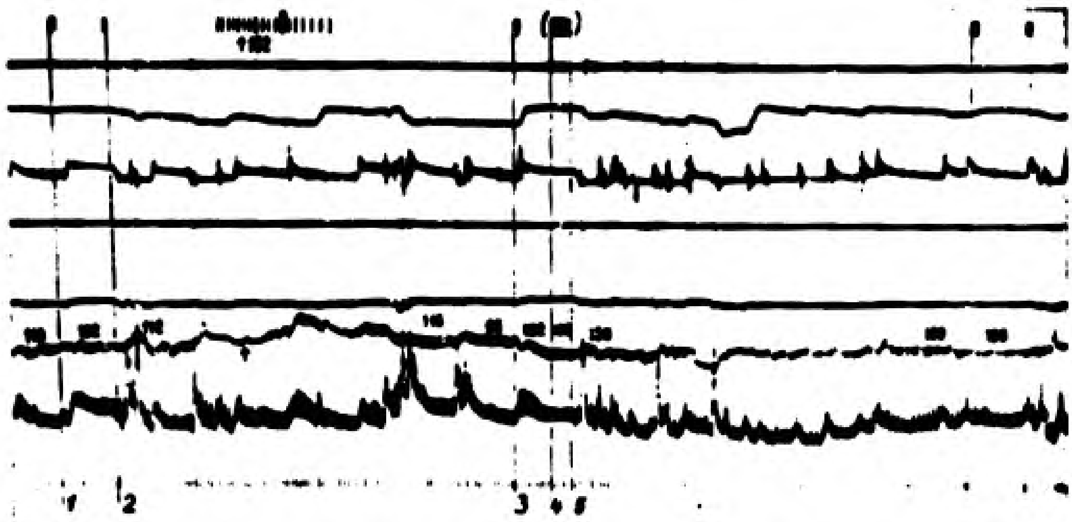

Fig. 26. Origin of compensatory reactions as reactions to situation and time during the formation of the defensive motor conditioned reactions according to the method of Petropavlovskiy in the dog Dzhul'bars. In the interval prior to application of the usual positive conditioned signal the compensatory switching of nervous activity to peripheral effectors — the respiratory apparatus and the cardiovascular system — is more strongly expressed than in the interval prior to the expected differential signal. 1,2) Start and finish of the differential signal; 3) positive conditioned signal; 4,5) place for blank signal, in the given case, electrodermal stimulus to right hind leg. Top to bottom: markers for arterial pressure (see Fig. 16), movement of lower jaw, head, right hindleg, forelegs and left hindleg; sphygmogram of carotid artery (numbers designate pulse rate); pneumogram.

As an example in which the actual or expected excess tension or overexertion of nervous activity may act as the conditioned signal which reproduces the prophylactic switching of cerebral activity to the periphery and which correlates the compensatory reactions may serve the figures presented above [1, 6, 17 (3,4), 21 (1), 26 as well as 50-60 (see Chapter 5)].

The following observations also may serve as illustrations which confirm the existence of the mechanism described for compensatory reactions.

Experimental animals (white rats) were timed in an experimental setting - chambers A and B which connected through the opening V (Fig. 28).

In the small chamber A, feeding conditioned reflexes were elaborated. Rationed portions of meat or bread, given through one of two glass (i.e., transparent) feeding troughs (see Fig. 28k) served as reinforcement. The tick of a metronome served as the conditioned signal (80 or 120 strokes) which indicated that food was placed into the trough (1 or 2). A metronome set at 100 served as

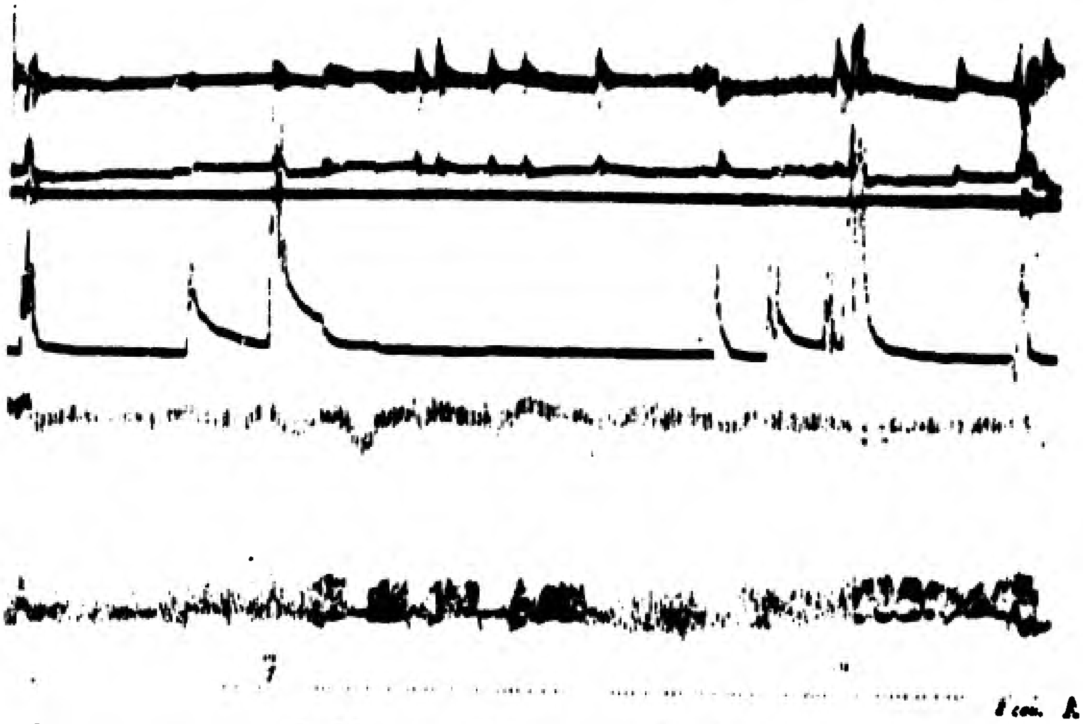

Fig. 27. Origin of compensatory reactions as aftereffects and situational reactions during formation of defensive motor reactions per time in the dog Moris (experiment by Dzh. Liyepa). In the first half of the interval between stimuli the impulses of nervous activity go out mainly to nonspecific effectors (we see tachypnea, tachycardia and repetitious head lifting). In the second half of the interval, as a result of conditioned reflex intensification of cortical tone and the level of effector integration the respiratory rhythm is optimalized and specific somatic effectors are activated (we see flexion of stimulated limbs). 1) Electrodermal stimulation of right hindleg. Top to bottom: movement of head, neck, sum of forelegs and right hindleg; sphygmogram of carotid artery, pneumogram. A) 2 sec.

the differential, not reinforced by food. The animals did not receive food after mistakes in running (the glass lid did not open).

With the beginning of a "work state" in the nervous system of the animal, as the result of overstrain of internal inhibition produced by alteration of the signal meaning of the conditioned signals, there arose in some rats a vigorous locomotor reaction; the rat ran from one trough to the other and also ran chaotically around chamber A. But since the chamber was very narrow, the running was extremely limited. As a result, some rats began "spontaneously" to run through the opening V to the larger chamber B and there continued chaotic running in all directions. Other rats, under similar difficult states of the nervous system remained in chamber A, frequently making extremely vigorous or sometimes wild self-reactions – washing motions, scratching, gnawing. These self-reactions sometimes occurred also in the rats which ran into chamber B but, however, were less marked and less prolonged. Running into chamber B was frequently observed in those experiments where the feeding conditioned reflex was elaborated against a background of relatively continuous sound stimulation – an electric bell (the noise level in chamber B was somewhat greater than in chamber A which favored the overstimulation and overstrain of the animal brain.

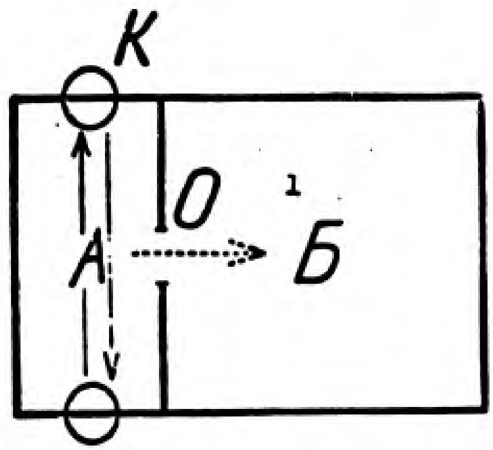

Fig. 28. Direction of compensatory motor reaction – running by the experimental animal from chamber A to chamber B with critical reinforcement of the stress of internal inhibition. For explanation, see text. 1) B.

In cases where an electric current was gradually switched on in the floor of chamber B and the rats which showed a tendency, by this time, to run into chamber B were "obliged" to remain in chamber A under difficult conditions, there were observed in the animals either extremely wild and prolonged self-reactions (most frequently washing motions) or the animals froze into one position, or ran into the corner of chamber A, etc.

Similar experiments on dogs (in an experimental room in which a small chamber was located) showed similar results in principle.

The experiments which have been described, from our viewpoint conclusively demonstrate that a deviation in the function of the brain away from optimum may serve as a signal which reproduces elaborated and ontogenically reinforced generalized motor stereotypes – locomotor reactions which permit a large number of impulses to be switched from the brain to the periphery and effectively decrease the tension of the nervous processes in the brain. It is interesting to note that the rats which ran into chamber B after difficulty differentiated conditioned signals and which continued much running about in there (sometimes in an investigative reaction) usually returned to chamber A after 1, 2, 3 minutes and continued to react to the stimuli applied by the experimenter.

CHAPTER 3

SELF-REGULATION OF HIGHER NERVOUS ACTIVITY THROUGH THE ESTABLISHMENT OF A REGIME OF AFFERENT INFLOW

(second type of self-regulation)

POSSIBLE MECHANISMS OF CONDITIONED REFLEX CONTROL OF AFFERENTATION

§1. As shown in the preceding chapter, the first type of self-regulation of higher nervous activity – the establishment of a regime of effective switching – induces various secondary effects which often counteract each other, thus limiting the possibility of maintaining with the aid of this type of self-regulation a stable optimum regime and a high level of higher nervous activity.

Much greater possibilities for the establishment of an optimum regime and high integration level of higher nervous activity is provided by the second type of self-regulation – through a change in the amount and quality of afferent impulses and humoral agents, the latter incoming through the blood and entering the brain. The important factor under these conditions is that, via regulation of the regime of afferent inflow, it is possible to secondarily influence the regime of effector flow, thus ensuring an activity level of the closed systems, which renders superfluous an excessively massive prophylactic switching of cerebral activity to the periphery.

Whereas the first type of self-regulation of neural activity is mobilized mainly for a compensatory balancing of those shifts of cerebral functions, which have been actually induced or are being induced by the preceding or present stimuli, the second type of self-regulation is mobilized chiefly for the purpose of extrapolating the functional state of the nervous system in the future, i.e., preparing it for the effective processing of the expected (forthcoming) stimuli.

The conditioned reflex setting up of an afferent inflow, adequate for a given situation (including the functional state of the brain), is realized by the following basic neural mechanisms:

1. Cortical (corticofugal) and subcortical (presumably, mainly reticular) control of transmission of afferent impulses through the central nervous system;

2. similar control of the activity level (excitation threshold) of the receptor organs;

3. cortical control of intracentral coordination, i.e., functional relations or mutual interactions between the neural cerebral structures;

4. reproduction of somatic (ideomotor, sensomotor, speech, motor, and postural tonic) and visceral effector reactions, which generate in the process of their realization afferent impulses and humoral agents, which secondarily act on the brain and correct the regime and level of higher nervous activity.

All these mechanisms, mutually interacting, organize the reception, the afferent inflow and intracentral coordination (for instance, the tonic influences of subcortical formations on the cerebral cortex), thus regulating the regime and integration level of higher nervous activity.

The fact that the fourth of above cited mechanisms is subordinated within a wide range to man's will, and can be voluntarily utilized for the purpose of regulating the nervous activity, including the psychic one, imparts to this mechanism and exceptionally important role in the process of conscious perfecting of his nervous activity by man – in personality training, ensuring personal psychic hygiene, and preventing the disturbances of higher nervous activity (cf. Chapter 8).

In this connection, the present chapter is devoted to an analysis of various facets of this mechanism of self-regulation of higher nervous activity – a mechanism which ensures a multiform, very delicately differentiated, local or generalized regulating effect on the cerebral functions.

The regulating (i.e., secondary adaptation) effect of the somatic and visceral reactions of the organism is conditioned by:

1. A change in the conditions of generation of afferent impulses in the receptors forming the basis of the acting effectors, as well as in the receptors of other parts of the body, participating in the effector reactions of the organism;

2. changes of secretion in the effectors of biologically active substances which affect the nervous system through the blood;

3. changes in the environmental effect on the organism, as a result of the behavior activity of the animal or man, directed toward a modification or reorganization (by man) of the environmental conditions.

The widest, more accurately, the exhaustive possibilities for man to influence his nervous system, his psychic activity and personality, is provided by work, as well as by any other social human activity, directed toward creative transformation of the conditions of human activity, directed toward creative transformation of the conditions of human existence within his community and within nature, and producing a mutual effect of these conditions on man. Man transforms his environments, and these in their turn transform man, and so forth.

However, also through changes of the functional state of the internal medium of the organism can man effectively influence the functioning of his nervous system and his higher nervous activity. Precisely this variant of self-regulation of nervous activity is discussed in this chapter.

Since we are interested first of all in those self-regulation mechanisms which ensure the voluntary regulation by man of his nervous activity and which represent the physiological basis of personal hygiene of the higher nervous, i.e., psychic activity, we shall limit our analysis to a discussion of the manifestations of effector activity, which are connected with the participation in it of somatic effectors, as well as the respiratory apparatus, the latter representing simultaneously a somatic and visceral effector.

Any of the aforementioned variants of secondary influences, which originate as a result of the effector activity of animals and man, act "inversely" on the nervous system, either mainly as unconditioned stimuli or mainly as conditioned signals, or in equal measure as both types.

An afferent influx, induced by unconditioned stimuli alters on one hand the intracentral coordination of the entire brain, especially its higher sections (for instance, the tonic effect of the reticular formation of the brain stem and diencephalon on the cerebral cortex and on other parts of the brain) and, on the other hand, the functional state of neural structures of the brain stem and spinal cord, which regulate the centripetal conduction of afferent impulses; as a result, a selective facilitation takes place of the transmission of impulses of one origin and inhibition of transmission of impulses of the other origin, or of all other origins.

An afferent influx, induced by conditioned stimuli, alters the functioning of the brain, in the first place, because it carries information concerning the course of effector activity of the organism and is thus responsible for the correction, reorganization, approval or cessation of the current effector activity (Anokhin, 1949, 1955, 1958) and, secondly, because it (i.e., the afferent influx) signalizes different stimuli and induces through the conditioned reflexes corresponding changes in the functional state of the brain, even prior to the genesis of expected stimuli.

The signaling significance of afferent impulses, which originate secondarily during the effector reactions of the organism, and the role of such secondary signal impulses in the self-regulation of higher nervous activity are discussed in the fourth chapter of the book.

In the present chapter the possible participation is discussed of the unconditioned reflex mechanisms of the afferent inflow, induced by the somatic and respiratory reactions of the organism, in the self-regulation of higher nervous activity.

REGULATION OF THE PROPRIOCEPTIVE INFLOW BY MEANS OF GAMMA EFFERENTATION

§2. Physiology established the exceptionally important role of skeletal musculature as a powerful source of highly differentiated and voluntarily man-regulated proprioceptive afferentation, capable of changing within a wide range the functional state of the brain.

It was found that various types of sensory stimuli, in their capacity of inducing an excitation reaction, are arranged in the following order: Pain, proprioceptive, aural, visual, etc. (Gellhorn, 1952; Bernhaut, Gellhorn, Rassmussen, 1953). It can be seen that the proprioceptive inflow is most important in setting the tonus of the cerebral cortex.

Besides, a strong proprioceptive inflow is capable within a wide range to reorganize the intracentral coordination in the brain stem, by facilitating or inhibiting the transmission in the centripetal direction of the afferent impulses of other origin.

The generating regime of proprioceptive impulsation is under a constant controlling influence of the higher sections of the brain, which extensively utilize the proprioceptive inflow for the purpose of self-regulation of higher nervous activity. The higher regulatory influences, including the conditioned reflex and voluntary influences (in man), are capable of a very fine differentiation in altering the generating regime of proprioceptive impulses by means of:

1. Closed contraction and tension, or relaxation, of strictly defined muscular groups of the body, thus inducing a dosed deformation, i.e., stimulation of muscular spindles and tensoreceptors of the tendons;

2. reflex changes of the background contraction and tension of the intrafusal fibers (i.e., muscle elements) and spindles on the part of the reticular formation and cerebral cortex.

The experience of human work activity shows that man is able to consciously exercise and perfect his "muscular sense" and, thus, exert a differentiated control of his muscular activity. For instance, a pianist, prior to playing, or an athlete before starting, is able by means of psychic influences (developed in the process of training) to establish an optimum activity level of the proprioceptors and central analyzers of proprioreception. As a result, he can more accurately control and correct the functional state of the musculature of movement and posture, as well as realize the most effective and more precisely coordinated contraction, stretching, tension and relaxation of the corresponding muscular groups.

Investigations of the past 15—20 years elicited the mechanisms of the so-called gamma efferentation, which ensures a reflex control of the functional state of muscle spindles and, thus, of the conditions of origin of proprioceptive impulsation (Matthews, 1931, 1933; Lexell, 1945, Hunt, Kuffler, 1951; Granit, Kaada, 1952; Eldred, Granit, Merton, 1953; Granit, 1955; Wagner, 1954, et al.).

It was found that during the state of relative rest of skeletal musculature, the length and tension of intrafusal fibers of the muscular spindles are adjusted to the length of the resting muscles in such a way as to stabilize the rate of proprioceptive discharges, and in a reflex manner (through the spinal cord) – the rate of discharges of gamma-motoneurons.

Active muscular contraction leads to the relaxation of muscle spindles and reduction of the extent of deformation of receptor elements, thus causing a decrease or cessation of discharges of the latter. As a result of reduced proprioceptivity of impulsation, there takes place reflexively – through the spinal cord – an activation of the gamma-motoneurons, which leads to the contraction and tension of the intrafusal muscle fibers and, hence, to the increase of deformation of receptor elements and increase of the rate of proprioceptive discharges, essential to the maintenance and coordination of activity of the alpha-motoneurons.

The greater the contraction of the muscles, the less is the compensatory contraction of intrafusal fibers capable of maintaining an intensive regeneration of proprioceptive impulsation in the spindle.

The passive longitudinal stretching of hitherto relaxed muscles (induced, for example, as a result of the reflex contraction of the antagonist muscles), represents a powerful stimulus which causes a marked tension of the spindles and, hence, a protracted increase of the rate of proprioceptive discharges. As a result, there originates reflexively the inhibition of gamma-motoneurons which leads to a compensatory relaxation of the intrafusal fibers of the spindle.

In the final count, there originates a relative stabilization of the regime of functioning of the entire system, and a level is established of the activity of receptor elements of the spindle, which ensures optimum conditions for subsequent contraction of the stretched muscle, as well as for the coordination of the performance of agonist muscles and antagonists muscles.

It has been elicited that the higher regulation of gamma-efferents, similarly to the suprasegmentary regulation of alpha-motoneurons, is realized by the neural structures of the tectum of mesencephalon along two pathways:

1) A fast conducting pathway which ensures gamma regulation during rapid movements, and 2) a low-conducting one which ensures gamma regulation during postural tonic muscular contractions.

Thus, reticular formation of the brain stem regulates not only the discharges of alpha-motoneurons which ensure postural tonic and phasic contractions of skeletal musculature but also the discharges of gamma-motoneurons and receptor elements of the muscle spindles.

Since the structures of reticular formation, thanks to the existence of double feedbacks, are under the control of the cerebral cortex, the brain is able to establish, via conditioned reflexes through the brain, a level of proprioceptive inflow which is needed for the maintenance of an optimal regime and a high level of higher nervous integration.

Hence, the higher cerebral sections are capable of exerting a facilitating or inhibiting effect on the activity of skeletal musculature by raising the activity of gamma-motoneurons and, hence, also of receptor elements of the spindles, and reflectorily - through the spinal cord - of alpha-motoneurons, or, by raising the activity level of the entire above mentioned closed functional system, to exert a "calming" effect on the skeletal musculature.

Man is able, following special training, to voluntary reduce the initial tonic tension of the skeletal musculature. The electrogenesis of these relaxed muscles is characterized by frequent low amplitude oscillations of the potential, taking place on the electromyograms of the state of "rest" and reflecting an asynchronous excitation of the small number of motoneurons and muscle fibers (Yusevich, 1963).

Yusevich (1963) emphasizes the point that in the organization of the initial tonus of the state of "rest" of skeletal musculature, cortical influences play a large part.

Besides the muscular spindles, of great importance in the genesis of a proprioceptive inflow into the brain are the proprioor, tensoreceptors of the tendons, the so-called Golgi apparatus. Stimulation of the latter, through stretching or contraction of the muscle induces a reflex inhibition of alpha-motoneurons of the homonymous muscle and its synergists and an excitation of the motoneurons of the antagonist muscles (Granit, 1950). The threshold of tensoreceptors is higher than that of muscle receptors (spindles).

The primary function of tensoreceptors consists of reflex inhibition, i.e., limitation of excessively strong contractions of the skeletal muscles. However, within certain limits, an increase in the degree of elongation of a tendon, increase the number of activated tensoreceptors and thus intensifies the reflex muscular contractions (Liddell, Sherrington, quoted from Wagner, 1954).

The secondary function of tensoreception is participation in the self-regulation of neural activity of animals and man.

One is well familiar with the strong stimulating effect of dynamic and static (postural-tonic) muscular exercises, connected with the marked passive elongation of antagonist muscles and their tendons, as a result of the strong isotonic contraction of agonist muscles, or passive flexion or extension of the corresponding joints (cf. §6).

REGULATION OF THE PROPRIOCEPTIVE INFLOW BY MEANS OF TENSION OF SKELETAL MUSCULATURE

§3. The exceptional role of skeletal musculature as a source of secondary influences which regulate the functional state of the brain is based on the fact that any more or less pronounced changes in the psychic activity of man are accompanied by changes in his muscular activity.

The genesis or intensification has been proved of electric activity of the skeletal musculature in the so-called ideomotor reactions of man, i.e., in "inner" speech or in speaking "to oneself," mental realization of movements, mental preparation to an actual execution of a given act, etc. (Allers, Scheminskiy, 1926; Jackobson, 1930, 1938; Shaw, 1938, 1940; Bassin, 1946; Yusevich, 1934, 1963; Kratin, 1955; Bassin, Serova, 1956; Faaborg-Andersen, Edfeldt, 1958; German, Krulikovskaya, 1960; Krychova, Steinhart, 1960, et al.).

It was found that when man is engaged in intellectual activity, there appears or increases an electric activity, as well as local and generalized contraction and tension in the skeletal musculature. Activation of the musculature increases if mental tension is accompanied by emotional tension (Freeman, 1930, 1931, 1938a, b, c, 1939, 1948a, b; Duffy, 1932, 1946; Jackobson, 1932, 1938, 1943; Hathaway, 1935; Clites, 1935, 1937; Ghiselli, 1936; Davis, 1937, 1938, 1939, 1940; Grinstead, 1939; Daniel, 1939; Freeman, Sharp, 1941; Rusch, Finesinger, 1943; Lundervold, 1952; Eiff et al.,1952, 1956; Berry, Davis, 1958; Meyer, 1958; Malmo, 1958; Serra, Covello, 1959; et al.).

A particularly pronounced postural tonic contraction and tension of skeletal musculature is observed during a strong emotional stress induced by conflicting situations, or the so-called "stress situations" (Jackobson, 1926, 1932, 1938; Freeman, 1939a, b, 1945).

It should be assumed that the activation of skeletal musculature in above mentioned cases is caused by the direct participation of skeletal musculature in the mental and emotional activity of man, including also self-regulation of the latter. Intensified muscular activity is an expression of a timely preparation of the effector pathways to specialized reactions and to the possible preventive effector switching, as well as an expression of compensatory regeneration of the afferent inflow.

It is a known fact that for the realization of specialized motor acts, there is needed not only a corresponding "trigger" afferentation which directly induces the motor act, but also a certain amount of "extra-trigger" afferentation which ensures an adequate general level of cerebral activity, as well as an activity level of the neural structures which realize the motor act.

If it proves impossible to mobilize the needed amount of extra trigger activity in the corresponding receptor zones, one can generate it compensatorily in other, substituting zones. In the absence of a needed amount of extra trigger afferentation, the animal substitutes within the compensation frame the given form of motor activity with another form (Anokhin, 1949; Beritov, 1957).

Local or generalized contraction and tension of the skeletal musculature represents a powerful source of this type of extra trigger or background afferentation, which maintains (through the reticular system of the brain stem) the tonus of the higher cerebral sections.

In the opinion of Freeman (1948a, b), the postural tonic contraction of body musculature, effected through the extrapyramidal system, ensures the economic background proprioceptive impulsation which is needed for the realization of manifested phasic reactions through the pyramidal system. An economic tonic contraction facilitates the realization of strong and protracted physical contractions, which are less economic, i.e., require a relatively high level of metabolism (Freeman, 1948a, b; Kuffler, Hunt, Quilliam, 1951, Zhukov, 1956).

Proprioceptive afferentation induced by a tonic contraction and tension of the musculature, is able to render more precise and modify the exteroceptive afferentation. Depending on the intensity and duration of tonic contraction, as well as on the intervals between contractions, muscular activity variously affects the higher cerebral sections.

It has been established that a preliminary voluntary tension of muscles which execute the forthcoming motor act, contribute to a precise and effective execution of the latter, and they accomplish it to a greater measure than the preliminary tension of muscles which have no direct relationship to this particular movement (Peak, 1931; Freeman, 1931; Daniel, 1939; Davis, 1939, 1942).

The effectiveness of specialized mental and physical exercises increases in the presence of an optimal background of tension of skeletal muscles, as for instance antigravitation muscles. The absence of an adequate background tension, as well as the presence of an excessively strong tension, reduces the effectiveness of the specialized reactions (Freeman, 1948a).

The facilitating effect of muscular tension on the performed specialized movement depends on many factors - for instance, on the localization, intensity and duration of tension, etc. (Sharp, 1941).

An increased complexity of the performed assignment leads to the increase of individual variability of the nonspecific muscular tension. For instance, it has been established that, upon dosed elementary mental and physical exercise on a typewriter, an approximately uniform tension of skeletal musculature was observed in all tested individuals, whereas during the solution of a given abstract, intellectual problem, the muscular tension manifested an extremely individual variability (Freeman, 1948b).

In the opinion of American psychophysiologists, muscular tension "energizes" the nervous system by contributing to sensory discrimination and differentiation of stimulation (Morgan, 1916; Freeman, Lindley, 1931; Freeman, 1932; Poffenberger, 1938; Seashore, Koch, 1938; Davis, 1940 et al.). Therefore, muscular tension is mobilized in every case when, despite fatigue and the stress state of the nervous system, man is in need of a precise differentiation of stimuli. The greater the fatigue and mental and physical load, the stronger and more generalized is the muscular tension. Muscular tension is capable of compensating the overfatigue caused by insomnia and prolonged work.

It is assumed that excessive muscular tension might be responsible for the fact that some individuals accomplish their work in a noisy and restless environment more effectively than under quiet conditions.

Hence, muscular tension may serve as a compensatory intensifier of current dominants, if they are fatigued.

It has been established that the effectiveness of work carried out by man after a 4-hour rest, often does not differ from the effectiveness of work carried out after an 8-hour rest. However, in the first case, a considerably more pronounced background tension of skeletal musculature is observed.

The energizing and tonic effect of intensified proprioceptive impulsation on the nervous centers (obviously, through the reticular formation of the brain stem) is taking place also in cases of the so-called "active rest," described by Sechenov (1891), when the work of muscles of one hand contributes to the effective rest of the muscles of the other hand, etc. Davis (1940) thinks that background muscular tension, originating when man is studying one scientific subject, may facilitate the simultaneous study of an additional subject.

Very detailed studies have been devoted to the problem concerning the influence of a voluntary dosed contraction and tension of skeletal musculature on the effectiveness of the performance of various mental tasks, such as solving a mathematical problem, memorizing words, or syllables unconnected as to their meaning, etc. Unfortunately, the data of various authors are difficult to compare, and are quite often contradictory.

It has been firmly established that, within certain limits (nonuniform in various tested individuals, and at different assignments), muscular tension may contribute to an effective execution of the task, whereas excessively strong or prolonged tension often nullifies this positive effect, or even hinder the execution of the assignment (Bills, 1927; Freeman, 1932; Cason, 1938; Ghiselli, 1936; Stauffacher, 1937; Poffenberger, 1938; Courts, 1939; Berry, Davis, 1958; Montague, 1953; Taylor, 1956; Malmo, 1957, 1958; Spence, 1958; Meyer, Noble, 1958; Sidovski, Eason, 1960, and many others).

It has been elicited that muscular tension usually increases as a result of increased emotional excitation in man. Muscular tension originates easier, is more strongly manifested and has a longer lasting aftereffect in individuals, who respond to different stimuli by means of diffuse and nonspecific reactions and who manifest a higher emotional approach. However, no direct relationship between the degree of muscular tension and the emotional excitation has been established (Lashley, 1929; Olson, 1929; Duffy, 1930, 1932, 1946; Freeman, Katzoff, 1932; Allport, Vernon, 1933; Davis, 1938; Hall, 1941; Kennard, Spencer, Fulton, 1941; Wenger, 1942; Freeman, Pathman, 1942.

REGULATION OF THE PROPRIOCEPTIVE INFLOW VIA RELAXATION OF THE SKELETAL MUSCULATURE

§4. The effect of voluntary relaxation of the skeletal musculature on the functions of the brain has been much less investigated.

Various schools and methods of empirical psychotechnique, which have set themselves the task of training in man the practical ability to prevent, by means of psychic and physical exercises, the state of anxiety and emotional overexcitation of the nervous system, are extensively using systematic exercises for muscular relaxation. For example, Schultz (1934) in describing his method of "autogenous training," underlines the fact that with the aid of effective relaxation of skeletal musculature and concentrating one's attention on interoception (eliminating as much as possible the effect of exteroception on human consciousness), it is possible to achieve a general "transformation" or "reorganization" of the psychic makeup of man.

Schultz (in analogy with the representatives of the well known Indian school of psychotechnique — the Yogi school) recommends to develop a fine sense of "weight and warmth" in the skeletal musculature, as subjective indicators of muscular relaxation.

Schultz underlines that the method of muscular relaxation represents an approach which is contrary to the violent and tense suppression by man of affects which have already originated. The method of relaxation and "self-reorganization" of one's personality is directed toward the elimination of the "soil" for the genesis of strong affects, i.e., psychic and muscular tension and overexertion.

The method of muscular relaxation is used by Schultz for the purpose of ensuring favorable conditions for the realization of self-suggestion in the tested individual. The method as a whole has no sufficient scientific substantiation, and is of little use to the psychohygiene of a healthy individual, as well as for the treatment of psychoneurotic patients. However, certain clinical data and the results of empirical observations and, in the first place the idea of creative influence of man on his nervous system via voluntary relaxation of his musculature (adapted by Schultz from the psychic technique of Indian Jogi) deserves attention.

The useful effect of systematic muscular relaxation on the nervous system and functions of internal organs has been investigated in detail by Jackobson (1926, 1932, 1938, 1956), who extensively employed clinical and clinicophysical methods of investigation.

Jackobson (1938) established that the use of electric stimulation of the skin against a background of voluntary relaxation of the skeletal musculature by the tested individual, causes a diminished response of the individual to stimulation, as well as a decrease of subjective sensation of an unpleasant irritation.

Against a background of muscular relaxation, a diminished knee reflex is observed.

The progressive muscular relaxation is accompanied by weakening of all psychic activities of man, i.e., weakening of memory, effective thinking and emotions. The inhibition of undesirable mental associations (the content of thoughts) is facilitated, when man relaxes effectively the muscles which are particularly tense during these associations.

Muscular tension which as a rule accompanies human emotions represents an essential component of the experience of these emotions. The suppression of motor manifestations of emotions, at a reduced muscular tension, only increases the subjective part of emotions. At the same time, the general relaxation weakens, or cheks the emotion.

It is well known that a rise in the tonus of skeletal musculature contributes to the rise in the tonus of the smooth muscles of the internal organs, and vice versa. It is also known that the tonus of smooth musculature increases under the effect of emotions. It is difficult to develop the ability of voluntary relaxation of the skeletal musculature in a man who has a high tonus of the smooth muscles.

Jackobson emphasizes that, according to the data of Sherrington, the skeletal musculature tonus is maintained by the afferent neural fibers of the muscles. This means that a voluntary progressive relaxation of skeletal muscles, resulting in the reduction of afferent (proprioceptive) impulsation, reflectorily induces a further, more pronounced relaxation of the musculature, etc.

Our observations showed that tension and relaxation of the muscles are very constant components of the conditioned reflex preparatory reactions (i.e., anxiety reactions), or the reactions of neuromuscular relaxation in healthy individuals (Krauklis, 1960a, 1963; cf. Chapter 6). The higher the initial mental and emotional tension of the tested individual and the stronger is his tendency of suppressing external manifestations of psychic tension, the more markedly are manifested the isometric contractions and tension of the skeletal musculature, which originate as a nonspecific component of the anxiety reaction, and the greater is the delay of the substitution of this reaction by a relaxation reaction (or antianxiety reaction).

According to the observations of Lundervold (1952), the majority of his investigated healthy individuals belonged to the "tense" type, i.e., possessing a prolonged electromyographic reaction to different stimuli, including verbal stimuli, and only a smaller part of the tested (about 36%) belonged to the "relaxed" type – with a short and less intense electromyographic reaction to similar stimuli.

According to our observation (cf. Chapter 6), in healthy individuals, 8 to 35 year-olds, under conditions of laboratory investigation of higher nervous activity, the tendency toward a generalized muscular tension, in response to "difficult situations" originating in the process of observation, is more clearly pronounced in young children, less manifested in older children, and very little – in adults.

As seen from above cited data, psychic tension or relaxation induces muscular tension or relaxation, and vice versa. It may seem very tempting to control psychic activity of man by voluntary dosing of intensification or inhibition of the function of skeletal musculature. Unfortunately, it is not so simple to accomplish in actual practice. The point is that in every case when it is necessary to obtain an urgent increase of intensity and tension of nervous activity, man quite frequently finds it difficult to voluntarily mobilize additional resources of nervous energy essential for the activation of skeletal musculature and conversely, in cases where nervous activity is excessively tense, man has difficulty of voluntarily creating new and strong dominants which would be capable of exerting an inhibiting effect on the neural mechanisms, which generate effector impulsation and induce an activation of the skeletal musculature.

Therefore, the effector utilization of skeletal musculature, as a secondary regulator of the functional state of nervous activity, requires in the first place the presence of a sufficient high tonus of the higher cerebral parts and secondly, a system of elaborated and previously reinforced (as a result of systematic training and self-education) conditioned associations capable of a timely mobilization through the second signal system of additional controlling and inhibiting influences on the pre-efferent nerve pathways, which realize the switching of impulses to the alpha- and gamma-motoneurons.

A very strong and cyclically changing (as to intensity and localization) afferentation and, in addition, considerable humoral shifts originate, when animals or man perform some type of muscular load – a static or dynamic muscular work.

According to the data of numerous investigations, the static as well as dynamic muscular work is capable, at corresponding doses, of exerting a tonic effect on the higher parts of the brain. However, upon intensification of the muscular load, static work contributes to the origin of a general inhibiting effect, whereas dynamic work contributes to the increase and irradiation of the state of hightened excitation. Heavy and protracted dynamic work finally induces a diffuse, inert and general inhibition in wide areas of the brain (Rozental', 1946; Pronskaya, 1949; Fol'bort, 1962; Vereshchagin, 1953, 1955; Novi, 1955; Pomel'tsov, 1957; Samsonova, 1958; Sakhnulina, Mukhamedova, 1958; Zima, 1958; Ashnaziy, 1958; Sukhanov, 1958; Filippova, 1961, 1963; Shabunin, 1962; Stepanov, Burlakov, 1963; et al.).

SIGNIFICANCE OF THE REGIME OF RESPIRATION IN THE REGULATION OF NERVOUS ACTIVITY

§5. Of the greatest importance in the regulation of the afferent inflow and intracentral coordination is the regime of the respiratory act and functional state of the respiratory center. By voluntarily altering the respiration regime, man can change the level and regime of his psychic activity.

Roitbach (1955) demonstrated that impulses from the respiratory center, transmitted along the extrathalamic pathways of the outgoing system of the reticular formation, exert a strong effect on the cerebral cortex by their participation in the maintenance of the cortical tonus. Periodic increase and reduction of cortical potentials, originating upon stimulation of neural receptors, as well as the periodicity of the alpharhythm during a physical load and after it, may be caused by the periodic changes of cortical excitability under the effect of impulses from the respiratory center (Stroup, Darrow, 1953; Roitbach, 1955).

There are reasons to assume that the respiratory center periodically alters the transmission of afferent impulsation along the brain stem (Roitbach, 1959).

According to the data of Roitbach, cortical regulating influences on the respiratory act are realized mainly through the nucl. retic. gigantocellularis, and further – through the reticulospinal tract.

It has been established that, depending on respiration phases, there originate changes in the functional state of the nervous and muscular systems. For instance, during inspiration one observes shortening of the chronaxy (Alekseyeva, 1949; Sergiyevskiy, 1950), a rise in the value of the muscular effort (Farfel, Freidberg, 1948), shortening of the duration of motor reaction of the fingers of the hand (Roitbach, Dedabrishvili, Gotsiridze, 1960).

Under certain conditions, a reduction takes place in the respiration rhythm of skeletal musculature, not directly connected with the respiration act (Kunstman, Orbeli, 1924; King, Blair, Garrey, 1931; Vinokurov, 1945, 1946; Sergiyevskiy, 1950; et al.).

In the course of our investigations we observed cases where, under a tense state of the nervous system, there appeared in the experimental animal, against the background of a continuing reaction of anxiety or a passive defensive reaction, an extensive irradiation of nervous activity corresponding the respiration rhythm: rhythmic isometric contractions were observed of certain muscle groups of the extremities or twitching of the latter. The twitching corresponding to the respiration rhythm was most pronounced against a background of the tonic flexion of the extremity in the process of its "reinforcement" (during the development of protective motor conditioned reflexes).

All these data attest to an extensive irradiation of the activity of impulses which originated in the respiratory center, along the entire nervous system as well as in the skeletal musculature.

The skeletal musculature in its turn affects the respiratory center. For instance, contraction or extension of skeletal muscles induces a reflex intensification of pulmonary ventilation.

The skeletal musculature in its turn affects the respiratory center. For instance, contraction or extension of skeletal muscles induces a reflex intensification of pulmonary ventilation.

The intensification of proprioceptive respiratory reflexes and respiratory muscles secondarily intensifies through the respiratory center the respiratory excursions (Marshak, 1961).

The air movement through all aeriferous pathways during inspiration and expiration is connected with a greater or lesser pressure on the receptors of the mucosa (Lumsden, 1923). Stimulation of mucous membrane of the trachea with an air current intensifies the electric activity in the cervical n. vagus (Gruzdev, 1941). Air movement in the respiratory pathways exerts a reflex effect on the respiratory center. An increase of this effect leads to the intensification of respiration in experimental animals (Lumsden, 1923; Adrian, 1933, 1941: Bukov, 1956; Sergiyevskiy, 1950, 1959; et al.).

As an illustration of the powerful effect of intero- and proprioceptive impulsation, originating during the act of respiration, on the higher cerebral sections, may serve the observation of Farfel (1954) and Marshak (1959) concerning the fact that man achieves a maximum (transitory) physical effort at the moment of expiration, or when he holds his breath with an effort.

There is reason to assume that afferent impulses, which originate during the respiratory act in the respiratory musculature, respiratory pathways and lungs, and which act on the nervous system as unconditioned stimuli, affect the higher cerebral sections through the respiratory center. The same impulses, acting as conditioned signals, affect the higher cerebral centers and the respiratory center through the cerebral cortex (Roitbach, 1955; Krauklis, 1957, 1960a, 1963; Marshak, 1961).

Taking into account the role of the respiratory apparatus is the gas metabolism, as well as the strong influence of the respiratory center and afferent impulses, originating during the respiratory act, on the nervous, muscular and cardiovascular activity, it becomes clear that the setting up of an optimum regime of functions of the respiratory apparatus is of paramount importance to the ensuring of an optimum regime and high level of higher nervous activity. It is not surprising, therefore, that some results obtained by the representatives of "schools" of ancient fold medicine (for instance, Indian, Tibetan and Chinese medicine) in the elaboration of systems of training of a respiratory regime, which permit an effective utilization of respiratory exercises and a change in the respiration regime for the purpose of influencing psychic activity and functions of internal organs of man, may be of definite interest to modern medicine and psychology.

Investigations of physicians and physiologists established that, by means of "static" respiratory exercises, i.e., relatively deep respiration with voluntary retardation of breathing and a forceful tension of respiratory musculature during inspiration (for a few seconds), it is possible to obtain a reduced excitation of many nervous centers, in particular, of the motor analyzer, and often also a general inhibition effect on the nervous activity, as well as a general tranquilization and distraction of man (Smirnov, 1960; Osipova, 1960; Bezrukova, Korkhin, Osipova, Smirnov, 1960; Smirnov, Baskovich, Osipova, Parashin, 1962).

It has been elicited that rational respiratory exercises, performed against a background of relaxed skeletal musculature and distraction from extraneous environmental influences contribute to the reduction of excessive pre-start excitation in athletes and the rise of optimum preparedness for competitive performances. After the end of the performance, the respiratory exercises reduce the residual excitation induced in the athletes by the previous load (Moshkov, 1934; Osipova, Dubravitskaya, 1962).

In order to ensure a useful effect, in the course of forced respiratory exercises, man has to strictly observe a number of methodical requirements and possess self-control, which would enable him to prevent in good time any possible undesirable effects. The exercises should be performed systematically, in a comfortable posture, the man concentrating his attention on the performance of his exercises and on the distraction from any extraneous disturbing thoughts, etc. If the corresponding requirements are not strictly observed, the respiratory exercises may prove to be useless, or even lead to opposite results - excessive excitation of the nerve centers (Roitbach, 1959).

Respiratory exercises are widely used for the prophylaxis and treatment of diseases in Chinese traditional medical practice. The Chinese respiratory gymnastics is directed toward the achievement of a general inhibition effect, so as to regulate the course of nervous processes in excessive fatigue, neurasthenia and in diseases connected with the disturbance of reflex regulation of the functions of internal organs. Respiration gymnastics develop rhythmic breathing, with a gradual extension of the pause during inspiration (with another variant - also during expiration), with the predominance of diaphragmatic breathing and the active participation of the lower part of the abdomen in the respiratory act. Respiratory gymnastics is comparable in the Chinese practice with "sleep" therapy which, however, is carried out under conditions of being awake (Smirnov, Lu Shao-chdzun, 1960).

The respiratory gymnastics of Indian Yogi sets itself the task of ensuring not only the health but also "transforming" the entire personality of man and achieving in the final count a complete detachment of man from "earthy passions."

It is easy to understand that the rhythmic, monotonous and deep breathing carried out by previously psychologically trained individuals in a quiet atmosphere, helps to establish a regime and a level of higher nervous activity which permits autosuggestion, genesis of sensory illusions and elimination of all psychic activity, except the one associated with autosuggestion. As pointed out by Smirnov (1960) and Makuni (1960), in the Yogi respiratory exercises the excitability of nerve centers is reduced, and the "self-orders" employed by individuals engaged in these exercises easily exert a true hypnotic state.

§6. We cite in this section, the results of our investigations, which supplement or make more precise the above cited data (cf. §§ 3, 4, and 5) concerning the participation of the musculature and respiratory apparatus in the self-regulation of higher nervous activity of man.

1. We established that by means of voluntary alteration of the activity of skeletal musculature, it is possible to produce the inhibition of specific and nonspecific response reactions of the tested individual to the employed or expected differentiation stimuli. The inhibition effect under these conditions can be obtained via an increase of contraction or tension of the musculature, or via its relaxation.

Under situations of the seance of observations which require an urgent increase and maintenance of the tonus of higher cerebral parts of the tested individual, as in situations requiring a very fast inhibition of the response reactions of the organism to the employed, or expected within the next few seconds, differentiation stimulus, the greatest inhibition effect is usually obtained with a voluntary tension of the skeletal musculature.

On the other hand, under situations which are characterized by a relatively high initial tonus of the cerebral cortex, and which permit the employment of a corresponding inhibition effect within a longer time segment, the best effect is obtained with a voluntary relaxation of skeletal musculature.

The inhibiting and tranquilizing effect of muscular relaxation is particularly well manifested in cases when the tested individual is compelled to get ready for the forthcoming repeated onset of very unpleasant sensations as well as when the initial excessively strong tension of the skeletal musculature is taking place.

It should be pointed out that the desired inhibitory and tranquilizing effect originates only in those cases where the tested is able to accomplish muscular relaxation without any special psychic tension and intensification. In the reverse case, instead of a calming effect, there can easily appear or become more pronounced the state of anxiety and excitation of the nervous system.

If in the tested individual, during his strenuous efforts to obtain muscular relaxation, there originates only a voluntary suppression of the external manifestations of response reactions of the organism to differing stimuli (or to situations of tense expectations of the latter), then as a rule a psychic or muscular tension originates or becomes intensified, i.e., an effect takes place which is the reverse of a psychic and muscular relaxation.

Hence, in order to successfully accomplish a muscular relaxation, the tonus of higher nervous activity of the tested individual must be sufficiently high (otherwise, it is impossible to obtain the necessary concentration of his attention to the execution of the relaxation process and of the concomitant inhibition of other psychic dominants which are responsible for muscular tension), and the individual must also have certain experience, i.e., the ability of voluntarily realizing and controlling relaxation.

In our observations of the tested we could not, of course, effect a complete or near-complete muscular relaxation. However, to ensure the positive effect on higher nervous activity, it usually sufficed to accomplish a partial muscular relaxation, i.e., to reduce the conditioned inadequately high level of muscular tension down to the optimum tension level.

As a result of such relative muscular relaxation (which produced an optimum tension level), a relaxation would take place of the specialized, and especially nonspecialized (general preparatory) reactions of the organism which originate in response to unpleasant, nociceptive stimuli, as well as in response to conditioned stimuli which signalled a probable appearance of the latter. The aftereffect reaction became weaker and shorter.

Against a background of relative muscular relaxation, a normalization would take place of the sensory rheobase and chronaxy, if prior to it they were reduced or increased as a result of muscular tension or a dynamic or static muscular load.

Against this background of relative relaxation of the muscles and nervous system, the tested easily tolerated painful stimuli, and the sensitivity threshold to disagreeable stimuli was higher.

At the same time, the use of strong, sudden stimuli (cf. Chapter 2, §4) against a background of relatively voluntary muscular relaxation often produced in the tested individual a stronger response reaction (including an aftereffect reaction), than the use of the same stimuli against a background of pronounced voluntary muscular tension.

Only in rare cases, when a deep muscular relaxation was accompanied by a deep psychic relaxation and a calm state of the individual, strong sudden reactions induced only a slight reaction of the organism. In the majority of cases, these slight reactions following sudden stimuli were observed in individuals with a balanced nervous system, which however, induced no voluntary tension or voluntary relaxation of the musculature.

Figures are cited below which illustrate some of the above described results (Fig. 29—33).

Fig. 29. Intensification of contraction of femoral muscles in the process of solution of a mental assignment by the tested individual Ya. Ya. – arrangement of haphazardly distributed numbers (from 1 to 100) in a consecutive order (cf. Chapter 8, §6). First fragment of the kymogram – the start of solution, second – continuation and end of solution of the problem. 1) Warning concerning the next assignment; 2,3) beginning and end of solution of the problem. A) 1 second. From above and downward: Plethysmograms of soft cranial tissues (at the front – occiput level) and of soft tissues of the neck and figer; sphymogram of the common carotid artery; pneumogram; contraction of flexors and contraction of extensors of the knee joint.

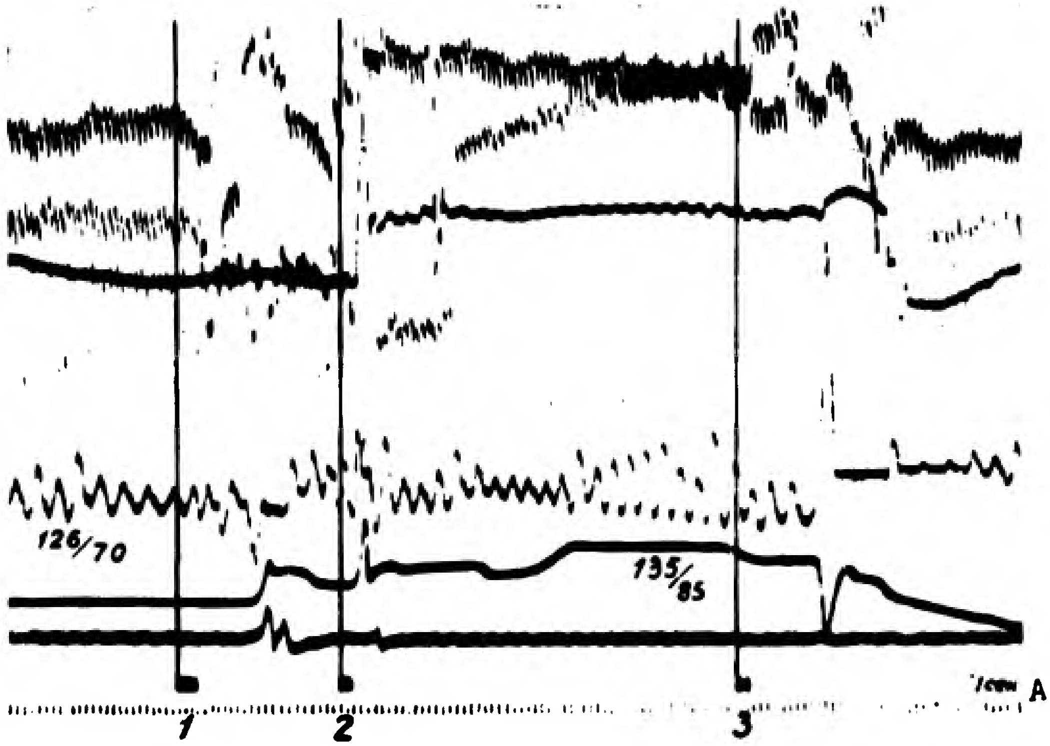

Fig. 30. Intensification of muscular contraction in tested A. R. during the solution of an arithmetical problem. 1 – Warning the tested individual concerning the next problem; 2,3 – beginning and end of the solution of the problem. A) 1 second. From above and downward: Plethysmograms of the soft cranial tissues and neck; contraction of flexors of the fingers; sphygmogram of the common carotid artery; pneumogram; contraction of flexors and contraction of extensors of the knee joint.

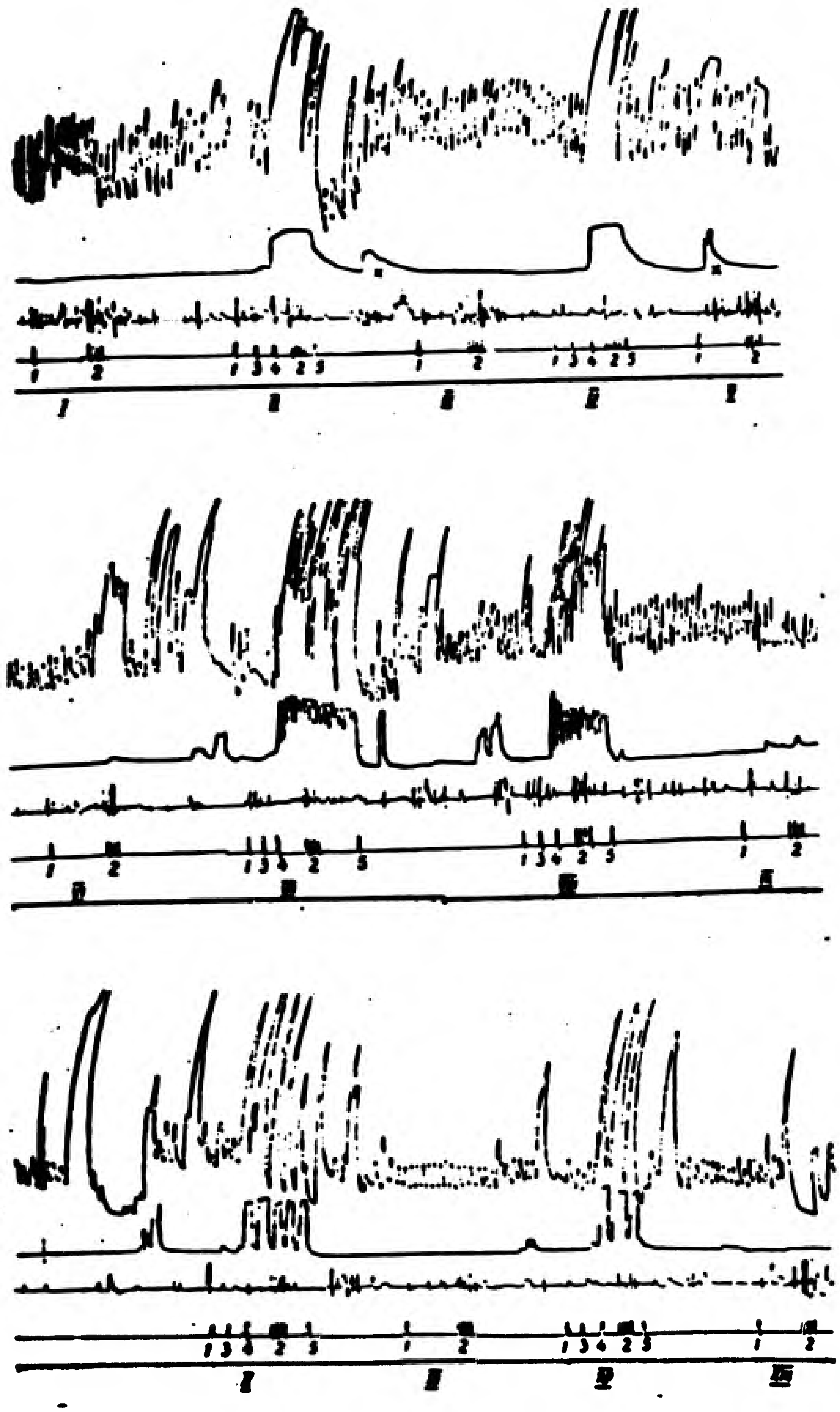

Fig. 31.

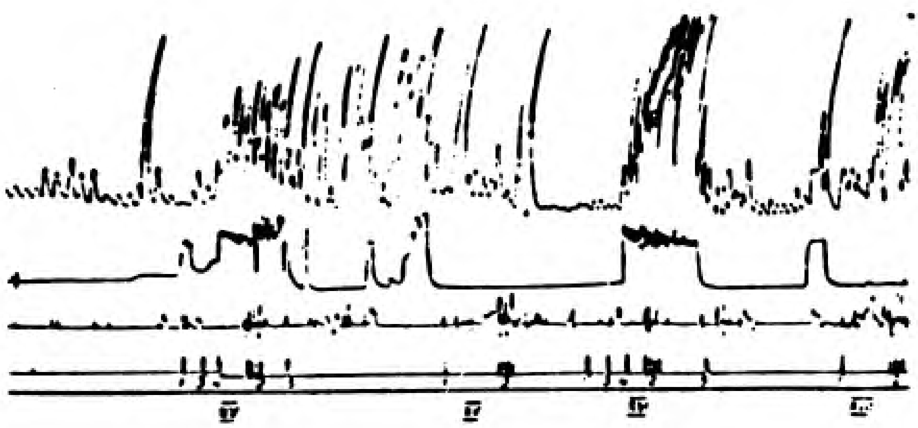

Fig. 31 Continued -

Fig. 31. Effect of voluntary change of the muscular activity regime in tested M.I., aged 11 years (the first two fragments). 1 - Conditioned signal, signaling within 20 seconds; 2,3 - a warning to the tested individual concerning the forthcoming exercise; 4,5 - the start and end of the muscular exercise. The cross (X) denotes involuntary contractions of finger flexors which cause deformation of a rubber transmitter attached to the dynamometer. The use of conditioned and unconditioned stimuli takes place against the background: I - Of a relative rest; II - of a small static load (15 kg) by means of prolonged pressure of a manual dynamometer by the right and left hands (the force of pressure is controlled via switching on of a light signal in front of the tested individual; the light is switched on automatically, when the pressure reached the assigned value); III - relative relaxation of the skeletal musculature (which the tested was trained to learn previously); IV - a strong static load (25 kg); V - relative rest; VI - relative rest; VII - strong static dynamic load (30 kg) 16 pressures successively; IX - relative relaxation of musculature; X - strong static dynamic load (35 kg); XI - relative relaxation of musculature; XII - small load (20 kg); XIII - relative rest; XIV - strong load (30 kg) - 22 pressures successively; XV - relative rest; XVI - load of medium intensity (20 kg) - 26 pressures successively; XVII - relative rest.

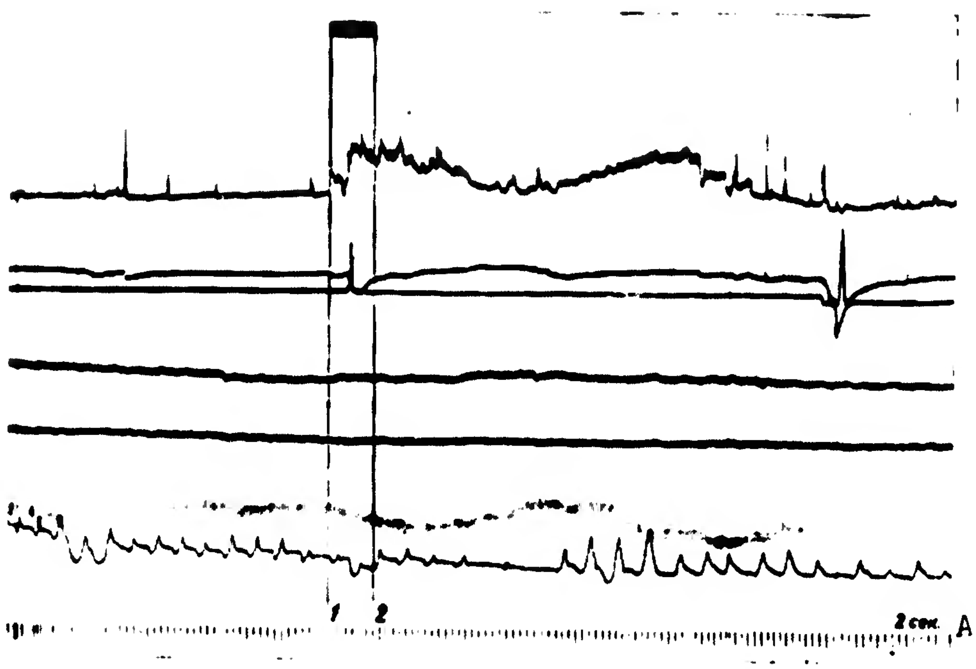

Fig. 32. Marked compensatory intensification of tonic and phasic contractions of musculus orbicularis oculi, following sudden application of slight electric stimulation against the background of voluntary relative relaxation of skeletal musculature, in tested A. V. 1, 2 — The start and termination of stimulation of the skin of the occiput with direct current impulses of low intensity. From above downward: Blinking movements; drawing together of eyebrows (drop of curve) or wrinkling the forehead (rise of curve); movements of mandibula; contraction of flexors and contraction of extensors of the knee joints; plethysmogram of a finger; pneumogram. A — 2 seconds.

2. As shown by observations, the most pronounced tonic effect on the higher cerebral sections, as well as the inhibiting effect on the afferent inflow caused by extraneous or unpleasant and nociceptive stimuli, originates as a result of simultaneous contraction and stretching of the muscles and tendons. Practically, it takes place upon a strong isotonic contraction of the agonist muscles which leads to a marked passive stretching of the antagonist muscles and their tendons. The effect is intensified, if against a background of passive stretching there takes place a simultaneous isometric contraction of the stretched muscles, which causes an extremely strong tension of the latter and thus – a most pronounced deformation of sensory elements of the muscle spindles and tensoreceptors.

The simultaneous contraction and stretching of the musculature takes place during dynamic and static physical exercises and physical work. During a dynamic muscular load, the proprioceptive inflow has a "pulsating" rhythmic character. On the other hand, during a muscular static load (postural tonic exercises), the proprioceptive inflow is of a relative monotonous nature. However, by periodically switching the activity from some muscular groups to other, it is possible to ensure a certain rhythm and variability of the proprioceptive inflow.

It is important to point out that, following a sufficiently intensive conduct of exercises with a simultaneous contraction and stretching of muscles, the tested can much easier obtain an effective muscular relaxation. In this respect, the static, i.e., postural tonic, muscular exercises proved to be particularly effective.

It is well known that during the state of anxiety and emotional tension, there most frequently originates in man a simultaneous isometric contraction and tension of the agonist and antagonist muscles. This contraction acts as an effective means of raising the tonus of higher cerebral sections only in the case when it does not last long. If, however, it is protracted for a large time segment, the monotonous proprioceptive inflow rapidly loses its initial tonic effect. It is possible that a certain adaptation takes place of the muscle spindles to a new deformation level, as well as a weakening of the proprioceptive inflow, and in addition, also an adaptation in the central structures to a given modality of the proprioceptive inflow. However, the effect of the monotonous inflow on the brain does not cease; it only seems to be distorted, and may induce a fatigue of higher nervous activity and skeletal musculature, possibly as a result of the synchronous influence of the monotonous afferentation on the cerebral cortex via the synchronizing structures of reticular formation of the brain stem (Moruzzi, 1958).

Following a prolonged performance of dynamic or postural tonic exercises, which ensure a simultaneous contraction and stretching of muscles, the tonic effect turns out to be much stronger, and the habituation or fatigue of the nervous system has virtually no time to develop or, within a relatively short time after the start of one phase of exercise, it is reflectorily replaced by a subsequent phase which is connected with the effective

Caption to Fig. 33 continued

to sit and breath quietly (the muscular contraction is controlled by the individual himself. On the screen in front of him are projected movements of a "sunray" induced by a rather slight contraction of the large muscles of the extremities). From above downward: Contraction of the muscles of the forearm; blinking movements; plethysmogram of a finger; contraction of flexors of the knee joint; wrinkling of forehead; contraction of extensors of the knee joint; pneumogram.

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weakening of hitherto contracted muscles, as well as with the contraction and stretching of other muscular groups. During the contraction and relaxation of skeletal musculature, as well as for a certain time after their cessation in the tested individuals as shown by our observations, there was a considerable weakening of the excessive speacialized and nonspecialized response reactions of the organism caused by different stimuli, and a rise in the threshold of pain sensation; however, at the same time, the sensory rheobase and a chronaxy often manifested an appreciable decrease (the chronaxy was determined with the use of standard current voltage, i.e., 45 volts) and there was a considerable increase of the force of muscular contractions, determined by means of dynamometry (Figs. 34-36).

3. Similar, though less stable and less pronounced changes of nervous activity were induced by respiratory exercises connected with holding the breath on inspiration, against a background of diaphragmatic breathing with active participation in it of the abdominal musculature (cf. Figs. 3, 37-40).

In cases when the tested individual manifested an inadequately strong, monotonous, generalized muscular tension, a voluntary improvement of the respiration regime (deep, rhythmic disphragmatic breathing with the participation of abdominal muscles) contributed to the abatement of tension and elimination of its monotony, in the sense that in correspondence with a change in the respiration rhythm, the intensity of muscular tension began to change (cf. Figs. 23, 41).

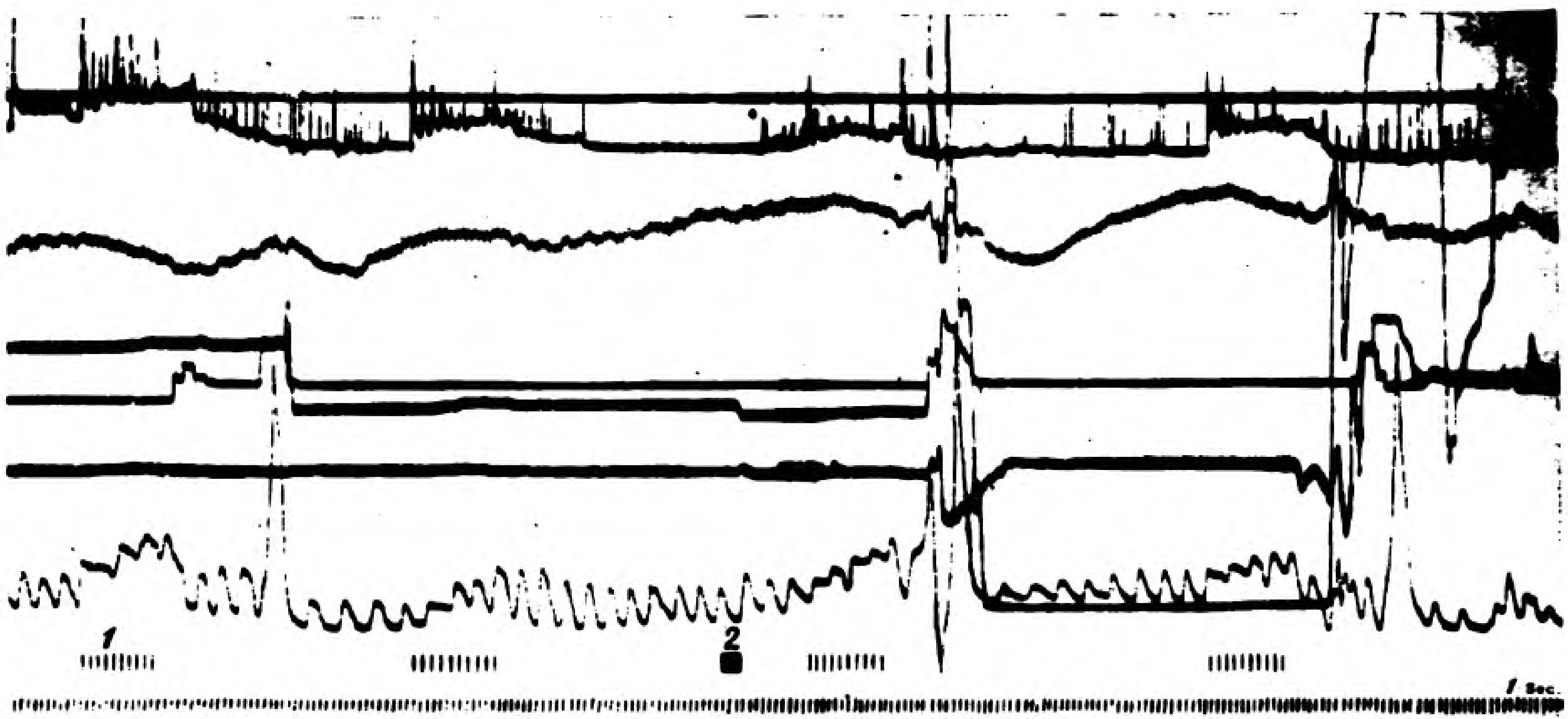


Fig.33. Onset of an anxiety state and compensatory effector switching of nervous activity, as a result of the unsuccessful attempt of relaxing the skeletal musculature, against the background of the use of nociceptive stimuli in tested L.M. Instead of relaxing the tested individual is attempting to suppress his motor reactions to stimuli. 1) Tenfold stimulation of cornea with an air current; 2) the individual is instructed to relax his musculature,

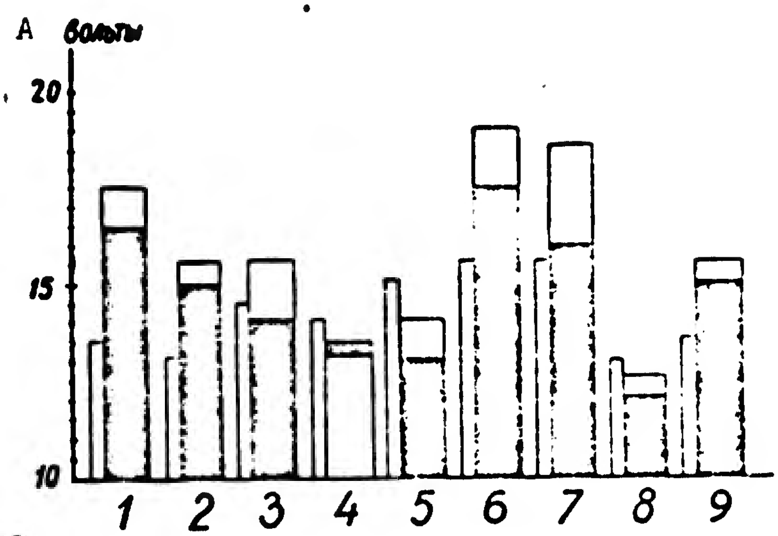


Fig. 34. Changes of the sensory rheobase of the skin (in volts) during the performance by the tested of dosed muscular and respiratory exercises (observations by L. Rotsen). White columns — rheobase values in tested athlete, R . R., who performed correctly all exercises; narrow lateral columns — values of the motor rheobase (contraction of musculus orbitalis oculi) in the same athlete; black columns — mean values of the sensory rheobase in 10 tested individuals. Rheobase determined against the background of: 1 — Relative rest; 2 — minute-long deep, formed respiration, with short holding of breath in the phase of inspiration and active participation of the abdominal muscles; 3 — 45-second holding of breath in the inspiration phase; 4 — 2-minute moderate voluntary tension of skeletal muscles; 5 — 2-minute moderate dynamic load (by means of the ergometer); 6 — strong static load (by pressing the dynamometer); 7 — strong dynamic load; 8 — postural tonic contraction and stretching of muscles; 9 — relative rest. The dynamics of sensory chronaxy, determined by the use of an electrocutaneous stimulus of standard voltage (45 volts), had similar, although less well-defined, direction. A) Volts.

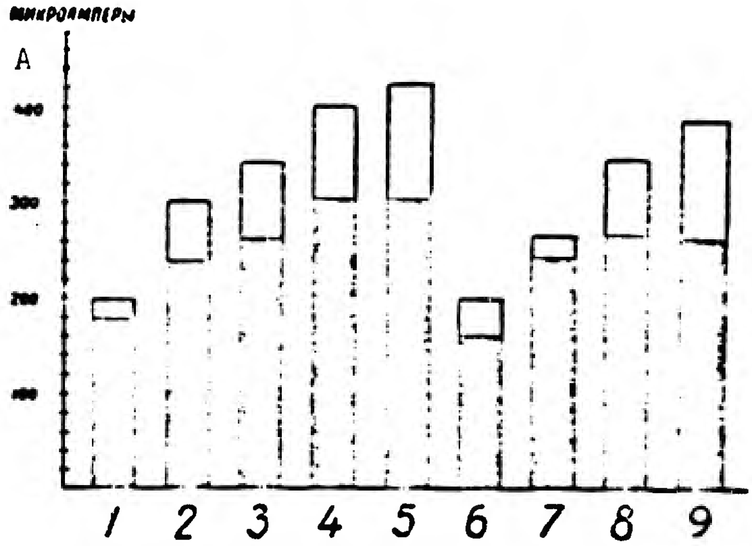


Fig. 35. Changes of the limit of subjectively maximally permissible force of stimulation of the skin of the forehead with impulses of a direct current (at which markedly pronounced unpleasant sensations requiring cessation of stimulation do not originate as yet), against a background of dosed respiratory and muscular exercises by the tested person. White columns – limit of subjectively tolerated electrocutaneous stimuli in the athlete R. R. (cf. Fig. 34); black columns – means values of the same boundary line in 10 tested. Determination of the stimulation force (in amperes) takes place against a background of: 1) Relative rest; 2 – holding of breath (40 seconds) in the phase of deep inspiration; 3 – voluntary tension of the skeletal musculature of mean intensity; 4 – dynamic load; 5 – strong static load with simultaneous stretching of the musculature; 6 – relative rest; 7 – small static load with simultaneous stretching of the musculature; 8 – the same, combined with deep forced breathing and short delays of breathing during the inspiration phase; 9 – voluntary relaxation of skeletal musculature. A) Microamperes.

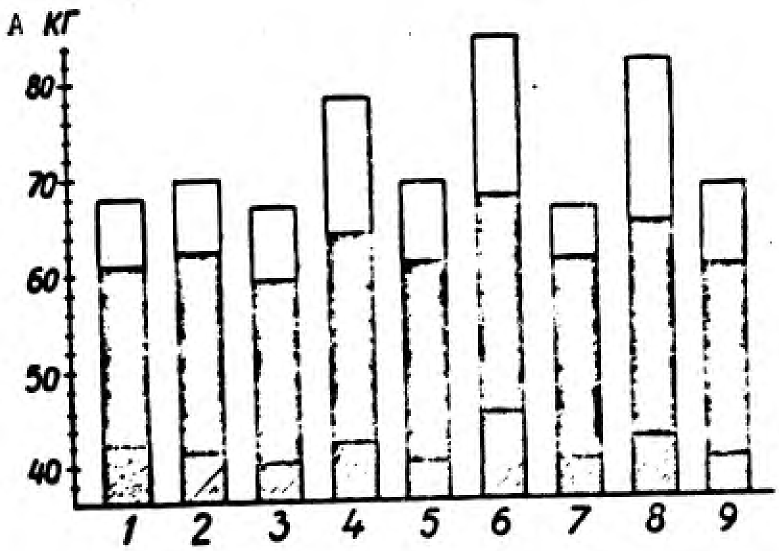


Fig. 36. Changes of the maximum force of pressure of a manual dynamometer (in kg), during dosed respiratory and muscular reactions of the tested individual. White columns – dynamometry values in a former athlete, A. O.; black columns – mean dynamometry values in 10 tested men. Crosshatched columns – mean values in 10 tested women. The force of pressure of the dynamometer is determined against the background of: 1 – Preliminary 5-minute rest period; 2 – deep forced respiration (2 minutes); 3 – voluntary strong tension of skeletal musculature (one minute); 4 – voluntary relaxation of musculature (2 minutes); 5 – regular 5-minute rest period (carried out after each test); 6 – dynamic load (gymnastics) with effective stretching of musculature (2 minutes); 7 – 5-minutes rest; 8 – moderate static load (postural tonic exercises) with relatively effective stretching of musculature (2 minutes); 9 – fast run on the spot (one minute). A) kg.

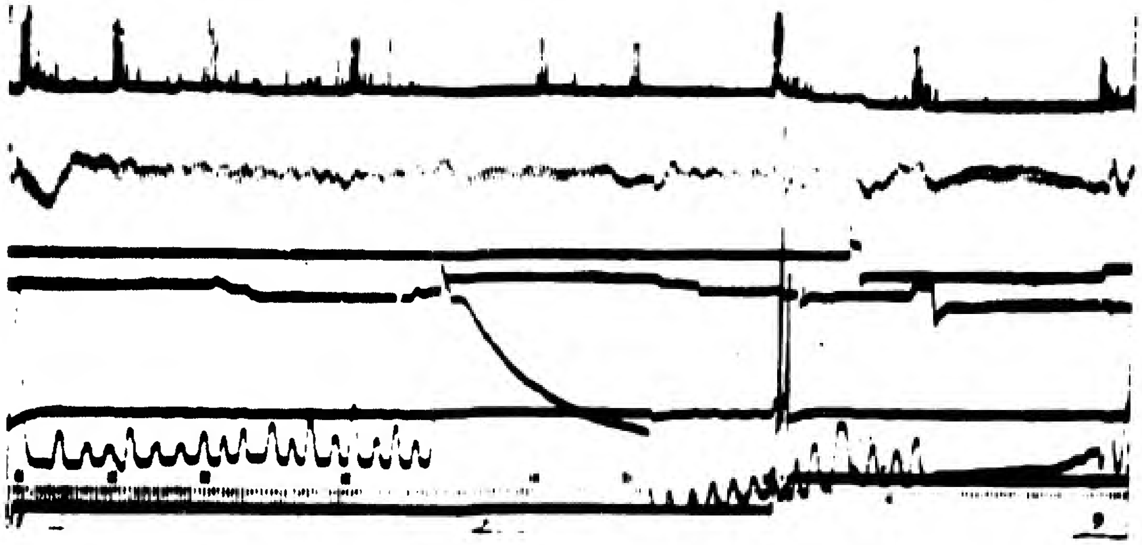


Fig. 37. Reduction of the unconditioned and conditioned blinking reaction (reaction to situation and time) against a background of delayed breathing during the phase of deep inspiration in tested I. R. 1 – Threefold stimulation of the cornea with an air current. From above downward: Blinking movements; finger plethysmogram; movements of mandibula; contraction of fingers muscles; contraction of flexors of the knee joint; pneumogram; contraction of extensors of the knee joint.

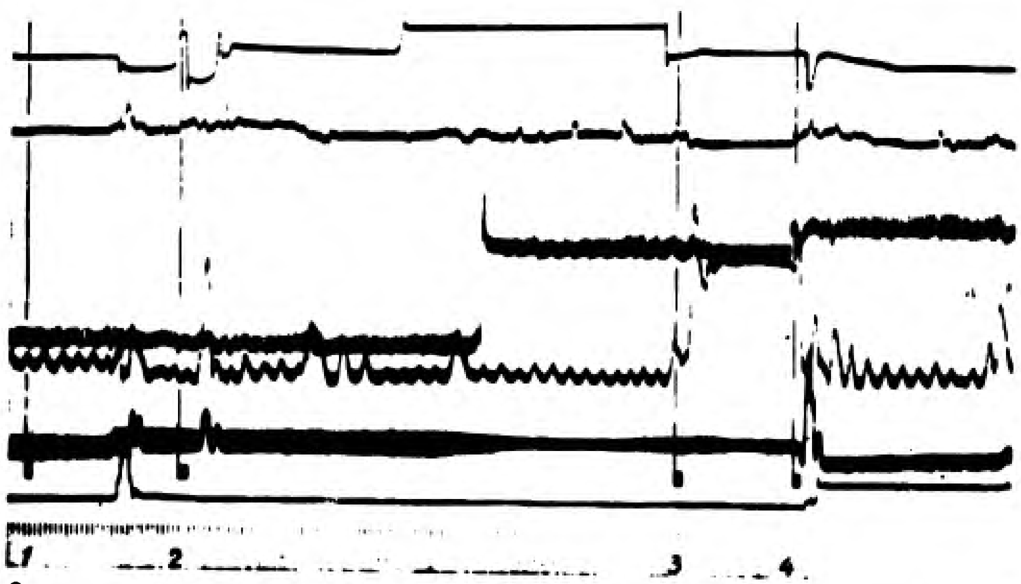


Fig. 38. Inhibition of somatic components of the general preparatory reaction of the tested L.R., against a background of delayed breathing during a deep inspiration phase. Emergence of muscular contractions immediately following expiration. 1 – Warning: "Get ready, a shot is coming!" 2 – pistol shot; 3 – warning about the next shot and an instruction to take a deep breath and hold the breath; 4 – a shot. From above downward: Bringing eyebrows together and wrinkling the forehead (a lower, or rising curve); blinking movements; sphygmogram of the radial artery; pneumogram; contraction of flexors and contraction of knee joint extensors.

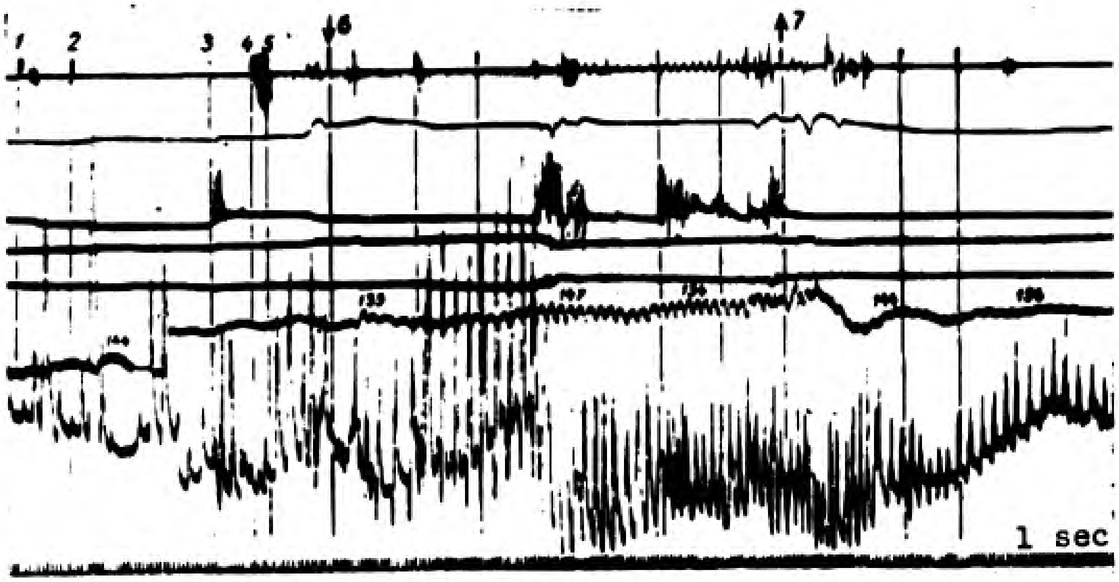


Fig. 39. Effect of a different respiration regime (regulated via changing the diameter of the tube immobilized in the trachea) on the dynamics of a conditioned reaction and differentiation, formed according to the method of Petropavlovskiy in a tracheotomized dog Pumpa. The beginning of the kymogram segment is recorded against a background of a slight decrease of the tube diameter. 1,2 – Beginning and end of the differentiation signal; 3 – conditioned signal; 4,5 – cutting in of the electric current which, however, the animal does not receive, on account of timely flexion of the right posterior extremity; 6 – further decrease of the tube diameter in the trachea; 7 – considerable increase of the tube diameter, thus enabling the animal to breath almost without artificial hindrance. From above downward: movements of the mandibula, head, right posterior extremity, anterior extremities and left posterior extremity (the last two curves are recorded by means of mechanoreceptors, placed under the platforms of the experimental table); sphymogram of the carotid artery; pneumogram.

Fig. 40. Release of the elaborated blinking conditioned reaction during a sharp increase of resistance to respiration without preliminary training (as a result of activation of the anxiety reaction) in tested L. O. 1 – Conditioned signal; 2 – threefold stimulation of the cornea with an air current; 3, 4 – beginning and end of induced resistance to respiration (upon breathing through a special mask). From above downward: Blinking movements; movements of the mandibula; contraction of femoral muscles; plethysmogram of a finger; pneumogram.

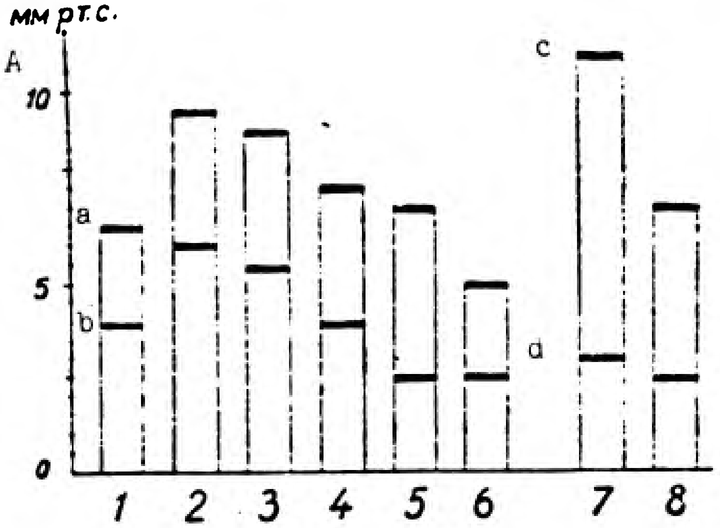


Fig. 41. Normalization of background tension of skeletal musculature in deep, rhythmic respiration during intensified mobilization of internal inhibition. Relative increase in muscular tension on deep inspiration and weakening on expiration. Subject: E.K. "a" and "b" are average limits of variation of total skeletal musculature tension of extremities (expressed in millimeters of mercury) during 1 min; "c" and "d" are the average limits of variation of musculature tension in the inspiration and expiration phases. The muscular tension boundaries were determined against backgrounds of: 1) Relative rest; 2) differentiation of conditioned signals conveying various minor nociceptive stimuli (tickling cornea with jet of air; irritation

of skin by induction current or a piece of ice, etc.) or the absence of such stimuli; 3) same, only in deep, labored respiration (1-2 min after start of deep respiration); 4) same (4-5 min after start of deep respiration). 5) same, combination of deep respiration with arbitrary relaxation of musculature; 6) same, combination of shallow respiration with relaxation of musculature; 7) very deep respiration without the use of conditioned or unconditioned stimuli (showing average limits of muscular tension variation for 100 inspirations and 100 expirations); 8) normal unlabored respiration (showing the average limits of muscular tension variation for 100 inspirations and 100 expirations). A) mm Hg.

Voluntary respiratory exercises helped in the realization of voluntary relative relaxation of musculature, i.e., the establishment of a better optimum of the tension level.

The greatest muscular relaxation would set in at a deep expiration. During a deep inspiration, the muscular tension increased, as a rule. Therefore, after the forced breathing produced a relative reduction of muscular tension, a more complete relaxation could be achieved by means of nonforced, easy and somewhat superficial respiration (cf. Fig. 41).

The greatest inhibition effect to the inflow of extraneous or undesirable, nociceptive afferentation was observed in our tests upon combination of respiratory exercises and static muscular exercises, connected with a simultaneous contraction and passive stretching of the musculature, or with effective voluntary relaxation of musculature (provided the tested possessed the necessary experience and a sufficiently high tonus of the cerebral cortex).

CONDITIONED REFLEX ACTIVITY OF THE SKELETAL MUSCULATURE AND RESPIRATORY APPARATUS IN SITUATIONS REQUIRING A RISE OF THE CORTICAL TONUS

§7. Based on above-cited data, one may conclude that skeletal musculature and the respiratory apparatus are extensively employed by the nervous system in the mechanism of self-regulation of nervous activity.

The fact that it is truly so is indicated by the conditions responsible for the genesis of muscular tension and changes of the respiration regime. The latter originate in every situation which requires a change in the afferent inflow into the brain for the following purposes: 1) A rise in the tonus of the higher parts of the brain (i.e., obtaining an optimum regime, improved work capacity, adequate tension and integration level of higher nervous activity), 2) inhibition of effects on the higher cerebral parts of extraneous stimuli, as well as nociceptive or other undesirable stimuli, 3) voluntary suppression of response reactions of the organism (including vocal reactions) to different stimuli.

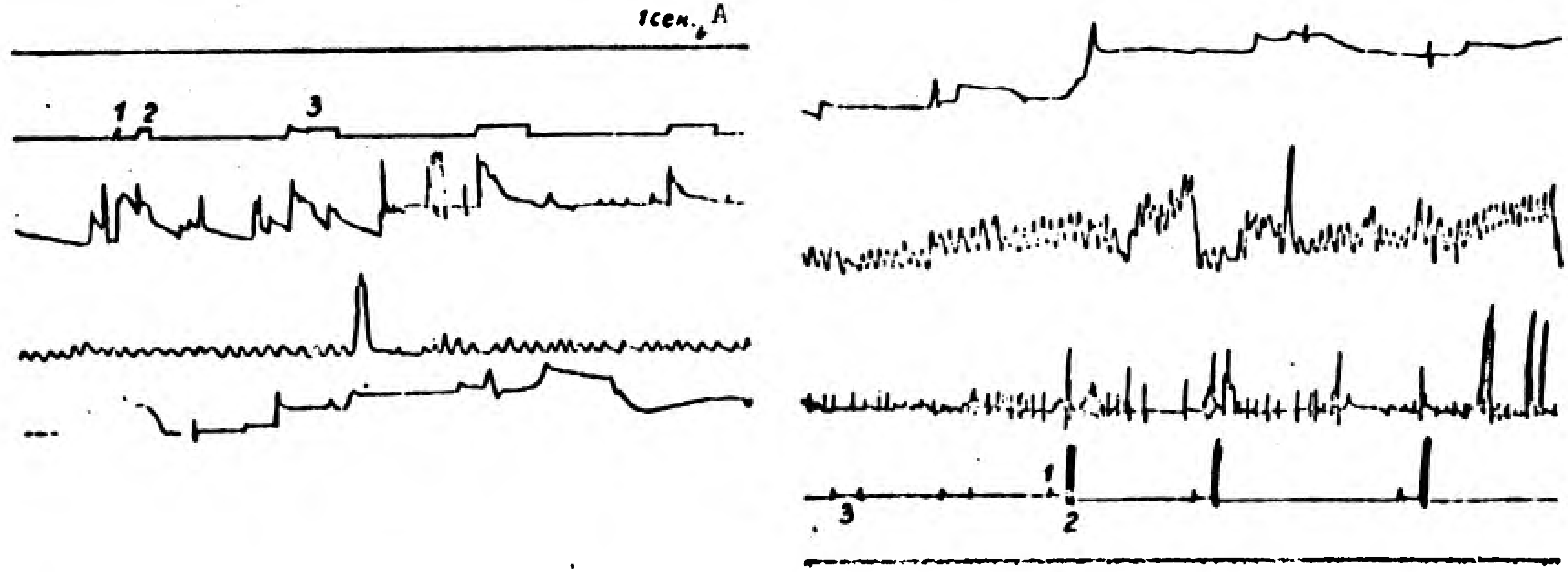


Fig.42. Intensification of muscular tension in situations requiring an increase of cortical tonus and mobilization of internal inhibition. Firt fragment – urgent damping of the elaborated blinking conditioned reaction in a tested woman, I.G. Second fragment – restoration of the urgently dampened blinking conditioned reaction in a tested woman, S.V. 1) Conditioned signal; 2) stimulation of cornea with an air current; 3) damping signal. A) One second. From above downward: (First fragment) blinking movements; pneumogram; curve of summary contraction of femoral muscles of both lower extremities; (second fragment) curve of contraction of femoral muscles; pneumogram; blinking movements.

It is well known that during the training of man for the forthcoming nociceptive or potentially nociceptive stimuli, disturbing situations, strenuous mental work, etc., man often experiences a tension of the skeletal musculature, a rise in the inspiration tonus, at times deep inhalations with subsequent delays in respiration, etc. When the higher nervous activity is fatigued as a result of strenuous mental work, monotonous mental and psysical work (for instance, as a machine tool in a factory), emotional overexertion, etc., there are observed in man voluntary or involuntary compensatory motor reactions, which produce an effective contraction and relaxation of skeletal musculature, deep inhalations and locomotor acts, which generate "fresh" discharges of proprio-, intero-, and exteroceptions and remove fatigue.

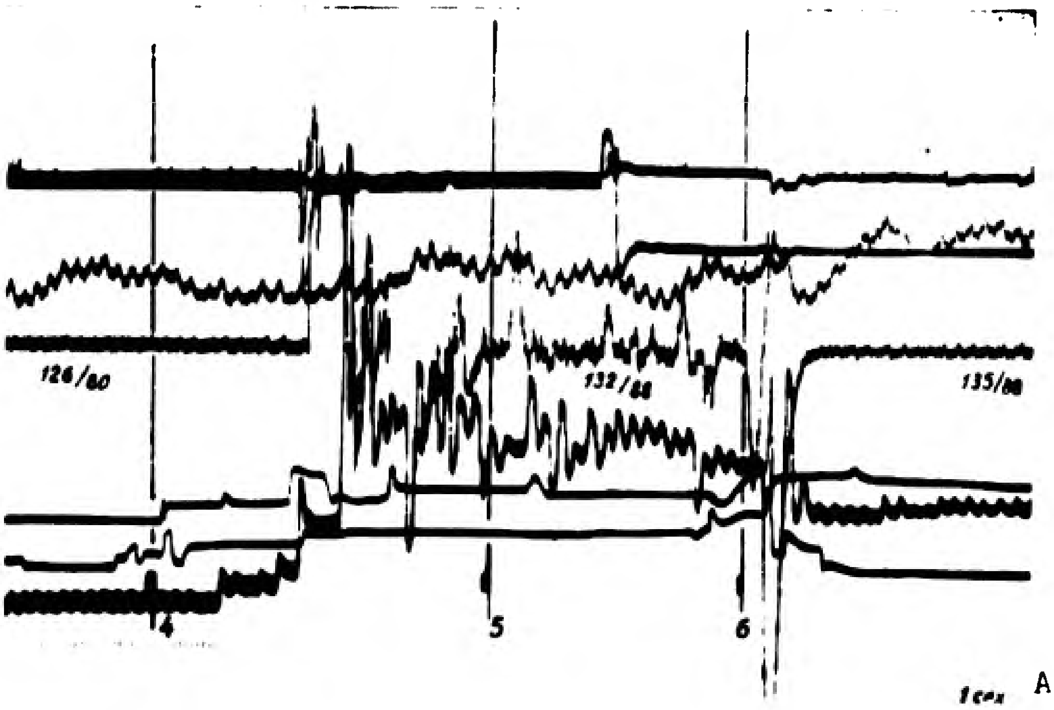
Laboratory observations confirm these empirical observations (Figs. 42-44, as well as 4, 29, 30, 33-35, 37, 38).

Closest connection between the conditioned reaction of anxiety and the tension intensity of skeletal musculature has been elicited in observations, where the activity of muscular components (as well as the respiratory component) of the anxiety reaction underwent a change, depending on the signal value of conditioned stimuli - verval warning of the tested concerning the forthcoming application of a different stimulus.

Fig. 43. Intensification of muscular tension and inspiration tonus is situations of voluntary suppression by the tested individual of various somatic reactions, connected with nociceptive stimuli or preparation for the latter. Tested: I. I. (first fragment) and K. L. (second fragment). 1 - Instruction: "Expect a strong stimulation, suppress any mimic and blinking reactions upon stimulation!" 2, 3 - Start and end of stimulation of the skin of forehead with a relatively mild direct current; 4 - instruction: "Expect a shot, suppress at the sound of the shot any motor and respiratory reactions!"; 5 - repetition of the same instruction; 6 - pistol shot. From above downward: (first fragment) blinking movements; knitting of eyebrows (rise of curve) or wrinkling of forehead (descent of curve); contraction of extensors of the knee joint; contraction of neck muscles; contraction of flexors of the knee joint; plethysmogram of a finger; (second fragment) blinking movements; knitting of eyebrows or wrinkling of forehead; plethysmogram of a finger; contraction of muscles of the neck (occiput); contraction of extensors and contraction of flexors of the knee joint; pneumogram. A) 1 sec.

During preparation of the tested to a stronger unpleasant stimulation, there appeared a more pronounced muscular tension, a rise in the inspiration tonus, etc., and vice versa (cf. Figs. 4, 44).

Fig. 43 continued



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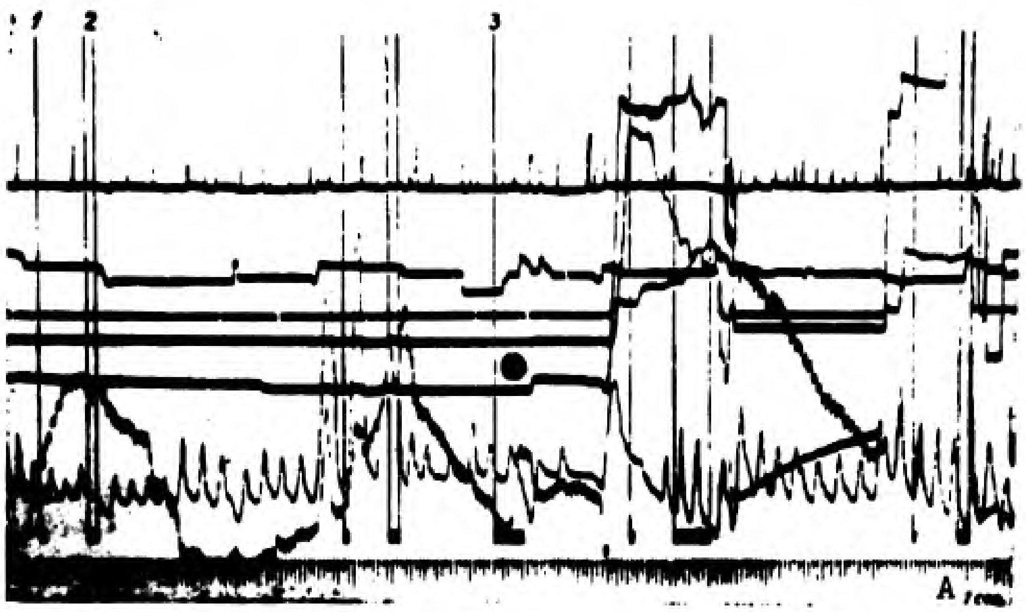

Fig. 44. Intensification of muscular tension and respiration, following oral warning of the tested Ya. S. concerning a considerable increase of intensity of the applied nociceptive stimuli. 1 – Conditioned signal; 2 – electrocutaneous stimulation; 3 – warning: "Attention, next stimuli will be much stronger!" (The actual strength of the unconditioned stimulation has not increased; only its duration increased). From above downward: the annotations are the same as in Fig. 43. A) 1 sec.

Experimental data indicating that in situations requiring from the individual an urgent rise of tonus of the higher cerebral parts, there appear compensatory effector reactions of the organism which generate secondary influences capable of raising the tonus, have been repeatedly obtained by many investigators of higher nervous activity of animals and man. Unfortunately, only some researchers attempted to analyze the origin of these compensatory effector reactions on the basis of their possible adaptation significance.

It should be mentioned in this connection that Trofimov (1952), in his investigation of the dynamics of motor and respiratory components of the conditioned blinking reflex in oligophreniacs, observed the following phenomenon. In some of the tested individuals, during the formations of conditioned reactions, there appeared a deep, rare and noisy respiration, the inspirations often alternating with yawning. In his opinion, this pnenomenon attested to the rapid tiring of the cortical processes and the development of hypnoid states in the tested subject.

At the same time, a deep and low rate respiration was accompanied, as a rule, in these individuals by emotional reactions (crying, laughing, grimacing, uttering some words), or motor stereotypes in the form of rhythmic tapping with the foot, or very rapid movements of the hand. Unusual liveliness and fussiness were observed in this group of tested, whereas other groups were quiet and did not move around much. During the first sessions of observations this liveliness and fussiness appeared only toward the end of the session. During subsequent sessions, these symptoms were manifested under the effect of laboratory environment at the very beginning of the seance.

As an explanation of these phenomena, Trofimov refers to the observations of I.P. Pavlov (1922), who interpreted the lively behavior and fussiness of dogs of the weak type of nervous system, as a unique adaptation to control the developing inhibition in the cortex. Pavlov wrote: "It can be accepted that the liveliness and fussiness of these dogs proceeds in such a manner that, with their easy excitability, a rapid exhaustion of a given stimulated locus takes place, which leads to inhibition, and the latter, in its turn, induces general excitation. This excitation forces the dog to move about, thus exposing other cells to new stimuli, and prevents under free conditions a strong development and diffusion of inhibition - sleep."

According to Trofimov, of analogous adaptive significance might be the motor anxiety originating in oligophreniacs during the development of hypnoid states which are the result of a rapid excessive overstraining of cortical activity in the tested individuals.

We are in accord with this interpretation. It can be assumed that the intensive motor activity of the experimental animals or tested individuals, described by I.P. Pavlov and Trofimov, is an expression of the conditioned reflex mobilization of the first and second type mechanisms of self-regulation of the higher nervous activity. In oligophreniacs, who have no reserves of nervous energy or functional possibilities which are needed for the mobilization of self-regulation by means of compensatory effector reactions, the latter have not originated, the struggle between awakening and inhibition was absent, and the tested remained calm and sluggish.

It is well known that under conditions of free movement, the experimental animals retain for longer periods of time a high tonus of higher nervous activity, and that it is much more difficult to induce in them a deep neurosis, as compared with animals which are immobilized in an experimental stand, or are placed in a narrow camera.

It has been established, for instance, that the limit of prolongation of differentiation stimulation and the limit of intensity of excitation turn out to be higher under conditions of free behavior of the experimental animal than under conditions of its immobilization, and that this increase remains for a long period of time, following termination of tests (Dzhurdzhev, Strungaru, Dumitresku, 1958).

It should be assumed that the frequent genesis and strong manifestation of the tonic tension of skeletal musculature (including respiratory, masticatory and mimic musculature) in man are closely associated with the habit of voluntary suppression, when among people of various physical motor acts, dynamic behavior reactions, etc.

Of course, a unilateral utilization by man of the isometric contraction of agonists and antagonists, instead of the cyclic alteration of contraction, stretching and relaxation of various muscular groups, has a negative effect on the effectiveness of those secondary influences, the realization of which often represents the sole adaptation task of the conditioned reflex reproduction of postural tonic reactions by an individual.

The physiological mechanisms of the origin and reproduction of effector reactions, induced for the purpose of secondarily generating the afferent and humoral influences on the brain, are apparently the same as the mechanisms described in Chapter 2 (cf. 2, §9).

CHAPTER 4

SELF-REGULATION OF HIGHER NERVOUS ACTIVITY BY MEANS OF SETTING UP A SYSTEM OF SIGNAL EFFECTS ON THE NERVOUS SYSTEM

(THIRD TYPE OF SELF-REGULATION)

SIGNAL REACTIONS AND THEIR CONDITIONED REFLEX REPRODUCTION

§1. As has been noted many times, stimuli produced in the process of carrying out various effector reactions of the organism have a secondary influence on the nervous system not only as unconditioned but also as conditioned stimuli.

In connection with this, the nervous system is capable of reproducing those somatic and visceral reactions which generate conditioned stimuli which signal and reproduce various changes in the functional state of the nervous system, useful in a concrete situation.

We call the conditioned reactions which secondarily generate conditioned stimuli signal reactions (Krauklis, 1960, p.218). Signal reactions are the most important component of self-regulation of higher nervous activity in man. The mechanism of their origin and reproduction is analogous to the mechanism of any effector reactions of secondary importance used in conditioned reflex regulation of the effector flow or afferent influx (see Ch.2, §9; Ch.3, §7).

Any effector reaction of the organism can acquire the significance of a signal reaction if it is repeatedly accompanied by changes in the functional state of the brain which are beneficial for nervous activity. In such cases, the very process of carrying out the effector reaction, that is, the stimuli arising in this case, becomes the conditioned signal capable of reproducing in a conditioned reflex way those secondary beneficial changes in the functional state of the brain which would otherwise develop only as a result of an unconditioned reflex or humoral effect of the same stimuli on the brain.

Of course, in some cases a relatively weak secondary afferent influx caused by effector reactions having important signal significance can affect the brain much more strongly than a secondary signal influx caused by reactions not having such signal significance.

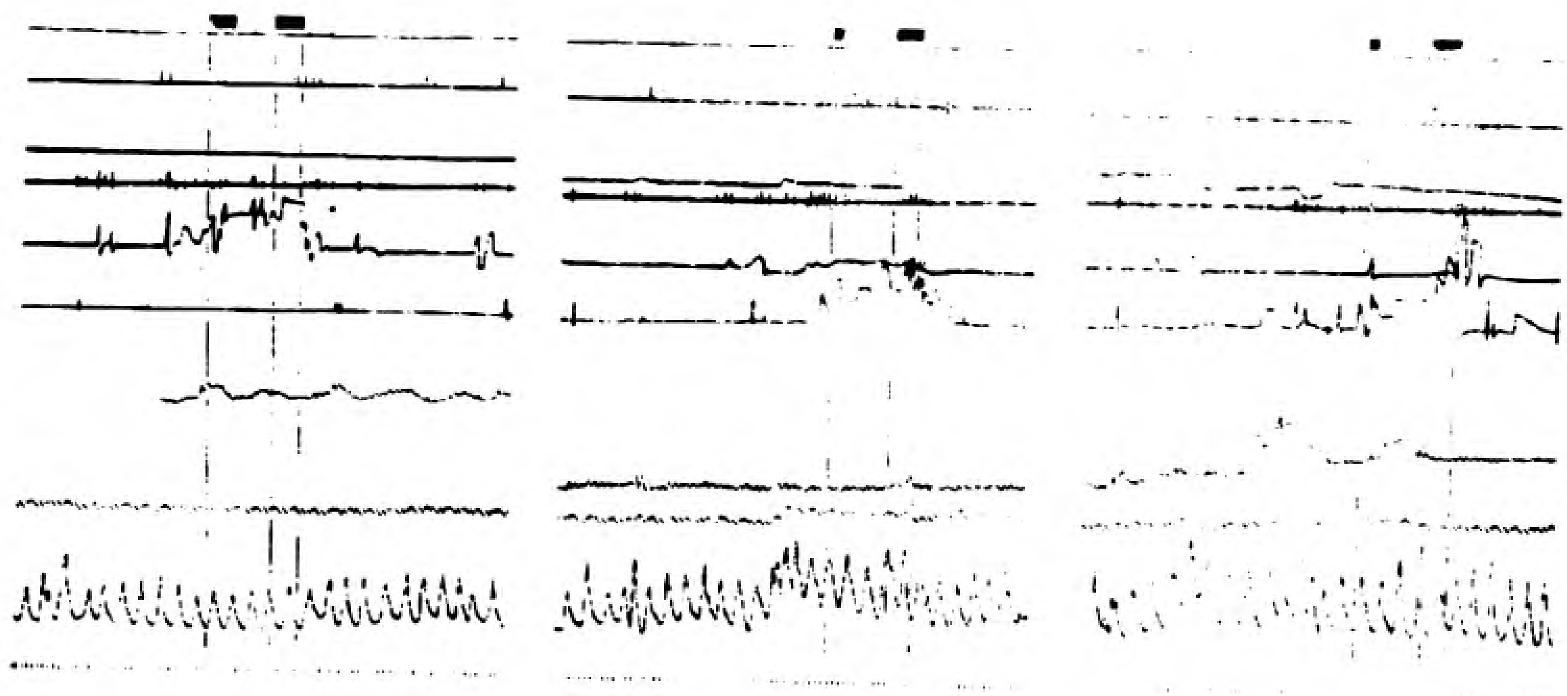

Fig.46. Compensatory flexure of the left rear extremity during mechanical blockade of the stimulated right rear extremity. The compensatory flexure acquires the significance of a signal reaction which develops even after deblocking of the stimulated extremity in the dog Mars (three fragments of the experiment; experiments of Yu.Briyedis, L.Rotsen and I. Rotsen-Krauklis). First fragment -- before blockade of right rear extremity, second -- during blockade, -- third -- 5 min after cessation of blockade. 1) Conditioned signal; 2,3) electrical skin stimulation of right rear extremity (conditioned reflexes were developed in the dog by the Bekhterev-Protopopov method). From top to bottom: secretion of saliva; movements of lower jar, head, total of front extremities, right rear extremity and left rear extremity; contractions of the stomach (with 100cm^3 volume of the sensing baloon); sphygmogram of the carotid artery; pneumogram.

As the result of the repeated coincidence in time or sequence of stimuli and functional changes (see Ch.2, §9) having a relationship to the conditions of the development of the signal effector reaction, a dynamic stereotype of the conditioned links is formed in the brain. The stimuli, that is, the changes in the nervous activity caused by the beneficial effect of the signal reaction on the brain (that is, by adjusting the system in the direction of the optimum) are the last in time and as if final link of the stereotype. In connection with this, the beneficial effect acquires the significance of reinforcement with respect to the preceding links of the stereotype.

Subsequently, the initial links of the stereotype -- the stimuli caused by deviation of the system of nervous activity from the optimum, as well as the existent stimuli can act as conditioned signals which reproduce the next link of the stereotype -- the appropriate effector signal reaction, while the latter generates signals which reproduce the beneficial changes in the functional state of the brain.

It is understood that the physiological mechanism of the production and reproduction of signal reactions is much more complex than the system noted above, which is only a working hypothesis.

At the same time, an analysis of the experimental and laboratory data obtained from a study of the conditioned reflex activity of animals and man, as well as an analysis of human behavior in situations of everyday life, makes it possible to assume that the theoretical system described above reflects certain important aspects of the third type (according to our classification) of self-regulation of higher nervous activity, that is, self-regulation by means of setting up a system of signal effects on the nervous system.

SIGNAL REACTIONS IN MAN'S DAILY LIFE

§2. We shall present several examples from man's daily life.

All the cases in which a person causes changes in his environment which influence him inversely through a second signal system and which modify or reorganize the system and level of his higher nervous activity are examples of the third type of self-regulation.

For example, a person sometimes provokes a pleasant conversation with comrades in order to get rid of his bad mood or his worries. A person sings a song in order to intensify a certain emotional state. A housewife lays a decorative, appetizingly-prepared table just so that the appearance of the meal will evoke a good mood in the guests (that is, the optimal functional state of the nervous system is created), etc.

Various habitual human motor stereotypes are also connected with the third type of self-regulation of higher nervous activity

-- gestures, mimicry, contraction and tension of the musculature of the extremities, respiratory and chewing apparatus, "reactions on oneself" which are inadequate for the actual situation, including on clothing (many adjustments of the tie, dress, etc.), reactions on surrounding objects (the person picks up unnecessary objects, "plays" with them, shifts them, etc.).

Usually these motor stereotypes are simultaneously linked with all types of self-regulation. For example, when in expecting the development of an unpleasant, for example, painful stimulus, a person's skeletal musculature contracts and is strained and inpiration tonus is increased, this can be: (1) the expression of intensified compensatory switching of the brain's activity to peripheral efforts, (2) the expression of a secondary generation of a strong proprioceptive inflow into the brain capable of decreasing the painful stimulus' expected biological (or psychological) negative effect on the nervous system and, finally, (3) the expression of conditioned stimuli signalling "final mobilization" of the mechanisms of self-regulation of nervous activity, the "starting readiness" of the organism to respond quickly to nociceptive stimuli by a defensive-motor reaction.

Another example. When a person in a situation of strong intellectual and emotional tension (for example, during a speech at a meeting, during an agitated conversation or discussion, etc.) performs motor reactions which are inadequate for the concrete situation -- many times unnecessarily adjusts his glasses, dress, suit, smoothes his hair, seizes a glass of water and drinks several mouthfuls of water, turns over the papers in front of him, picks up unnecessary objects, coughs, etc., etc. -- all these motor stereotypes serve as a means not only for carrying out the first and second type of self-regulation of higher nervous activity, but also as a source of afferentation which signals the brain concerning the successful accomplishment of one or another motor act which is, however, quite unnecessary for the given situation.

Thus, for an agitated person, and to a certain degree also for the people present, an illusion is created that some expeditious movements are being performed. The disorganization and inadequacy of the person's effector integration, the presence of a pessimal system and the relatively low level of integration of his higher nervous activity are thereby masked.

Thus, components of the complex motor stereotypes, in acquiring the significance of signal reactions, take part in the self-regulation of higher nervous activity. As the result of the formation and strengthening of functional connections between the links of the stereotype which have different signal significance, conditions can be created in which activation of the link having actual adaptive significance for the concrete situation cannot be carried out until various links functionally connected with the first link, but not having any significance for the situation are activated.

For example, some smokers "cannot" begin any serious work, conversation or discussion of business matters if first of all they have not performed the appropriate "ritual" of motor reactions connected with preparation for smoking and have not carried out the latter.

Some people have become so accustomed to stereotyped gestures and phrases that, having said no more than three or four phrases cannot continue the conversation further since they are "compelled" to perform their standard gesture or imitative reaction or to pronounce their standard words ("there," "it means," "so to speak," etc.)

It happens that a superstitious person permits himself to step over the threshold of a room only with the right leg. Another superstitious person cannot leave the house without crossing himself, etc., etc.

Signal reactions, including inadequate ones, develop intensely in situations causing in an individual intensification of the tension of higher nervous activity and thereby the mobilization of all types and variants of self-regulation of nervous activity.

Signal reactions participating in self-regulation of higher nervous activity also take place in animals.

SIGNAL REACTIONS IN EXPERIMENTAL ANIMALS

§3. Somatic and visceral signal reactions are accessible to physiological analysis. Experiments which have been carried out on animals for the purpose of studying conditions of the onset and the biological characteristics of behavioral signal reactions are examined in this section.

1. In one series of experiments a defensive-motor conditioned reflex was developed in dogs by the Petropavlovskiy method (conditioning signal which causes a clear conditioned reflex raising of the stimulated extremity was not reinforced by an electroskin stimulus). Differentiation also developed, however it remained very unstable.

It turned out that in the experimental dogs the conditioned reflex raising of the extremity developed not only upon the appropriate conditioning signal but also under the influence of the experimental situation, from the use of differential or extinguishing signals and in general from any s ress of internal inhibition.

After stabilization of the developed conditioned reflex, the experiments were stopped. After a week in some of these dogs another type of defensive conditioned reflex was developed which was reinforced by pouring a solution of 0.6% hydrochloric acid into the mouth, and in other dogs, conditioned food reflexes were formed. Other light and sound stimuli, differing from those which were used in developing a defensive-motor reflex according to the Protopopov method, served as the conditioning signals.

It developed that in some dogs with a difficult state of the nervous system connected with overstrain of internal inhibition, a more or less unmotivated tonic raising of the right rear extremity sometimes develops. In certain situations from the use of a differential or extinguishing signal, a very prolonged tonic flexure of the right rear leg developed in the animal. The impression was created that by raising the extremity the animal is attempting as if to "eliminate" the difficult state of the nervous system and to get rid of probable erroneous reactions which are possible in the animal as the result of inaccurate differentiation of the signals.

If it is considered that in experiments on the development of defensive-motor conditioned reflexes, the timely raising of the extremity freed the animal not only from the electro-skin reinforcement, but also from the necessity of accurately distinguishing positive conditioning signals from differentiating signals, then it becomes clear that the raising of the extremity has acquired in the animal the significance of a signal reaction signalling that in the near future the animal is not threatened with danger and exertion of nervous activity is not required. When in the same laboratory situation new conditioned reactions were developed in the animal on the basis of a different type of reinforcement and difficult states of the nervous system which are not eliminated by the newly developed reactions were created, then the earlier developed signal reactions were observed, that is, forms of self-regulation of higher nervous activity which formerly produced a beneficial adaptive effect were mobilized.

2. The Bekhterev-Protopopov method is the method of developing defensive-motor conditioned reflexes in dogs and certain other animals (rabbits, sheep and goats) which is most widely used by Soviet and foreign physiologists. In spite of the fact that the conditioned signals, as a rule, are reinforced by electric skin stimulation of the extremity independently of the presence or absence of the conditioned reflex (raising of the extremity being reinforced), conditioned reflexes are usually developed, differentiated, extinguished and restored by the same rules as any other conditioned reflexes having primary adaptive significance. The question arises of how to explain the fact that the animal performs conditioned reflex flexure of the extremity many times although this is not dictated by the external situation in any way.

Liddell (1956), who studied the development of conditioned flexure of the front leg in sheep by a similar method, believes that conditioned flexure, that is, raising of the front leg is a symbolic motor act replacing (as a surrogate) the motion of the animal's running away from the experimental situation.

It seems to us that it is most important to answer the question of why all animals in response to an electric skin stimulus, as a rule, flex, that is, raise the stimulated leg, in spite of the fact that such raising does not involve instantaneous cessation of the stimulus. Evidently, raising of the stimulated extremity is a defense reaction which was developed and strengthened during the animal's life, a natural conditioned reflex which under natural conditions of the animal's existence usually led to the elimination of a nociceptive stimulus, in connection with which it acquired the significance of a signal reaction.

It is very natural that under experimental conditions in which electrodes are firmly attached to the extremities, the animals respond to the stimuli with a stereotyped natural conditioned reflex, the accomplishment of which is a conditioned signal of adequate response for the animal's nervous system.

It makes no difference at all to the animal at which position of the extremity the latter receives the stimulus. If, for example, the stimulated extremity is mechanically obstructed in such a way that the animal cannot raise, flex or straighten it, the application of an ordinary electric skin stimulus causes compensatory raising of the symmetical extremity and if it is also blocked, the animal develops severe excitation which is manifested in the somatic and visceral sphere of the organism (see Ch.2, §4).

It was established as a result of observations that electrical stimulus of the extremity is more easily withstood by the animal if the animal in response to this stimulus can raise, that is, flex the extremity, and if this is impossible or difficult (for example, by artificial restriction of movements of the extremity in certain directions), can straighten it. Continuation of the stimulus against the background of a raised leg is withstood more easily than against the background of a lowered and artificially blocked leg.

The fact that with the usual method the electric skin stimulus is applied only for a few seconds (or non-continuously 2-3-4 times in a row, each time for ½-1 sec with an interval of 1-2 sec) promotes strengthening of the signal significance of the flexure of the extremity since the electric stimulus always stops in the next seconds after flexure.

In certain dogs, in spite of stabilization of the reaction of flexure of the extremity in response to electrical stimulus, the conditioned reflex is not stable or is not developed (more accurately, it is first developed and then fades away). This indicates that raising of the extremity in response to the applied conditioned signal loses its initial signal significance and, possibly, acquires the opposite signal significance, signalling the imminent beginning and continuation of a nociceptive stimulus.

In some cases during the formation of a defensive-motor conditioned reflex by the Bekhterev-Protopopov method, a conditioned reflex is developed which has the oppositive direction in comparison with an unconditioned reflex, that is, it is expressed not in flexure, but in straightening of the extremity which is a typical signal reaction, only of a more complex origin than flexure. The fact is that the flexure, repeatedly coinciding in time with the application of an electric skin stimulus, becomes as if the signal of this stimulus, whereas straightening which replaces the initial flexure acquires the opposite significance. Thus, the dog, being incapable of eliminating the stimulation of the leg by flexing it, resorts to a reaction which is opposite in direction -- to straightening. The signal significance of straightening of the leg is reinforced by the fact that it usually develops only as a conditioned reflex since from an electric skin stimulus flexure is found. The dog evidently attempts timely "prophylactic" straightening of the leg as if to prevent the subsequent nociceptive stimulus and compelled flexure.

4. In experiments on the introduction of a rubber probe with an inflated baloon into a dog's stomach in order to record the stomach's motility, the following unique signal reaction of the animal was observed.

Two dogs developed a nonspecific general preparatory conditioned reaction (anxiety reaction). A 10-second electrical stimulus of the skin of the back served as the unconditioned reinforcement. A loud electric bell which acted in isolation for 120 seconds served as the conditioned signal. After several combinations of the bell with the electric skin reinforcement, the use of the bell alone caused a strong anxiety reaction and emotional excitation in both dogs, changing after several seconds into a general defensive reaction, which, as a rule, which ended with ejection of the probe. After ejection of the probe the dog immediately became calmer and upon the application of an electric skin stimulus did not display a general defensive reaction.

In those experiments in which a probe was not introduced into the stomach, the dog reacted to the bell considerably more calmly. It is interesting that ejection of the probe was repeated during any difficult states of the animal, including in experiments in which an electric skin was never used, for example, during extinction of the signal significance of the bell.

The same thing was repeated during overstress of internal inhibition in experiments in which other conditioned reflexes were developed on the basis of different reinforcement, for example, repeated pistol shots close to the animal's head. At the beginning of the experiment, when positive and differential signals had still not been used, the dog stood relatively quietly and the probe functioned normally. However, one only had to turn on the conditioning signal (light or metronome) and the dog responded with a strong anxiety reaction and ejected the probe.

It should be emphasized that the interceptive influx due to the probe and inflated baloon introduced into the stomach caused a latent reaction which, in adding to the anxiety reaction caused by the conditioned signals, promoted the development of severe emotional excitation and overstress of conditioned reflex inhibition.

As a result, the mechanisms of self-regulation of nervous activity were mobilized and urgent shifting of a large number of brain activity impulses to the peripheral effectors occurred. Violent motor and respiratory reactions developed, and often -- a real general defensive reaction which sometimes did not produce a positive effect: after all, the animal could not escape from the experimental support and from the straps. Then the animal ejected the probe and immediately became quiet. The ejection of the probe which is an expression of the first type of self-regulation of higher nervous activity acquired still another, secondary adaptive effect: it became a signal of the successful accomplishment of the equivalent of a general defensive reaction, that is, of freeing the animal, if not from the entire nociceptive experimental situation, at least from the harmful stimulus -- the probe. The ejection of the probe thereby acquired the significance of a conditioned stimulus signalling subsequent cessation of a difficult state of the animal's nervous system.

5. In experiments with free movement of the animal in the experimental cage, locomotor signal reactions were produced in white rats.

In response to positive conditioned signals, the rat had to run over to the opposite side of the chamber, otherwise it received an electric skin stimulus from a metallic wire at the bottom of the chamber. In response to negative signals the rat had to remain on the same side of the chamber where it was at the time of the signal, in the opposite case, if it ran to the opposite half of the cage, there it received an electric skin stimulus. In cases in which differentiation of positive and negative signals proved to be too difficult for the animal and caused severe stress of its higher nervous activity (for example, differentiation of M_{120} and M_{140}), the animal developed a sharp motor disturbance or a severe reaction within itself. Then a small platform was placed in the experimental cage (see Fig.45,platform C). In running over to this platform, the rat received an electric skin stimulus which was considerably weaker than the stimuli received by the animal in the case of an incorrect response reaction to conditioned signals. If the animal remained on the platform longer than 15 sec, a stronger current was turned on and the rat received a stimulus of the same intensity as in areas A and B. As a result the rat ran from the platform to the original side of the cage.

It turned out that some rats developed from difficult differentiation a unique defensive reaction: instead of "risking it" and running to the opposite half of the cage or remaining in the same half, the rat "preliminarily" ran to the platform and from there after 10-15 seconds returned to the original area of the cage.

However, the most interesting thing was observed in the next series of experiments in which food-motor conditioned reflexes were developed in the rats. Upon difficult differentiation of the conditioned stimuli signalling a supply of food sometimes on the left and sometimes on the right side of the case or the absence of food, the previously developed reaction of running to platform C was disinhibited in some animals which evidently had acquired in the animal the significance of a signal reaction permitting a temporary release from the necessity of solving a difficult problem -- differentiation of the conditioned signals.

A similar running over to the platform (entirely inadequate for the actual situation) sometimes was also observed in those cases of experiments in which a strong sound stimulus -- continuous ringing of a loud electric bell -- was used as the unconditioned stimulus.

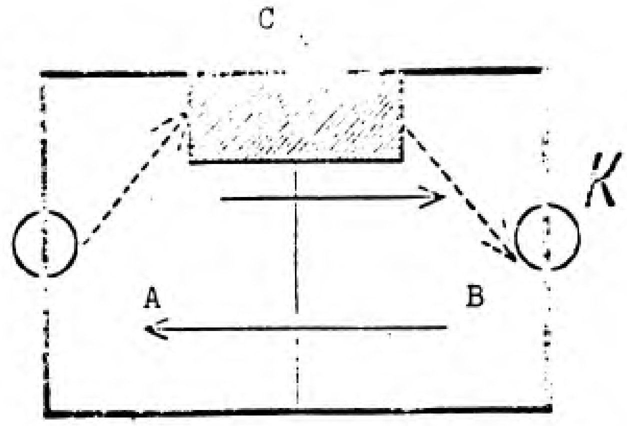

Fig. 45. Schematic illustration of experimental cage and conditioned reflex running of the experimental animal. The dotted line designates the direction of the signal reaction -- the running of the animal to platform C (see test).

Essentially similar observations were carried out on cats and dogs in an experimental room in large chambers constructed on the principle of the chambers used in experiments on rats. Some cats showed similar reproduction of a signal motor reaction having, as in the rats, only "symbolic" significance in new situations of the experiment. Less convincing results were obtained with dogs, however, they also showed a tendency for reproduction under conditions of severe stress of internal inhibition of a (previously developed) signal locomotor reaction inadequate for the situation.

SIGNAL REACTIONS OF PRIMARY AND SECONDARY ADAPTIVE SIGNIFICANCE

§4. The data presented indicate that any motor reactions of an animal if, in one or another situation they repeatedly promote the achievement of a biologically beneficial effect or coincide in time with stimuli or reactions providing such an effect, can acquire signal significance, can be reinforced in a conditioned reflex manner and can be reproduced in situations analogous to some degree with the initial situations. In the experiments described above, the analogy lay in the fact that the experimental animals were in the same experimental room or cage and that the new situations required from the animals similar stress of higher nervous activity.

However, the signal reactions did not have any primary adaptive significance in the new situation. The question arises of why it is necessary to believe that they had any secondary adaptive significance at the same time. It is possible that in the new situation they were both primarily and secondarily inadequate and were the expression only of inadequate functioning of the mechanisms of the conditioned links reproducting them in virtue of inertness and stereotypicalness.

Where is the guarantee that the "signal reactions" which we described were actually signals and participated in the mechanisms of self-regulation of nervous activity? The question is rather complicated and it is not easy to answer it. After all, motor reactions which are similar in origin have been described by many authors and none of them have connected these reactions with mechanisms of the self-regulation of the processes and level of higher nervous activity.

For example, cases are well-known in which an animal approaches a conditioned stimulus which signals a biologically useful reinforcement and turns away from a conditioned stimulus which signals biologically negative reinforcement. It is also known that an animal sometimes turns away from differential stimuli signalling an uncertain position of the animal -- when the animal has to differentiate the signal meaning of the stimuli and this differentiation proves to be very difficult. For example, with the application of a differentiated signal the experimental rat sometimes turns away from it, and in some cases even runs to a corner of the experimental cage in order to thus "avoid" a difficult situation (Karuklis, 1952, 1955, 1960a, 1962).

In Kupalov's laboratories cases have been observed many times in which under conditions of free movement an experimental dog in response to inhibitory signals ran in the direction of the door, attempting to avoid an experimental situation which requires too severe exertion of higher nervous activity as well as similar "biologically negative" reactions. Kupalov has also described very curious cases in which the application of a conditioned stimulus -- turning on a light -- which signals the arrival of food caused a unique reaction in a dog -- salivation not only developed but the dog also began to lock the electric lamp. Thus, the conditioned signal became as if a substitute for food (Kupalov, Khananishvili, 1958; Kupalov, Volokhov, Voronin, 1960).

"Substituting" motor reactions developing against a background of severe stress of higher nervous activity have been described by many Soviet physiologists (see Krauklis, 1960a, p.191). For example, cases have been described in which an experimental dog upon application of a differential stimulus begins to lick the feed box and drink the water standing near it (Pavlova, 1949). Another example. An experimental monkey when a rabbit was brought into the room under a bell jar became very excited, collected the food residues scattered around the room and greedily ate them up (Dolin, Zborovskaya, Zamakhover, 1958).

All the mentioned and similar "substituting" reactions or reactions directed toward avoidance of conditioned inhibitory signals are distinguished by the fact that, first, they do not have any primary adaptive significance in the concrete situation (since they do not satisfy the organism's requirements and do not promote to any degree the achievement of positive unconditioned stimuli or the avoidance of nociceptive stimuli), and second, they are caused by difficult states of the nervous system or stimuli signalling the development and deepening (actual or likely in the future) of the difficult states. In view of the considerations presented in the first three chapters of this work, there can be no doubt that the motor reactions being considered are components of the first and second type of self-regulation of higher nervous activity. At the same time, the fact that these reactions according to the conditions of their development and secondary adaptive significance are equivalents, or surrogates, of primary adaptive reactions (being thereby as if "symbolic"substitutes of real adaptive reactions) speaks of the signal nature of these reactions.

Thus, the signal reactions which we are describing are characterized by the fact that they "serve" the interests of self-regulation of higher nervous activity. They differ in this from other signal reactions of the organism which directly provide a primary adaptive effect.

An analysis shows that any behavioral and respiratory reaction of animals can be considered as a signal reaction of their own type. Actually, any behavioral reaction in adult animals is a component part of a more or less complex stereotype of reactions, that is, it signals the next link of the stereotype. Moreover, any effector reaction continually signals the brain of its course, of the achievement or nonachievement of the given adaptive effect.

It is understood that visceral reactions, being a component part of various stereotypes of the organism's effector activity can acquire signal significance and emerge as signal reactions. However, their role in the self-regulation of higher nervous activity (with the exception of respiratory reactions) has been studied very insufficiently.

The approaching of an experimental animal to the feed box and the pressure of the paw on the pedal, as a result of which the feed box is opened and the animal receives food, can serve as an example of a signal reactions of primary adaptive significance.

The animal's turning away from the feed box and the pedal, as well as turning away from turning on the metronome if it signals the necessity of fine differentiation and the probable nonobtaining of food can serve as an example of a signal reaction of secondary adaptive significance. A dog's approach to a metronome which usually signals the obtaining of food, intensive wagging of the tail, etc. is such a signal reaction of secondary significance.

Thus, there is a basis for distinguishing the following two categories of signal reactions (similar to the way in which we distinguished two categories of the adaptive effect -- primary and secondary).

1. Signal reactions reproduced as components of various motor stereotypes for the purpose of signalling and causing by conditioned reflex means the following components (links) of the

stereotype, leading in the final analysis to the immediate accomplishment of the primary adaptive effect desirable in the given situation.

2. Signal reactions reproduced as components of self-regulation of higher nervous activity.

Signal reactions of the first group can be designated as signal reactions of primary significance, signal reactions of the second group -- as signal reactions of secondary significance.

In the present work we shall mainly consider signal reactions of secondary significance.

In our previous work (Krauklis, 1960a) signal reactions were not divided into two groups according to the predominance of primary or secondary adaptive significance. In characterizing the third type of self-regulation of nervous activity, we had in mind signal reactions of secondary significance as the means of the nervous system's secondary effect on its functional state. However, the absence of a demarcation of signal reactions of primary and secondary significance could lead to a misunderstanding since any conditioned reaction signalling various subsequent stimuli or functional changes in the nervous system could be considered as a signal reaction evoked for purposes of carrying out self-regulation of higher nervous activity.

Of course, practically any conditioned and unconditioned reaction to one or another degree participates in self-regulation of higher nervous activity, that is, it has some secondary adaptive significance. This also pertains to signal reactions. But at the same time it is methodologically expedient to discriminate signal reactions primarily providing a primary effect from signal reactions primarily or exclusively providing a secondary effect.

We might observe the development of a signal reaction of secondary significance in the following experiment. A conditioned reflex was developed in a dog -- flexure of the right hind leg. The duration of the unconditioned reinforcement -- electrical stimulation of the skin of the paw with an induction current -- varied depending on the presence or absence of flexure of the extremity at the moment of application of the reinforcement. If the animal in response to a special conditioned signal (for example, sound) or in response to a time factor before the application of the reinforcement carried out sufficient flexure of the stimulated extremity, the electrical stimulus was turned on for ½ second. If the animal flexed the extremity only in response to the stimulus, the length of the latter was greater, that is, the stimulus was turned off only after definitive flexure of the extremity. After the development of conditioned reflex flexure, during the experiment the right rear extremity was blocked with the help of a special mechanism.

Against the background of blocking of the "stimulated" extremity, the conditioned signals used, as well as electrical skin stimulus, began to cause strongly expressed compensatory flexure of the free symmetrical extremity. In this case, such expressed (in frequency and intensity) compensatory flexure of the left rear extremity continued for a long time after deblocking of the right rear extremity. The more the exertion of the animal's higher nervous activity was intensified from the effect of the experimental situation and the stimuli applied, the more frequent the compensatory flexure became in the intervals between stimuli, especially at the end of the interval when the compensatory flexures developed as a conditioned reflex in time (Fig.46, as well as 16).

The development of strongly expressed compensatory movements during blocking of the reinforced extremity evidently is the result of the mobilization of the first type of self-regulation of higher nervous activity (see Ch.2). However, the continuous development of frequent and strong compensatory flexures of the left extremity after cessation of blocking of the right extremity and the comparatively less frequent and strong flexures of the right extremity in the period after deblocking of the latter indicates that not only the first, but also the third type of self-regulation is mobilized.

Evidently, the compensatory flexures of the left hind extremity during blocking of the reinforced extremity acquired the significance of a signal reaction signalling the presence of a relatively "optimal system" of stimulation when the current is turned on only for ½ second. The compensatory flexure thereby became the signal of a more optimal system of higher nervous activity and was reproduced in a conditioned reflex way for purposes of self-regulation of the functional state of the brain.

All the stimuli(extero- and interoceptive) signalling the probable (expected) onset of nociceptive stimulation and, accordingly, intensification of nervous strain, as well as possible deviation of the system of nervous activity from the optimum served as the conditioned stimulus which reproduces the compensatory flexure. Since by the end of the interval between stimuli the probability of the repeated onset of nociceptive stimulation has increased more and more, compensatory flexure at the end of the interval developed more frequently than in the middle of the interval.

The question arises of why the leading compensatory and signal reaction after deblocking of the dog's stimulated extremity became flexure of the left, and not the right rear extremity. After all, before deblocking of the right extremity the left had not participated in the carrying out of either the first or the third type of self-regulation of nervous activity. If before the blocking the increased nervous strain required the mobilization of mechanisms of self-regulation, this was realized by intensification and increased frequency of the flexures of the right extremity or intensification of the animal's general motor activity.

What has occurred as the result of the blocking and deblocking of the reinforced extremity? Evidently, the left rear extremity became the leading effector in carrying out self-regulation of nervous activity precisely because it never had received reinforcement by an electrical current and the function which it is realizing -- flexure -- never had adaptive significance for the left extremity itself, but was always only a "symbolic" substitute for the adaptive reaction of the right extremity. As observations of people show, the movements and behavioristic acts which do not have direct adaptive significance in an actual situation most frequently become signal reactions of secondary significance.

The difficult extinguishability of the compensatory flexure of the left extremity is evidently explained by the fact that mechanisms of self-regulation of nervous activity are continuously activated by the experimental situation and the actual exertion of nervous activity. As a result of a decrease in cortical tonus and the level of integration of effector activity, the individual easily reproduces previously developed motor stereotypes, including stereotypes participating in mechanisms of self-regulation.

It is possible that the difficult extinguishability of flexure of the left extremity as a signal reaction of secondary significance is also connected with the fact that not one or another primary adaptive effect, one or another extero- or interoceptive stimulus, but the definite intracentral coordination which determined the nervous mechanism serves as reinforcement of the signal reactions. Therefore, the absence of various extero- or interoceptive stimuli, for example, cessation of the application of electrical skin stimulation of the right rear extremity in the experiment, has little effect on the dynamics of signal reactions.

Actually, when we carried out extinguishing of the developed conditioned reflex -- flexure of the right rear extremity, from the effect of the experimental situation and the extinguishing stimuli, flexure both of the right and of the left extremity still developed for a long time in the dog, in this case flexure of the right (that is, the previously reinforced) extremity developed considerably more infrequently and was weaker than flexure of the left extremity.

When several months after cessation of the experiments, in a different experimental situation other conditioned reflexes began to be developed in the same dog, for example, food or acid-defensive reflexes, frequently during severe exertion of higher nervous activity the previously developed flexure reflex was de-inhibited in the animal. In this case, flexure of the left rear extremity developed much more frequently than flexure of the right extremity.

So-called conditioned reflexes of the 2nd type according to Konorskiy can serve as examples characterizing the necessity of delimiting signal reactions of primary and secondary significance (Konorskiy, Miller 1933, 1936; Konorskiy, 1948, 1950, 1962; Konorskiy, Wyrwicka, 1950; Wolf, 1963).

According to Konorskiy (1948) any movement of an animal which leads to satisfaction of various biological needs or coincides in time with stimuli (situations) signalling satisfaction (or non-satisfaction) of these needs has a tendency to be reproduced in analogous situations (Krauklis, 1960a, p.221).

If in an experimental dog the flexure of one or another extremity accidentally (or as a result of organized interference on the part of the experimenter) coincides with food reinforcement, then in a situation of alimentary stimulation, without the use of special signals, conditioned reflex flexure of the same extremity can develop in the dog. The latter represents a conditioned reflex flexure of the animal's extremity in itself is not reinforced by food (the entire situation in which the animal is found is reinforced by food), it does not have any immediate, that is, primary adaptive effect, and in connection with this it can be considered as a signal reaction of seconday adaptive significance.

If the conditioned reflex flexure of the experimental animal's extremity (or of one or another subsequent component of the stereotype caused by the flexure), as a rule, is reinforced by food, then flexure of the extremity becomes a typical example of a signal reaction of primary adaptive significance. Any components of motor stereotypes or motor chain reflexes are signal reactions of primary significance.

The flexure of the extremity which was developed in the first case (that is, a conditioned reflex of the 2nd Konorskiy type) is distinguished by very difficult extinguishability. At the same time, the flexure developed in the second case (a conditioned reflex of the 1st type) fades in proportion to the increase in the number of nonreinforced by food flexures.

Thus, signal reactions of secondary significance are as if "symbols" (equivalents or surrogates) of signal reactions of primary significance. In order to emphasize the tremendous importance of the development of mechanisms capable of reproducing such "symbolic reactions," it is necessary to indicate the face that a child's verbal signaling and speech evidently develop on the basis of similar in principle, only considerably more complex, nerve mechanisms.

THE STUDY OF SIGNAL REACTIONS BY THE METHOD OF "SELF-STIMULATION" OF THE BRAIN IN EXPERIMENTAL ANIMALS

§5. The method of "self-stimulation" by an animal of the nerve structures of its brain opens broad possibilities for the study of self-regulation of higher nervous activity with the help of signal reactions in experimental animals (Olds, 1958, 1962; Brady, 1958; Lilly, 1959, 1962; and others).

In particular, this method makes it possible to study the acquisition of primary and secondary adaptive significance by signal reactions.

As is known, the principle of the method of "self-stimulation" lies in the fact that the experimental animal with electrodes implanted in the brain can by means of various motor acts close the circuit and pass an electric current through these electrodes, thus carrying out "self-stimulation" of the brain. Usually this occurs with the help of depression of a lever (pedal) by the front extremities or by means of running through a labyrinth to a specific place. Depending on the location of the electrodes in the animals after the first attempts at pressing the lever, a continuous tendency toward repeated depressions develops, that is, toward self-stimulation, or a refusal of further depressions develops.

Evidently, such a selective attitude toward depression of the lever (or toward running through the labyrinth, if the labyrinth method is used) is connected with the development of biologically positive or negative reactions in the brain with appropriate subjective sensations and experiences of the animal.

It should be emphasized that depression of a lever or running through a labyrinth are typical signal reactions of primary significance providing a specific primary adaptive effect -- the achievement of a biologically beneficial intracentral reaction and a pleasant subjective experience or the avoidance of a biologically negative intracentral reaction and an unpleasant subjective experience.

The depressions, emerging as signal reactions of primary significance, are developed and fade like well-known classical conditioned reflexes.

Olds (1962), for example, observed the following phenomenon. Running through a labyrinth was developed in experimental rats. If the animal ran "correctly" it received electrical stimulation of a specific section of the brain which causes a biologically positive experience. However, in the repeated absence of a biologically positive "electroreinforcement," conditioned reflex running through the labyrinth, as a rule, began to die out.

Thus, extinguishment of the runs, that is, of signal reactions of primary significance, occurs in accordance with principles of the extinguishment of classical conditioned reflexes.

At the same time, under certain experimental conditions it is possible to observe the involvement of signal reactions in mechanisms of self-regulation of the system of higher nervous activity, that is, the development of signal reactions of secondary significance.

For example, Olds in experiments on monkeys observed the following extremely interesting phenomenon: in difficult states of the experimental animal's nervous system, the frequency of motor reactions causing self-stimulation and generating a biologically positive emotional effect increases considerably.

It was established in Lilly's experiments (1962) that a monkey will apply (by means of pressing a lever) stimulation to itself much sooner and more frequently when it is frightened. In this case it continues to press and release the contact lever even when it no longer receives a biologically beneficial reinforcement.

Thus, against the background of severe stress and pessimalization of the system of higher nervous activity, the pressing of a contact lever rapidly acquires in the animal the significance of a signal which is reproduced for purposes of self-regulation, that is, for purposes of optimalization of the system of higher nervous activity. In this case, signal reactions of primary adaptive significance simultaneously became signal reactions of secondary significance.

Lilly emphasizes that self-stimulation by animals of the nerve structures of the brain which generate a positive emotional effect causes a clear positive emotional aftereffect: the monkey becomes less excited and displays a positive attitude toward the investigators. Self-stimulation is capable of lessening the depressed emotional state which develops in an animal in isolation.

Olds (1962) believes that as a result of "self-stimulation" innate "systems of reinforcement" located in the visceral brain (that is, in the archeocortex), thalamus, tegment or in other nerve structures around the hypothalamus are activated. A combination of the self-stimulation method with the Pavlovian method of studying higher nervous activity can, it seems to us, be of much help in a more thorough study of many questions concerning the origin, physiological mechanisms and, particularly, the biological and psychic characteristics of different types and variants of self-regulation of higher nervous activity in higher animals. However, it should be recognized that authors who have used the method of self-stimulation in carrying out their investigations have still not formulated the problem of conditioned reflex self-regulation, or self-adjustment, of the system and level of higher nervous activity and therefore could not study this self-regulation.

SPECIFICS OF THE THIRD TYPE OF SELF-REGULATION IN MAN

§6. Self-regulation of higher nervous activity by means of establishing a system of conditioned signaling in animals is carried out with the help of the signal reactions considered above which modify the stereotype of conditioned stimuli evoked by the surrounding world or by the functioning of the animal's organism. In this case, modification or reorganization of the stereotype of the stimuli of the ternal world which act on the organism occurs in animals mainly as the result of approaching stimuli signaling biologically useful changes in the functional state of the nervous system which optimalize and stabilize the system of higher nervous activity, or as the result of avoiding stimuli signaling pessimalization of the system. An active influence over the external world which is expressed in the "creative" transformation of the stereotype of signals of the external world in accordance with the demands of the functional state of the nervous system plays a comparatively smaller role.

The ability for active transformation of the stereotype of conditioned signals of the surrounding environment for purposes of maintaining an optimal system and level of higher nervous activity is more developed in higher animals which live in herds, and especially, in monkeys.

In man the third type of self-regulation acquires not only extremely important, but also leading significance in the self-adjustment of the system and level of nervous activity, especially of mental activity.

In contrast to animals, man carries out the third type of self-regulation mainly by means of the creative transformation of those complex systems of stereotypes of conditioned signals which occur in the world around him -- in nature and society. However, the most fundamental difference is that man uses speech for purposes of self-regulation of nervous activity which emerges as a universal "substitute" for or signal of real objects and attitudes.

Thus, in man the third type of self-regulation achieves the most complete development: with the help of words, that is, of thinking and speech, man is capable of influencing to an unlimited degree the system of conditioned signaling which acts on his nervous system. Each word, each phrase, each thought of a man is simultaneously a signal reaction of primary and secondary adaptive significance. Thus, man as the result of his historical development has obtained an effective "weapon" with whose help he can potentially sovereignly act not only on the minds of other people, but also on his own mind. However, man often uses these vast possibilities of the effect of the "word" on the nervous activity of other people and on his own nervous activity insufficiently effectively.

Man carries out self-regulating of his mental activity, not knowing and not thinking about it, and in connection with this, not taking into account the objective principles of self-regulation. A new scientific discipline must be created which includes mental hygiene and psychoprophylaxis and studies the physiological, biological, psychological and social aspects of self-regulation of human higher nervous activity. Here, a determination of the fundamental principles of self-regulation of human mental activity by means of conscious organization of the system of conditioned signaling which acts on the nervous system will be particularly difficult, but at the same time, extremely useful for man. It should be expected that in a study of these principles, physiologists, psychologists and doctors will widely use mathematical and cybernetic methods of analyzing the observed phenomena.

We believe that the third type of self-regulation -- self-regulation by means of the establishment of one or another system of influx of conditioned signaling into the brain -- cannot be successfully studied in people with the help of traditional physiological and psycho-physiological methods of investigation. At the same time, the development of new, effective methods of study is very difficult since it is necessary to simultaneously take into account physiological and psychological principles, as well as criteria of the social effectiveness of the third type of self-regulation.

In connection with the fact that the existence of the third type of self-regulation in man is convincingly demonstrated by man's daily experience, and adequate methods for a thorough physiological analysis of the third type of self-regulation are still absent, there is no need to present the data of observations proving the fact of the mobilization of this type of self-regulation.

It should be assumed that all types and variants of self-regulation of higher nervous activity which are accompanied by one or another secondary adaptive effect acquire in man signal significance and affect the functional state of the nervous system also through a second signal system, that is, through mechanisms of the third type of self-regulation.

In this connection, it should be noted that some subjects, in trying to explain after the end of a session of observations their development during the session of an expressed anxiety reaction (in the form of contraction and expansion of the skeletal musculature, an increase in the inspiratory tonus of the respiratory muscles, etc.), declare that in those cases in which they strain the musculature and take the position of "starting readiness," it is as if their "assurance" is increased, in that they are "prepared" for any possible sudden, and perhaps, unpleasant stimuli. It is evident that in a situation of laboratory observations when the subject expects the probable emergence of different known and unknown stimuli, the state of a patient in a dentist's office who expects the probable development of painful sensations as the result of drilling the teeth or of other manipulations of the oral surgeon in the oral cavity is repeated in miniature. It is well-known that the patient's timely mobilization of the reaction of physical and mental "readiness" for probable painful stimuli and for the appropriate response reactions sometimes helps the patient to overcome a state of uncertainty and apprehension. At the same time, is is well-known that an inadequately strong reaction of anxiety and emotional tension caused by a person's unmotivated ideas and by autosuggestions of a negative character can promote not optimalization, but pessimalization of the system of his nervous activity. In both cases, the third type of self-regulation of higher nervous activity takes place, which is also accompanied by the first and second type of self-regulation.

The deep inspiration which develops immediately after the cessation of different stimuli and which is a component part of the reaction of neuro-musculature relaxation (see Ch.6,§6) often acquires the significance of a signal reaction in man. Frequently, in situations requiring from the subject severe exertion of higher nervous activity, the deep breath is reproduced many times in the intervals between stimuli. This is noted especially frequently in neurotic children (Krauklis, 1956, 1957) (fig.47).

It must be assumed that the deep breath can act as a signal signaling subsequent relaxation, that is, a decrease in inadequately strong neuro-muscle tension. Of course, at the same time it can also serve as an expression of the first and second type of self-regulation.

SELF-GENERATION OF IDEOLOGICAL MOTIVATION -- THE MOST CHARACTERISTIC VARIANT OF THE THIRD TYPE OF SELF-REGULATION IN MAN

§7. The most typical and important type of self-regulation of higher nervous activity in man is self-regulation with the help of verbal signals in the form of thought and speech acts.

Verbal signals, like any signal reactions, can have primarily primary or secondary adaptive significance or both simultaneously. The secondary significance of verbal signaling is used in mechanisms of self-establishment of the system and level of higher nervous activity. The primary significance of verbal signaling is used in human creative work activity which transforms nature and society.

Verbal signaling conveys information to an individual about past, present and probable future events of the external world and his body (the primary adaptive effect of signaling), as well as information about past, present and probable future subjective intellectual and emotional attitudes of the individual toward the indicated event, about subjective moods and feelings, the person's desires, aspirations and dreams (the secondary adaptive effect of the signaling).

As the result of the transformation of the information entering the nervous system, information coming out of the nervous system develops which signals to other people, as well as back to the person himself, about how events of the external world and of his body, particularly his mental activity, are reflected by the person.

With the arbitrary establishment of attention toward various aspec s of the content of the incoming and outgoing information, a person is capable within certain limits of regulating his intellectual and emotional mood, the level and the working capacity of mental activity.

If self-regulation of mental activity through word signaling is directed toward facilitation of the person's achievement of a primary adaptive effect which is adequate for the situation (actual or expected in the future), then thanks to this, it becomes an exceptionally important factor in the providing of high adaptive effectiveness of higher nervous activity.

It is well-known that socially adequate ideological motivation, creative ideas, positive emotions, good spirits and a happy mood are capable of optimalizing the functions of the nervous system and the whole human organism, even if very difficult situations occur in the person's life.

At the same time, socially inadequate ideological motives, uncertainty of the future, thoughts reflecting only the bad sides of life, prolonged negative emotions, pessimistic moods, etc. are capable to a considerable degree of pessimalizing the functions of the nervous system and the entire organism, and under certain

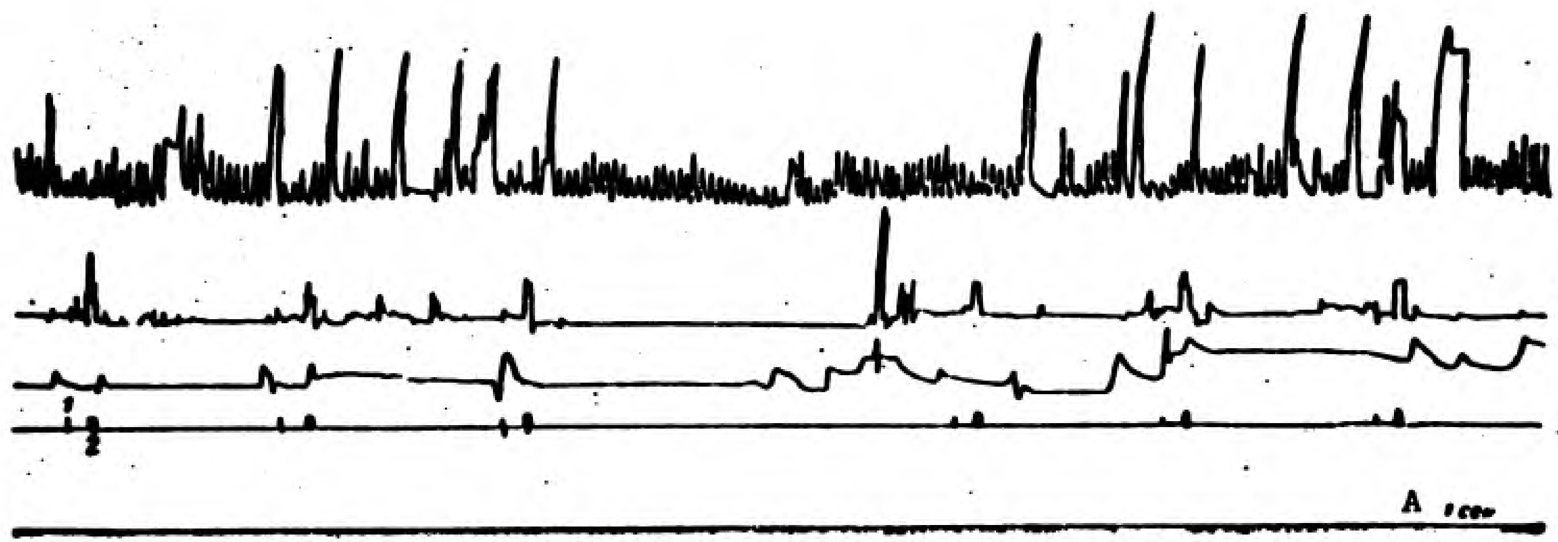

Fig.47. Reproduction of a deep breath as a signal reaction which expresses the nervous system's tendency toward providing neuro-musculature relaxation in the intervals between stimuli in the child neurotic subject L.L. (age 11 years) during development of blinking conditioned reactions. *1*) Conditioned signal; *2*) three-fold stimulation of the cornea with a jet of air. From top to bottom: pneumogram; blinking movements; total contraction of femoral muscles and forearm muscles. A) 1 sec.

unfavorable conditions, of even causing pathological changes in them.

In an analysis of the first and second type of self-regulation (see Ch. 2 and ?` it was pointed out many times that as a result of inadequate organization of self-regulation, negative secondary effects can arise in place of positive secondary effects which pessimalize the system and decrease the tonus and level of human higher nervous activity. The third type of self-regulation exceeds the first two types of self-regulation both in possibilities of providing a high optimalizing effect and in possibilities of causing a sharply pessimalizing effect on the function of the brain in man.

A leading variant of the third type of self-regulation in man, however, which was not mentioned above, is the primary psychic effect of the individual himself on his own mind (that is, autosuggestion), and the primary creative influence of a person on the external world -- on society, on social attitudes, on nature -- with the help of work and any other social activity. As the result of conscious organization of action on the surrounding world, the person thereby regulates the reverse effects of the external world on his nervous system. This reverse effect has the character of verbal signaling or occurs with the direct participation of verbal signaling.

The essence of the third type of self-regulation, thus, lies in the controlling and use of continuous circulation of verbal signalling, that is, of verbal information, between the individual and the social environment for purposes of establishing an optimal system and adequate level of integration of the individual's higher nervous activity.

Therefore, a person acts on the surrounding world not only for purposes of providing a primary adaptive effect (of balancing his body and personality with the external world), but also for purposes of providing a secondary effect -- optimalization of the functions of his nervous system which sometimes in perspective can prove to be more important than providing an optimal primary effect. Of course, the secondary effect, in the final analysis, must serve to provide the person with a socially and personally adequate primary adaptive effect.

In the case in which provision of an optimal system of higher nervous activity through the third type of self-regulation becomes an end in itself for the individual, and does not serve the realization of social labor activity, then (if such a tendency is repeated systematically) the adaptive effectiveness of the individual's higher nervous activity decreases and self-regulation becomes a source not of progressive improvement of the personality, but its degradation (see Ch.8).

The tremendous importance of verbal signaling in self-regulation of human nervous activity is confirmed by the fact that man created and uses music, philosophy, poetry, literature, art, theater and many other forms of ideology not only for reflecting the external and internal world of man, but also for influencing the

the nervous system for the purpose of optimalization and stabilization of the system and reorganization and improvement of the level of its operation.

An effective combination, on the one hand, of cognitive and ideological, that is, social, values and, on the other hand, of an optimalizing effect on the nervous activity makes musical and literary works, as well as the theater, opera and films powerful methods for educating people.

The more effectively these works help a person to optimalize his nervous activity, the more frequently and willingly the person will reproduce these works (or fragments of them) in his thoughts and conversations, the more frequently he will repeatedly read the corresponding poem, repeatedly listen to the song or symphony, etc.

It is well-known that in situations causing a difficult state of the nervous system, a person very frequently carries out self-regulation of his mental activity with the help of the reproduction of suitable ideological motivation -- musical motives, literary samples, moral considerations, etc.

A necessary condition so that the use of ideological, including artistic, motives in self-regulation of human higher nervous activity be highly effective and promote an increase in the level of human creative activity is deep and truthful reflection of human life and times in these motives.

There are a tremendous number of musical, literary and other artistic works which in their content do not promote an increase in the level of creative intellectual and emotional activity of the human brain, but on the contrary, establish (with the help of relatively stereotyped and intellectually primitive themes) a level of brain activity at which it is easy, with minimal expenditure of energy, to maintain an optimal system of nervous activity and to evoke objectively pleasant feelings and experiences.

In many cases artistic works of this type can prove to be beneficial for amusing a person, that is, for elimination of mental stress and fatigue by means of the formation of new themes, whose maintenance requires minimal expenditures of nervous energy and at the same time effectively optimalizes the system of mental activity.

The mentioned artistic works can promote relaxation, however, they will not produce stimuli for the improvement of human mental functions, stimuli for educating people.

At the same time, there are works which provide such stimuli. In their content they are directed primarily toward increasing the level of human perception and creative activity, and not toward optimalization of the system of nervous activity. However, as the result of a stable increase in the level of reflection of the world and of the person himself and the level of human effector creative activity, as a rule, conditions are created which also promote maintenance of an optimal system of nervous activity.

Usually, the greatest expenditures of nervous energy and reserves of the brain's functional capacities occur during reorganization of the original level and stabilization of a new higher level of integration. If a new level is established and stabilized, then its maintenance is usually possible with a relatively economical system of brain functioning.

In man the third type of self-regulation, as a rule, is the initiator and organizer of complicated cycles and complexes which unite several variants and types of self-regulation (see Ch.5).

For example, a person consciously generates (through a second signal system) motivation which evokes and maintains creative work activity for the purpose of effectively "abreacting" "excessive" nervous tension or overstrain, caused by emotional excitation whose external manifestations were suppressed, as well as for the purpose of creating new, secondary positive themes capable of restraining primary biologically and mentally negative themes.

Another example. A person provokes an argument or discussion in order to increase in the course of the argument his emotional tonus to such a degree that the emotional themes inhibit those primary restrictive motives which block free switching to effector paths of "accumulated" and suppressed until then intellectual and emotional tension. As a result, the person succeeds in temporarily eliminating all the inhibitory effects of motives of higher order on the paths of nervous activity switching and he freely "abreacts" through speech, mimicry and gestures all his previously inhibited thoughts, opinions, desires, anger, sympathy, etc.

A mass of similar examples drawn from man's daily life can be presented. The physiological mechanism in all such and similar example is the same -- the third type of self-regulation (that is, self-regulation through self-generation of verbal signaling and idea motivation) which organizes adequate realization of the other types of self-regulation.

An analogous organizing role of the third type of self-regulation takes place within the limits of the functioning of a second signal system -- in fantasy, thoughts, subjective experiences.

Man very frequently mobilizes such themes of the second signal system, that is, such idea motives which provoke intensive reflections, the inner struggle of different points of view, discussion "to oneself" with accompanying emotional experiences of the person, etc. As a result the person sometimes to one or another degree "abreacts" "to himself" the nervous tension which he did not succeed or was not able to "abreact" in real situations of life, or, on the contrary, increases emotional tonus and mental stress to such a degree that it promotes the development of behavioristic activity directed toward a creative influence on the external world and the "resolution" of internal tension and intellectual and emotional activity in real life situations.

The organizing role of the third type of self-regulation in providing the establishment of an optimal system and the desired level of higher nervous activity through the multiple use of different types and variants of self-regulation is also manifested in cases in which collective self-regulation of a larger or smaller group of people occurs.

The creation by members of a collective of a "psychological atmosphere" at work and at home in the family circle, as well as in collective celebrations, cultural trips, excursions, amusements, sports, evening parties, etc., etc. can serve as examples of collective self-regulation of higher nervous activity.

Collective self-regulation of higher nervous activity occurs in all religious rituals. This will be gone into in more detail in the eighth chapter of this book.

It is understood that the adaptive effectiveness and social adequacy of the third type of self-regulation entirely depend on the ideological education of the person, on the social structure and the ideology prevailing in the society.

CHAPTER 5

THE INTERACTION BETWEEN DIFFERENT TYPES OF SELF-REGULATION OF HIGHER NERVOUS ACTIVITY

OPTIMAL AND PESSIMAL CYCLES OF INTERACTION

CYCLES OF INTERACTION IN WHICH THE INITIAL LINK IS THE FIRST TYPE OF SELF-REGULATION

§1. All types and variants of self-regulation of higher nervous activity interact with each other and depend on each other. In order to evaluate the adaptive effectiveness of one or another variant of self-regulation, it is necessary to characterize its interaction with the other variants and to show whether it increases or decreases the effectiveness of other variants of self-regulation.

In the first case, it promotes the formation of an optimal functional cycle of interactions between mechanisms of the different variants of self-regulation. Such an optimal cycle (circulus optimalis facilitates progressive optimalization of the system of higher nervous activity when the latter deviates from the optimum.

In the second case, the corresponding variant of self-regulation promotes the development of a pessimal cycle of interactions between mechanisms of different variants of self-regulation. Such a pessimal cycle, or "vicious circle" (circulus pessimalis, or vitiosus) inhibits optimalization of the system of higher nervous activity or even progressively increases deviation of the system from the optimum.

We shall examine several of the most typical cycles of interaction of the principal types of self-regulation, as well as the conditions of their optimalization or pessimalization.

One of the most frequently encountered cycles is the following. As the result of deviation from the optimum of the relation between the activity impulses entering and retained in the brain, on the one hand, and the impulses coming out of the brain, on the other hand, intensive compensatory switching of the brain's activity to the peripheral effectors develops causing a certain decrease in intensity and exertion of brain activity. More or less expressed compensatory effector organism reactions develop.

Secondary effects develop during carrying out of the compensatory reactions: the afferent inflow into the brain increases, and sometimes also the inflow through the blood of neurotropic humoral agents. As was shown in the third chapter, the proprioceptive inflow and influences on the higher sections of the brain on the part of the respiratory center are often very considerably intensified.

As a result of the secondary effects the intracentral coordination in the brain changes. Combined inhibitory effects arise on the part of the activity systems which are supported by the secondary efferent inflow on the conducting of afferent impulses of different origins along the neural relay of the brain stem in a centripetal direction. The activity of the tonic system of the reticular formation and cortical tonus increase. Thus, on the one hand, cortical centrifugal control of the afferent inflow intensifies and the possibility of the conditioned reflex freeing of the higher sections of the brain from undesirable afferentation is increased, and on the other hand, the tonus of the cortex of the large hemispheres increases and the possibility of delaying and equilibrating in the closed systems of the brain the additional number of impulses is increased.

In connection with this, the lack of correspondence between the neural activity circulating in the brain and coming out of the brain is decreased, the compensatory switching of the activity to the periphery is weakened and the conditions of brain operation approach the optimum.

As follows from what has been stated above, the first type of self-regulation causes activation of the second and third types of self-regulation (the third type because the secondary effects arising during the carrying out of compensatory reactions can also have signal significance, that is, emerge as conditioned signals acting inversely on the brain). The conditioned signals, in their turn, promoted the development of such changes in the functioning of the brain as a result of which progressive optimalization of the conditions of brain operation was provided and the necessity of mobilizing the first type of self-regulation progressively decreased. This means that a dynamic functional cycle of the optimal interdependence and interaction of all three types of self-regulation was formed.

Schematically, such an optimal cycle of self-regulation (where the initial component of the cycle is the first type of self-regulation) can be depicted as shown in Fig.48.

However, under certain conditions the optimal cycle mentioned can be transformed into a pessimal cycle. This occurs when compensatory reactions arising as a result of carrying out the first type of self-regulation cause an inadequately strong monotonic and continuous secondary inflow of afferentation, particularly secondary inflow through the blood of humoral agents sharply increasing excitation of the higher sections of the brain.

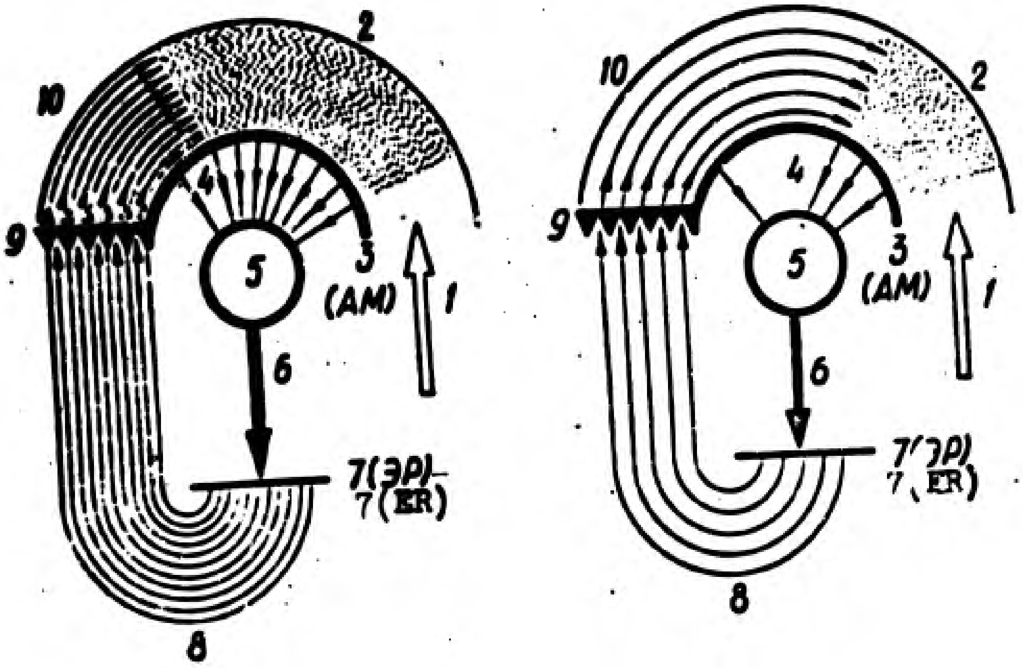

Fig.48. Schematic illustration of an "optimal cycle" (circle) of self-regulation of higher nervous activity in the case in which the first type of self-regulation acts as the initial link of the cycle. *1)* Primary afferent inflow into the brain; *2)* functional systems of neural links activated by the afferent inflow (primary dominant "focus" of activity); *3)* (AM) afferent, or prescribed model, of response reactions of the organism (see Fig.49); *4)* transfer paths, nervous activity to effector neurons; *5)* efferent, that is, effector, integration of nerve activity; *6)* effector current to somatic and visceral effectors; *7)* effector result of organism's reactions; *8)* secondary afferent inflow (so-called "inverse" or "correcting" and "sanctioning" afferentation); *9)* interaction of activity of neural elements of the afferent model and secondary afferent inflow; *10)* functional systems of the neural links activated by the secondary inflow (secondary "focus" of activity having an inhibitory and restricting effect on the primary "focus" of activity).

In such a case pessimal stress and fatigue of the neural processes of the higher sections of the brain progressively increase, the deviation of the proportion between the incoming, retained and outgoing impulses deviates from the optimum to a greater and greater degree, the necessity for intensifying compensatory effector switching of impulses continually increases, and as a result of extremely strong compensatory effector reactions even stronger inadequate secondary effects develop, etc., etc., that is, a pessimal cycle of interactions of three or two types of self-regulation, a real "vicious circle" is formed. It is schematically illustrated in Fig. 90 (see Ch.7,§4).

In the above-mentioned cases, the initial link of the cycle is the first type of self-regulation, and the link closing the cycle is the second or third (or second and third) type.

The closing function of the second type has already been examined above. In man the third type has the greatest significance in this respect.

It should be mentioned that the third type of self-regulation in man is capable of very effectively closing both the optimal and the pessimal cycle. For example, if in man, in conflicting situations with inadequately strong exertion of nervous activity, t there develops compensatory switching of the impulses through speech and behavioral reactions which increase the nociceptive, anxiety ("affectogenic") character of the conditioned signalling acting on the human nervous system from the external environment, then a more or less optimal cycle of self-regulation is closed leading to progressive optimalization of the individual's nervous activity.

If the compensatory switching of impulses through speech and behavioral acts causes intensification of the nociceptive, traumatizing and fatiguing nature of the conditioned signalling acting through a second signal system on the human brain (for example, as the result of a deterioration in the relations between people participating in a conflict situation, of "firing up of passions" and affects, etc.), then a pessimal cycle (vicious circle) of self-regulation is closed leading to progressive fatigue and overexertion of the individual's nervous activity.

The same thing occurs during compensatory "abreaction" of extreme nervous strain through a person's thought acts and subjective experiences which however are not displayed outwardly. In cases in which as a result of intensive intellectual and emotional discussion "to oneself" of the questions disturbing him and imagining different variants of solutions of the difficult situations interesting him, the person succeeds in mobilizing positive intellectual and emotional dominants which inhibit the negative dominants, an optimal cycle of self-regulation is closed leading to the progressive relaxation and balancing of the person's nervous activity.

And, on the other hand, in cases in which intensive reflection and experiencing in fantasy of the situations disturbing the person causes only further intensification of the negative dominants traumatizing the nervous system, a "vicious circle" is closed -- this is the most evil enemy of the self-regulating systems which leads to progressive strain and overfatigue of the person's nervous activity.

THE CYCLE OF INTERACTION IN WHICH THE INITIAL LINK IS THE SECOND OR THIRD TYPE OF SELF-REGULATION

§2. The second or third type of self-regulation can also act as the initial link in the cycle of interactions of mechanisms of self-regulation. In man both types of self-regulation act together, in some cases the second, and in others, the third type is controlling.

The second and third types of self-regulation, as a rule, are mobilized in situations requiring an urgent increase in the tonus of the higher sections of the brain, especially, of the cortex of the large hemispheres, and the formation of secondary strong dominant systems of nervous activity capable of inhibiting the primary dominants and of blocking the passing of afferent impulses of one or another origin along the brain stem in a centripetal direction.

The second type of self-regulation provides for carrying out of the above-mentioned changes in intracentral coordination with the help of conditioned reflex mobilization of the compensatory generation of a strong proprio- and exteroceptive inflow and central effects on the part of the respiratory center (see Ch.3,§4-7).

The third type of self-regulation provides the above-mentioned changes through generation in the organism, and especially in the external world, of those stereotypes of conditioned signals which act inversely on the human brain through a second signal system and by conditioned reflex means reproduce corresponding changes in the functional state of the brain (see Ch.4,§6 and 7).

In cases in which the initial link of self-regulation is the second or third type of self-regulation, secondary activation of the first type of self-regulation can be absent. In view of this, the cycle of interaction of different mechanisms of self-regulation can be absent or relatively weakly expressed. Or such a cycle may take place only between the second and third types of self-regulation without involvement of the first type.

This is also the fundamental difference in cases in which the initial link is the second or third type of self-regulation from cases in which the initial link is the first type which, as a rule, is always accompanied by secondary activation of the other types of self-regulation (see preceding section). This difference is very important. It determines the higher adaptive effectiveness of the second and third type in comparison with the first. The fact is that exclusion of the first type of self-regulation promotes stabilization of the mechanisms of self-regulation and decreases the likelihood of the development of a large number of compensatory reactions which are inadequate for the situation.

However, the fact that the second or third type of self-regulation can be carried out without involvement of the first type in the cycle does not mean that such involvement is always absent. On the contrary, it frequently occurs and closes the very complex cycle of self-regulation.

The secondary activation and involvement of the first type of self-regulation in the cycle occurs in cases in which as a result of the carrying out of the second or third type of self-regulation the intensity and exertion of nervous activity of the higher sections of the brain increase to such a degree that the optimal equilibrium between the incoming, circulating and outgoing impulses of nervous activity is disturbed and compensatory switching of the activity impulses to the periphery is mobilized. For example, as a result of extremely severe and continuous strain of the large muscle groups and monotonous concentration of a person's attention, excessive stagnant activation of various functional systems of the brain can develop which is capable of becoming the cause of inadequate exertion of nervous activity in broad areas of the brain. Another example. As a result of a person's generation into the surrounding world and in his brain of conditioned signalling causing the reproduction of a dominant -- of strong emotional excitation and stress, conditions can easily be created in which the necessity arises of mobilizing the first type of self-regulation which closes the cycle of interactions of self-regulation mechanisms.

Depending on whether involvement of the first type of self-regulation in the cycle causes a progressive increase in the tonus of the large hemispheres, intensification of corticofugal control of the afferent inflow, etc., or, on the contrary, a progressive decrease in tonus, intensification of inadequate exertion and overexertion of nervous activity, etc., the cycle which is closed by the first type of self-regulation is optimal or pessimal.

According to psychological observations and theoretical considerations, the most effective and optimal cycle in man in situations requiring an increase in the level of integration of higher nervous activity is the cycle which includes as the initial ("initiative") link the third type of self-regulation (the generation of an adequate and effective dominant in the second signal system), as the middle link the second type of self-regulation, and as the final, that is, closing link -- again the third type of self-regulation.

Schematic illustrations of certain variants of dynamic cycles of self-regulation presented in Figures 48 and 92 can serve as a simplified illustration of this.

AFFERENT MODEL OF EFFECTOR REACTIONS. THE ROLE OF CHRONIC NON-CORRESPONDENCE BETWEEN THE DESIRED AND ACTUALLY ACCOMPLISHED ADAPTIVE EFFECTS IN THE ORIGIN OF PESSIMAL CYCLES OF SELF-REGULATION

§3. An excessively severe and lingering reaction of anxiety and emotional stress causing or increasing deviation of the system of nervous activity from the optimum in the direction of sharp predominance of circulating activity and thereby provoking progressive intensification of prophylactic and compensatory switching of the brain's nervous activity to the periphery has great importance in the development and maintenance of pessimal cycles of self-regulation.

The source of a strong and lingering anxiety reaction most frequently is non-correspondence between the primary adaptive effect desirable for the individual in the actual situation and the effect actually achieved, as well as the individual's inability to eliminate this lack of correspondence. Mobilization of the first type of self-regulation in such difficult situations often only deepens the difficult state of the nervous system and hampers resolution of the situation.

As a result of the forced prophylactic and compensatory switching of nervous activity to the peripheral effectors which occurs against the background of severe unresolved intellectual and emotional strain, compensatory reactions inadequate for the situation often develop which deepen the lack of correspondence between the desirable and actual primary adaptive effect and, consequently, intensify the anxiety reaction.

A diagram is presented below which explains what has been stated and reflects the working hypothesis which we have introduced of the role of lack of correspondence between the afferent model, that is, of a given (desirable in a given situation) adaptive effect and the actual effect (Fig.49).

Anokhin's idea (1933, 1949, 1956, 1958, 1962) of the role of "sanctioning," or "correcting," afferentation in the functions of neural mechanisms which control the occurrence of behavioral acts of animals and man is used in the diagram presented. According to Anokhin's concept, the leading control mechanism is the so-called "acceptor of effect." In our opinion, the leading mechanism is the afferent model or the prescribed model of the adaptive effect desirable for the organism, that is, of the corresponding effector reactions.

By afferent, or prescribed, model we mean that dominant functional system of conditioned and unconditioned links which is activated in the brain as a result of analysis and synthesis of the afferent inflow, that is, as a result of the transformation of the incoming information on the basis of acquired experience.

The dominant functional system is a complex of previously developed stereotypes of neural links which were deinhibited by the actual stimuli and functionally integrated into new combinations corresponding to the new situation (Krauklis, 1960a, p.68-69).

the more the actual situation carries within itself the elements of newness, the more the previously developed combinations of stereotypes undergo expressed reorganization and the more the new dominant system, that is, the prescribed model, is a source of new forms of behavior, new ways of equilibrating the individual with the external environment.

Evidently, the closed self-activating neuron networks and the circles of the higher sections of the brain which determine the paths of the switching of nerve activity impulses to efferent

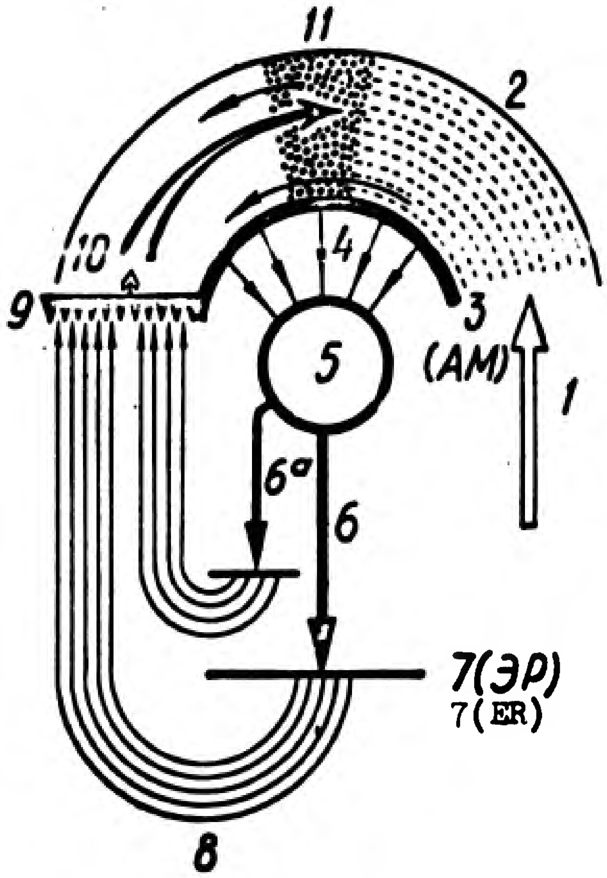

Fig.49. Schematic illustration of the functions of the afferent, prescribed, model of the organism's effector activity. *1-9)* Designates same as in Fig.48. (*6* -- effector inflow to somatic, *6*[a] -- to visceral effectors); *10)* signalling caused by noncoincidence of secondary inflow with the afferent model caused by the primary inflow; *11)* activation of the functional systems of the anxiety reaction and of research activity (simulating or reorganizing the afferent model or its individual parts).

neurons and effector paths, as well as the time characteristics, that is, the sequence of this switching, are the morphological and physiological basis of the prescribed model.

The prescribed model of effector activity develops before switching of neural activity to the effector paths and can remain active for a more or less long period of time without intensive outflow of circulating activity to the peripheral effectors, as psychological observations and experimental data of Anokhin's laboratory (Anokhin, 1962, Usyvayev, 1963), as well as the numerous data of different authors who studied higher nervous activity of animals and man, show (for example, the fact of the inhibition of a previously developed behavioral reaction from the use of an extinguishable conditioned signal and the manifestation of this same reaction or fragments of it after cessation of the signal, etc.).

The dominant functional system of the brain organizes efferentation in the broadest sense of this concept, that is, not only the organism's effector activity but also establishment of the functional state of the analyzers -- of the sensory organs and "transfer stations," or of the relays conducting afferentation in a centripetal direction.

Thus, the dominant functional system determines not only the efferentation adequate for a given situation, that is, the efferent and effector current, but also prepares centrifugal (includ ing corticofugal) control of the expected afferent inflow.

Thereby the dominant functional system is capable, on the one hand, of controlling and correcting the effector current with the help of the afferent inflow which makes it possible to carry out a comparison of the results of the organism's effector activity with the initial functional structure of the system, and on the other hand, to control and correct the afferent inflow with the help of organization, that is, reorganization of efferentation.

These functions of the dominant system allow one to call this system the afferent, or prescribed, model of the adaptive effect desirable for the actual situation and of the reactions integrated for carrying out this effect.

It is seen from what has been stated above that we consider the prescribed model as the organizer (and reorganizer) of the organism's current activity, including the organizer of various types and cycles of self-regulation of higher nervous activity.

The dominant functional system continually changes, reflecting more or less adequately changes in the organism's external and internal environment which are significant for the individual. The efferent, that is, effector, current and the organism's corresponding effector reactions are sanctioned, corrected or reorganized in accordance with the changes in the functional constellation of the dominant system.

Effector activity is always late to a greater or lesser degree in comparison with the changes in the functional constellation of the dominant system. Moreover, it cannot entirely adequately reproduce the functional constellation of the afferent dominant since the organism's efferent possibilities of "reflecting" the changing conditions of the individual's existence are relatively limited and stereotyped in comparison with the afferent possibilities.

The relative restrictedness of the individual's effector activity to reproduce the afferent constellation of the brain is determined not only by the fact that the number of efferent neural elements is considerably less than the number of afferent elements, but also (particularly) by the fact that the possibilities of the functioning of the effector link of nerve activity are limited by the physico-chemical and mechanical characteristics of the effectors, as well as by the conditions of the external environment, whereas the possibilities of the afferent link of nerve activity are limited only by the functional structure of the brain.

In connection with this, a clear lack of correspondence between the afferent dominant, that is, the prescribed model and the actually achieved result of the individual's adaptive activity continually arises to a greater or lesser degree in the individual's behavioral activity.

Depending on the degree and significance of such a lack of correspondence, functional systems causing an orienting reaction or an anxiety reaction of different degrees are activated in a conditioned or unconditioned reflex manner. As a result, activation of the ascending reticular formation, and frequently of the limbic system develops, and consequently -- a reaction of awakening of the cortex and a reaction of emotional awakening which promote modification or reorganization of the switching of impulses from the closed systems of the afferent dominant to the efferent neurons or the reorganization of the afferent dominant itself.

Mechanisms of the conditioned reflex reckoning of time play an important role in the functioning of the afferent model.

A study of the dynamics of the effector structure and the adaptive specifics of conditioned behavior reactions in the intervals between stimuli, as well as during the action of special conditioned signals (for example, sound, light and oral signals) shows that from the effect of the time factor continuous modification or reorganization of the dominant afferent model of the individual's effector reactions occurs. For example, in the initial phase of the interval between stimuli the behavioral activity of the individual being studied is frequently manifested as a reaction of aftereffects having the form of neuro-muscular relaxation (see Ch.6, §6). With the approach of the middle of the interval elements of a nonspecific anxiety reaction sometimes begin to dominate in the effector structures of the individual's behavior (see Ch.6, §1-4), which at the end of the interval are replaced by elements of a more or less specialized anxiety reaction which prepares the organism for the next special conditioned and unconditioned stimuli.

In the first seconds of the action of a special conditioned signal, activation of specialized conditioned and unconditioned components of the individual's reaction are often noted (for example, blinking movements during the development of blinking conditioned reactions in people, repeated transient raisings and lowerings of the reinforced extremity in the development of defensive-motor conditioned reactions in dogs, etc.) which with the approach of the time of the next application of the conditioned signal sometimes begins to be manifested as a reaction to time. In the next seconds of the isolated action of the conditioned signal -- in the case of its relatively continuous isolated use -- specialized components of the conditioned reaction can be weakened or inhibited. In later seconds with the approach of the time of the combining of the conditioned and unconditioned stimulus, specialized components of the individual's reaction are often again activated and begin to prevail and they sometimes acquire a tonic character (for example, the tonic contraction of the round muscle of the eye, continuous tonic flexure of the reinforced extremity) (Krauklis, 1960a, b, 1963; Liyepa, 1964a, b, c; Briyedis, 1964a, b, c).

In this case the time factor, being a component part of the experimental situation and the stimuli being used, acts as a conditioned signal informing the brain of the successive change in the signal significance of the situation and the stimuli applied. Activation, maintenance, correction or reorganization of the dominant in the given situation of the afferent model occurs in accordance with this information.

The participation of mechanisms of time reckoning in the development of the afferent model is not limited by conditioned reflex reproduction of the time intervals of stimuli of the external world. With the help of these mechanisms the time structure of the afferent model reproduces the time structure of the secondary ("inverse") afferentation, signalling that the organism's effector activity is taking place.

The development of an afferent model, like the development of any system of neural links, is connected with the development of a specific stereotype of changes in the activity of the components parts of the model -- of various functional ensembles of neural elements.

It is logical to assume that the development of this time stereotype in many respects is determined by the sequence of effector reactions, and thereby by the sequence of the secondary afferentation entering the brain. As a result, the activity of the model which was evoked by the signals of the external world is maintained at a high level for a specific time interval corresponding to the time interval necessary for carrying out of the effector link of the reaction and the generation of secondary afferentation.

In the case in which the secondary afferentation appropriate for the model, that is, the secondary signalling, enters the brain in a definite developed time interval, it causes the activation of the next links of the current model. In accordance with the developed stereotype, the impulses circulating in the closed circuits of the model continue to go out to the effector paths or are retained and are equalized in the neuron circuits of the brain.

In case of the absence of a timely influx of secondary afferentation, corresponding to the model, the time facto , more accurately, the cyclic changes in the activity of various ensembles of the model's neural elements becomes signals which activate the anxiety reaction and promote the reorganization, that is, a change in the current model and the corresponding effector activity of the individual.

Thus, the process of comparison of the afferent model of effector activity with the actual result of the latter is connected with the comparison of the time characteristics of the model with the time characteristics of the secondary afferentation.

When both time characteristics do not coincide, the anxiety reaction is mobilized. As observations show, the anxiety reaction is mobilized. As observations show, the anxiety reaction is also mobilized in situations in which such noncoincidence is expected in the near future. For example, it is known that during the experimental formation of a new stereotype of conditioned links often before the time of the next application of a special conditioned signal (for example, the beats of a metronome as a reaction in time) an anxiety reaction develops (Krauklis, 1960a, b).

Evidently, in such situations the likelihood of exact coincidence of the result of the individual's future effector activity with its model, that is, with the model of the desirable adaptive effect, is relatively small. Therefore, from the effect of the situation, especially of the time factor, "prophylactic" mobilization of the anxiety reaction occurs, against whose background (in the case of noncoincidence of the effector result with its model) it is possible to carry out rapid mobilization of the current model or the complex dominant stereotype of the models.

Observations show that the individual's realization of one or another adaptive task is possible by the use of different effector reactions. If the concrete reaction turns out to be incapable of providing an actual adaptive effect, it can be replaced by other reactions providing this effect. If the given adaptive task is difficult to carry out, it can be modified or replaced by another task.

It follows from this that it is necessary to distinguish an afferent (prescribed) model of higher order -- the model of the desirable adaptive effect of the individual's entire activity -- and afferent models of lower order, that is, models of the concrete reactions carried out for purposes of realizing the entire effect.

Evidently, models of concrete reactions enter into the functional structure of a model of higher order. The secondary afferentation coming into the brain is comparable both with models of lower order and with a higher order model. In this case, the correction, reorganization or change of the lower order models can occur without the reorganization or change of higher order models.

Special investigations should clear up the question of the dynamics and interrelations of the indicated models, as well as the question of the role of higher and lower order models in the mobilization of the anxiety reaction (in the case of noncoincidence of the model and the effector result).

As our experimental observations showed, the anxiety reaction is most expressed in those cases in which it develops as a result of actual or expected noncoincidence of the model of the adaptive effect desirable for the situation with an actually achieved or achievable effect.

In cases in which noncorrespondence (actual or expected) between the afferent model of the desirable effect and the actual or probable effect has great biological or psychological significance for the individual, but cannot be eliminated in the near future, the limbic component of the anxiety reaction is considerably intensified and clear and lingering emotional excitation and strain of the individual's nervous system develops causing deviation of the system of nervous activity from the optimum.

Intensive mobilization of mechanisms of self-regulation of nervous activity develop in response to the latter. If the self-regulation is incapable of causing optimalization of the system and, moreover, occurs at a low level of integration (reproduction for purposes of self-regulation of effector reactions, primarily inadequate for the situation and secondarily of little effectiveness), then as a result the above-mentioned noncorrespondence is increased and the reaction of anxiety and emotional tension is intensified.

The significance of the latter in the origin of pessimal cycles of self-regulation was examined at the beginning of this section.

THE SIGNIFICANCE OF THE THIRD TYPE OF SELF-REGULATION (THAT IS, SELF-GENERATION OF VERBAL SIGNALLING) IN THE ORIGIN OF PESSIMAL CYCLES IN MAN

§4. Empirical psychological and clinical observations, as well as a theoretical analysis, show that conditioned signalling, pessimal in content, caused by effector reactions of the individual inadequate for the situation (which develop for purposes of self-regulation of higher nervous activity or for purposes of equalizing the organism with the environment) play an important role in the origin and reinforcement of pessimal cycles of self-regulation.

For example, the isometric contraction of the skeletal musculature and the increase in inspiratory tonus of the respiratory muscles developing as components of the second type of self-regulation are simultaneously a source of secondary effects which change the intracentral coordination (see Ch.3, §3) and a source of conditioned signalling informing the brain of the realization of the compensatory generation of secondary tonic centripetal effects, as well as of the realization of effector (behavioral) reactions adequate or inadequate for the situation. The latter case deserves special examination.

Let us assume that a person is in a difficult situation which can be resolved only by an active, bold and creative effect on the external world around him. However, instead of such adequate active behavior, the person tries to "make over" the situation, by resorting to the help of sterile mental discussions and fantasies. At the same time, by habit he tries to generate tonic secondary effects and to "abreact" the primary emotional stress by means of inadequately strong and monotonous exertion of the large muscles -- the agonists and antagonists, increasing the tonus of the respiratory and mimetic muscles, etc.

In such a case, the stimulations caused by the effector reactions which carry out the described passive closing of the person "within himself" (that is, passive general preparatory or "passive-defensive" reaction, see Ch. 6), act as conditioned stimuli signalling the absence of adequate reactions of the individual and thereby small likelihood of an adequate resolution of the difficult situation and cessation of the difficult state of the nervous system.

A further intensification of the anxiety reaction and emotional tension is often the result of such psychologically negative signalling. The latter promotes further pessimalization of the system of higher nervous activity, further unpromising intensification of prophylactive and compensatory "abreacting" of the inadequately strong nervous activity through inadequate effector reaction and, consequently, closing of a pessimal cycle ("vicious circle") of self-regulation.

A person's development of a verbal (thought) dominant signalling lack of confidence in himself, fear of the difficulties and habitual passive "overcoming" of the difficult situation with the help of a passive-defensive reaction and arbitrary suppression of active speech and behavioral reactions has a similar, only considerably stronger negative effect on higher nervous activity in a similar situation.

The mentioned psychologically negative conditioned signalling in its origin is the result of repeated noncorrespondence between the adaptive effect desirable for the given situation and the actual effect, or, more exactly, is the result of the struggle between the desirable, that is, adequate for the situation, afferent model (whose activity nevertheless obtains an outlet to the effectors) and the previously developed, stereotyped and inadequate for the situation, model (whose activity obtains an outlet to the effectors).

THE INTERCONNECTION BETWEEN THE LEVEL OF INTEGRATION OF HIGHER NERVOUS ACTIVITY AND THE EFFECTIVENESS OF ITS SELF-REGULATION IN ANIMALS AND MAN

§5. Considering what was stated above, it is possible to understand why pessimal cycles of self-regulation develop under conditions of severe strain of higher nervous activity which are maintained and intensified by the lack of correspondence which is difficult to eliminate in an actual situation between the prescribed (afferent) model and the actual result of the individual's effector activity and the lack of correspondence of the anxiety reaction and emotional excitation caused by this.

In cases in which the lack of correspondence is not too great and continuous and, consequently, the anxiety reaction is not too expressed, the pessimal cycles of self-regulation of

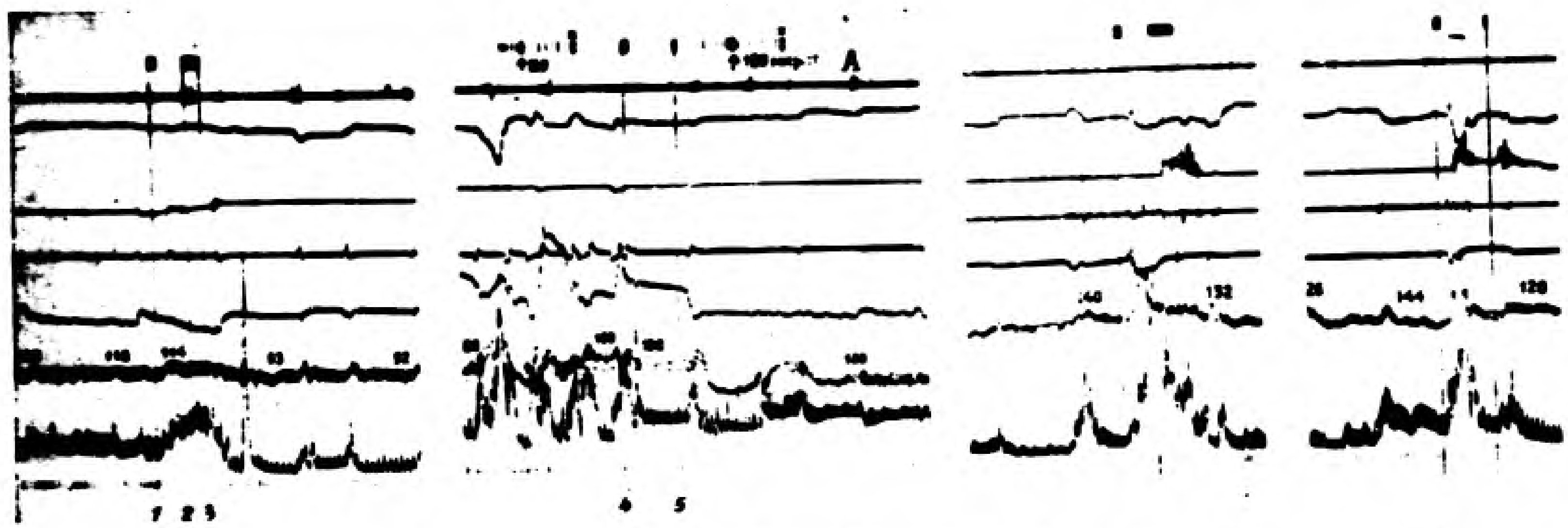

Fig. 50. The increase in cortical tonus, decrease in inadequate compensatory reactions, including compensatory tachypnea and the development of more adequate behavioral and visceral reactions from the effect of using special conditioned signals and unconditioned reinforcement (see 3rd fragment) during the development in dogs of defensive-motor conditioned reactions by the Petropavlovskiy method. Second fragment was recorded against the background of blocking of the movements of the stimulated, that is, right rear, extremity, the third and fourth fragments against the background of loading the stimulated and symmetrical rear extremity with a weight of 2 kg. *1)* Conditioned signal; *2,3)* electrical skin stimulation of the right rear extremity (in the first fragment the dog did not receive a stimulus since he flexed the extremity upon the conditioned signal); *4, 5)* differentiation signal. From top to bottom: recording of arterial pressure (see Fig. *16)*; movements of the lower jar, head, right rear extremity and left rear extremity; postural-tonic contraction of the muscles of the coxofemural joint; sphygmogram of the carotid artery; pneumogram. A) 160 mm Hg.

Fig. 51. Increase in cortical tonus and decrease in inadequate compensatory reactions from the effect of the application of special conditioned and unconditioned stimuli during the development of conditioned reactions in dogs. The development of conditioned reactions on the basis of the use of food reinforcement -- the pouring of 30 g of milk through a tube into the mouth (first fragment), on the basis of the use of pouring 5 cm^3 of a 0.5% solution of hydrochloric acid into the mouth (second fragment) and on the basis of electrical skin reinforcement (third fragment). *1)* Conditioned signal; *2,3)* pouring of milk into mouth; *4,5)* pouring of hydrochloric acid solution into mouth; *6,7)* electric skin stimulation of right hind leg. From top to bottom: first two fragments -- movements of the lower jar, head and total of all extremities; sphygmogram of carotid artery; pneumogram; third fragment -- movements of the head left and right front legs, right and left hind legs (drop in the curve -- raising of the leg, and vice versa); pneumogram, sphygmogram of carotid artery. A) sec.

nervous activity are usually not closed and progressive disorders of higher nervous activity do not develop. In such cases, a larger or smaller number of relatively low adequacy or inadequate for the situation somatic and visceral reactions are displayed which characterize the low level of self-regulation of higher nervous activity which, however, at the same time can have a certain secondary adaptive effect preventing a further decrease in the level of integration.

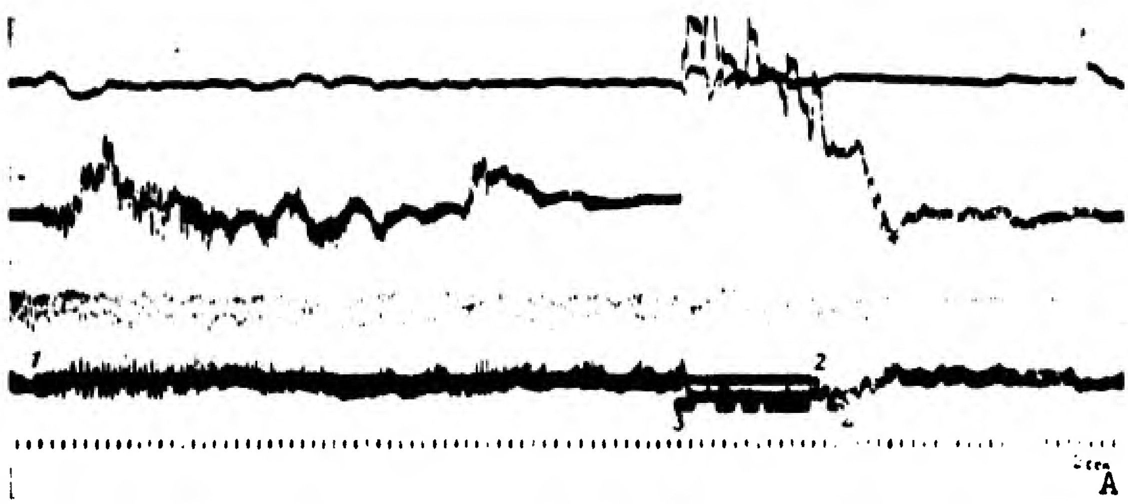

Fig.52. Changes in the cortical effects on the subcortical vegetative centers from the use of a special conditioned signal, nociceptive reinforcement and after cessation of the special stimuli in the dog Mars (experiments of I. Rotsen-Krauklis). *1,2)* Beginning and end of strong sound signal (electric bell); *3,4)* beginning and cessation of discontinuous electric skin stimulus on the back (a nonspecific conditioned general preparatory reaction was developed in the dog). From top to bottom: total movements of extremities (general motor reaction); contraction of stomach (100 cm^3 baloon was introduced into the stomach); sphygmogram of carotid artery; pneumogram. *A)* Sec.

It should be emphasized that at a low level of integration of higher nervous activity the first and second types of self-regulation also are performed at a low level of integration. Only with the help of the third type of self-regulation is the individual capable of significantly increasing the level of his higher nervous activity.

This fact has tremendous significance in the life of man and society. As the result of carrying out self-regulation with the help of verbal signalling, man is capable not only of forming powerful dominants of the second signal system which control and increase the level of integration of nervous activity in different sections of the brain, but also arbitrarily mobilize such variants of the first and second type of self-regulation (for example, effective physical and respiratory exercises, optimal muscle

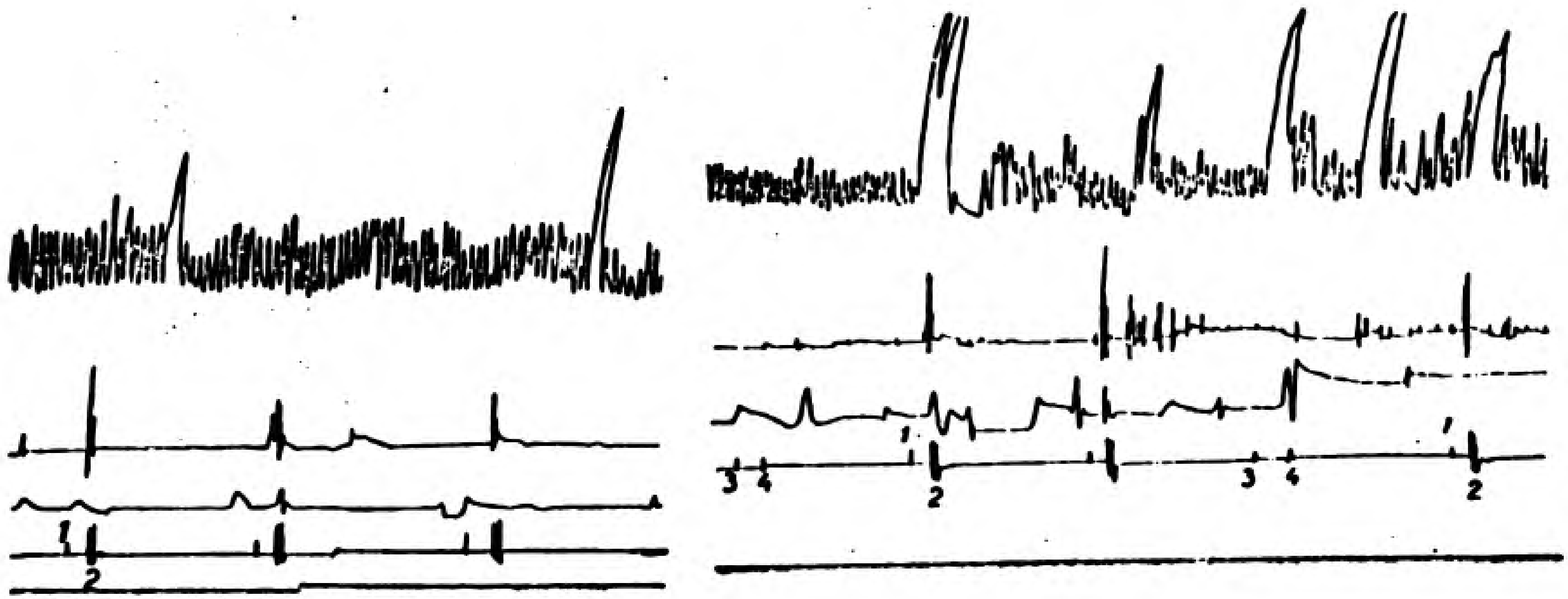

Fig.53. The development and strengthening of inadequate compensatory reactions indicating a decrease in cortical tonus and level of integration, as well as a pessimal system of nervous activity, as the result of fatigue of higher nervous activity during prolonged developed of blinking conditioned reactions and internal inhibition in subject I. S. (age 12 years) with first stage neurasthenia. First fragment -- initial stage of the development of conditioned reactions; second fragment -- further stage (at the end of the session of observations). *1)* Conditioned signal; *2)* threefold stimulation with a jet of air; *3,4)* differentiating signal. Top to bottom: pneumogram; blinking movements; total contraction of femoral muscles of both extremities.

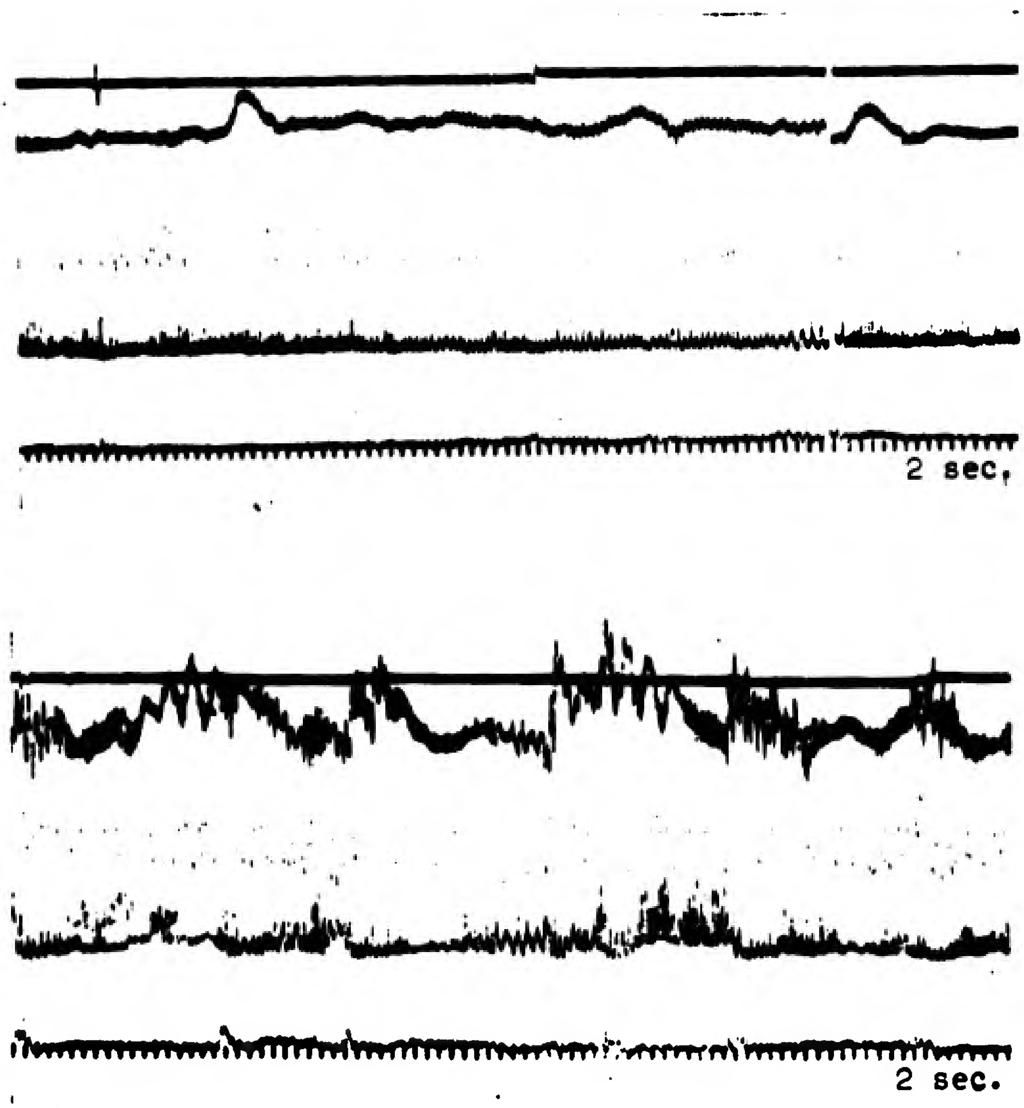

Fig.64. Decrease in cortical tonus, sharp intensification and compensatory "abreaction" of nervous activity directly through the respiratory center during a state of anxiety and emotional stress at the end of the experiment in the dog Viltsin'sh. A conditioned general preparatory reaction is developed in the bog on the basis of the application of electric skin stimulation of the back (experiments of I. Rotsen-Krauklis). First fragment -- initial period of the experiment before the application of special conditioned and unconditioned stimuli: second fragment -- period at the end of the experiment after cessation of the application of special stimuli. From top to bottom: movements of extremities (general motor reaction); stomach contractions; sphygmogram of carotid artery; pneumogram at level of chest cage; pnεumogram at level of abdomen.

relaxation, etc.) which would make it possible to provide not only an optimal system but also to increase the level of integration of higher nervous activity.

With the help of the first and second type of self-regulation, if it is not controlled and not organized by the third type, it is possible to provide only maintenance of the system the prevention of a further decrease in the level, and not a significant rapid increase in the level of higher nervous activity.

If as a result of carrying out the first and second type of self-regulation a certain increase in the level of integration develops in the individual, then this usually occurs because the self-regulation prevents a further decrease in the level up to the moment when the stimuli causing pessimal strain of higher nervous activity cease.

Therefore, in experiments on animals cases are very frequently observed when in situations causing considerable strain of higher nervous activity and a decrease in cortical tonus in the intervals between the stimuli, the level of integration of the animal's effector activity decreased sharply and a large number of somatic and visceral reactions which are inadequate or of low adequacy for the situation were displayed which indicate the prevalence of the

first type or the first and second types of self-regulation which are incapable of increasing cortical tonus and of establishing a higher level of integration.

The use of conditioned signals, unconditioned reinforcement or extraneous stimuli often causes a rapid increase in cortical tonus and level of integration which is expressed in a decrease in the number of inadequate reactions and in the appearance of reactions which are adequate for the situation (see Ch. 6, §2 and 3 as well as Fig. *16* (2), *17* (2-4) *25*, *27*, *43* and *50-52*).

Thus, in experimental animals in which the first and second type of self-regulation predominates, it is very difficult to establish a higher level of integration of higher nervous activity. The use of special conditioned signals by the experimenter often promotes the establishment of a higher level of nervous activity, including a higher level of self-regulation.

Thus, the increase in the level of integration in animals occurs as a result of a change in the situation and the effects of stimuli of the external environment.

In adult human subjects in whom, as a rule, the third type of self-regulation prevails, the level of integration usually (with the help of self-generation of psychologically positive conditioned signalling) is sufficiently high. Therefore, in adult subjects the development of a large number of inadequate behavioral reactions is very rarely observed during the session. And if they develop, it is mainly as a result of the activation of the first and second type of self-regulation (for example, of severe strain of the skeletal musculature, an increase in inspiratory tonus, an

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increase in the frequency of blinking reactions, etc.). However, they are controlled by the third type of self-regulation, as a result of which they usually do not become inadequate for the conditions of the observations and do not contradict the conventional rules of human behavior in a laboratory situation.

Sometimes in human subjects at the end of a session of observations a state of anxiety and emotional stress appears which is accompanied by a decrease in cortical tonus and intensive prophylactic and compensatory switching of brain activity to peripheral effects which occurs at a decreased level of integration. As a result a large number of quantitatively or qualitatively inadequate compensatory reactions are displayed (*Fig.53*).

Evidently, this is connected with the greater fatigability of a child's nervous system in comparison with the nervous system of adults under conditions of laboratory observations where it is necessary to sit relatively quietly for 10-20-30 minutes.

In experimental animals fastened with straps and placed in an experimental holder, it is very easy to cause a severe, and sometimes progressive state of anxiety and emotional tension since difficult states of the nervous system caused by a lack of correspondence between the afferent model of desirable and the actually possible effector activity easily arise and are maintained (see *Fig.54*).

In connection with this, any more or less severe additional exertion of nervous activity by the experimental animal caused, for example, by the animal's development of internal inhibition easily causes a noticeable but frequently relatively brief decrease in cortical tonus and level of integration of higher nervous activity.

Therefore, in experiments on animals it is possible to observe very graphically the dynamics of the establishment of various levels of integration of higher nervous activity not only in the course of the entire experiment but also in the course of a relatively small segment of time -- the interval between stimuli.

Several examples are presented below which illustrate the dynamics of the level of integration and primary adequacy of the conditioned somatic and visceral reactions of an experimental

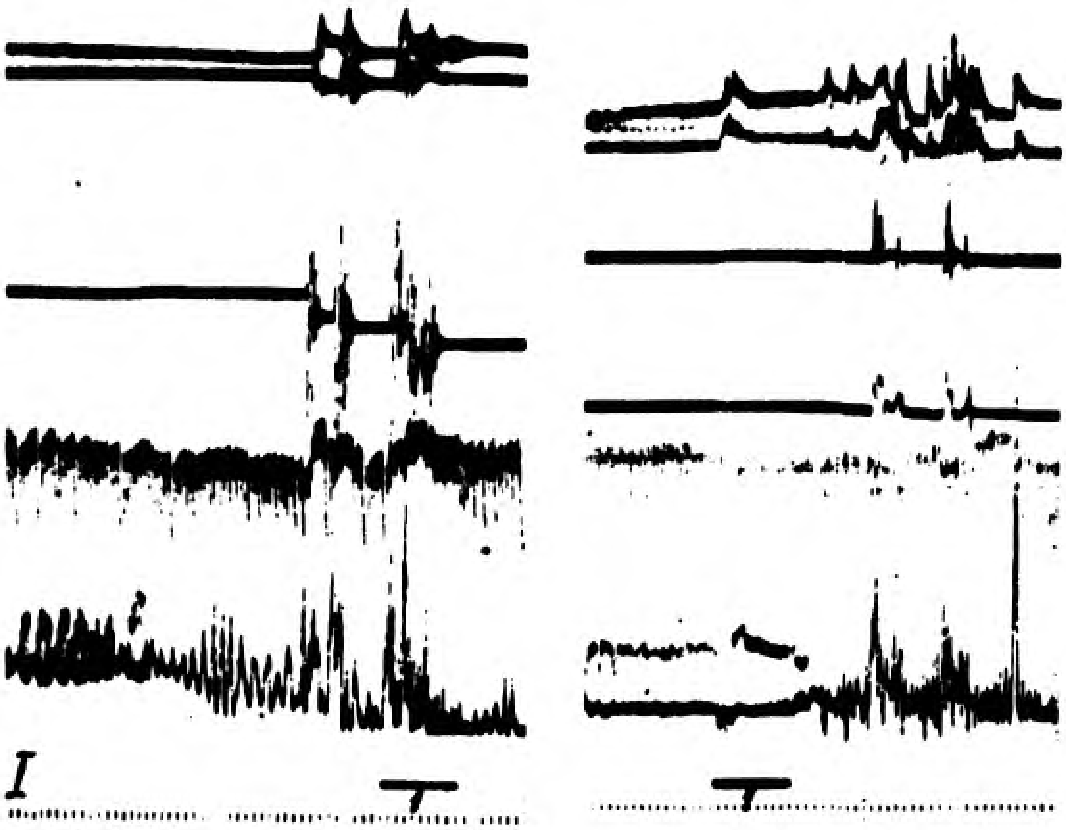


Fig.55. Dynamics of the level of organization of compensatory reactions during the development of internal inhibition. Different stages of the development of new differentiation after alteration of the signal significance of positive and inhibitory conditioned signals in the dogs Shalits (first two fragments) and Moris (last two fragments)(experiments of Dz. Liyep). Conditioned reactions were developed in the dogs by the Bekhterev-Protopopov method. *1)* Differentiating signal; *2)* Sec. Top to bottom: movements of the head, neck (2nd and 4th fragments), total of both front legs and right hind (stimulated) leg; sphygmogram of carotid artery; pneumogram.

Fig. 55 continued

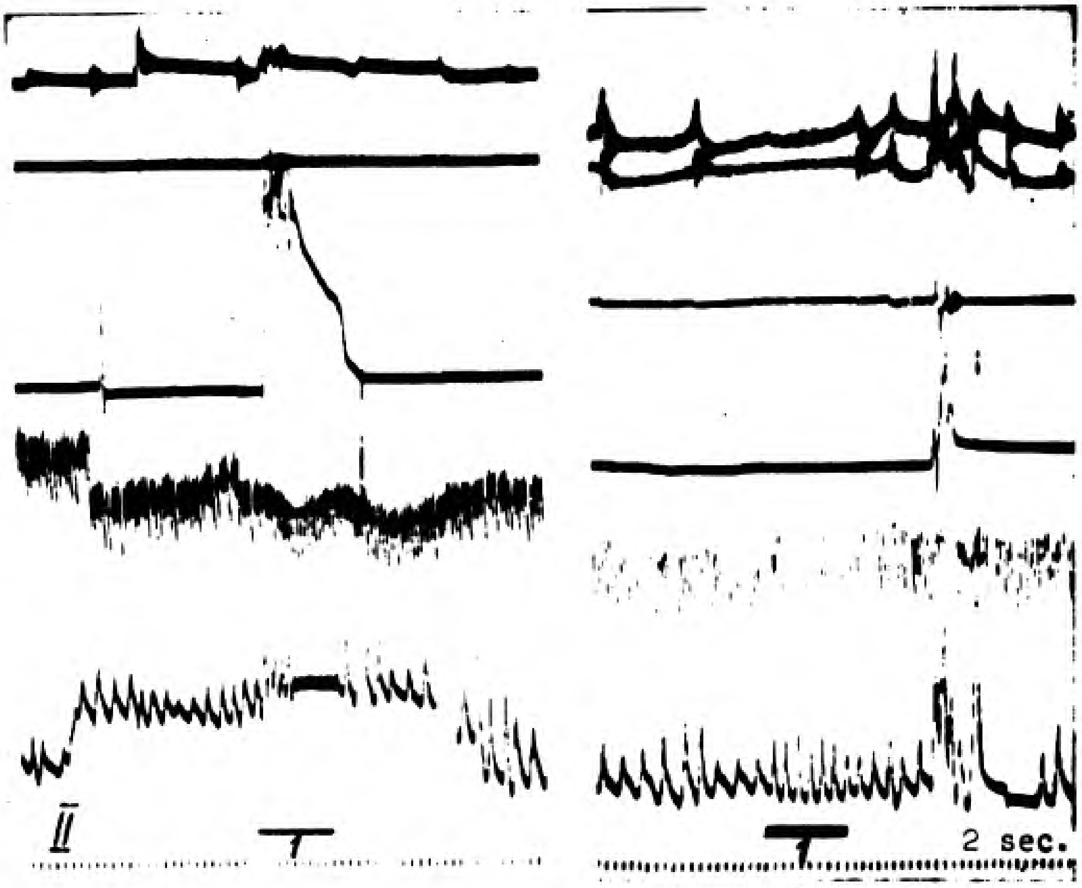
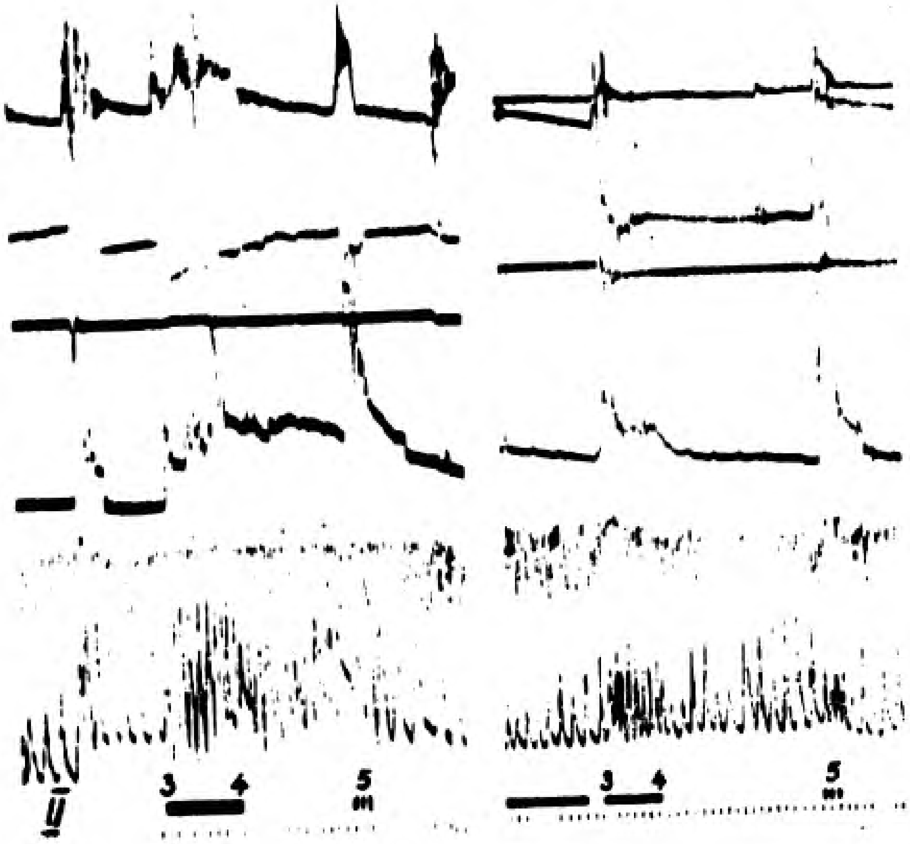


Fig. 56 continued



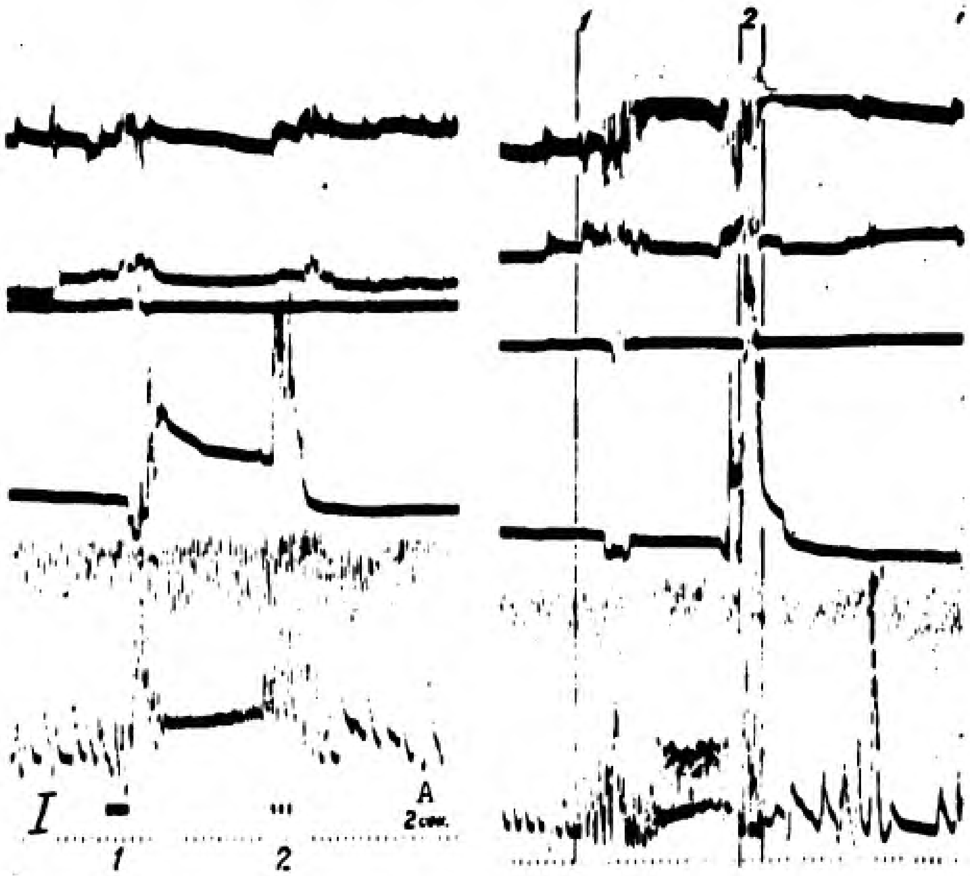


Fig. 56. Dynamics of the level of organization of compensatory reactions during the formation of internal inhibition. Different stages of the development of delayed (first two fragments) and trace (last two fragments) conditioned reactions by the Bekhterev-Protopopov method in dogs (experiments of Dz. Liyep). *1)* Start of conditioned signal; *2)*threefold electric skin stimulation of right hind leg (conditioned and unconditioned stimuli ceased simultaneously); *3,4)* beginning and end of conditioned signal in the development of trace reactions; *5)* electric skin stimulation of right hind leg. Top to bottom: notation same as in *Fig.55*. A) 2 sec.

animal which develop during the formation and differentiation of conditioned links (Fig.54-60).

§6. In carrying out any reflector reaction of the organism it is necessary to establish an optimal system of incoming, circulating and outgoing nervous activity which provides the least expenditure of nervous energy and the functional state of the corresponding neural structures which is most adequate for the actual situation.

At the same time it is necessary to provide an effective test -- control of the course of the reaction being carried out, as well as its possible correction.

As is seen, in carrying out any reaction neural mechanisms are mobilized which we consider as mechanisms of self-regulation of nervous activity.

These neural mechanisms function on the basis of conditioned and unconditioned links and are activated by conditioned and unconditioned stimuli. Considering the fact that any different unconditioned stimulus acting on the organism has in an adult some signal significance (since it has certain features of stimuli known to the individual, acts against a background of some situation always having specific signal significance and has a beginning, sequence and end which act as conditioned signals), it is possible to believe that during the carrying out of reflector reactions of the organism, at least of behavioral reactions, mechanisms of the conditioned reflex self-regulation of nervous activity practically always participate.

In cases in which the duration of the stimuli causing the conditioned and unconditioned reactions is relatively short (for example, 1-2 seconds), the conditioned reflex self-regulation often does not succeed in developing during the action of the stimulus. In such a case, it develops in the period after cessation of the stimulus, that is, it acts as an aftereffect.

Those aftereffect reactions which develop after the cessation of stimuli causing a strong increase in the activity of closed neuron systems, if the switching of this activity to effector paths continues or even is intensified after cessation of the stimuli, also are an expression of self-regulation of higher nervous activity (see Ch.2, §5, and also Ch.6, §5).

Many components of specialized and unspecialized preparatory reactions which developed by conditioned reflex means before the onset of different expected stimuli and which prepared the organism, including the nervous system and the sense organs, for probable subsequent stimuli and response reactions are an expression of self-regulation.

The question of the participation of self-regulation of higher nervous activity in preparatory reactions (anxiety reactions) and aftereffect reactions (for example, in reactions of neuromusculature relaxation) is considered in more detail in Chapter 6.

It is necessary to mention the following fact. In the same way as the development of conditioned reactions and new stereotypes of behavior and thinking occur on the basis of previously developed functional systems of conditioned links (as a result of the recombination and reorganization of these systems and their fragments into qualitatively new combinations and new systems)(see §3), new variants and cycles of self-regulation of nervous activity also are developed on the basis of previously developed variants.

Therefore, the more effective the already developed and reinforced variants and cycles of self-regulation are and the fewer the ineffective and potentially pessimal var-ants among them, the more possibilities there are for the development in the individual's brain of new variants adequate for any situation.

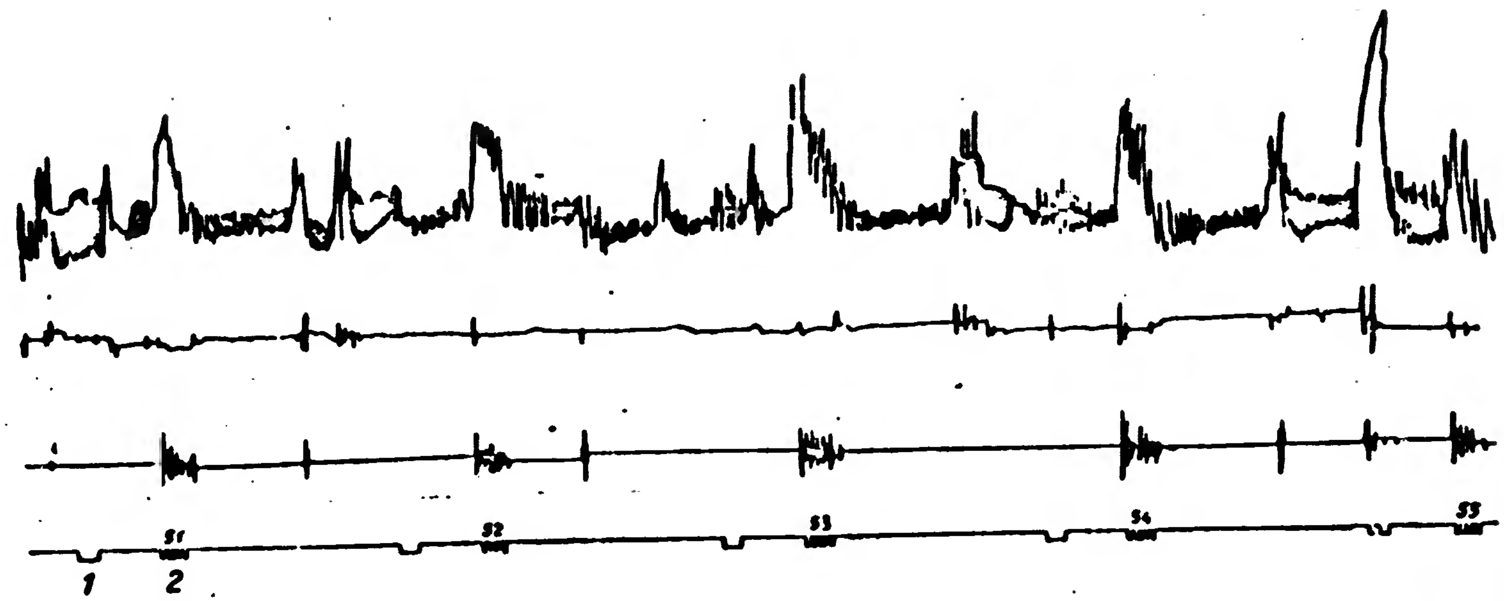


Fig.57. Two systems of respiration as the expression of two levels of effector integration of nervous activity in the development of trace conditioned reactions by the Bekhterev-Protopopov method in the dog Helli. The strongest tachypnea and increase in inspiratory tonus (sometimes accompanied by movements of the head and legs) which develop as an anxiety reaction to the situation and to time, with the use of a special conditoned signal are replaced by cessation of tachypnea and normalization of respiration indicating an increase in cortical tonus, that is, the predominance of the reaction of cortical awakening over the reaction of emotional awakening in the structure of the reaction (see Ch. 6,7). *1)* Conditioned (sound) signal; *2)* five-fold electrical skin stimulation of the right hind leg. Top to bottom: pneumogram; movements of the head; movements of the right hind leg.

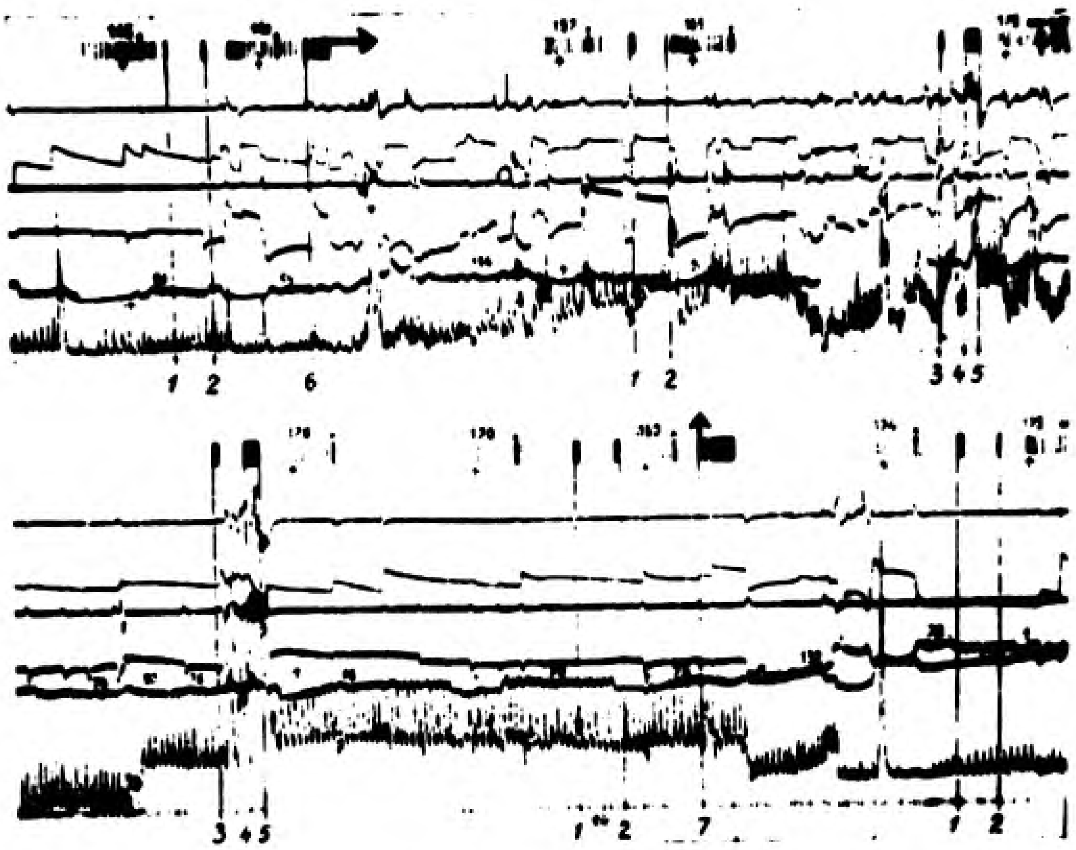


Fig. 58. Dynamics of the level of organization of compensatory reactions during the development of defensive-motor conditioned reactions and differentiation against a background: of the usual experimental situation, of a heavy weight placed on the animal's back (5 kg, that is more than 1/3 of the animal's weight), removal of the weight. The dog Dzhulis (experiments of Yu. Briyedis). *1, 2)* Beginning and end of differential signal; *3)* conditioned signal; *4, 5)* beginning and end of stimulation of mucosa of the mouth by direct current impulses (conditioned and unconditioned stimulation are stopped at the same time); *6)* beginning of weight; *7)* cessation of weight. Top to bottom: recording of arterial pressure *(see Fig. 16)*; movements of lower jar, head and total of all extremities (general motor reaction); postural-tonic contraction of muscles of the coxofemoral joint; sphygmogram of carotid artery; pneumogram. A) mm Hg.

However, in view of the fact that in man there are practically unlimited possibilities of creating, that is, of reorganizing, self-regulation with the help of conscious generation of verbal signalling, man is capable as a result of conscious effective exercises and efforts of will of inhibiting and extinguishing any ineffective variants and of replacing them with new, more effective ones.

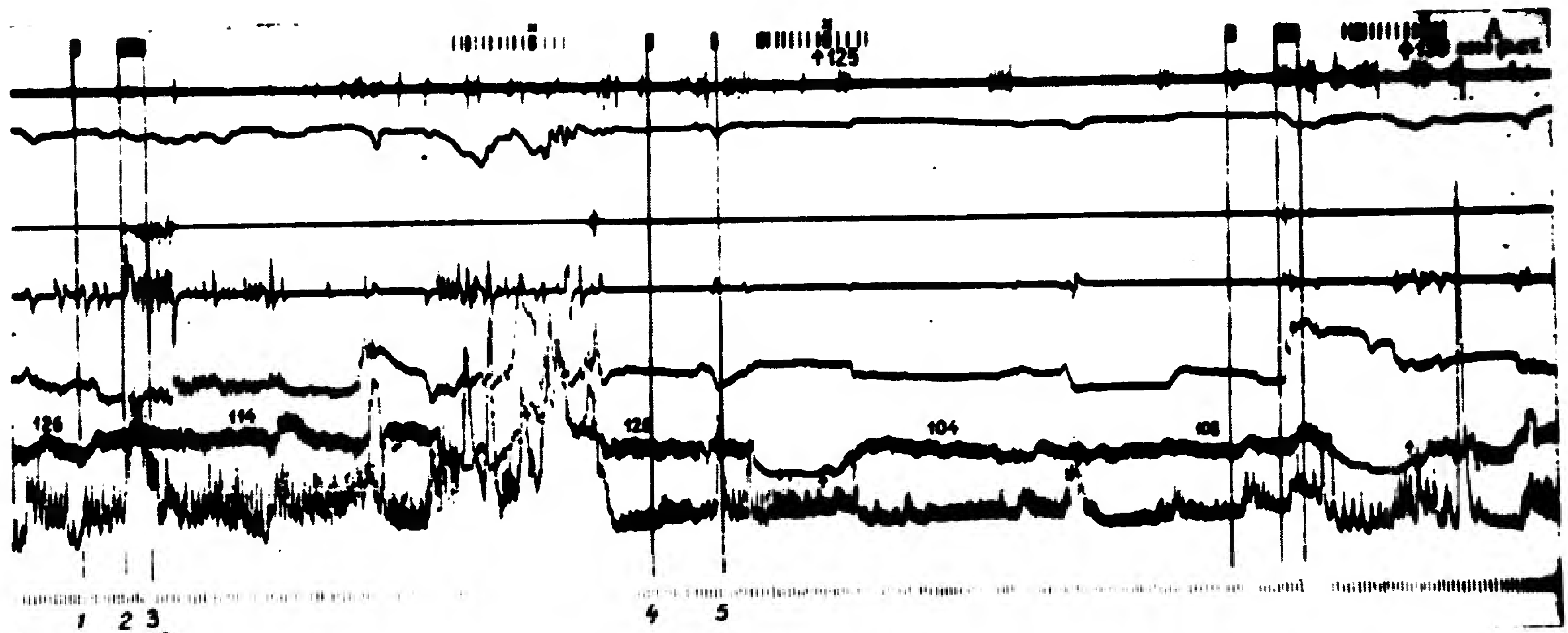


Fig.59. Dynamics of the level of compensatory switching of conditioned reflex intensified nervous activity during the development of conditioned reactions by the Petropavlovskiy method against a background of a weight of 2 kg on the stimulated extremity of the dog Dzhul'bars. *1)* Conditioned signal; *2,3)* electric skin stimulation of the right hind leg (as a result of the weight the animal does not raise the leg at the conditioned signal and in connection with this receives a current -- the first time after many combinations); *4,5)* the beginning and end of the differentiating signal; the second time (at 2 and 3) the animal receives only a very brief electric skin stimulus since it rapidly raises the stimulated extremity. Top to bottom: notation same as in *Fig.50.* A) mm Hg.

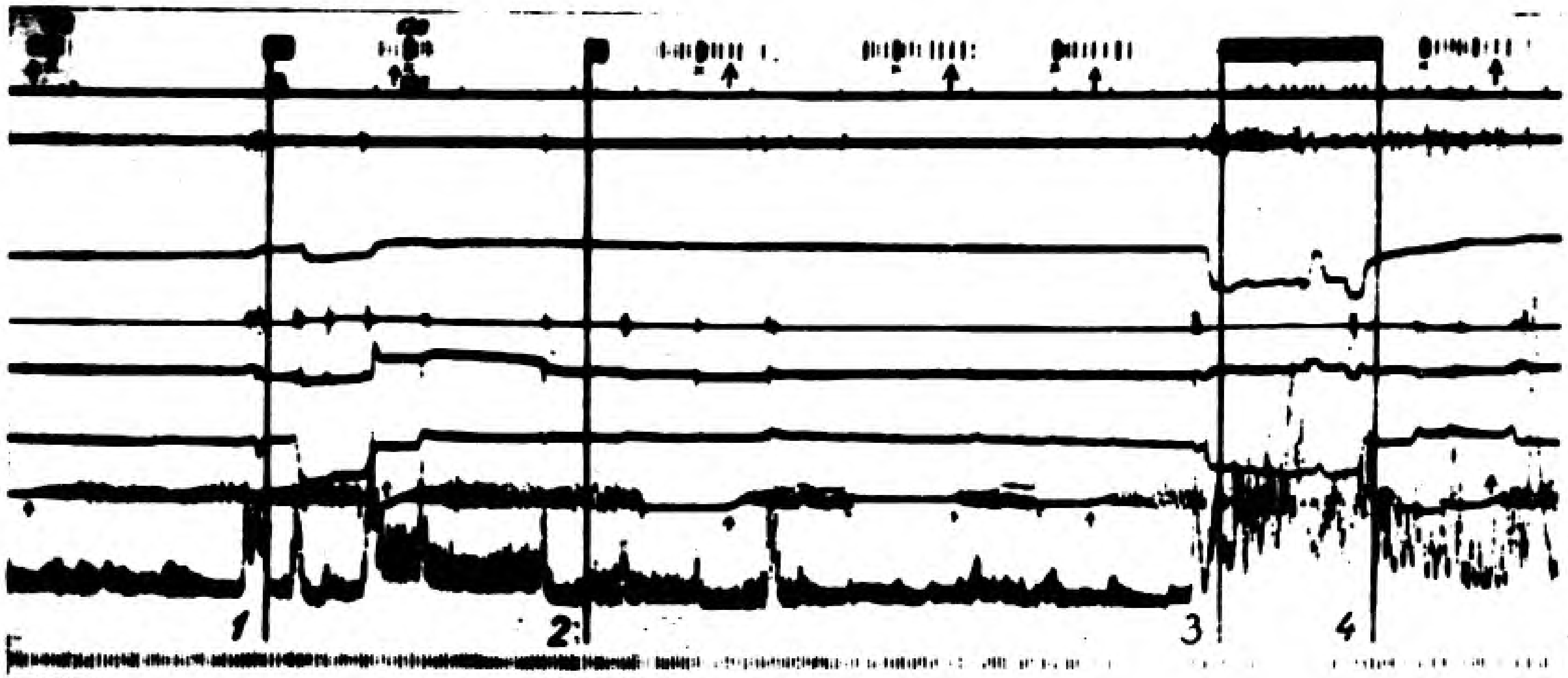


Fig. 60. Dynamics of the level of compensatory switching of conditioned reflex intensifies neural activity during the development of food conditioned reaction in the dog Dzhek (experiments of L. Rotsen and Yu. Briyedis). *1)* Beginning of light signal; *2)* showing the animal the feed box containing food (the animal stands in the straps and cannot approach the feed box); *3)* the food box is placed near the animal, the animal eats the food placed in the food box; *5)* removal of the food box, cessation of conditioned signal. Top to bottom: recording of arterial pressure (see *Fig. 16*); secretion of saliva; movement of lower jaw, head, total of front and total of rear legs; postural-tonic contraction of muscles of the coxofermoral joint; sphygmogram of carotid artery; pneumogram.

CHAPTER 6

ANXIETY AND NEURO-MUSCULAR RELAXATION REACTIONS AND THEIR PARTICIPATION IN SELF-REGULATION OF HIGHER NERVOUS ACTIVITY

THE ADAPTIVE CHARACTER AND EFFECTOR FUNCTIONAL STRUCTURE OF THE ANXIETY REACTION

§1. Conditioned stimuli signalling the expected development of changes in the surrounding situation which are significant for the individual, as a rule, cause to a greater or lesser degree the animal's or person's expressed preparatory reaction which mobilizes the nervous system and sensory organs, as well as the skeletal muscularture, for carrying out reception of the expected stimuli, transformation of the incoming information and organization of effective response reactions, that is, of the outgoing information. In order to provide for the increased metabolic, that is, energetic needs of the nerve and muscle tissues, the internal organs and metabolic processes, especially the respiratory apparatus and cardiovascular system, are frequently also mobilized.

In cases in which the expected change in the situation, that is, the expected different stimuli, which to a certain degree is known to the individual, the conditioned preparatory reaction bears a more or less specialized character. In cases in which the new situation affects the individual's nervous system or stimuli are expected whose adaptive significance is unknown, the preparatory reaction which develops in this case bears a non-specific character.

The preparatory reaction is a constant component of any conditioned behavioral reactions in the period of the development and strengthening of these reactions. In this case, along with specialized components, unspecialized components of the anxiety reaction fade in proportion to the automation of the behavioral reactions, and the specialized components fuse with the developed and automated behavioral reaction. Any change in the situation which is potentially significant for the individual provokes disinhibition of the unspecialized preparatory reaction.

The conditioned preparatory reaction is considered by many authors as an orienting reaction, or as a reaction of biological alertness (Krauklis, 1960a, p. 241). However, such an approach narrows the biological and psychological (in man) content of this basic adaptive act of animals and man, which determines the individual's active and selective attitude toward various stimuli of the external world.

The preparatory reaction unites the organism's various adaptive reactions into a complete behavioral act: the orienting reaction, the adaptation reflex, the reflex of biological and psychological alertness, visceral reactions, reactions carrying out self-regulation, that is, self-establishment of an optimal level and system of nervous activity, sometimes passive-defensive reactions and others.

All these adaptive reactions are integrated in order to provide for the principal task: to prepare the organism for rapid and effective equilibration with the expected or already beginning changes in the external environment. In order to emphasize the general directedness of these reactions, we consider it expedient to combine them under the term "anxiety reaction" which accurately reflects both the mobilizing and the preparatory character of the reactions.

According to data of the physiology of higher nervous activity, as well as of neurophysiology, the following components enter into the functional structure of the anxiety reaction.

I. Electrophysiological (Electroencephalographic) Components

The electroencephalographic components reflect changes in the intracentral coordination of the brain: reactions of generalized or to a greater or lesser degree differentiated cortical awakening, reactions of limbic (emotional) awakening, corticofugal, selective facilitation of the passage of the afferent impulses actual for the situation along the central nervous system and of inhibition of the passage of nonactual impulses, cortico- and reticulo- spinal facilitation or inhibition of the activity of the gamma-efferents, etc.

Penfield and Jasper (1958) believe that the centrencephalitic system regulates through two-way neural links which functionally unite the cortex of the large hemispheres with the thalamitic reticular formation man's conscious attention (which is the leading mental component of the anxiety reaction). However, if data of the physiology of higher nervous activity which demonstrates the leading importance of the cortex of the large hemispheres in the realization of higher mental functions of animals and man, as well as data of the electrophysiology of the brain demonstrating the presence of corticofugal control of the passage of all impulses along the central nervous system both in ascending and in descending directions is taken into account, then it is advisable to change Penfield and Jasper's formulation in the following way: the cortex of the large hemispheres through the centrencephalitic system regulates higher mental functions, including conscious attention.

French (1962), in correlating neurophysiological data on the mechanisms of alertness, emphasizes that the reticular formation controls the passage of the alerting afferent inflow along the sensory paths, and also forms the effector current determining the external manifestation of the anxiety reaction itself is under the direct selective concentration of the alerted attention of the brain with respect to a small number of afferent signals out of the tremendous influx which constantly "fills" the whole brain.

II. Sensory Components

1. The establishment of a level of activity (excitability) of the stimulated receptors, that is, analyzers, which is adequate for the actual or expected stimuli: an increase in the level of activity if the stimulus is not too strong, a decrease -- if the stimulus is a strong adaptation reflex (Sokolov, 1958) or a tuning conditioned reflex (Makarov, 1940, 1956: Gavrilova, 1960a, b).

The establishment occurs by means of centrifugal actions on the receptor elements, intrafusal fibers of the muscle spindles and other elements of the propriomuscular apparatus of the sensory organs (Kvasov, 1956), on the sensory nuclei and transmission relays which pass the sensory impulses in a centripetal direction (Khagbart, Kerr, 1954; Granit, 1955; Hernandez-Peon et al, 1955, 1956; Galambos, 1956, Rossi, Zanchetti, 1957; Megun, 1958).

2. The arrangement of distant sensory organs in the direction of the stimulus with the help of movement of the eyeballs, ears, turning of the head, change in position, etc.

3. Cessation of current motor active and attenuation or brief delay of respiration as measures promoting the establishment of the analyzers in the direction of the stimuli and concentration of attention on these stimuli.

III. Postural-Tonic and Locomotor Components

1. A nonspecific reaction of alertness or "starting" readiness -- postural-tonic, and sometimes a locomotor reaction providing preparation of the skeletal musculature and locomotor apparatus for the performance of any motor acts which may prove necessary during the expected actions on the organism of various different stimuli.

2. A specialized reaction of "starting" readiness which provides preparation of the skeletal musculature and locomotor apparatus for the carrying out of a specialized local or generalized motor act caused by the expected development of a more or less known stimulus, whose duration and biological or psychological significance is, however, not exactly known.

In cases in which some important elements of the future situation are more or less known, but the situation as a whole is unknown or difficult to determine since it can vary within wide limits, both unspecialized and more or less specialized "starting" readiness develops in the individual.

If the qualitative and quantitative characteristics of the expected stimuli and situations are relatively accurately known or an automated stereotype of motor acts is developed, the specialized preparatory reaction can completely coincide with the developed motor stereotype and cease to be a component of the anxiety reaction.

IV. Motor Reactions Primarily Inadequate For The Situation

Postural-tonic or locomotor reactions, local movements, reactions on oneself, etc. which were reproduced as a result of self-regulation of higher nervous activity and not having significance for the preparation of a posture of "starting" readiness or even preventing the establishment of the latter sometimes develop.

Depending on whether reactions providing mainly the first or second type of self-regulation prevail, it is possible to conditionally distinguish the following two groups of primarily inadequate motor reactions.

1. Primarily inadequate postural-tonic reactions -- the isometric contraction and tension of those muscle groups (simultaneously antagonists and agonists or primarily one or the other) which do not participate in carrying out the above-mentioned pose of "starting" readiness of the locomotor apparatus, and are only the result of the second type of self-regulation (that is, self regulation by means of a compensatory increase in proprioceptive inflow) (see Chapter 3), and partially also of the first type.

2. Phasic motor acts not having primary adaptive significance and which are only the result of the first type of self-regulation (that is, prophylactic and compensatory effector switching), for example: crossing from leg to leg, movements of the extremities, movements of the head (not connected with the orienting reaction), increased frequency of blinking movements, movements of the lips and tongue and deglutitory acts, reactions on clothing or surrounding objects, reactions on oneself (scratching, etc.), in dogs -- squealing, barking, growling, etc.

V. Respiratory Components

Respiratory components are an integral part of the alerting reaction, that is, of the reaction of "starting" readiness and, moreover, have great significance in the self-regulation of nervous activity.

An increase in the inspiratory tonus of the respiratory muscles, increased frequency and intensification of respiratory excursions are observed. Sometimes deep breaths with a subsequent brief stop in respiration occur. The deep breath does not lead to quieting of respiration if the anxiety reaction continues (in contrast to the reaction of neuro-musculature relaxation, where immediately after the deep breath more or less quiet breathing, more accurately -- the initial system of respiration -- usually follows (see §6).

VI. Visceral Components

Some increase in the amplitude of the sphygmogram, a small decrease in the frequency of pulsation, is often noted which sometimes changes to increased frequency of pulsation or vice versa (with deep breaths relative bradycardia is more sharply expressed, with a considerable increase in the frequency of respiration slight tachycardia is frequently observed).

More or less expressed regional vascular reactions develop. In a majority of cases vasoconstriction is noted in the fingers and toes (especially the fingers). Slight vasodilation is often observed in the soft tissues of the skull (at the forehead-occiput level)(Krauklis, Briyedis, Rotsena, 1963).

During a prolonged (especially, increasing) state of anxiety and emotional stress, the vascular reactions in different regions of the body can acquire the opposite (in comparison with the initial) direction which (together with the change in the level of the arterial pressure) indicates a radical redistribution of blood between the vascular reservoirs of the body (Krauklis, Briyedis, Rotsena, 1963).

During a severe anxiety reaction an increase in the systolic and middle, and frequently to an even greater degree -- in the diastolic arterial pressure is often noted. An especially considerable increase in arterial pressure is observed in experimental animals in those cases in which the limbic component of the anxiety reaction is intensified, that is, expressed emotional excitation develops. At the same time, it should be mentioned that in our observations of certain dogs (males) against a background of the most severe emotional excitation of nervous overstress, a sharp decrease in arterial pressure was noted.

A connection between the dynamics of the postural-tonic and cardiovascular components of the alertness reaction was established in Surnev's experiments (1963) -- stabilization of the functions of the skeletal musculature at one level of activity (the establishment of a fixed watchful position of the experimental animal) was usually accompanied by stabilization of the blood pressure and pulse rate.

In addition to the cardiovascular system and respiratory apparatus which are most closely connected with the individual's mental and behavioral reactions, the digestive tract also sometimes takes a very active part in anxiety states. We became convinced of this in our observations by studying the dynamics of the stomach's motility. We noted three basic variants of the stomach's "behavior" during an anxiety reaction: 1) the absence of a noticeable reaction on the part of the stomach's motor activity, 2) intensification and increased frequency of periodic contractions of the stomach musculature, 3) inhibition of the periodic contractions. During a rather severe anxiety reaction the latter variant was observed most frequently. The second variant frequently occurred in experimental animals when as a result of an "unresolved" difficult situation severe emotional excitation and a prolonged difficult state of the animal's nervous system developed.

Changes in the cutaneogalvanic effect during an anxiety reaction and other vegetative changes have been described in the literature. Of course, during a severe anxiety reaction, more or less expressed changes in endocrine regulation and metabolic processes also develop. However, these changes have been studied only in cases of extremely severe, pathological anxiety states representing a so-called stress-state.

VII. Mental Components

The objective expressions of attention concentration, mental preparation for perception and the response reactions of an individual's mental and emotional stress were noted above.

A subject's subjective experiences are characterized by a feeling of intellectual and emotional tension and a sense of the organism's "readiness" for any (or specific) urgent response reactions to the expected stimuli. If the onset of nociceptive stimuli is expected, the subject manifests a striving "to do everything" to decrease the strength of the probable stimulus -- with the help of attention concentration and efforts of will, contraction of the musculature, changes in respiration, increases in interoceptive sensations if the nociceptive stimulus is exteroceptive, or increases in exteroceptive sensations if the nociceptive stimulus is of interceptive origin.

The most important mental component of the anxiety reaction in man is the voluntary mobilization ("self-generation," see Chapter 4, §5-7) of verbal (thought) signalling which reproduces such a dominant of the second signal system which controls by means of corticofugal influences the afferent inflow and the efferent current and provides the concentration of attention which is adequate for the situation and an adequate volitional act.

In other words, the most important component is the mobilization of the third type of self-regulation through self-generation of adequate verbal, that is, thought, signalling.

The figures presented below illustrate the somatic and visceral components of the effector structure of the anxiety reaction which developed in animals and human subjects during observations (Fig. 61-66 and also 14-16 (1-3), 18-20 (1,2), 43, 44, 50, 51, 55, 56).

THE CONDITIONED REFLEX ORIGIN OF THE ANXIETY REACTION

§2. Anxiety reactions in adult animals and man usually develop by conditioned reflex means in response to conditioned stimuli signalling the probable onset of biologically and psychologically significant stimuli or situations. In the action of unconditioned stimuli on the nervous system the latter cause an anxiety reaction if they also have signal significance, that is, if the start of the stimulation signals the possible onset of an even stronger stimulus or a likely change in the situation.

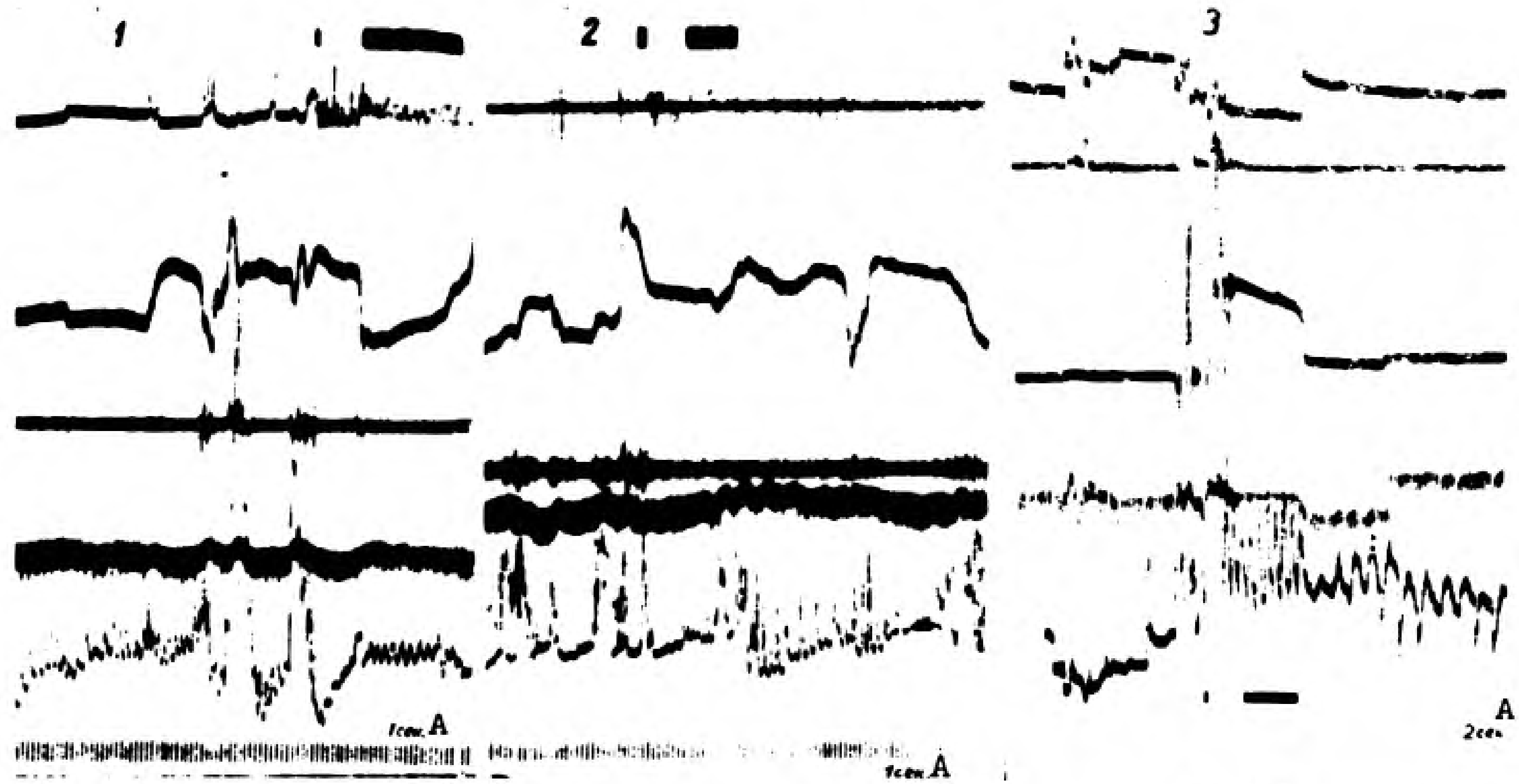


Figure 61. Combination of unspecialized components of a conditioned anxiety reaction -- raising of the head, general motor reactions, increase in inspiratory tonus and intensification of respiration -- with specialized components which prepare the organism for subsequent different stimuli: pouring of milk into mouth (first fragment of kymogram),of 0.5% hydrochloric acid solution (second fragment) and electric skin stimulation of the right hind leg (third fragment) in experimental dogs. "Nonspecific" raising of the head (and contraction of the extensor muscles of the brachial belt) during the action of the conditioned signal is replaced by a "specific" reaction -- lowering of the head, connected with preparation for swallowing the liquid poured into the mouth (see first two fragments and also Fig. 62). Notation same as in Fig. 51 (1) (first fragment), Fig. 51 (2) (second fragment) or Fig. 14 and 55 (3) (third fragment). A) sec.

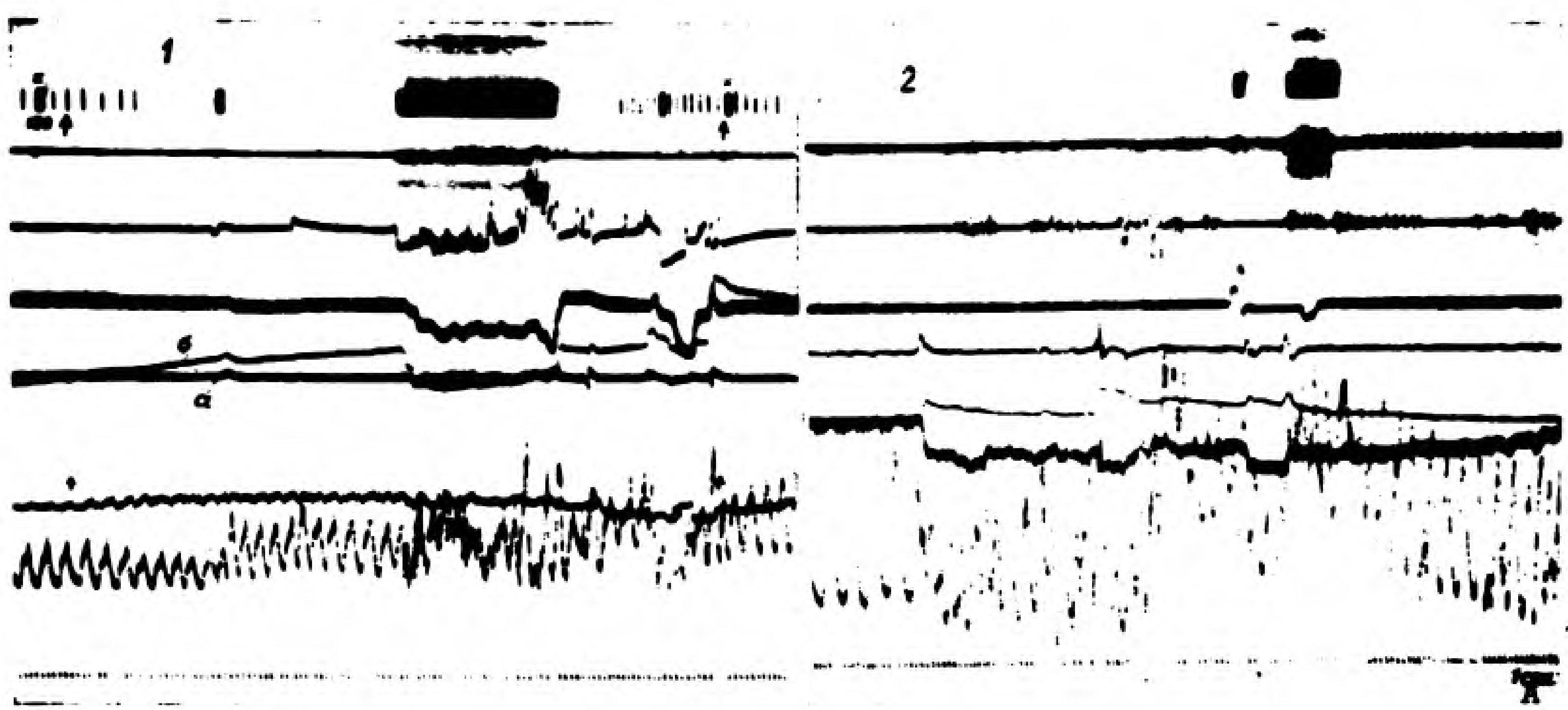


Figure 62. Unspecialized and specialized components of the anxiety reaction during the development of food (eating of pieces of meat from feeder) and acid-defensive conditioned reactions in dogs. Notation in first fragment same as in Fig. 24 and 60 (curves a -- total movements of all extremities, b -- postural-tonic reaction), in second fragment -- same as in first fragment only in place of food reinforcement, reinforcement with 0.5% acid is used. A) 1 sec.

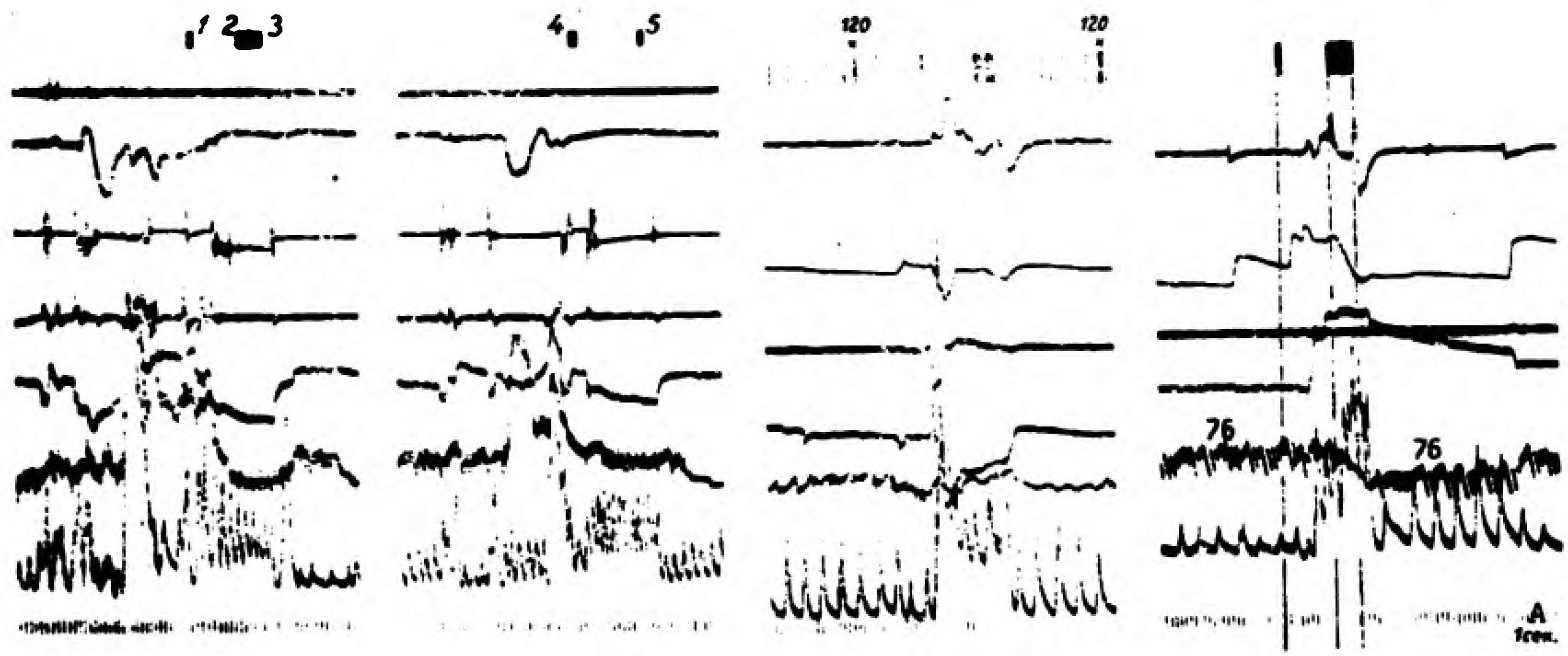


Figure 63. Various directions of postural reaction during state of anxiety in experimental dogs depending on the signal significance of the experimental situation and the stimuli used. First three fragments -- initial moving away or drawing back of the animal in straps (see rise in the curve of postural-tonic contraction of the coxofemoral muscles) is replaced by slight movement of the animal forward (drop in the curve). Fourth fragment -- moving back of the animal develops immediately upon the conditioned signal. First two fragments -- the development of defensive-motor reaction and differentiation by the Petropavlovskiy method. Notation same as in Fig. 59. Last two fragments -- development of a conditioned reaction on the basis of stimulation of the oral mucosa. Notation same as in Fig. 58. A) sec.

In cases of the action of strong unexpected stimuli on animals or man, in which they do not succeed in reproducing the conditioned anxiety reaction, an innate stereotyped reaction of shock and surprise usually develops. An anxiety reaction develops only in the ensuing seconds of the action of the stimuli or (if the stimulus is very brief, for example, the sound of a pistol shot) after cessation of the unexpected stimulus (see Chapter 2, §4) when from the effect of the signalling of the unexpected stimulus and the situation conditioned reflex activation of the subcortical and efferent structures which organize the anxiety reaction occurs.

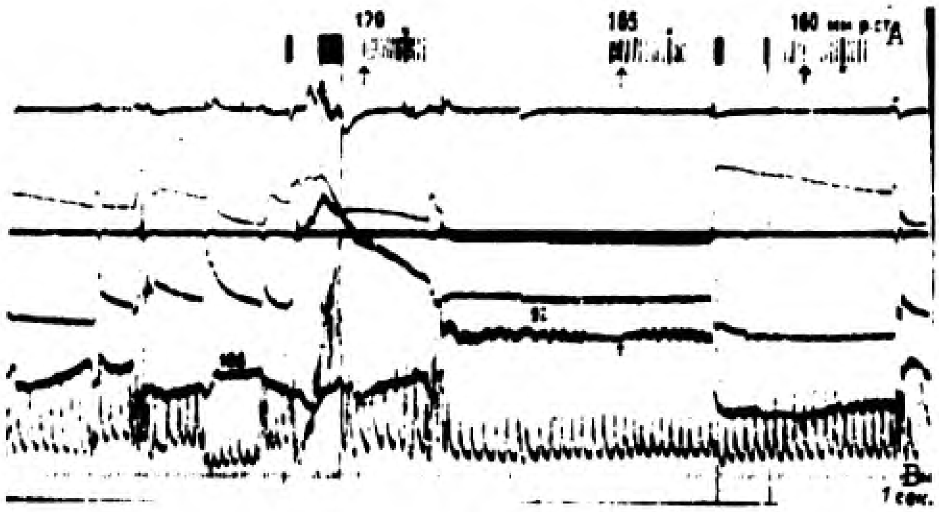


Figure 64. Various directions of the postural reaction of the dog Dzhulis during a state of anxiety in response to a positive conditioned signal (drawing back) and to a differentiated signal (moving forward). Notation same as in Fig. 58 and 63 (3,4). A) mm Hg; B) sec.

All observations on the development in experimental animals and human subjects of various conditioned reactions on the basis of sufficiently strong unconditioned reinforcements can serve as examples of the conditioned reflex origin of different forms of anxiety reactions having the above-described components in their structure (see §1).

We shall present examples from our observations of experimental rats in whom a differentiated conditioned motor reaction was developed -- running from chamber A through one of the openings in the wall (Opening 1, 2 and 3) to the opposite chamber B and vice versa -- from chamber B to chamber A (Fig. 67).

Three conditioned stimuli were used in the experiment: Nos. 1, 2 and 3. In response to each of these stimuli, the rat must run to the opposite chamber through a strictly determined opening (that is, accordingly through Opening 3), as well as in the absence of running for 10 seconds after the beginning of the signal, an electric current was passed through the floor of the cage and the rate received electrical skin stimulation of the paws.

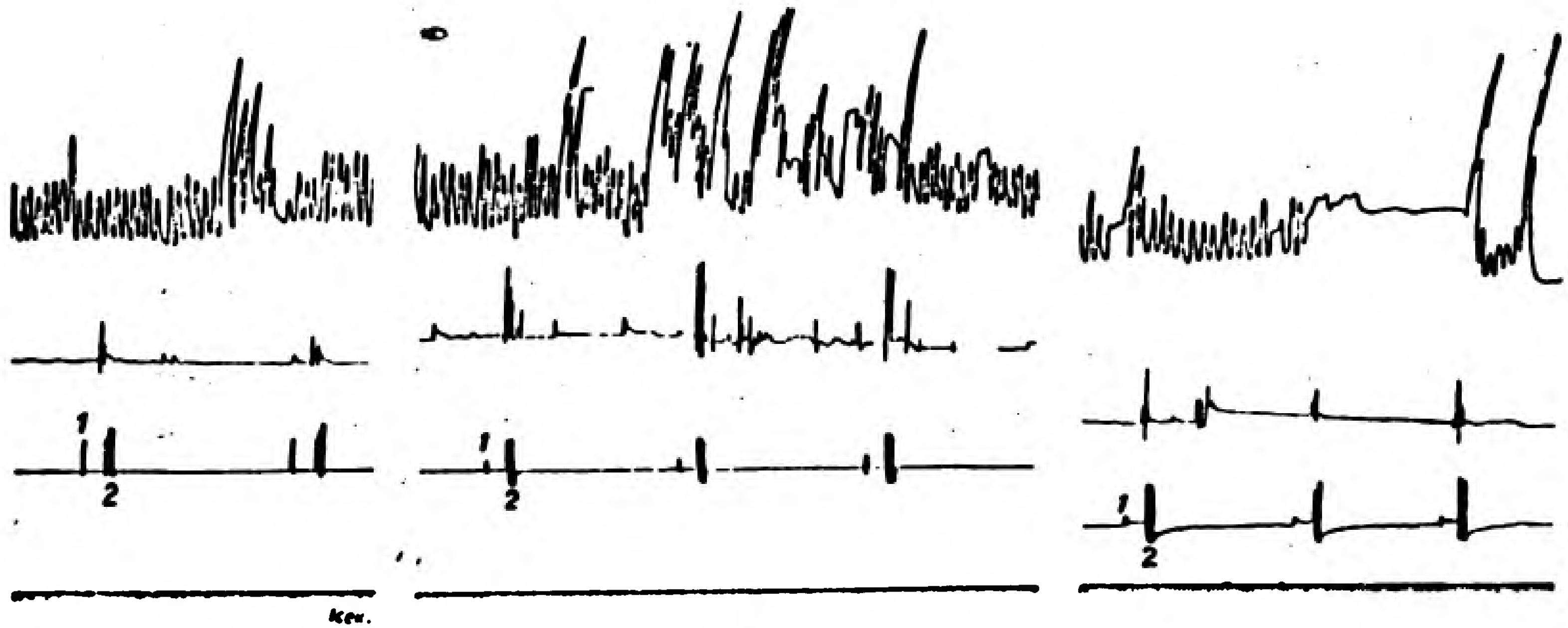


Figure 65. Various forms of the anxiety reaction in different subjects during the development of blinking conditioned reactions. Notation same as in Fig. 47 and 53.

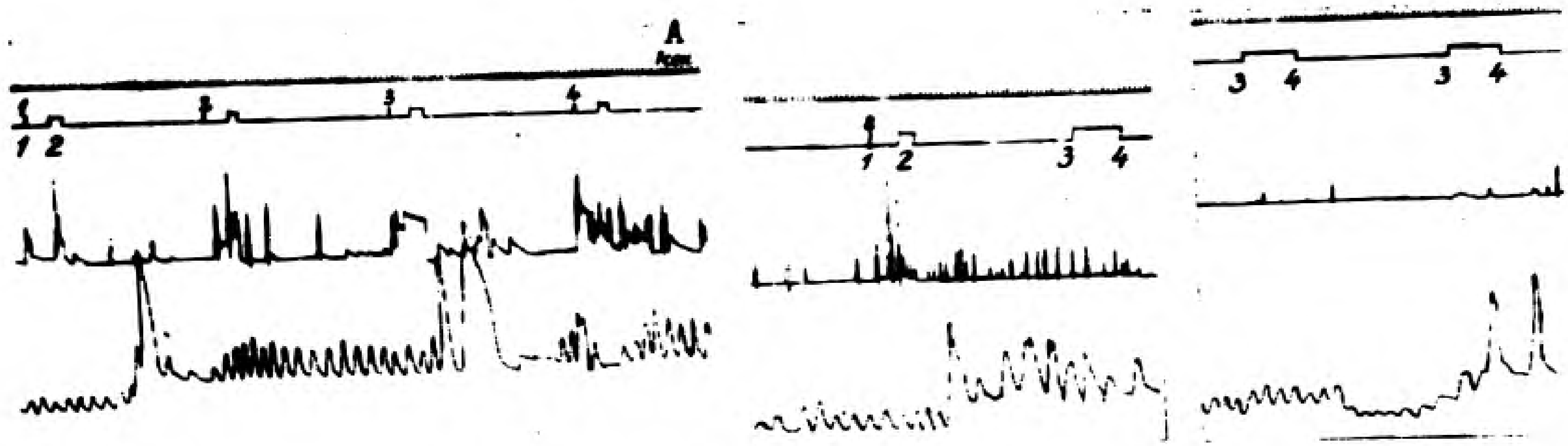


Figure 66. Anxiety reaction arising as a reaction to the situation and to time in different subjects during the development (first fragment) and extinguishing of a blinking conditioned reaction (third fragment). In the second fragment the anxiety reaction develops after the eighth (in order) combination of conditioned and unconditioned stimuli, following which the use of a conditioned signal of unconditioned stimuli, following which the use of a conditioned signal of unconditioned reinforcement usually begins. In connection with this, the end of the eighth combination acts as a signal causing an anxiety reaction. Notation same as in Fig. 42 (1). A) sec.

In the initial period of the development of differentiated running in the interval between stimuli and upon application of the signal the animals began to display an alerting reflex, on the strength of "starting" readiness (the rat sometimes raised itself on its hind legs): turning of the head and neck in the direction of the conditioned sound signal. Soon turning the head in the direction of the signal was replaced by turning the head in the direction of the partition. In subsequent experiments, the rat approached the partition and the reaction of "starting" readiness was carried out in front of one of the openings. In the period in which correct runs through the appropriate openings had already developed in the animals, some rats in the middle or at the end of the interval between stimuli ran to the appropriate opening and stopped there, taking the position of "starting" readiness to run through the opening, which indicated that a conditioned anxiety reaction to the situation and to time had been developed.

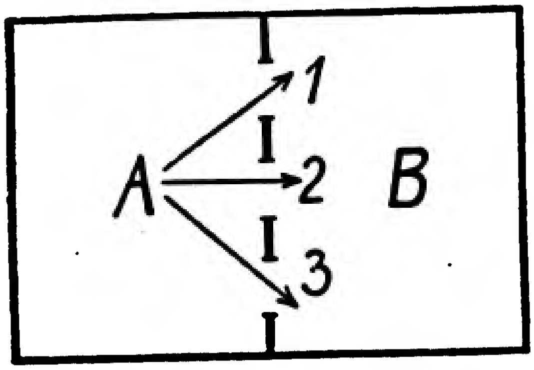


Fig. 67. Diagram of runs of experimental animal in experimental chamber. See text for notation.

Sometimes running to the opposite chamber took place even before the use of the appropriate conditioned signal -- solely in response to the time factor or to a certain extraneous stimulus. In this case the "premature" conditioned running usually was carried out through the opening which corresponded to the signal significance of the subsequent conditioned signal (the signals were used according to a specific stereotype).

The observations presented indicate the formation of functional systems of conditioned and unconditioned links differentiated in time and space which functionally unite both those subcortical structures in which the effector manifestations of the anxiety reaction are integrated and those subcortical structures which have an ascending tonic (awakening) effect on the cortex of the large hemispheres of the brain.

The conditioned reflex organization of all the manifestations of the anxiety reaction takes place through the cortex, that is, corticofugal paths: both the manifestations characterized by tonic, somatic, respiratory and visceral components and the manifestations characterized by electrophysiological, that is, intracentral, components.

If the anxiety reaction develops against a background of one or another strong biological (in man also psychological) dominant, then it (that is, the anxiety reaction), in its turn, can cause further activation and modification of this dominent. Anokhin (1958a) indicates that the orienting reaction under certain conditions can intensify the current biological dominant. The same pertains to an anxiety reaction, a component part of which is the orienting reaction described by Anokhin.

For example, in the experiment presented above on rats, the typical reaction of alertness in many rats was brief or absent, but in its place in the intervals between stimuli or at the signals, the motor-defensive reaction developed or being developed immediately arose -- running through one or another opening into the opposite chamber.

It should be mentioned that under conditions of the free movement of the experimental animal in a relatively spacious experimental chamber or cage, the external manifestations as well as the visceral components of the anxiety reaction in many animals are less expressed or entirely absent, which is not observed in those cases in which the animals are in a fixed position on an experimental table or in a relatively narrow cage; this pertains especially to those experiments in which nociceptive stimuli of relatively little significance or biologically positive stimuli are used.

The significance of the combining of unconditioned activation (through the reticular formation of the brain stem) of the intracentral components of the anxiety reaction with background signalling in the manifestation of the actual dominant is graphically shown in the experiments of Zubkov and co-workers (Zubkov, Marits, 1960) who established that electrical stimulation (through an implanted electrode) of the rostral region of the brain stem disinhibits a defensive-motor or food conditioned reflex depending on whether the experimental animal is in a defensive or food situation at this time.

On the basis of these experiments, the conclusion was drawn that stimulation of the reticular formation causes the relative predominance in the cortex of the large hemispheres of excitation which disinhibits the conditioned reflex to the situation. The reticular formation's activating effect on the cortex in the given case is not specific since the specifics of the animal's behavior determines precisely that cortical dynamic stereotype which at the given moment is prepared for the actual situation.

In observations on people, the manifestation of one or another form of anxiety reaction, of some or other of its components, depends to a large degree on the person's voluntary control of his behavior, as well as on subjective reflection through a second signal system of the signal significance of the stimuli used in the observation session.

The kymogram fragments presented in Figs. 1, 2, 4, 38 and 44 can serve as an illustration of what has been stated above.

Thus, conditioned reflex mechanisms play an important role in the mobilization and formation of the anxiety reaction.

At the same time, the anxiety reaction has no less significance in the development of conditioned reflexes and in the carrying out of higher nervous activity in animals and man. This significance has been confirmed by numerous investigations in the area of brain morphology and electrophysiology which have been conducted in the last 15-20 years (Rossi, Zanchetti, 1957; Magoun, 1958;

Penfield, Jasper, 1958; Anokhin, 1958a, b: Brodal, 1960; Beritov, 1961; and others, the Reticular Formation collection, 1962).

The most important role of the orienting reaction during the formation and extinguishing of conditioned links (Anokhin, 1958a, b: Sokolov, 1958a,b; Sokolov and Paramonova, 1961; and others), as well as in conditioned reflex self-regulation of the functional state of the brain (Krauklis, 1959a,b, 1960a) has been shown by the work of Soviet physiologists.

Our observations shows that during the formation of internal inhibition in animals and man expressed activation of the mechanisms of self-regulation of higher nervous activity usually takes place to a greater or lesser degree and that this activation is closely connected with mobilization of the anxiety reaction and its dynamics (Krauklis, 1959a,b; 1960a,b; 1962, 1963; Krauklis, Briyedis, Rotsena, 1963; Liyepa, 1963, 1964a,b; Briyedis, 1964a, b,c).

There is a basis for assuming that the development of internal inhibition is linked, first, with activation of the general preparatory reaction, that is, the anxiety reaction, during which a nonspecific generalized anxiety reaction (having expressed comatic and visceral components) is replaced by a specialized localized anxiety reaction (having mainly intracentral components) which promotes more and more effective inhibition of the excitement caused by the inhibitory, that is, differentiated or fading signals and, second, with subsequent extinguishing of the anxiety reaction and automation of the conditioned reflex inhibition which is being carried out with minimal participation of the cortex of the large hemispheres and of the reaction of cortical awakening.

It has been established that during the development of internal inhibition a stage occurs when the absence of a developed specialized conditioned reaction and of the external manifestations of an anxiety reaction upon the inhibitory signal is accompanied by the development of these reactions in the intervals between stimuli (as a reaction to the situation and to time, as well as an aftereffect reaction following cessation of the inhibitory signal).

The aftereffect reaction, being a valuable indication of the stage of development of internal inhibition, is either a disinhibited anxiety reaction or ordinary compensatory reaction (see Chapter 2) or an active reaction of neuro-muscular relaxation (see §6). The anxiety reaction is inhibited (at least its somatic and visceral components) in proportion to the degree of stabilization and automation of the functional system of conditioned links which determines the development of internal inhibition not only at the application of the inhibitory signal but also in the intervals between stimuli.

The data which we have obtained indicate that the development of internal inhibition is connected with mobilization of the anxiety reaction, with the development of a new system of conditioned links and with the more and more effective inhibition and equalizing of the impulses caused by the inhibitory signals in the closed neuron systems of the brain, that is, with inhibition of the outflow of these impulses to the effector paths or to the activating structures of the brain.

PARTICIPATION OF THE ANXIETY REACTION IN SELF-REGULATION OF HIGHER ACTIVITY. ROLE OF THE SITUATION'S SIGNAL SIGNIFICANCE IN THE ORGANIZATIONAL STRUCTURE OF THE ANXIETY REACTION

§3. All the components of the anxiety reaction which were presented in the first section of this chapter participate to one or another degree in the self-establishment of an optimal system and adequate level of integration of higher nervous activity.

They participate mainly in the carrying out of the second and third types of self-regulation, that is, in the compensatory generation of an intensified afferent inflow and positive conditioned signalling which promote an increase in cortical tonus and level of integration of nervous activity, as well as in the selective facilitation and combined inhibition of various afferent impulses, etc. (see Chapters 3 and 4).

In the case of an inadequately strong exertion of the activity of the dominant closed systems, activated situations and stimuli used, the somatic and visceral components of the anxiety reac tion can serve as "channels" through which the urgent prophylactic and compensatory switching of the activity impulses of these systems of the brain to the periphery takes place.

Thus, the intensity and stress of the primary systems of activity are relatively weakened by this means and "regulating" and "optimalizing" secondary systems of activity are formed which equilibrate the primary and increasing, if this is possible, level of integration of the afferent and effector impulses.

As seen from the diagram of the functional structure of the anxiety reaction (see §1), there exists a whole series of somatic, respiratory and visceral components which carry out both a primary and the secondary adaptive effect (the arranging of the analyzers in the direction of the stimuli, postural-tonic and locomotor reaction of "starting" readiness with corresponding changes in respiration and visceral organs).

However, in many cases the secondary significance of these reactions predominates over the primary to such a degree that the reactions easily become primarily inadequately strong. Sometimes the mentioned somatic and visceral reactions become not only quantitatively, but also qualitatively primarily inadequate, that is, not having primary significance. Observations in which in a subject (frequently in a child), during the development of a blinking conditioned reflex, in response to the conditioned signal develops a position of "starting" readiness with sharp intensification of the lung ventilation, increase in heart contractions and a subjective "feeling" of a state of stress and anxiety can serve as example. If the conditions of the observations are taken into consideration, as well as the fact that the subject is already accustomed to these conditions and acquainted with measured out brief and harmless unconditioned stimulus -- stimulation of the conjunctiva of the eyeball with a jet of air, then it becomes clear that the position of "starting" readiness and any other general preparatory reactions of the subject do not have any adaptive significance but are only a means of carrying out self-regulation of higher nervous activity. Therefore, such "compensatory" primarily inadequate general preparatory reactions usually develop against the background of severe nervous strain, emotional excitation or fatigue of the subject's nervous system, especially in neurasthenics [see 68-80, as well as 53 (2), 65 (2,3), 66 (1-3)].

Very frequently, not a definitive reflex of alertness, that is, a reaction of "starting" readiness, but its "surrogates" (or equivalents), develop in subjects for purposes of self-regulation of nervous activity, for example, contraction and extertion simultaneously of the muscle-agonists and muscle-antagonists or primarily one of them.

In such cases, the postural-tonic reactions acquire the character of so-called passive-defensive reactions which, in origin and effector structure, are primarily inadequate, arising only for purposes of self-regulation (see §4).

Various phasic motor reactions also belong among primarily inadequate reactions -- the development or the increased frequency and intensification of masticatory, swallowing and blinking movements, movements of the head and extremities, reactions on oneself, etc., which are an expression of the first type of self-regulation (see §1, item 4). In connection with this, the question comes up of what difference it makes whether self-regulation is carried out by means of primarily adequate adaptive acts (for example, the reaction of "starting" readiness) having specific and important primary adaptive significance or by means of primarily inadequate motor reactions (for example, so-called passive-defensive reactions, various primarily unmotivated tonic contractions of the musculature and movements).

We believe that the difference lies in the fact that in the carrying out of a primarily adequate adaptive act secondary ("inverse") afferentation is caused which signals the brain of the readiness of the organism for rapid response to possible different, for example, harmful, stimuli. At the same time in the carrying out of primarily inadequate acts, the secondary afferentation signals the brain of the absence of the organism's readiness for active response reactions and of readiness only for "passive" perception and for "conversion" by the nervous system of future different stimuli.

In accordance with secondary signalling of different biological and psychological content (which participates in the carrying out of the third type of self-regulation), one or another intellectual-emotional dominant is supported in the brain by conditioned reflex means. Depending on the concrete situation in which the individual is found, both the "active" and the "passive" form of anxiety reaction can have definite secondary adaptive signifi-

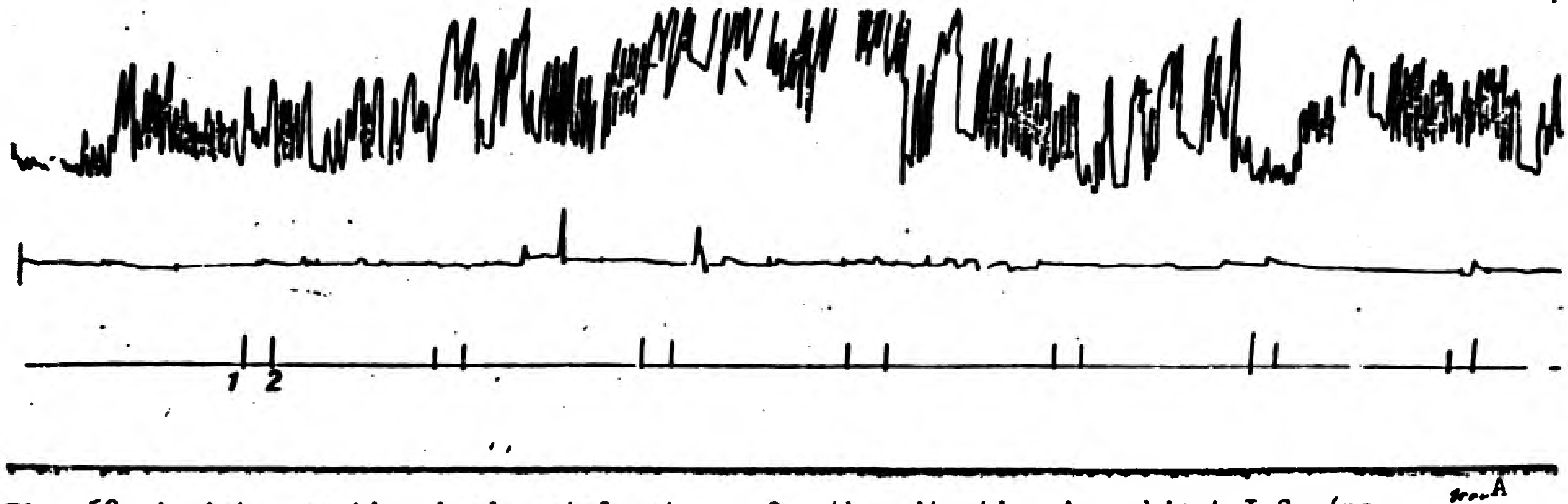


Fig. 68. Anxiety reaction inadequately strong for the situation in subject I.S. (patient with neurasthenia) in first observation sessions with increase in the frequency of the orienting reaction to sound stimuli (beats of a metronome) used without reinforcement (that is, before the start of the development of conditioned reactions). 1,2) Beginning and end of "indifferent" sound stimulus. Notation same as in Fig. 47 and 53 (see also Fig. 65). A) sec.

cance. In a situation requiring the individual's active work, the active form frequently predominates. In a situation requiring restraint, cautiousness and the suppression of active actions, the passive form predominates (see §4).

Of course, in all situations in which it is necessary to accomplish a primary adaptive effect by means of an anxiety reaction, for example, the arranging of the analyzers in the direction of the stimuli and a pos-tion of "starting" readiness, it is advisable to use for purposes of self-regulation primarily adequate adaptive acts.

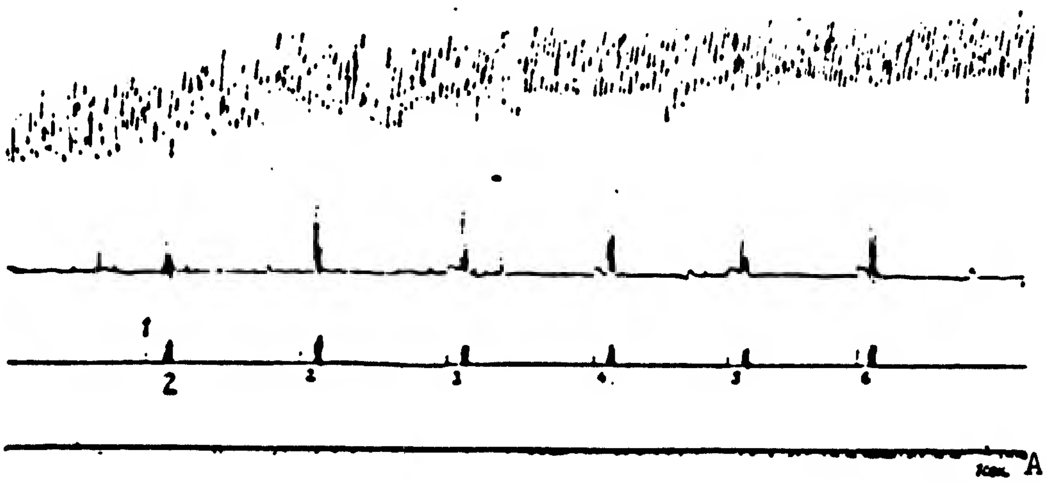


Fig.69. First sessions of subject I.S. (see Fig.68) with the use of unconditioned reinforcement (that is, the beginning of the development of a blinking conditioned reaction). Increase in cortical tonus and inhibition of inadequate anxiety reaction which took place before the use of the unconditioned stimulus. The gradual increase in inspiratory tonus of the respiratory musculature and intensification of the isometric contraction of the femoral muscles indicate the presence of a certain more or less "adequate" anxiety reaction which promotes maintenance of an optimal system of respiration with adequate dynamics of the specific component of the conditioned reaction being developed -- blinking movements. Notation same as in Fig.47 and 53 (see also Fig.65 and 68). A) sec.

Thus, the anxiety reaction can be carried out at different levels of integration and, accordingly, have a different functional structure, different primary adaptive effect and a different role in the self-regulation of higher nervous activity.

In situations in which all the forms and variants of the anxiety reaction have important adaptive significance, that is, the nervous system, skeletal musculature and locomotor apparatus and the organism's internal environment should be mobilized and ready (more or less differentiatedly), the anxiety reaction can be considered adequate in the case in which adequate arrangement of the analyzers and a position of "starting" readiness are provided for, and those behavioral and visceral reactions except the intracentral components, which are mobilized for preparing for adequate locomotor

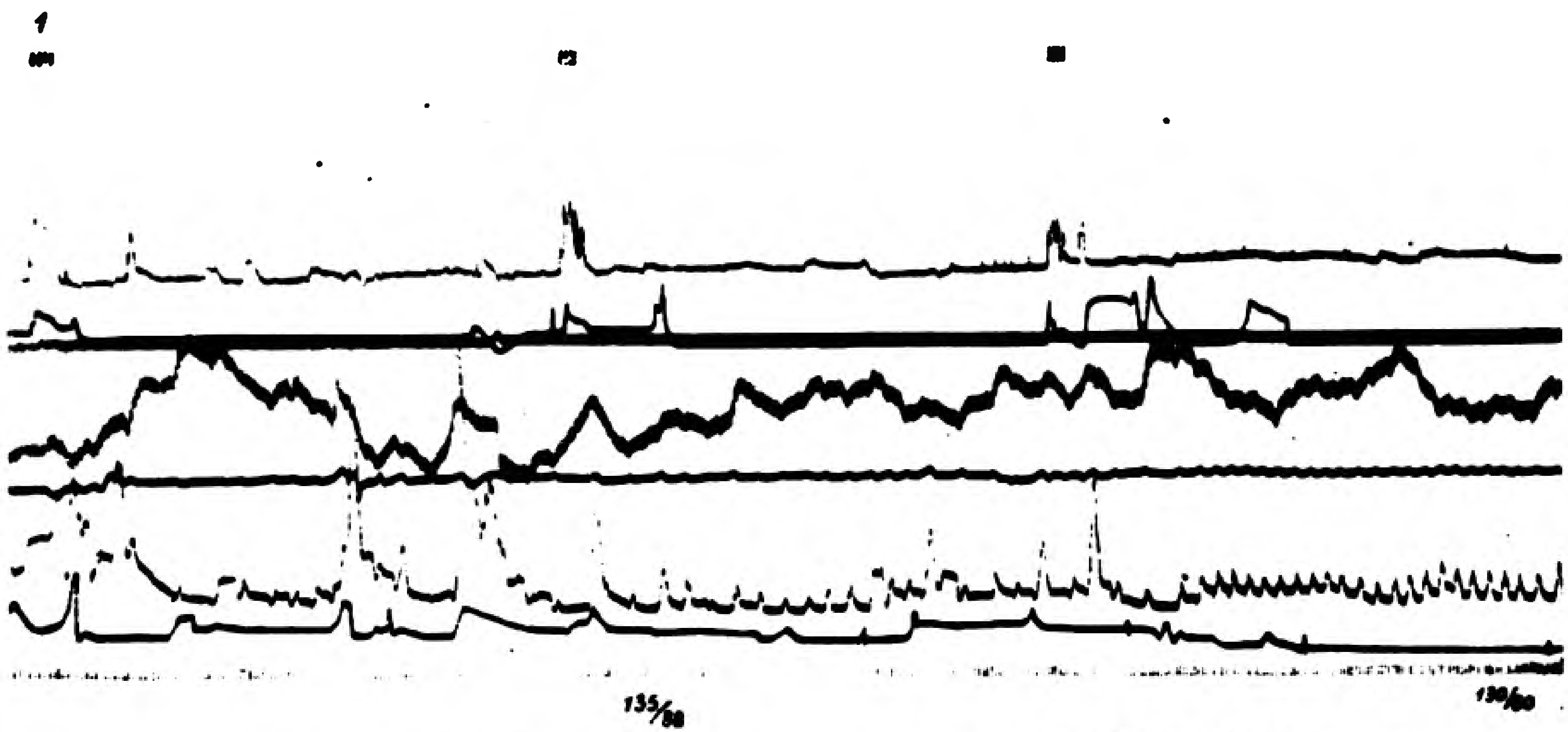


Fig.70. Replacement of a state of inadequately strong anxiety and emotional stress (see first two thirds of kymogram fragment) with a state of relative relaxation of the nervous systems and musculature and an optimal system of respiration (see last third of fragment) as a result of acclimatization of subject A.L. to circumstances of observation session. The subject is easily excited, "fights" the possible use of nociceptive, and especially, electric stimuli in the session. He easily develops a passive-defensive reaction. 1) Four-fold stimulation of the cornea with a jet of air. Top to bottom: blinking movements, displacement of the eyebrows (rise in curve) or wrinkling of the forehead (drop in curve) (in last third of the fragment, the curve is fixed at the zero level, reflecting the relaxation of the mimic musculature of the face); movements of lower jar (in the last third of the fragment, the curve is fixed at the zero level); plethysmogram of the fingers; contraction of knee joint extensors; pneumogram; contraction of the knee joint flexors.

acts are used for purposes of self-regulation of the nervous system.

In situations in which one aspect of the anxiety reaction to begin with or exclusively has significance -- the mobilization and preparation for an optimal system, exertion and level of integration of higher nervous activity -- the anxiety reaction can be considered adequate when mainly the corresponding intracentral components, as well as those effector components which provide a positive secondary effect, while not preventing in this case adequate behavior of the individual and being economical and optimal with respect to the system of functions of the internal organs, are used for purposes of self-regulation. It is understood that any postural-tonic, respiratory and other reactions can be used as such auxiliary components which are employed only for purposes of self-regulation, if they satisfy this criterion.

In cases in which the anxiety reaction loses its adequacy, it can become a source of overexertion of higher nervous activity and cause the most severe somatic and visceral inadeauate reactions. Thus, this occurs in so-called difficult states of the nervous system. In such cases, the anxiety reaction causes, instead of an optimal reaction of cortical awakening, a strong reaction of emotional (limbic) awakening which intracentrally generates very strong nervous activity which cannot be equalized in the brain and causes a sharp deviation of the system of higher nervous activity from the optimum. Strong prophylactic and compensatory switching of the activity impulses to the periphery is mobilized, a mass of primarily inadequate compensatory reactions develops which are easily capable of closing a "vicious" circle of self-regulation (see Chapter 5). Depending on the functional state of the nervous system (on the retention or absence of reserves of nervous energy and the functional possibilities), as well as on the type of nervous system and previous developed "habits" (in animals -- developed with the help of training) or the person's education, either there develops in the person violent general motor activity which is inadequate for the actual situation, frequently aggressive activity, h sterical fits or inadequate intensification of the functions of the internal organs, for example, the most severe tachypnea in experimental dogs (up to 300 respiratory excursions per minute and more), tachycardia, an increase in arterial pressure and sometimes a sharp intensification of the motor activity of the stomach (Fig.71 and others).

THE PASSIVE-DEFENSIVE REACTION -- A VARIANT OF THE ANXIETY REACTION

§4. Frequently authors who study the behavior of animals and man speak of the so-called passive-defensive reaction, meaning by this behavior reactions very different in effector structure and adaptive significance.

In some cases, reactions which are designated as a passive-defensive reaction in essence are an active defensive-motor reac-

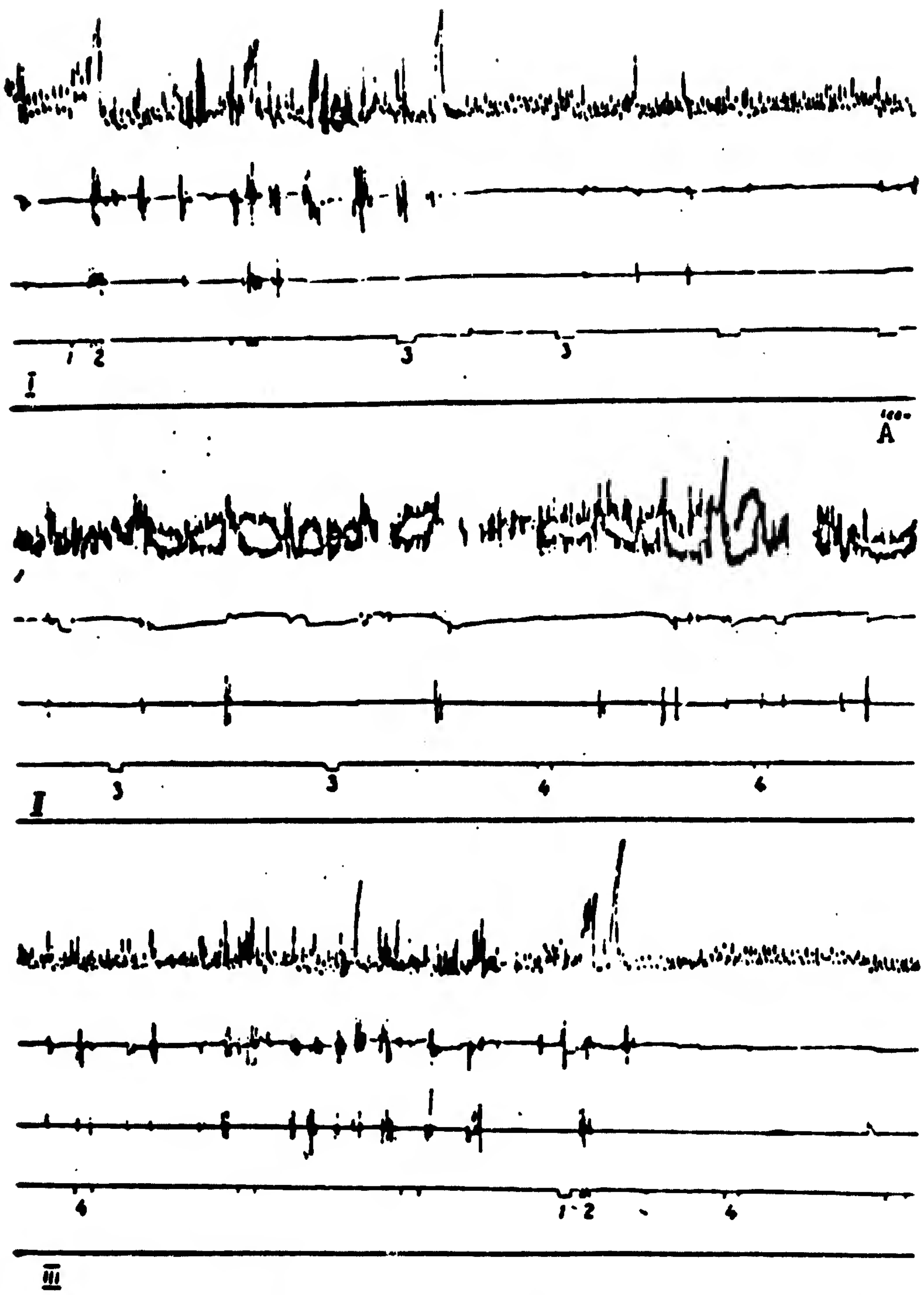


Fig.71. The onset, dynamics and cessation of an inadequately strong anxiety reaction which causes a difficult state of the nervous system during the extinguishing of a defensive-motor reaction in the dog Buratino. First fragment -- cessation of reinforcement of conditioned (sound) signal by electric skin stimulation; second -- cessation of use of (extinguishing) conditioned signal; third -- one use of conditioned signal and unconditioned reinforcement after which the absence of stimuli continues. 1) Conditioned signal; 2) three-fold electric skin stimulation of right hind leg; 3) extinguishing conditioned signal (absence of reinforcement); 4) usual place (in time) of use of conditioned signal which is absent at this stage of the experiment. Top to bottom: pneumogramm; movements of head; movements of right rear leg. A) sec.

tion, for example, the falling back before an obstacle, the drawing back of the head or upper part of the body from possible injurious agents, protection of the face, head and front parts of the body with the help of sharp bending of the body, etc.

In other cases, reactions designated as a passive-defensive reaction are a special variant of the anxiety reaction. We shall attempt to analyze this variant.

As already mentioned, anxiety reactions prepare the organism for rapid and effective response acts to likely different stimuli. In behavior, the readiness for effective response reactions is expressed in a position of "starting" readiness which permits the individual at any moment to produce a rapid locomotor act which is adequate for the actual situation.

The position of "starting" readiness (alertness reflex) is characterized by contraction and simultaneous slight expansion and, in connection with this, more or less strong (optimal) tension of those muscle groups which will carry out the first cycles of the expected motor act. Usually, such a preliminary increase in initial tonic contraction is observed in those motor acts in which large antigravitational muscles participate, that is, mainly the extensor-muscles.

The contraction of the extensor-muscles of the back, brachial band and neck is a constant component of the reaction of "starting" readiness. As a result, a more or less expressed lifting of the head develops as a rule. In animals lifting of the head is usually sharply expressed in an anxiety reaction, in man it is more or less inhibited.

Some authors erroneously consider the lifting of the experimental animal's head as an orienting reaction. However, the orienting reaction proper -- the turning of the head in the direction of the conditioned signal or unconditioned stimulus -- often fades away at the initial stage of the experiments in experimental animals. Turning of the head fades away particularly rapidly in dogs in an experimental holder.

However, the anxiety reaction does not always prepare an individual for active action on the external world. Sometimes the animal or person is prepared for "passive redevelopment" of the innovation or nociceptive, that is, potentially nociceptive, stimuli in its organism, more accurately, in its nervous system. This occurs in the following cases:

1) when the expected or present different stimulus is strong enough to cause activation of the nervous system, but not significant enough to respond to it with a specialized locomotor act, for example, with a defensive or investigative reaction;

2) when the nociceptive stimulus is strong and significant, but the individual does not have real possibilities for acting on it or on the external world for purposes of avoiding this stimulus;

3) when the individual's nervous system is fatigued, cortical tonus is decreased, the reserves of the functional capacities of

the higher sections of the brain are depleted, in connection with which there are no opportunities to organize successful active action on the external world and to eliminate the nociceptive or potentially nociceptive stimulus or situation;

4) when the individual has developed the habit of reacting to specific stimuli and situations by passive "redevelopment" and "internal" "abreaction" of the difficult situation, thus avoiding attempts at a real resolution of the situation.

In contrast to the reaction of "starting" readiness, the passive-defensive reaction is characterized by relative predominance of isometric contraction of the flexor muscles (the individual as if "closes within himself") or the flexor and extensor muscles of the same joint simultaneously (the individual as if "freezes"). In place of straightening of the back, brachial band and neck and raising of the head, some flexure of the back (the individual sometimes as if "stoops"), drawing of the neck and head into the shoulders and lowering of the head develops. In dogs "putting the tail between the legs", drawing back, sometimes develops or intensifies.

Respiration during a passive-defensive reaction becomes more frequent, the amplitude of the respiratory excursions is increased or decreased. In animals, particularly in dogs, the most severe tachpnea frequently develops.

The pulse rate is frequently considerably increased. Arterial pressure is increased more frequently than during the active form of the anxiety reaction.

A prolonged, lingering passive-defensive reaction easily changes into a difficult state of the nervous system which characterizes an inadequately strong and ineffective (carried out at a low level of integration) anxiety reaction.

With a sharp depletion of the energetic and functional resources of the higher sections of the brain, the difficult state of an animal's nervous system can acquire the form of passive drooping in the straps accompanied by the absence of active behavior reactions, by the most severe tachypnea, by a sharp increase in the pulse rate, and sometimes by a considerable increase in pressure which can be replaced by hypotension or by a change to continuous hypertension.

The anxiety reaction provides the optimal background functional state of the nervous system necessary for organization of specialized acts of behavior. The intracentral components of the anxiety reaction, an organizing reaction of awakening of the cortex of the large hemispheres, as well as a reaction of limbic (emotional) awakening, are leading in this respect.

The greater the initial tonus of the cortex of the large hemispheres and level of integration of the anxiety reaction, the more differentiated and adequate for the actual or expected situation is the awakening reaction.

Usually the intracentral components are supported by somatic components which are used for purposes of compensatory strengthening or, more accurately, reorganization of the afferent inflow (for example, optimal tension of the skeletal musculature, activation of respiration, etc.). The higher the level of integration of the anxiety reaction, the greater the degree of adequate and effective use of the effector components of the reaction for purposes of self-regulation of nervous activity.

In connection with the fact that the cortical tonus is established by conditional reflex background stimuli, the dynamics of the cortical tonus (and thereby the effectiveness and adequacy of corticofugal control of the passage of the impulses in the subcortical formations) depends in many respects on the dynamics of the signal significance of the background stimuli.

In laboratory observations the signal significance of the experimental situation changes in the course of the observation session, as well as during the interval between stimuli. The nearer the moment of time to the probable subsequent different stimulus, the more the signalling of the background stimuli acquires a more specialized content appropriate to the specifics of the stimuli used in the observations (Krauklis, 1960a, Chapters 2 and 3).

In connection with this, the anxiety reaction which develops at different moments of the session or interval between stimuli (the time factor is a component part of the circumstances, that is, the situation in which the individual is found) can occur at different levels of effector integration, that is, have different effector structures.

In a situation which signals the individual of the necessity of "avoiding" probably nociceptive stimuli, a prolonged anxiety reaction sometimes develops which has a sharply expressed limbic component. The strong emotional excitation arising in this case causes deviation of the system of nervous activity in the direction of relative predominance of activity circulating in the brain. As a result, the first type of self-regulation is mobilized and compensatory reactions develop which, as a rule, do not resolve the difficult situation. Therefore, the state of anxiety and emotional excitation (biologically of negative sign) continues together with pessimalization of the system, the level of integration of nervous activity decreases and the number of inadequate effector (somatic and visceral) reactions of the organism increases. In certain cases, for example, in experiments on animals in a "defensive" situation, such a lingering, ineffective anxiety reaction (which does not promote resolution of the individual's difficult situation) changes into a clear difficult state of the nervous system.

The approach of the time of the next nociceptive stimuli or the use of special conditioned signals signalling the subsequent use of nociceptive reinforcement, mobilizes in a conditioned reflex manner the intracentral components of the anxiety reaction, particularly those which carry out the reaction of differentiated cortical awakening. As a result, cortical tonus, corticofugal control and the level of integration of the individual's effector activity, including the level of integration of the effector components of the anxiety reaction itself, are considerably increased.

Frequently, after cessation of the nociceptive stimulus, the differentiated reaction of cortical awakening is relaxed, under the influence of a difficult situation (when the individual is in an "indefinite" and unresolved situation of "expecting" probable nociceptive stimuli), a more or less generalized reaction of awakening and expressed activation of the reaction of emotional awakening again begin to predominate. As a result, an undifferentiated anxiety reaction and emotional excitation again develop, a large number of primarily inadequate reactions is manifested and a difficult state of nervous activity is again present.

We have described one of the numerous possible variants of the dynamics of the functional structure and adaptive effectiveness of the anxiety reaction which was caused by the dynamics of the situation's signal significance (including the time factor). Experiments on animals, as well as observations on human subjects, produce rich material for a study of these variants which shows the closest interaction between the primary effects and the signalling originating from the external world (as well as from the organism's internal environment), and the secondary influences and the secondary signalling generated as a result of carrying out self-regulation of higher nervous activity.

Several examples are presented below which show the dynamics of the effector structure of the anxiety reaction depending on the situation's signal significance, that is, the stimuli used in the observations. These examples also show the dependence of the adequacy and effectiveness of self-regulation of higher nervous activity, realized through components of the anxiety reaction, on the functional structure, that is, on the level of integration of nervous activity (Fig.72-75 and others).

The passive-defensive reaction does not have any primary adaptive effect, it arises exclusively in the interests of self-regulation of higher nervous activity.

By means of contraction of the skeletal musculature, changes in the system of respiration, the conditions of operation of the internal organs and the arranging of the sensory organs in the direction of the stimuli or by means of turning away from the stimuli, the individual supports self-regulation of nervous activity which is carried out by the intracentral components of the second type of self-regulation. By carrying out a behavioral act which is typical of a passive-defensive reaction -- "passive" closing of the individual "within himself" (both in the physical and psychological sense of this word) -- and the mobilization of the appropriate verbal (intellectual-emotional) dominant (in man), the individual provides for the third type of self-regulation. By means of the "abreacting" of inadequately strong nervous activity of various functional systems of the brain through compensatory, somatic, respiratory and visceral reactions (contraction of the musculature, increased frequency and intensification of blinking, chewing and swallowing movements and reactions on oneself, for example, licking in dogs, increased rate of respiration up to sharp tachypnea in dogs, increased pulse rate, rise in arterial pressure, intensification of the motor acticity of the gastrointestinal tract, etc.), the individual carries out the first type of self-regulation.

The question arises of why in some cases a passive-defensive reaction appears in an individual, while in others -- an active anxiety reaction, if both in those and in the other cases the individual has to provide only mobilization of the nervous system (with the help of self-regulation of nervous activity), and not "starting" readiness of the locomotor apparatus for subsequent active actions on the external world.

According to our observations, there is no essential difference between the compensatory proprioceptive inflow evoked as the result of contraction and tension of the anti-gravitational muscles (which carry out the "starting" reaction) and the compensatory proprioceptive inflow evoked as a result contraction and exertion of the flexor muscles (which carry out the behavioral components of the passive-defensive reaction).

There is a difference between secondary effects caused by deepening and intensification of the respiratory excursions and by an increase in inspiratory tonus which are accompanied by a "starting" reaction, and secondary effects caused by increased frequency, and sometimes by relaxation of respiration and which are frequently accompanied by a passive-defensive reaction. The first have a considerably more expressed positive effect on nervous activity than the second. However, sometimes during a passive-defensive reaction the same changes in the conditions of respiration develop as in "starting" readiness.

If you judge by the behavior of experimental animals and human subjects, by the qualitative characteristics of the individual's response reactions during the observation session, as well as by the subject's subjective evaluation of his state of health after the session, then the passive-defensive reaction can be connected with a well differentiated but insufficient reaction of cortical awakening. Unfortunately, we have not found comparative data on the electrophysiological characteristics of both forms of the anxiety reaction in the literature.

It should be emphasized that the intracentral components of the passive-defensive reaction provide a less expressed, in comparison with an active anxiety reaction, activating and tonic effect on the higher sections of the brain.

It has already been mentioned above that the accomplishment of an active anxiety reaction generates secondary conditioned signalling (third type of self-regulation) which promotes preparation of the individual's nervous system (including mental preparation) for an active effect on the external world. At the same time, the secondary signalling arising during realization of the passive-defensive reaction sustains the individual's preparation for "reorganization" and "abreaction" of a difficult or potentially difficult situation in the nervous system itself, as well as of the individual's musculature and internal organs.

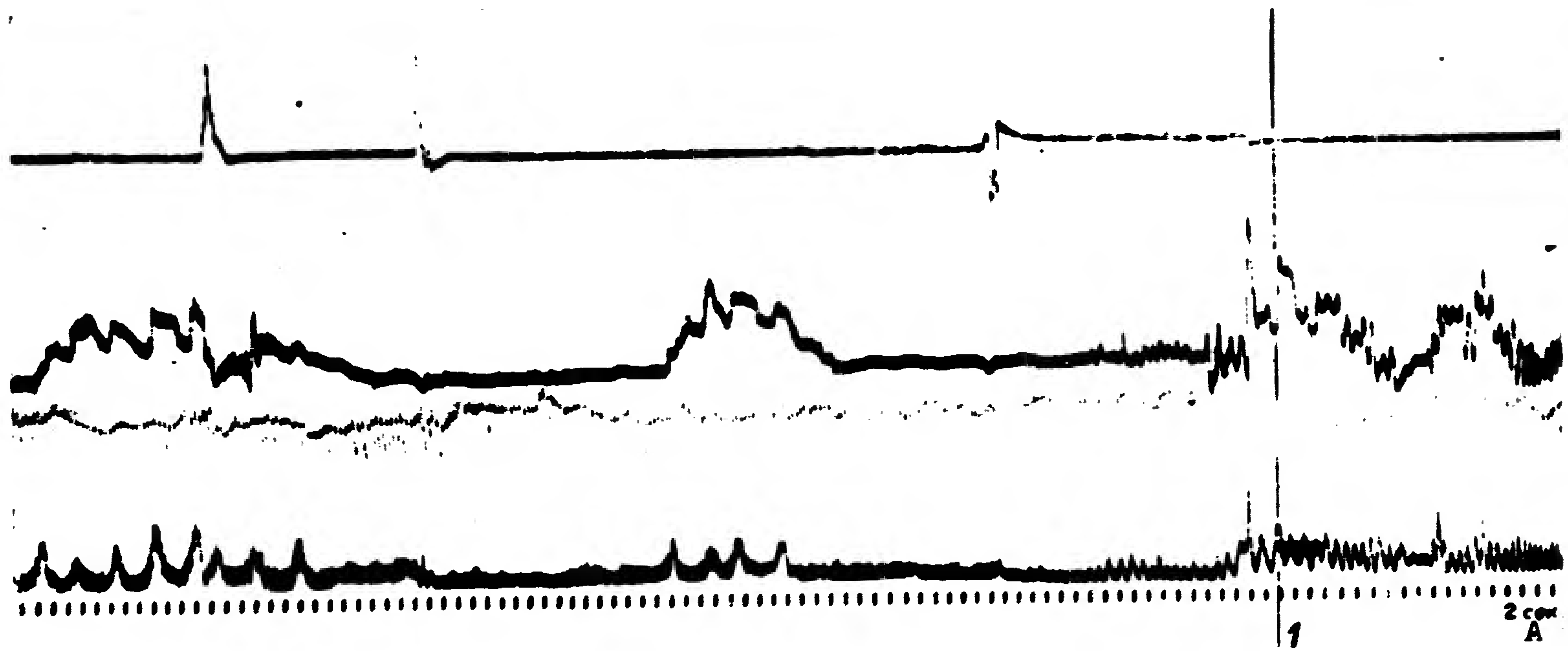


Fig.72. Increase in cortical tonus and level of integration of anxiety reaction caused by a conditioned signal under the influence of the time factor, that is, approach of the time of the next different stimulus and the reinforcement (sound of pistol shot) in the dog Dzhek (experiments of I. Rotsen-Krauklis). 1) Pistol shot near the animal's head [warning conditioned (light) signal turned on several seconds before the events reflects in the kymogram fragment]. Top to bottom: total movements of all extremities, that is, general motor reaction; contraction of stomach; sphygmogram of carotid artery; pneumogram. A) sec.

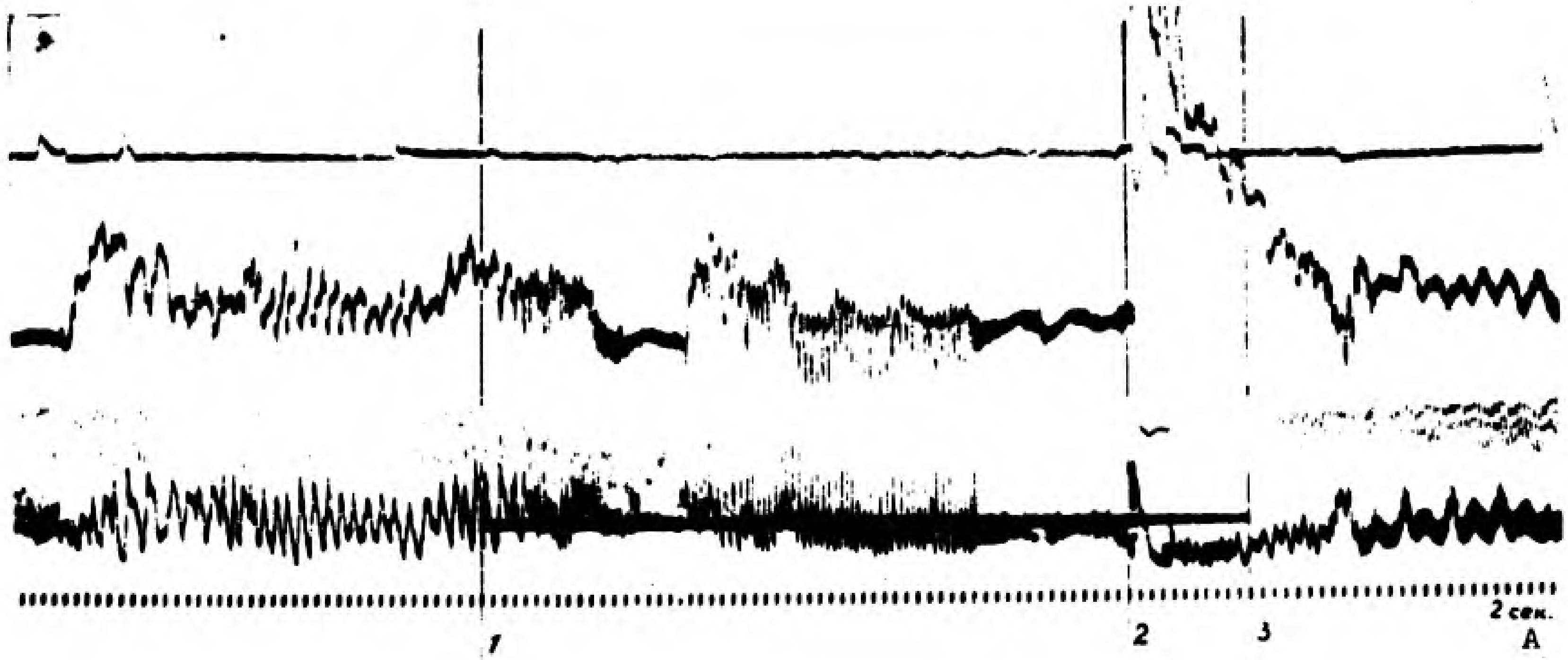


Fig.73. Dynamics of level of integration of anxiety reaction caused by experimental situation, including time factor (approach of time of strong sound conditioned signal), by special conditioned signal and by nociceptive reinforcement in the dog Mars (experiments of I. Rotsen-Krauklis). 1,3) Beginning and end of conditioned signal (sound of loud electric bell); 2,3) beginning and end of interrupted electrical skin stimulation of the experimental animal's back. Top to bottom: notation same as in Fig.72. A) 2 sec.

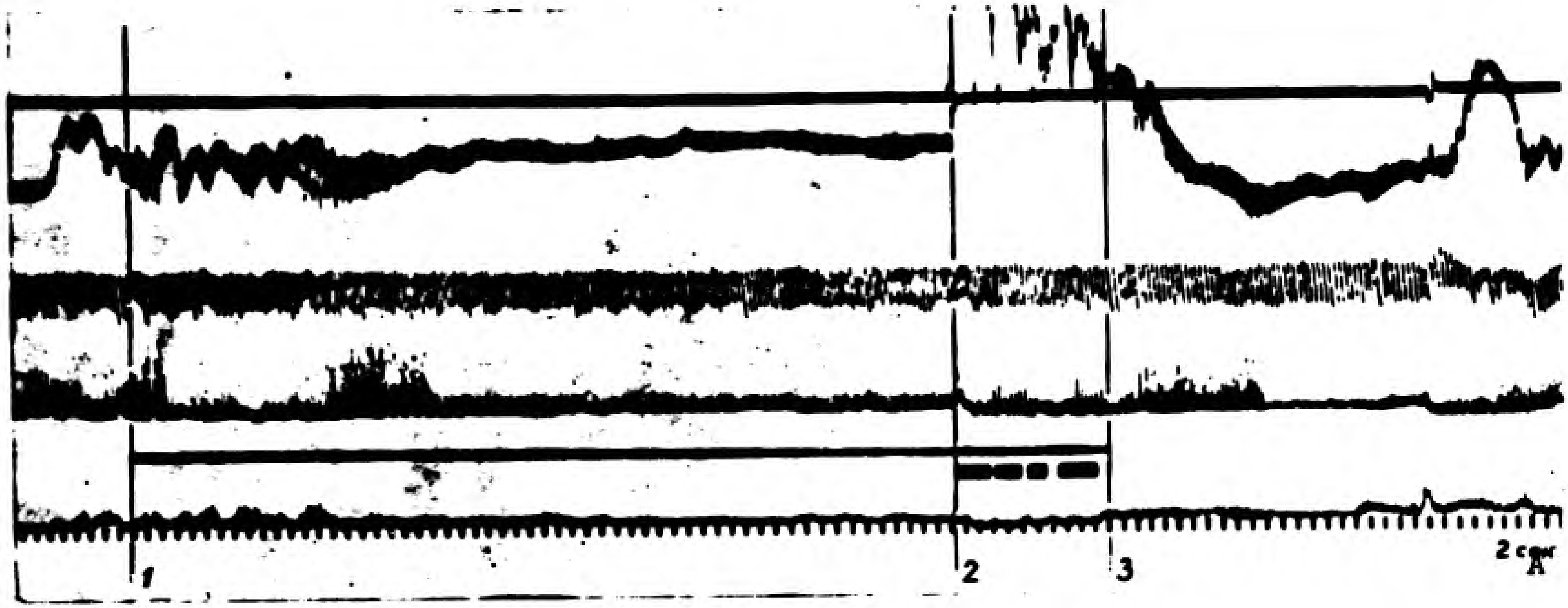


Fig.74. Dynamics of level of integration of anxiety reaction caused by experimental situation, by conditioned and unconditioned stimuli in the dog Mars (experiments of I. Rotsen-Krauklis). A very prolonged anxiety reaction dominates the components of emotional excitation in the functional structure. Signs of expressed difficult state of the nervous system are present in the dog. Notation same as in Fig.73. A) sec.

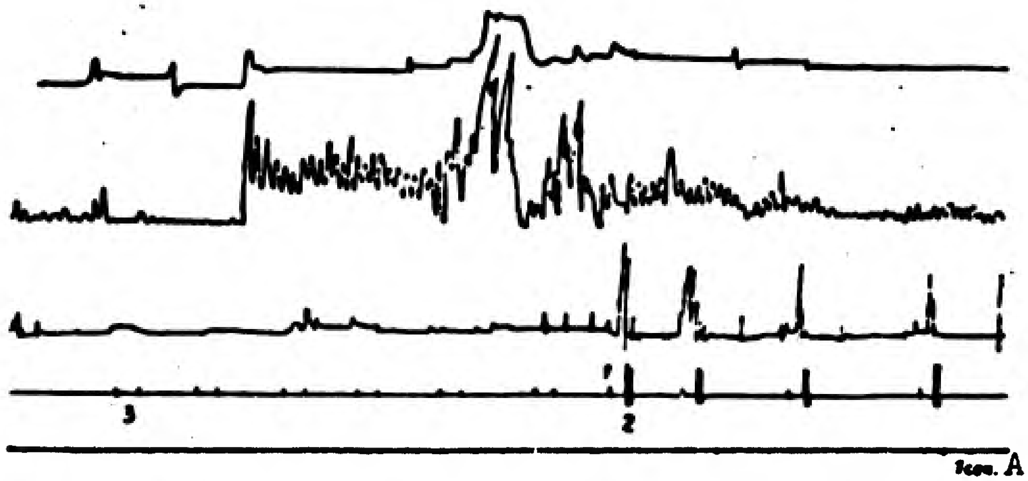


Fig.75. The onset of a nonspecific anxiety reaction during the extinguishing of a blinking conditioned reaction and cessation of the anxiety reaction during restoration of unconditioned reinforcement in the subject Ye. P. Notation same as in Fig.42 (2). A) sec.

EXTRAVERSAL AND INTRAVERSAL FORMS OF THE ANXIETY REACTION. OPTIMAL AND PESSIMAL INTRAVERSAL (PASSIVE-DEFENSIVE) REACTION

§5. In summing up the considerations expressed above, it is possible to draw the conclusion that the passive-defensive reaction is a special form of the anxiety reaction characterized by the following fundamental properties:

1) by a biological and psychological tendency toward "closing" of the individual "within himself;"

2) by the secondary generation (during the third type of self-regulation) of conditioned signalling which sustains and deepens the tendency for "internal reworking" of the external situations;

3) by inadequately strong involvement in the reactions of th internal organs;

4) by ineffective -- at least in many cases -- intracentral components which are not capable of providing a sufficient increase in cortical tonus and level of subcortical effector integration.

In the absence or lack of sharp expression of the third and fourth properties (see above), the passive-defensive reaction can be an entirely adequate form of the individual's reaction in situations of actual or expected action on the individual of unavoidable or relatively insignificant biologically and psychologically negative stimuli.

For example, the passive-defensive reaction is completely adequate under conditions of an observation session when only relatively insignificant stimuli, including nociceptive, act on the subject. In this case the nociceptive stimuli frequently are difficult to eliminate (for example, stimulation of the cornea or of the eye by a jet of air), if only the subject is ready to observe the rules of the observations which forbid the subject to remove the equipment attached to him.

There can also be a passive-defensive reaction which is very adequate for the situation when the person has to mobilize the nervous system for carrying out intensive mental work, for overcoming strong emotional excitation, for suppressing external manifestations of emotions and affects, etc., if a passive-defensive reaction is used in the interests of self-regulation of higher nervous activity instead of an active anxiety reaction.

Thus, in certain situations in the presence of a specific optimal functional structure which provides for realization of sufficiently effective self-regulation of higher nervous activity, the passive-defensive reaction can prove to be entirely adequate for the situation and effective for maintaining an optimal system of nervous activity.

In such cases the passive-defensive reaction differs little in its external manifestations from an ordinary anxiety reaction. Only objective recording of the contractions of several muscle groups simultaneously (for example, the flexor and extensor muscles of the knee joint) and other effector components of the reaction, as well as a determination of the subject's mental condition, allows one to differentiate both variants of the anxiety reaction.

Since a definitive anxiety reaction (examined in the first three sections of this chapter) is directed toward preparing the individual for an active behavioral act, for an effect on the surrounding world, while a passive-defensive reaction is directed toward preparing the individual for internal abreacting and equilibrating different stimuli and situations, the first, "active," variant of the anxiety reaction can be called an anxiety reaction directed toward the external world, or extraversal, and the second, "passive," variant -- an anxiety reaction directed within, or intraversal.

Both the common properties and specifics of both variants are thereby emphasized and at the same time the physiologically and biologically inadequate expression, "active" or "passive" reaction, is avoided.

In cases in which the concrete situation requires from an individual an active effect on the external world or rapid preparation for an active effect, but a passive-defensive reaction, that is, an intraversal anxiety reaction, is reproduced in the individual by conditioned reflex means, in a functional structure which contains all the four above-mentioned criteria ("minus-signs") of the passive-defensive reaction, the latter is primarily inadequate for the situation and, at the same time, secondarily ineffective (that is, incapable of providing effective self-regulation and setting up an optimal system and an adequate level of integration of higher nervous activity).

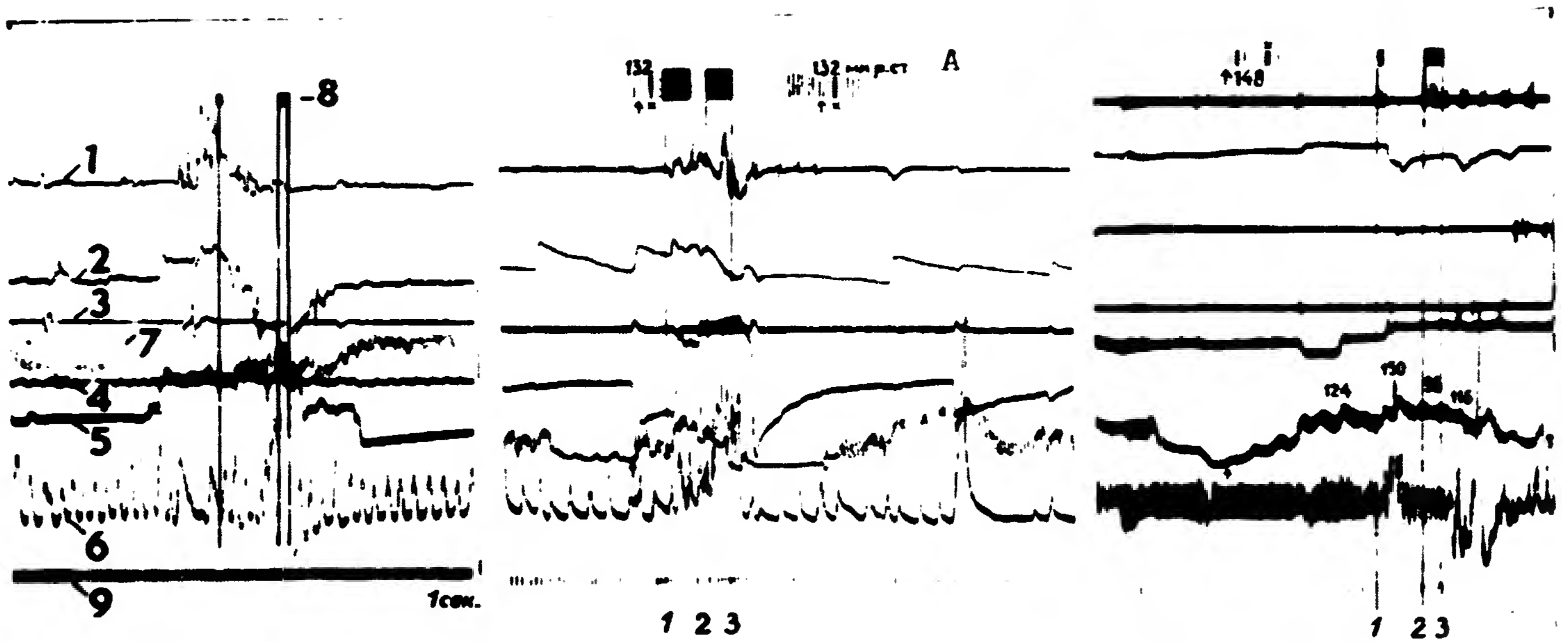


Fig.76. Examples of anxiety reaction having some elements of a passive-defensive reaction. First fragment -- anxiety reaction acting as a reaction to time and to a special signal during the development of a general preparatory conditioned reaction in the subject L.L. Contraction of the flexors of the knee joint predominates, the subject intensively "closes within herself," briefly slowing down respiration (notation same as in Fig.32, only (from top to bottom) the curve of the contraction of the extensors is located over the curve of the contraction of the knee joint flexors); second fragment -- anxiety reaction during the development of a defensive-motor conditioned reaction [see Fig. 63 (3,4), 64] in the dog Dzhulis. A postural reaction is noted during the reaction to time -- movement of the animal forward, at the conditioned signal -- drawing back and intensified tucking in of the tail; third fragment -- anxiety reaction which is expressed in the form of a passive-defensive reaction (most severe tachypnea, tachycardia, drawing back of the animal, tucking in of the tail and "closing in itself", lowering of the head, inhibition of general motor reaction and specialized respiratory reactions, etc.) during the development of a defensive motor conditioned reaction by the Petropavloviy method against a background of a 2 kg weight on the stimulated right hind leg (see Fig.50, 59, 63 (1,2). A) mm Hg.

In such situations the reproduction of an intraversal anxiety reaction in place of an extraversal reaction is either a symptom of a considerable decrease in cortical tonus and level of integration of higher nervous activity as a result of overstrain and overfatigue of the latter, or a manifestation of a pathlogically inert stereotype of the individual's reaction to innovation and difficult situations which require an active creative influence on the environment or a sympton of one and the other.

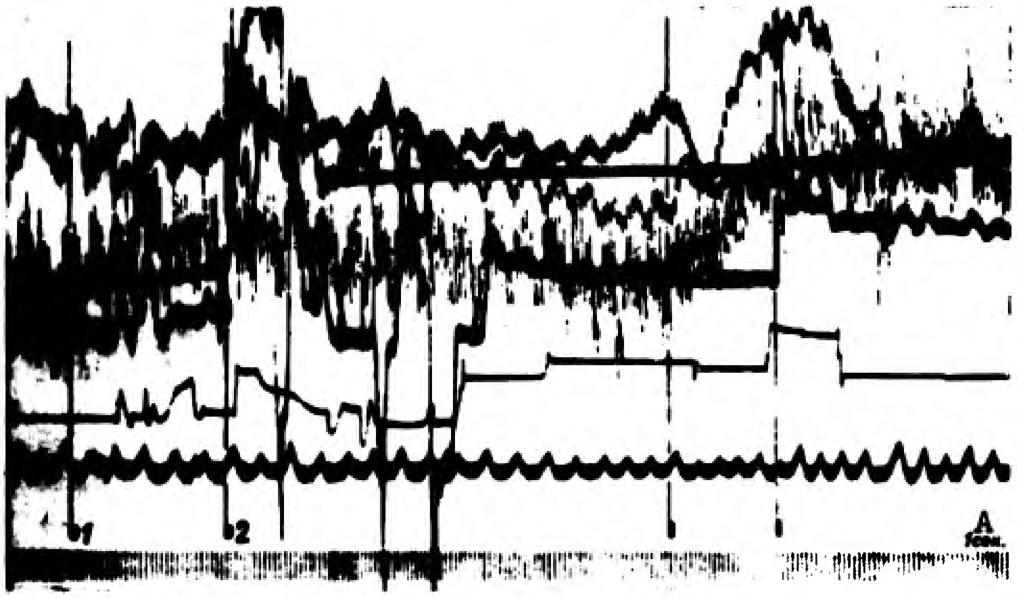


Fig.77. Example of an anxiety reaction in the subject P.O. (who, as all subjects, was in a sitting position), in whom the extraversal character of the reaction is relatively sharply expressed. The curves were recorded during the subject's preparation for an expected sound stimulus (pistol shot). 1) Warning: "Attention, there will be a shot!"; 2) shot. Top to bottom: plethysmogram of soft tissues of the skull (at the forehead-occiput level); plethysmogram of the fingers of the left hand, plethsmogram of the neck (also reflects elements of the sphygmogram of overall carotid artery); contraction of the extensor muscles of the right arm and forearm; contraction of the extensors and flexors of the knee joint; pneumogram. A) sec.

Acting in man as a "substitute," that is, surrogate, of an extraversal anxiety reaction, the intraversal anxiety reaction acquires the significance of the individual's "symbolic reworking" of the difficult situation not in real life, but in fantasy, in thoughts and subjective feelings, in the skeletal musculature and internal organs.

The intraversal anxiety reaction thereby acquires a pessimal character. It is capable of closing a "vicious circle" of self-regulating and of leading -- from frequent chronic development -- to neurotic conditions or of deepening the latter (Krauklis, 1960a, p.256; as well as Chapter 7 of this book).

It is clear that there is a fundamental difference between a pessimal intraversal reaction and the above described optimal reaction which differs from an extraversal reaction only in the absence of a reaction of "starting" readiness and in the presence of a certain intraversal introspective mental tendency of the person.

In healthy human subjects, especially in adults, a pessimal intraversal anxiety reaction is encountered very rarely, whereas an optimal reaction, on the other hand, very frequently. In reserved, disciplined people or in people with a so-called weak inhibited type of nervous activity, an optimal intraversal reaction, as a rule, dominates over an extraversal reaction.

In highly reactive and less reserved people in whom a reaction of limbic (emotional) awakening easily develops, a more or less strong extraversal anxiety reaction is found relatively more frequently.

In experimental animals, particularly if they are fastened in a holder or placed in a narrow experimental chamber, a pessimal intraversal anxiety reaction is observed much more frequently and is often manifested in the form of a difficult state of nervous activity.

Kymogram fragments showing the effector structure of certain variants of the anxiety reaction are presented above (Fig.76, 77).

REACTION OF NEURO-MUSCULAR RELAXATION, OR CONDITIONED REFLEX CHANGE IN THE ANXIETY REACTION

§6. Man's daily experience and laboratory observations show that very frequently following the cessation of various conditioned and unconditioned stimuli the organism's somatic and visceral reactions, which are designated by the terms "aftereffect" or "aftereffect reaction," develop or are intensified.

The mechanisms of the origin, and even more, the adaptive significance of the aftereffect reactions have been studied relatively little.

It was shown in the second chapter of this work that the aftereffect reaction frequently has the character of compensatory switching of inadequately strong nervous activity of various functional dominant systems of the brain to the peripheral effectors. Thereby the somatic (including speech) and visceral aftereffect reactions are an expression of the first type of self-regulation of higher nervous activity.

However, the adaptive significance of the effector aftereffect manifestations is not exhausted by this. The effector aftereffect manifestations developing as a result of carrying out the first type of self-regulation become the initial link in a complex cycle of self-regulation which includes not only the first, but also the second and third types of self-regulation. As a result, reorganization of the whole system of higher nervous activity can be provided.

In order to clarify what has been stated, we shall cite the well-known fact that both the beginning and the end of any different stimulus (both conditioned and unconditioned) acts in animals and man as a conditioned signal.

The cessation of a different stimulus signals: 1) the cessation of a state of anxiety and emotional tension caused by the stimulus or 2) its continuation, expected intensification or its onset anew.

In cases in which an anxiety reaction which prepares the organism for a future different stimulus was caused by previous conditioned signals, the cessation of this stimulus often serves as a signal of the cessation or relaxation of the anxiety reaction.

The cessation or relaxation of an anxiety reaction can be carried out both more and also less rapidly and effectively depending on the mechanisms which are activated by the signal -- by cessation of the stimulus. We shall examine some of these mechanisms.

As a result of the conditioned signal -- cessation of the corresponding different stimulus or situation -- the new situation no longer signals probable danger or innovation and does not reproduce the anxiety reaction. However, this does not involve cessation of nervous tension (often having an emotionally negative character) which was caused by previous stimuli and was a component part of the anxiety reaction.

The fact of the matter is that an anxiety reaction always increases the intensity and strain of the activity of closed systems of the brain which may prove to be inadequately high for the new situation -- after elimination of the cause of the anxiety reaction. Moreover, the fact that during the action of different stimulus or situations on the nervous system, rapid or free switching of nervous activity to the periphery usually is restricted or inhibited to a greater or lesser degree should be taken into account. This occurs because the effector channels which are adequate for the situation frequently are not "roomy" enough to provide rapid outflow of a large number of brain activity impulses to the periphery even during action of the stimuli, and possible auxiliary, or "compensatory" channels are inhibited by conditioned reflex means by the inhibitory signals of the situation.

Therefore, it is important that the cessation of the stimuli, acting as a conditioned signal, should cause by conditioned reflex means the disinhibition of the neural paths of the switching of impulses from the closed systems to the effector neurons and peripheral effectors.

The onset of an expressed aftereffect reaction following the cessation of an inhibitory conditioned signal used in the observations for purposes of developing extinctive or differentiated internal inhibition can serve as a very representative example of the conditioned reflex disinhibition of the outflow of impulses from the closed systems to the effector paths in response to the cessation of a different stimulus. (Fig.78 and 79).

The more efficiently the compensatory switching of nervous activity proceeds after cessation of the stimulus, the more rapidly an optimal system and exertion of nervous activity adequate for the actual situation is restored.

However, in connection with the fact that a decrease in nervous tension inadequate for the new situation does not occur immediately but during a more or less prolonged time interval after the cessation of the different stimulus, more or less expressed contraction and tension of the skeletal musculature (including respiratory), increased activity of the respiratory apparatus, cardiovascular system and other internal organs is also frequently maintained.

As a result of the increased activity of the effectors (which were components of the anxiety reaction being extinguished) the generation of secondary effects continues which secondarily maintain increased nervous tension and which protract the process of demobilization of nervous activity and the replacement of the anxiety reaction.

Therefore, for rapid and effective cessation of an anxiety reaction it is necessary to carry out rapid and effective relaxation of the skeletal musculature (up to optimal background tension) and normalization of respiration and activity of the internal organs.

In cases in which the cessation of different stimuli or situations causes by conditioned reflex means a rapid and effective decrease in the tension of the nervous system and skeletal musculature and a decrease in the level of activity of the internal organs to the optimum in the given situation, we are faced with an active conditioned reflex adaptive reaction -- a reaction of neuro-muscular relaxation which represent an active change (organized by the nervous system itself) from a state of anxiety and nervous tension to the initial state or, more accurately, to a new initial state of "relative quiet."

Thus, the reaction of neuro-muscular relaxation in its adaptive significance is the antipode of the anxiety reaction, that is, it is as if an "anti-anxiety" reaction.

The physiological mechanisms of the onset and the adaptive characteristics of the "anti-anxiety" reaction have still been studied extremely little. According to our observations, the "anti-anxiety" reaction plays an important role not only in the self-regulation of higher nervous activity in the period after cessation of biologically or psychologically significant stimuli or situations (when it is necessary to rapidly change an anxiety reaction which is inadequate for the new situation), but also in the intervals between the different stimuli and in situations signalling the expected onset of difficult states of the nervous system.

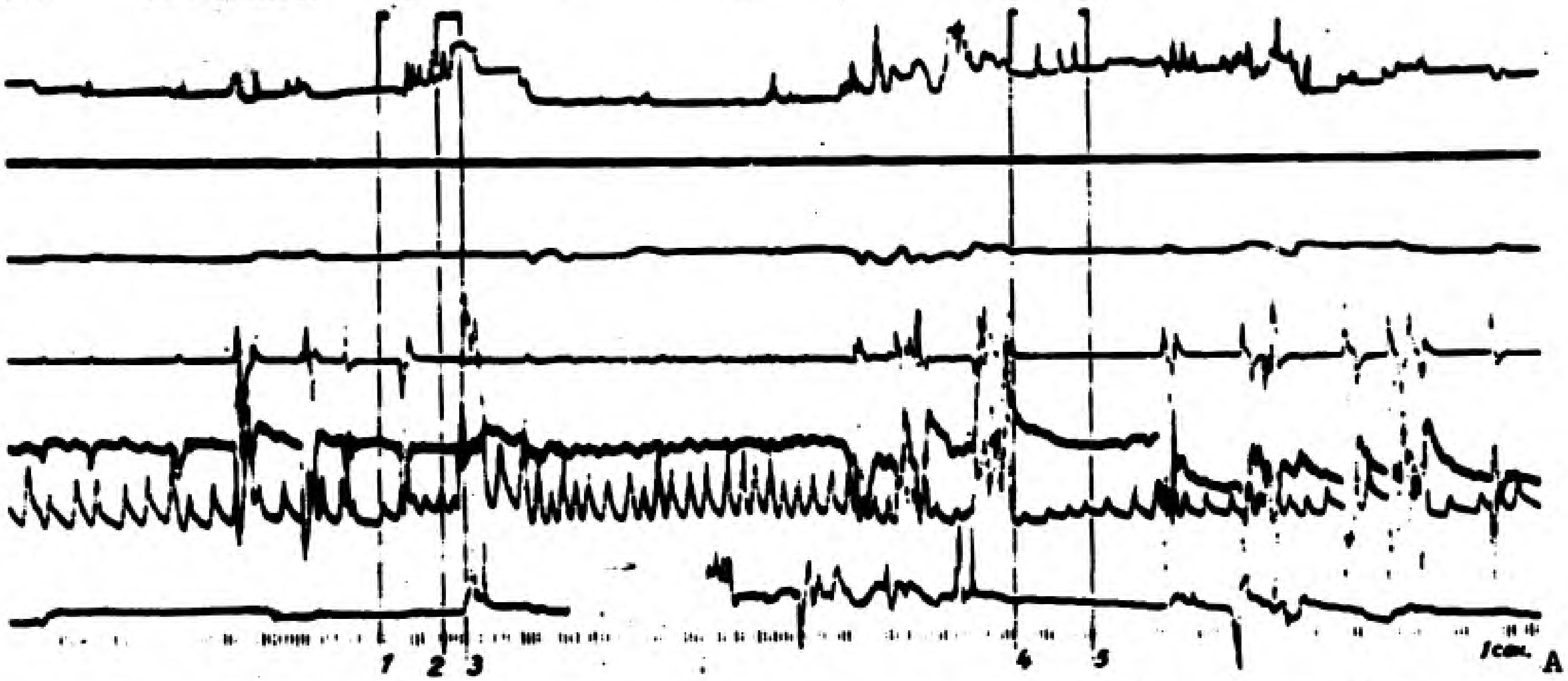


Fig.78. Intensified outflow of nervous activity of the brain to the peripheral effectors after cessation of an inhibitory conditioned signal in the dog Iks. 1) Positive conditioned signal; 2,3) stimulation of oral mucosa by direct current impulses; 4,5) beginning and end of differentiated signal. From top to bottom: movements of the lower jar; secretion of saliva; movements of the head; total movements of all extremities; contraction of neck muscles; pneumogram; postural-tonic reaction (contraction of coxofemoral joint muscles). A) sec.

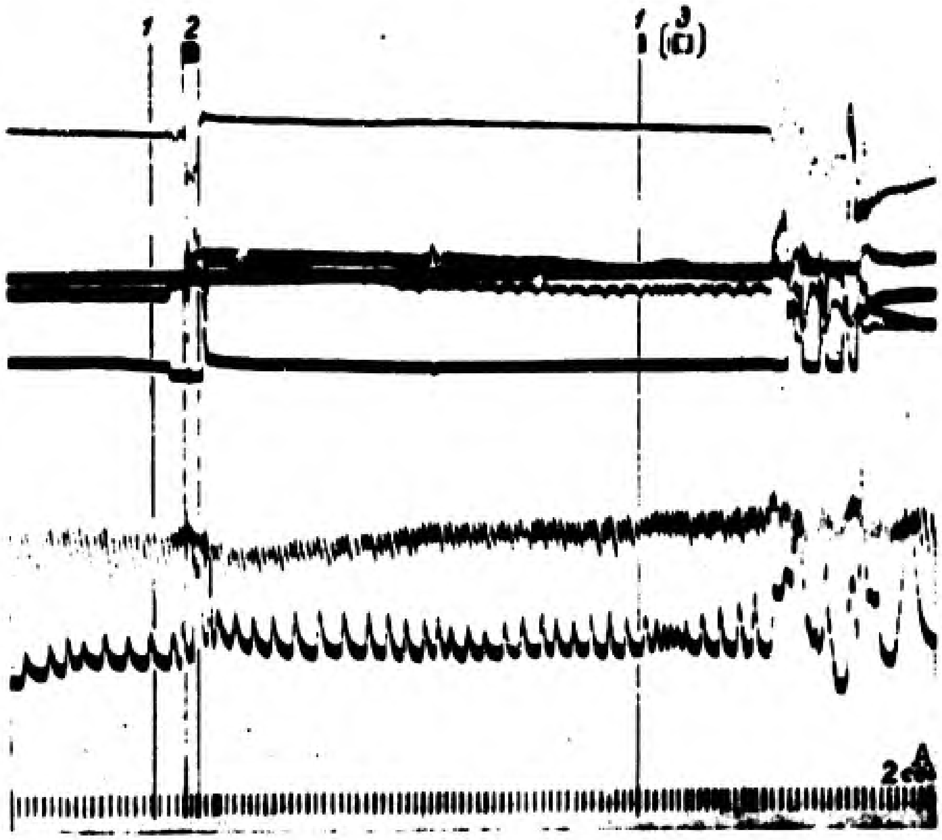


Fig.79. Intensified outflow of nervous activity of the brain to the peripheral effectors after cessation of a conditioned signal which was not reinforced by electric skin stimulation of the right hind leg (in the initial stage of the development of a conditioned motor reaction by the Petropavlovskiy method) in connection with the fact that the experimental dog before and during the action of the conditioned signal first held the right hind leg raised. 1) Conditioned signal; 2) electric skin stimulation of the right hind leg (in connection with the fact that the latter was not raised at the conditioned signal); 3) turning on of electric skin stimulus which is not received by the animal as a result of timely flexure (raising) of the right hind leg. Notation same as in Fig.51 (3) (curve of right hind leg denoted by cross). A) sec.

Evidently, during the training and self-training of man in adequate forms of behavior and mental reacting to stimuli of the external world the organism must pay special attention to this very useful adaptive act. After all, a very expensive (for the nervous system and internal organs) inadequately strong and prolonged (difficultly extinguishable) anxiety reaction is too frequently mobilized by conditioned reflex means in man even upon slight annoyances. The instilling in man of an automatic, but at the same time, voluntarily adjustable effective reaction of neuromuscular relaxation has the greatest importance for preventing or stopping an anxiety reaction.

FUNCTIONAL STRUCTURE OF THE REACTION OF NEURO-MUSCULAR RELAXATION. ROLE OF SITUATION REFLEX IN ITS ORIGIN

§7. The leading components of the functional structure of the reaction of neuro-muscular relaxation are, of course, the intracentral effects which provide conditioned reflex (through cortico-reticular and corticohypothalamic links) relaxation of the reaction of cortical awakening, and expecially relaxation or cessation of the reaction of limbic (emotional) awakening.

Since not only stimuli of the surrounding world, for example, the cessation of different stimuli, but also the conditioned signalling which develops during the carrying out of the third type of self-regulation (in man -- dominants of the second signal system) act as conditioned signals activating the appropriate corticofugal links and changing through these links intracentral coordination, the third type of self-regulation has great importance in the origin of the reaction of neuro-muscular relaxation, as in the origin of the anxiety reaction.

The characteristics of the effector structure of the reaction of neuromuscular relaxation follow from its adaptive task -- to rapidly stop or decrease the activity of those effectors and sensory organs whose functioning serves as the sourcesof the strong afferent inflow which sustains inadequate nervous tension and the intracentral constellation which characterizes the anxiety reaction.

The following are typical components of the reaction:

1. Deep inspiration with a subsequent decrease in background tonus, including inspiratory tonus of the respiratory musculature, decrease in amplitude and restoration of the original rhythm of respiratory excursions.

It should be emphasized that normalization, that is, quieting of respiration, usually begins immediately after the deep inspiration noted above (Fig.80-83, as well as 24 and others).

2. Cessation of the reaction (position) of "starting" readiness or "closing" of the individual "within himself."

The animal or man takes a position which is convenient for the new situation, sometimes realizes brief locomotor reactions, movements of the extremities, head, etc.

3. Relaxation of the skeletal musculature, including respiratory and mimic.

Sometimes brief intensification of the contraction and tension of different muscle groups which is the expression of compensatory switching of brain activity in the form of an aftereffect reaction precedes the relaxation.

In other cases contraction of some and expansion of other muscle groups is observed.

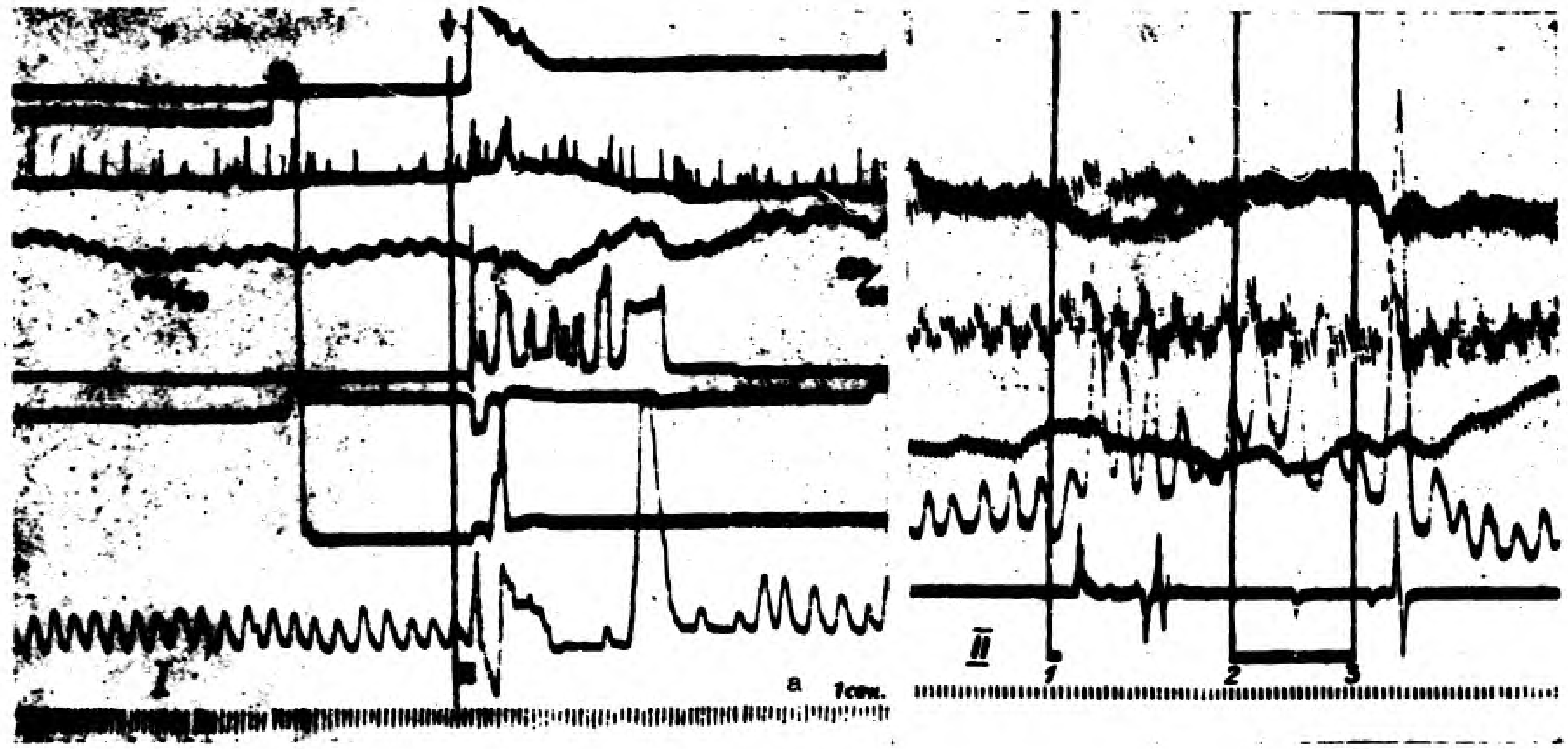


Fig. 80. Deep breathing with subsequent normalization of respiration — a characteristic component of the neuromuscular relaxation reaction that arises after withdrawal of different stimuli in experimental human and animal subjects. First fragment (I): deep inspiration after pistol shot; second (II) after withdrawal of special conditioned signal and electrical tickling of skin in subjects V.K. and A.K. (key same as for Fig. 43 (2), i.e., for Fig. 30, except that the hand-muscle contraction curve has been replaced by the plethysmogram of a finger); third III: after withdrawal of conditioned signal and food reinforcement in a dog [see Fig. 62 (1)]; fourth (IV) and fifth (V): after withdrawal of conditioned signal and electrical tickling of skin in dog (see Figs. 58 and 60). a) sec; b) mm Hg.

Fig. 80 continued

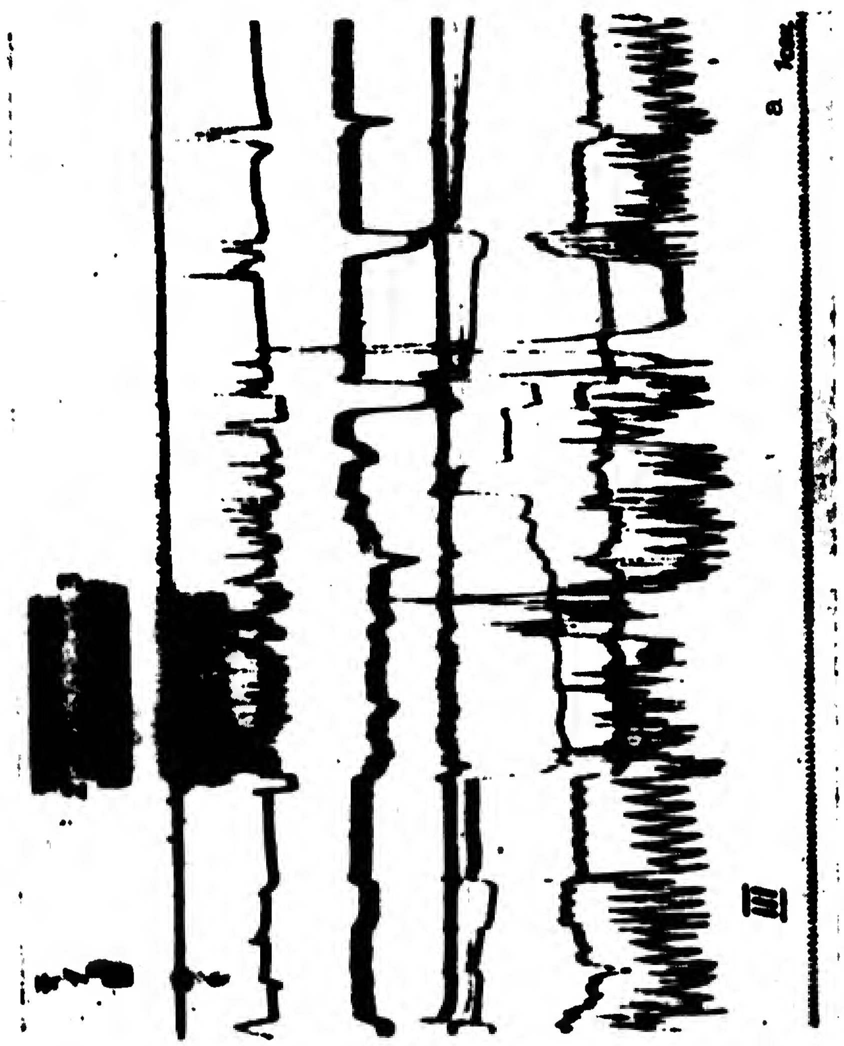
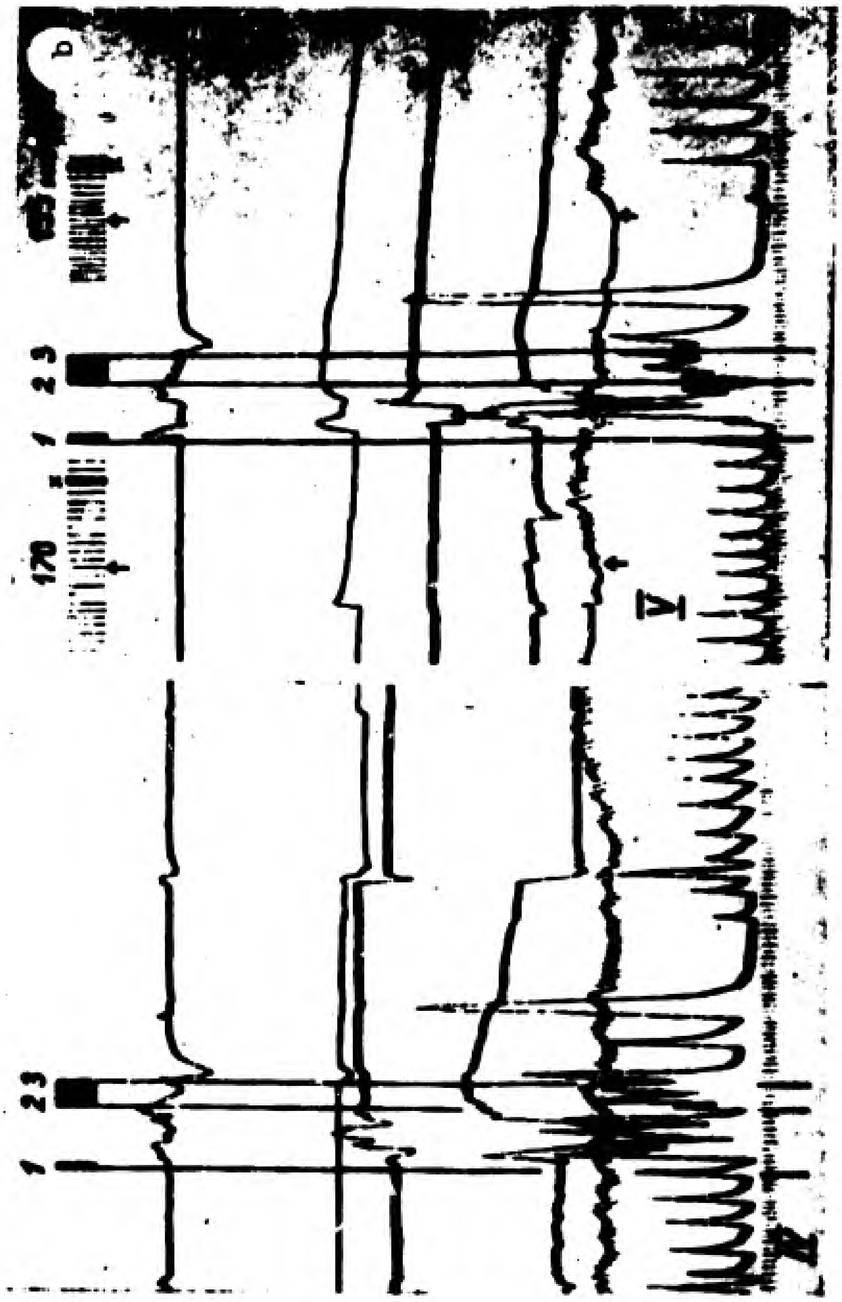


Fig. 80 continued



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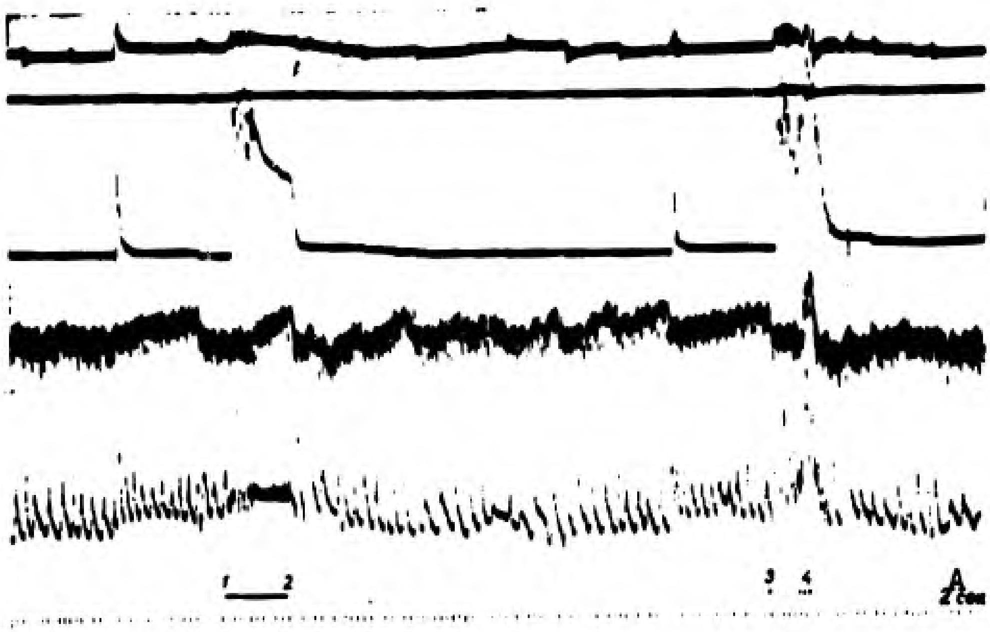


Fig.81. Deep inspiration after cessation of differentiated signal (1,2) as well as of positive conditioned signal and electrical skin stimulation (3,4) at the initial state of alteration of the signal significance of conditioned and differentiated signals during the development of a defensive-motor reaction in the dog Moris (experiments of Dz. Liyepa). Notation same as in Fig.55 (3) and 61 (3). A) 2 sec.

4. Rapid normalization, that is, a return to the original level, of functions of the cardiovascular system, somewhat more slowly -- of functions of the digestive tract (for example, motor activity of the stomach), if they were involved in the anxiety reaction.

5. The appearance of a subjective feeling of "relief," and "easing" of nervous activity.

It should be noted that deep inspiration is a very typical and constant component of the relaxation reaction and differs essentially from those inspirations which sometimes develop during an anxiety reaction.

The deep inspirations (one or several, and sometimes even many) which arise at the beginning of an anxiety reaction take place at increased-inspiratory tonus are accompanied by inhibition or relaxation of respiration, in this case the respiration again soon intensified and increases in frequency.

The deep inspiration (usually only one) arising after cessation of stimuli usually is accompanied by a decrease in inspiratory tonus (if the latter was increased), by immediate quieting of respiration and rapid return of the conditions of respiration to the original level (see Fig.80-83, 84).

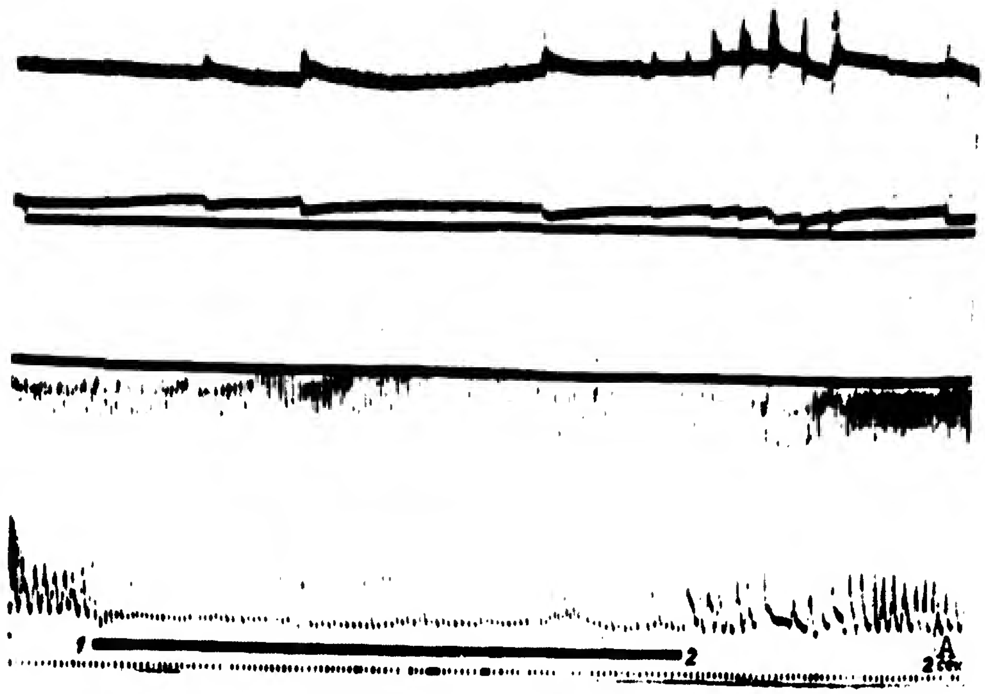


Fig.82. Deep inspiration, brief intensification of head movements and subsequent quieting of respiration and somatic components of behavior in the dog Moris after cessation of the prolonged action of a differentiated signal in the period of extinguishing of a defensive-motor reaction (experiments of Dz. Lieypa). 1,2) Beginning and end of differentiated signal. Notation same as in Fg.55 and 61. A) sec.

Of course, the reaction of neuro-muscular relaxation is not always accompanied by full and stable restoration of the original level of effector activity of the organism. Frequently the relaxation reaction is replaced by repeated flare-ups of the anxiety reaction which again are quickly replaced by relaxation and so forth.

If the situation developing after cessation of a different stimulus signals only the brief absence of repeated different potentially nociceptive stimuli and if the likelihood of such an absence is not very great, the situation can become a source of the signalling of several variants of possible, more or less likely subsequent events. As a result periodic replacement sometimes of the relaxation reaction, at others of the anxiety reaction, at others disinhibition of the specialized behavioral acts being developed or previously developed, etc.

In cases in which the cessation of a different stimulus does not cause a change in the signal significance of the situation and the latter continues to reproduce or even to intensify the anxiety reaction, instead of aftereffect reaction and relaxation reaction which we have described, one or another form of the anxiety reaction which is reproduced in the form of a reaction to the situation develops, continues or is intensified.

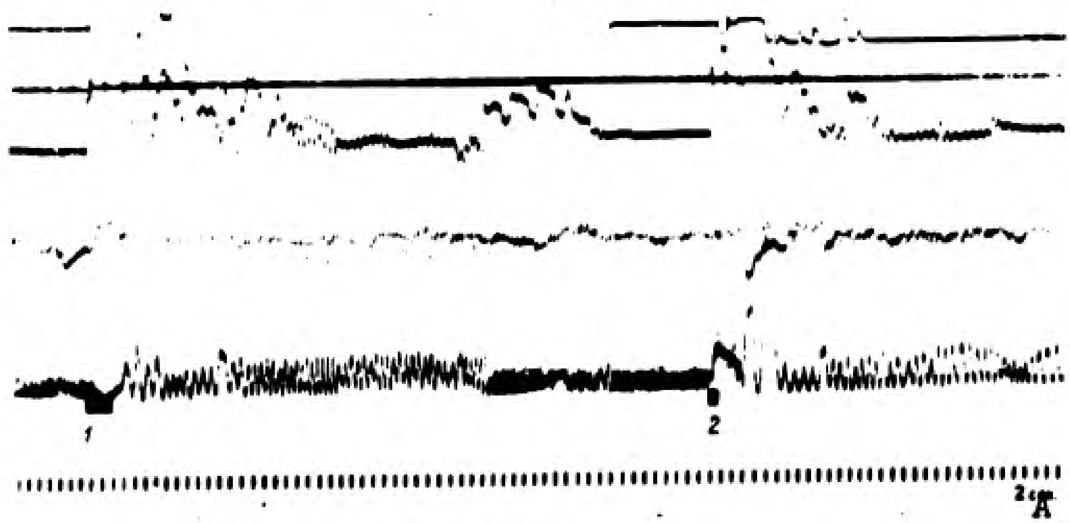


Fig.83. Deep inspiration, brief activation of somatic effectors and contraction of stomach and subsequent quieting of respiration, heart activity, motor activity of the stomach and general motor activity in the dog Dzhek after a pistol shot and cessation of conditioned (light) signal. 1) Start of conditioned (light) signal; 2) shot (and end of signal). Notation same as in Fig.72-74. A) sec.

Thus, not all effector reactions arising after cessation of different stimuli are an aftereffect reaction.

The aftereffect reaction always, as a rule, is combined with a reaction to the situation. The compensatory switching of the activity of the closed systems of the brain to effector paths increases the level of activity of the appropriate preefferent and efferent neurons and promotes disinhibition of the effector manifestations of the reaction to the situation.

At the same time, the latter can be added to the effector manifestations of the aftereffect reaction (Krauklis, 1960a, p.157).

The reaction of neuro-muscular relaxation is an expression of a conditioned reaction to the new situation (new -- as a result of the cessation of different stimuli) and of an aftereffect reaction simultaneously.

Therefore it is no wonder that side by side with typical components of a relaxation reaction in the aftereffect period components of the actually being developed or previously developed specialized behavioral acts which were disinhibited by the situation are sometimes encountered.

Activation of mechanisms of the second (relaxation of musculature) and third (self-generation of "demobilizing" mental dominant through second signal system in man) types of self-regulation of higher nervous activity occurs mainly in the form of a reaction of the cessation of the stimuli, that is, a reaction to the new situation.

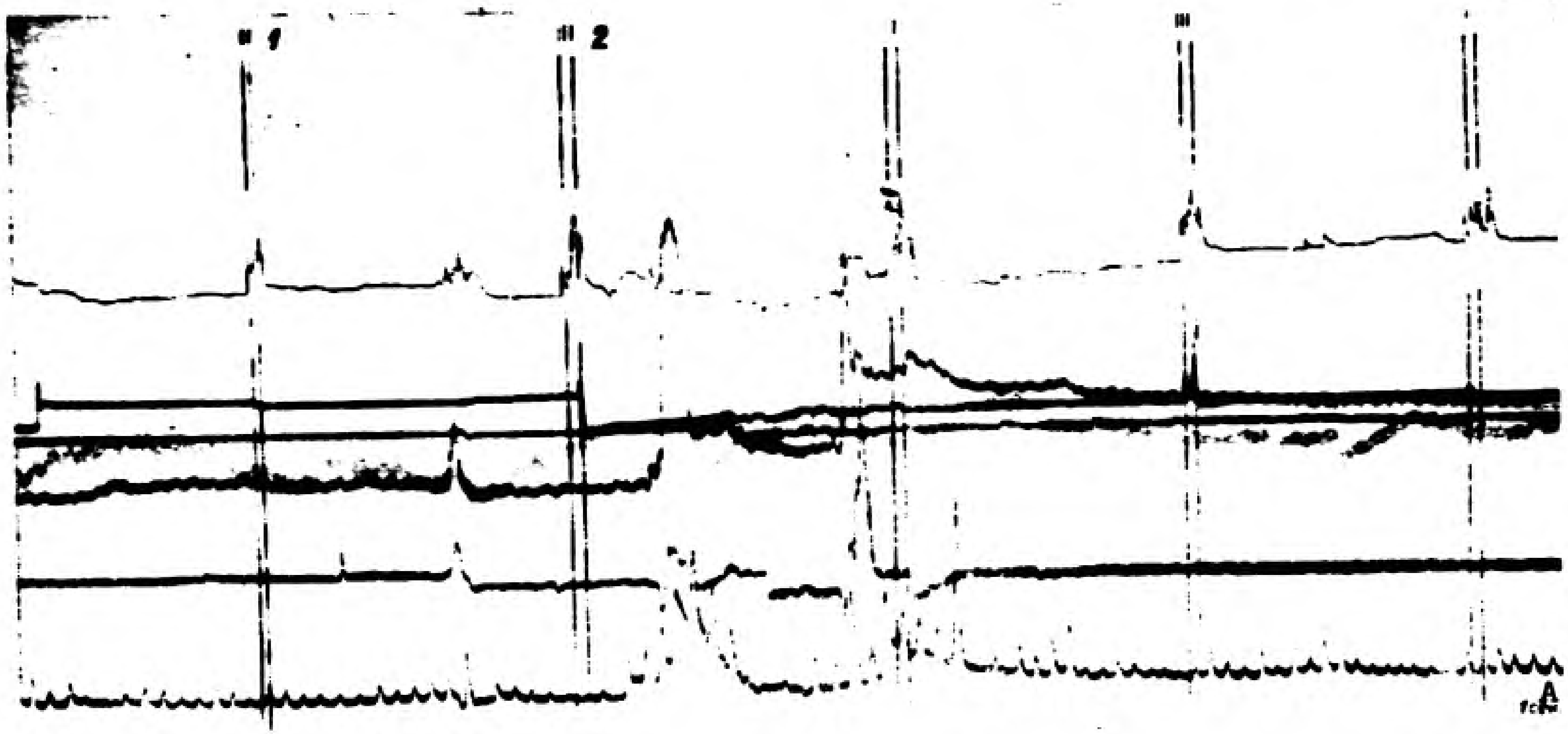


Fig.84. Difference between deep inspiration which is a component part of the reaction of neuro-muscular relaxation and deep inspirations which are a component part of the anxiety reaction. Fragment of development of blinking conditioned reaction to time in the subject T.R. 1) Two-fold stimulation; 2) three-fold stimulation of cornea with a jet of air. The reaction developing after cessation of the second stimulus in connection with intensification of the latter (three-fold stimulation is used instead of the usual two-fold) is not a relaxation reaction but an anxiety reaction. The anxiety reaction also develops as a reaction to time before the third stimulation, after which a relaxation reaction with typical deep inspiration is manifested. Notation same as in Fig.70. A) sec.

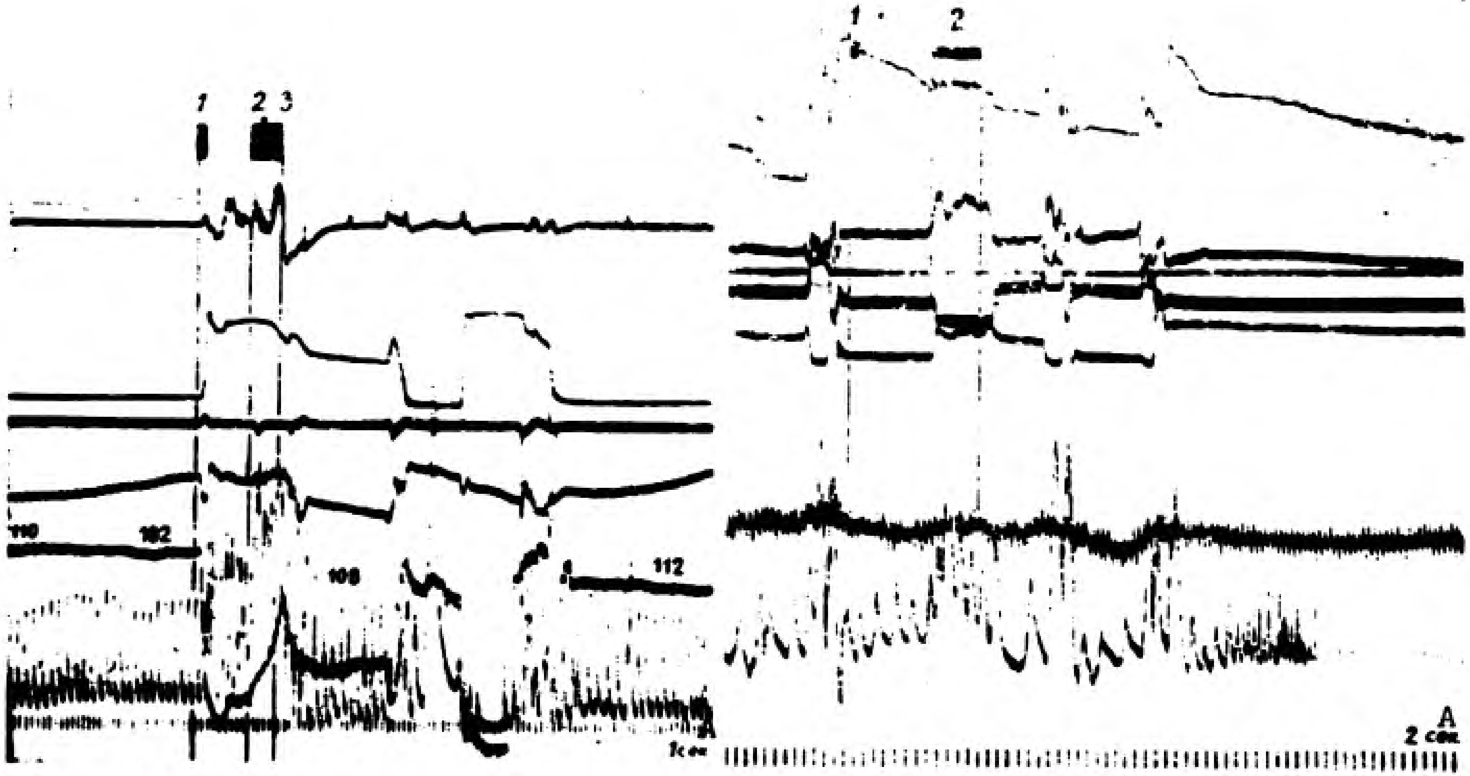


Fig.85. Aftereffect reaction (compensatory effector switching of nervous activity of the brain arising after cessation of stimulus) acting as a reaction of demobilization of nervous strain, that is, as a component part of the reaction of neuro-muscular relaxation in dogs. First fragment -- aftereffect reaction ends with normalization of respiration and quieting of behavioral reactions (notation same as in Fig.58, 60, 80 (4,5); second fragment -- aftereffect reaction in which repeated deep inspirations are not accompanied by real neuro-muscular relaxation, but are replaced by a new system of effector activity which is characterized by a lower level (see tachypnea and inhibition of activity of somatic effectors). Notation same as in Fig.51 (3), 79. A) sec.

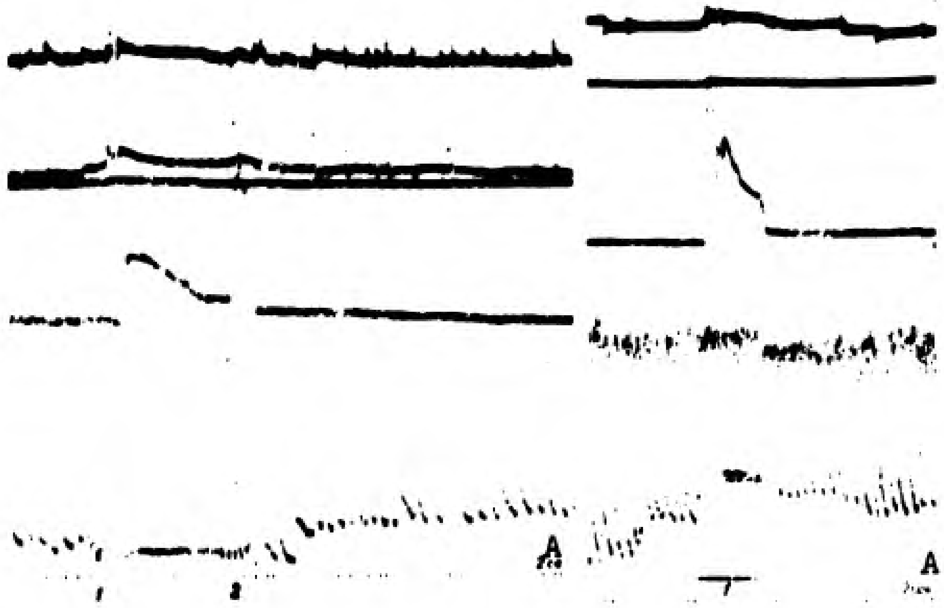


Fig.86. First fragment -- aftereffect reaction (compensatory switching of nervous activity of the brain) which continues after deep inspiration in connection with the fact that the situation continues to cause relatively strong tension of higher nervous activity of the experimental dog Moris; second fragment -- aftereffect reaction as the immediate continuation of an anxiety reaction developing as a reaction to time before the use of a differentiated signal in the dog Whalis (period after alteration of the signal significance of positive and differentiated signals) (experiments of Dz. Liyepa). Notation same as in Fig.55 (1,2,3) and 56 (1,2). A) sec.

Activation of the mechanisms of the first-type of self-regulation occurs as a result of the deblocking of the paths of switching of the circulating nervous activity to effector paths, that is, also as a result of a reaction to cessation of stimuli and a reaction to the situation.

The aftereffect reaction is an expression of the first type of self-regulation -- compensatory behavior, respiratory and visceral reactions taking place before the start, as well as at the start of the relaxation reaction (deep inspiration, change in the individual's position, contraction and expansion of the muscles, increased frequency of blinking movements, etc.) down to the establishment of the original level or of a new background of the organism's effector activity (Fig.85-87).

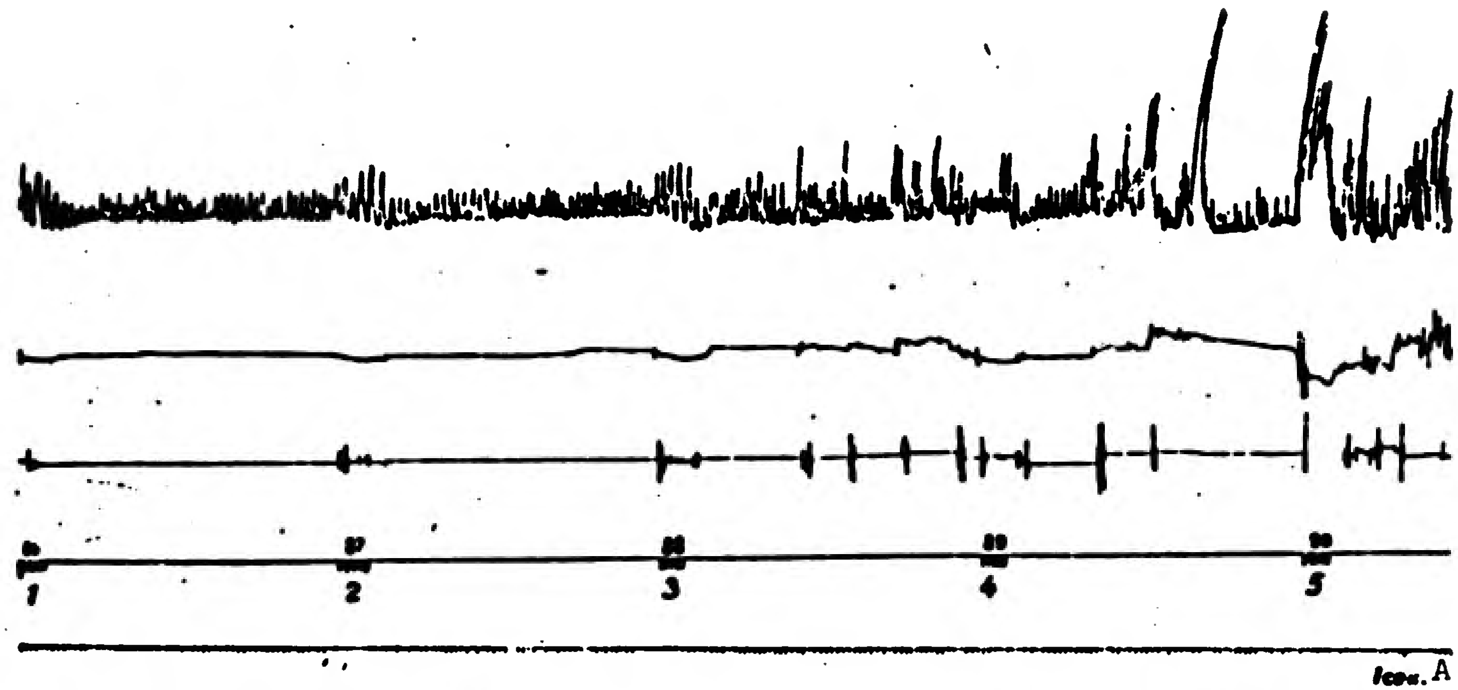


Fig.87. Deep inspiration (see second part of the time interval between stimuli 89 and 90) which expresses the tendency of the nervous system to reproduce the relaxation reaction (see brief normalization of respiration) and subsequent anxiety reaction (see sharp increase in inspiratory tonus which develops as a reaction to time and which continues during the action of electrical skin stimulation). The anxiety reaction continues in the aftereffect period (compensatory effector switching of brain's nervous activity does not lead to quieting of the experimental animal's behavior and respiration). Experiments on the development of a defensive-motor conditioned reaction to time by the Bekhterev-Protopopov method in the dog Reks. 1-5) Five-fold stimulation of the skin of the right hind leg by an induction current. Top to bottom: pneumogram; head movements; movements of the right hind leg. A) sec.

CHAPTER 7

CHRONIC PESSIMALIZATION OF SELF-REGULATION OF HIGHER NERVOUS ACTIVITY AND ITS ROLE IN THE ORIGIN OF NEUROSES

CLARIFICATION OF THE CONCEPTS: PRIMARY AND SECONDARY ADEQUACY, ADAPTIVE EFFECTIVENESS, OPTIMALIZATION AND PESSIMALIZATION OF SELF-REGULATION

§1. It has been mentioned many times that self-regulation of the higher nervous activity of animals and man can be carried out at different levels of afferent and efferent integration of nervous activity. Here the level and conditions of nervous activity do not always change in parallel with each other. Optimal conditions can be established for a relatively low level of activity, and vice versa. Within certain limits, which differ in different species of animals, in different individuals and at different functional states of the brain, the following relationship is not noted between both characteristics of nervous activity: 1) the greater the innovation in the situation and the higher the level of integration established, the more difficult it is to rapidly provide stable conditions for it, and 2) the more stable and optimal the initial conditions, the easier it is to keep them the same with an increase in the level of integration.

However, this relationship is not a general rule. Under certain conditions an increase in the level of integration promotes establishment of optimal conditions in man (see Chapter 8, §1).

The nervous system of higher animals, and especially of man, organizes the level of its activity in a given situation taking into account probable future situations.

Very frequently it is advantageous to man to provide maximal economy of the energetic and functional resources of the higher sections of the brain in an actual situation for the purpose of preserving these resources for subsequent situations which, in all probability, will have more adaptive significance for the individual than the actual situation.

At the same time the person must reflect as adequately as possible the external world and react to its changes in any, even in relatively insignificant and stereotyped situations.

Therefore, it is necessary to develop and secure a wide "assortment" of stereotypes of reflection and reaction permitting the person to reproduce with maximal economy a level of integration sufficiently adequate for stereotyped situations of life.

The establishment and maintenance of an adequate level of higher nervous activity require more or less considerable expenditures of nervous energy, frequently only during the individual's adaptation to the new situation, that is, in the period of the development and consolidation of stereotypes of reflection of a situation and of reaction to a situation which provide effective equilibration of the individual with the conditions of the external world (that is, stabilization of the system "individual-environment").

When new stereotypes of reactions have been developed, consolidated and automated, the establishment and maintenance of a (relatively) adequate level of higher nervous activity usually proceeds very economically and does not cause deviation of the conditions of the brain's operation from the optimum. On the contrary, the maintenance in such cases of a high level of integration of higher nervous activity promotes the provision of optimal conditions of brain operation. This occurs as a result of the fact that at a high level of afferent and efferent integration of nervous activity the probability of a lack of correspondence between the afferent (prescribed) model and the actual effector result is decreased and thereby the probability of the development of a severe anxiety reaction (with the predominance of the limbic component of the reaction, that is emotional awakening) and overstrain of higher nervous activity is decreased (see §4 and also Chapter 8, §1).

Of course, it is incomparably more difficult to develop adequate stereotypes of reflection of the external world and reaction (behavior) in new and complex situations of life, as well as during resolution of new and complex creative tasks than in more or less known situations.

Therefore, wide "reserves" of developed, tested in social practice and stabilized effective stereotypes of afferent and efferent integration of higher nervous activity capable of guaranteeing maximal economy of brain operation in relatively and uncomplicated and known situations of life must be continually enriched and be in readiness which promotes preservation of the energetic and functional resources of the higher sections of the brain for more complex and difficult creative tasks and situations of life.

A high level of higher nervous activity is, as a rule, an adequate level, a low level is less adequate or inade uate.

A criterion of the degree of adequacy of the level of higher nervous activity in man is the actual or potential social significance of the individual's effector activity (including creative activity), as well as the individual' personal interest (biological, psychological, economical, etc.).

It is clear that in a class society this criterion is interpreted from the viewpoint of people's class interests.

In Soviet socialist society the criterion of the adequacy of a person's social activity is defined as the Moral Code of the builders of communism which was introduced in the Program of our Party.

In animals the criterion of the adequacy of the level of effector activity is the biological effectiveness of the behavior (and of the internal organs providing its functions) in an actual situation with "consideration" of the animal's "interests" in probable subsequent situations.

As follows from the criteria mentioned, the effector activity of the animal or man which organizes higher nervous activity at a high level of integration of nervous processes is more or less primarily adequate, that is, it provides the primary adaptive effect which is desired in the concrete situation (see Chapter 2, §7).

There is still another -- secondary -- adequacy of an individual's effector activity. The criterion of secondary adequacy is the secondary adaptive effect, that is, the effect which is carried out with the help of effector reactions which have an "inverse" effect on the functional state of the brain.

An individual's effector activity sometimes can be secondarily adequate (that is, can promote the establishment of optimal conditions of nervous activity), but primarily inadequate, and vice versa.

Self-regulation of higher nervous activity is directed toward the provision first of all of a secondary adaptive effect. However, the criterion of the latter is to what degree it promotes organization by the nervous system of a primary adaptive effect.

Thus, in the final analysis, self-regulation is directed to ward the provision (through a secondary effect) of a primary effect.

Consequently, mechanisms of self-regulation of nervous activity can be both secondarily and primarily adequate.

The higher the primary and secondary adequacy of self-regulation, the higher its adaptive effectiveness. Since in the final analysis the principal criterion of nervous activity is its primary adequacy, it is clear that self-regulation can be effective only when it is adequate not only secondarily, but also primarily. As already noted, the primary adequacy of self-regulation sometimes can be expressed not actually, but in perspective, in probably future situations.

The question arises: if we distinguish a primary and secondary adaptive effect, and primary and secondary adequacy, then is it not necessary also to distinguish primary and secondary effectiveness?

Of course, it is necessary to distinguish them. However, in view of the fact that the final goal of any activity of the organism, including nervous activity, consists in the realization of a primary adaptive effect, it is necessary to have a criterion which unites both aspects of the adaptive effectiveness of the organism's functions -- primary and secondary -- and at the same time, which emphasizes the principal importance, the priority, of primary effectiveness.

Such a criterion, in our opinion, is the general adaptive effectiveness which reflects the brain's capacity to maintain a stable optimal balance of the system "organism-environment" under any changing conditions of the external environment. When we speak of the adaptive effectiveness of the organism's functions and the nervous system's functions, including self-regulation of the latter, we have in mind precisely this general, final effectiveness which unites both its aspects.

The more the mechanisms of self-regulation promote the establishment of the functional state of the brain which is necessary for the provision of high primary effectiveness of the organism's functions, the higher the general adaptive effectiveness of the self-regulation, and vice versa.

The increase in the adaptive effectiveness of self-regulation is due, on the one hand, to optimalization of the conditions of higher nervous activity and, on the other hand, to the establishment of the level of integration of nervous activity necessary for the situation.

Optimalization of the conditions (or maintenance of optimal conditions) takes place mainly with the help of the first and second types of self-regulation. However, organization and continual regulation of the first two types of self-regulation in man occurs under the guidance of the third type of self-regulation.

The establishment of a level of nervous activity adequate for the situation occurs mainly through the third type of self-regulation.

If an increase in the level of nervous activity in man involves considerable pessimalization of the conditions of nervous activity and if the person's attempt to maintain a high level with the help of the third type of self-regulation causes progressive overstrain of nervous activity, then maintenance of the level is possible only with large expenditures of nervous energy, with a very uneconomical and dangerous, in perspective, expenditure of the functional reserves of the higher sections of the brain. Such a lack of correspondence between the level and conditions cannot continue very long, in connection with which the person's nervous system either mobilizes those variants of self-regulation which stop the progressive pessimalization of the conditions and cause its optimalization, or the level of integration of nervous activity is decreased.

Chronic progressive pessimalization of the conditions of higher nervous activity and the closing of pessimal cycles ("vicious circles," see Chapter 5) of self-regulation represent one of the principal mechanisms in the origin of neurotic disorders of nervous activity, including behavioral disorders and disorders of the regulation of the internal organs.

DIFFICULT STATES OF THE NERVOUS SYSTEM AND "SITUATION NEUROSES" AS EXPRESSIONS OF PESSIMAL SELF-REGULATION

§2. Primarily inadequate effector reactions can be the expression of inadequate conversion by the brain of incoming information and, consequently, of the individual's "erroneous" reaction to this information or the expression of the effector participation in self-regulation of higher nervous activity which is occurring at a relatively low level of integration of nervous activity. In the present work we are interested only in the latter aspect of the origin of inadequate reactions.

Frequently effector reactions are qualitatively adequate, but quantitatively inadequately strong and lasting. Usually, such a phenomenon is observed in cases in which these reactions are used by mechanisms of self-regulation (most frequently by the first type of self-regulation) which were mobilized as a result of a deviation of the conditions of higher nervous activity from optimum.

Primarily and secondarily inadequate reactions develop during ineffective and pessimal self-regulation of nervous activity which is not capable of causing optimalization of the conditions of nervous activity or which causes its further pessimalization.

The most inadequate reactions develop during so-called difficult states of an individual's nervous system which develop as a result of the nervous system's inability to resolve adequately a situation which is difficult and significant for the individual. Difficult states are observed very frequently in experimental animals during the development and overstrain of internal inhibition, as well as during the onset of an inadequately strong and unresolvable reaction of anxiety and emotional strain.

Difficult states of the nervous system (more accurately – difficult states of higher nervous activity) are the result of sharp pessimalization of the conditions and of a decrease in the level of integration of higher nervous activity and the nervous system's inability to compensate these pessimal changes by effective corrective actions with the help of self-regulation of nervous activity.

The cause of pessimalization of nervous activity is the critical weakening of the dominant which is adequate for the situation as a result of overstrain of higher nervous activity, as well as the onset of an inadequate (qualitatively and quantitatively) anxiety reaction. Instead of an optimalizing differentiated reaction of cortical awakening, a generalized reaction of limbic, that is, emotional, awakening dominates in the animal which causes a most severe increase in the intensity and exertion of the activity of closed systems in the subcortical structures and cortical-subcortical functional cycles.

In order to equilibrate the brain's nervous activity, massive compensatory switching of the activity to peripheral effectors occurs. Violent compensatory reactions of the experimental animal develop which, however, do not have primary adaptive significance in the concrete situation and therefore only deepen the lack of correspondence between the desirable and actually attainable adaptive effect which, in its turn, secondarily even further intensifies the reaction of anxiety and emotional strain which, thus, becomes the leading link in pessimalization of higher nervous activity.

All the effective variants of the second and third types of self-regulation are inhibited. The first type of self-regulation dominates - rapid "abreaction" of "excess" nervous activity through any available (that is, free from inhibition at the given moment of time) levels of effector integration of activity, even the most primitive and inadequate for the situation.

In the initial phase of the difficult state when the experimental animal's nervous system still has some energetic and functional reserves, the nervous system is capable of organizing a battle with the developing pessimalization of its work.

Therefore, the third type of self-regulation is mobilized - the animal attempts to turn away from the stimuli traumatizing nervous activity, to avoid the experimental situation, to take a position which provides probable safety with respect to expected nociceptive stimuli, sometimes displays "investigative activity": looks at the place where the experimenter is, examines the experimental chamber, table, holder, sometimes growls or whines, crosses from leg to leg, takes a position of "starting" readiness, etc.

In cases in which the resources of internal inhibition are already beginning to be depleted, in which the dominant adequate for the situation is considerably weakened and the anxiety reaction, especially its limbic (emotional) components, progressively intensifies, its least differentiated mechanism - the first type of self-regulation - begins to predominate in the mechanisms of self-regulation. The third and second types of self-regulation make a "last" (already more or less inadequate) attempt to optimalize the conditions and to maintain the level of higher nervous activity and to merge from the difficult situation with the help of active defensive reactions.

In some experimental animals violent general defensive reactions begin: dogs, for example, try to tear off the apparatus, bite the straps and tubes, bark, snap, try to tear out of the holder; rats dash around the experimental cage, gnaw the wire of the cage, etc.

With a more expressed decrease in cortical tonus and inhibition of higher levels of integration, stereotyped motor reactions develop in the animal which are the equivalents of active defensive acts or fragments of previously developed motor reactions, or violent continuous reactions on itself develop in the animal. The latter are especially sharply expressed in rats and cats (washing and scratching movements).

With further irradiation of the inhibited state along the neural structures of the higher sections of the brain an intense phase of the difficult state of the nervous system develops in

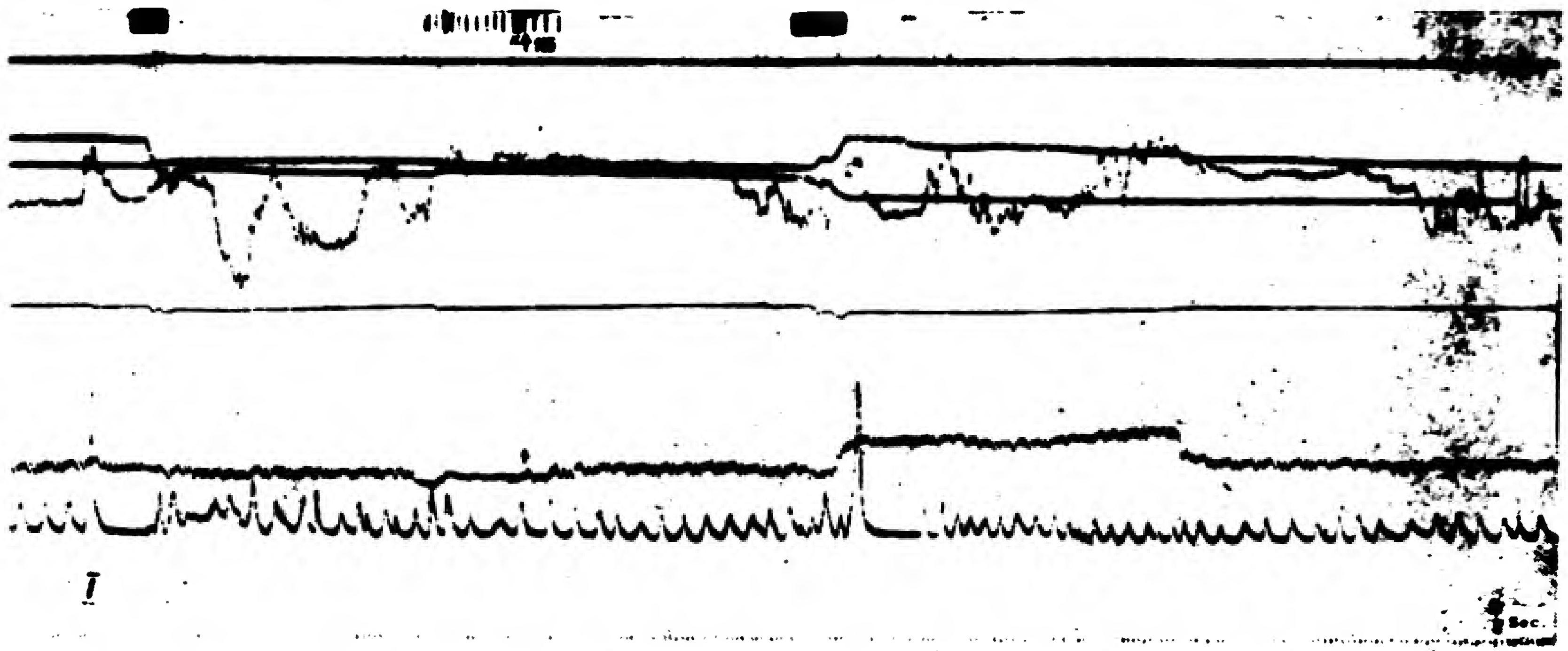
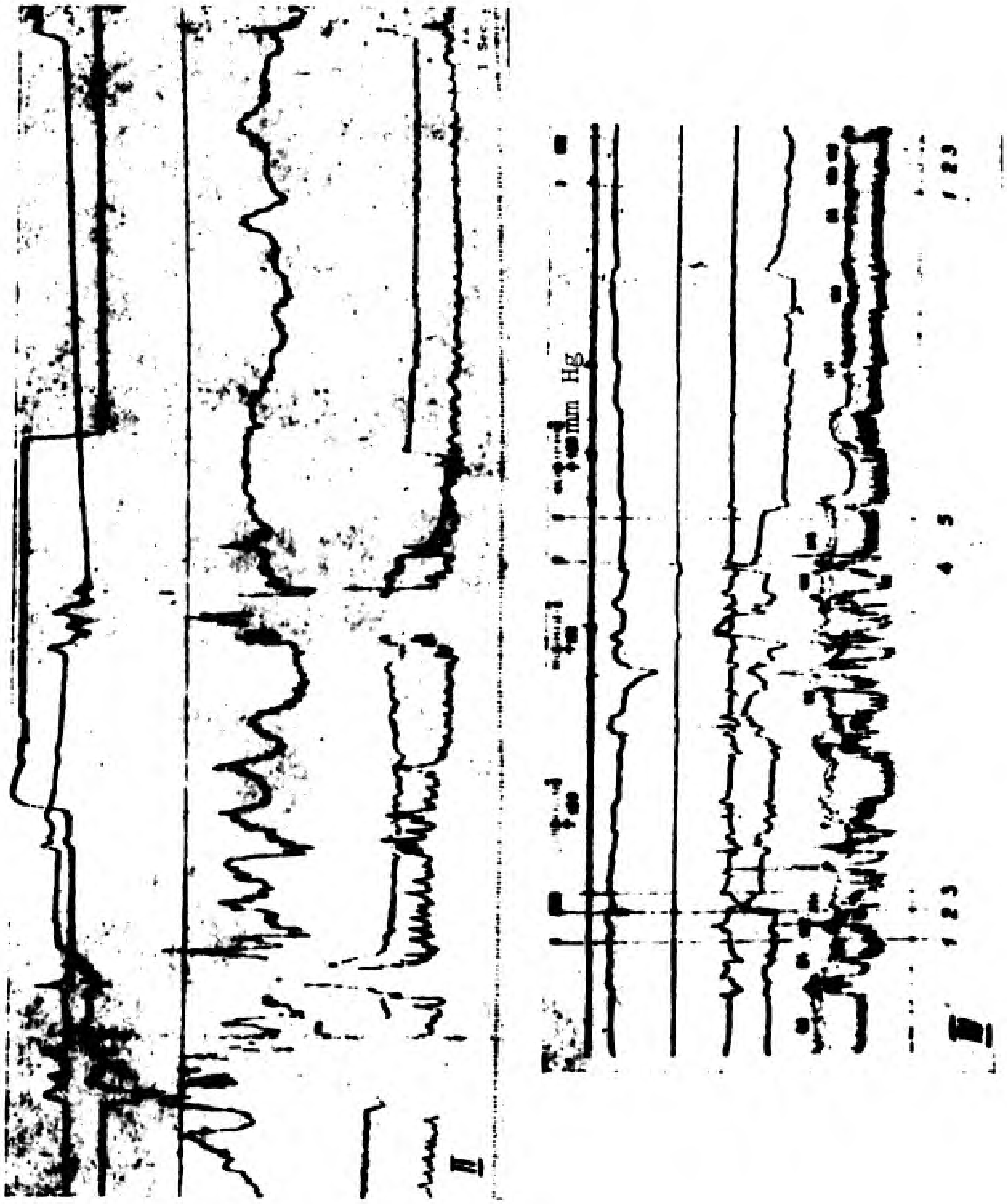


Fig. 88. Different manifestations and different phases of the development of difficult states of nervous activity and "situation neuroses" in experimental animals. First (I) fragment — experimental dog's relatively adequate reaction to experimental situation and stimuli used (development of general preparatory reaction to time on the basis of systematic application after different intervals of time of electrical skin stimulation of right hind leg (see Fig. 98); second (II) fragment — signs of beginning of difficult state of higher nervous activity as a result of cessation of application of electrical skin stimulation at the end of a prolonged experiment in the same dog (see first fragment); third (III) fragment — difficult state of nervous activity in dog and dog's attempt to eliminate difficult situation created by the experimenter as a result of mechanical blocking of the movements of the right hind leg (in the process of development of defensive conditioned reactions on the basis of electrical stimulation of the orgal mucosa) (see Figs. 19 and 20); fourth (IV), fifth (V) and sixth (VI) fragments — repeated change in various levels of effector integration depending on the degree of the difficult state of nervous activity during the development of defensive-motor conditioned reactions (See Figs. 21, 51 (3), 79).

Fig. 88 continued



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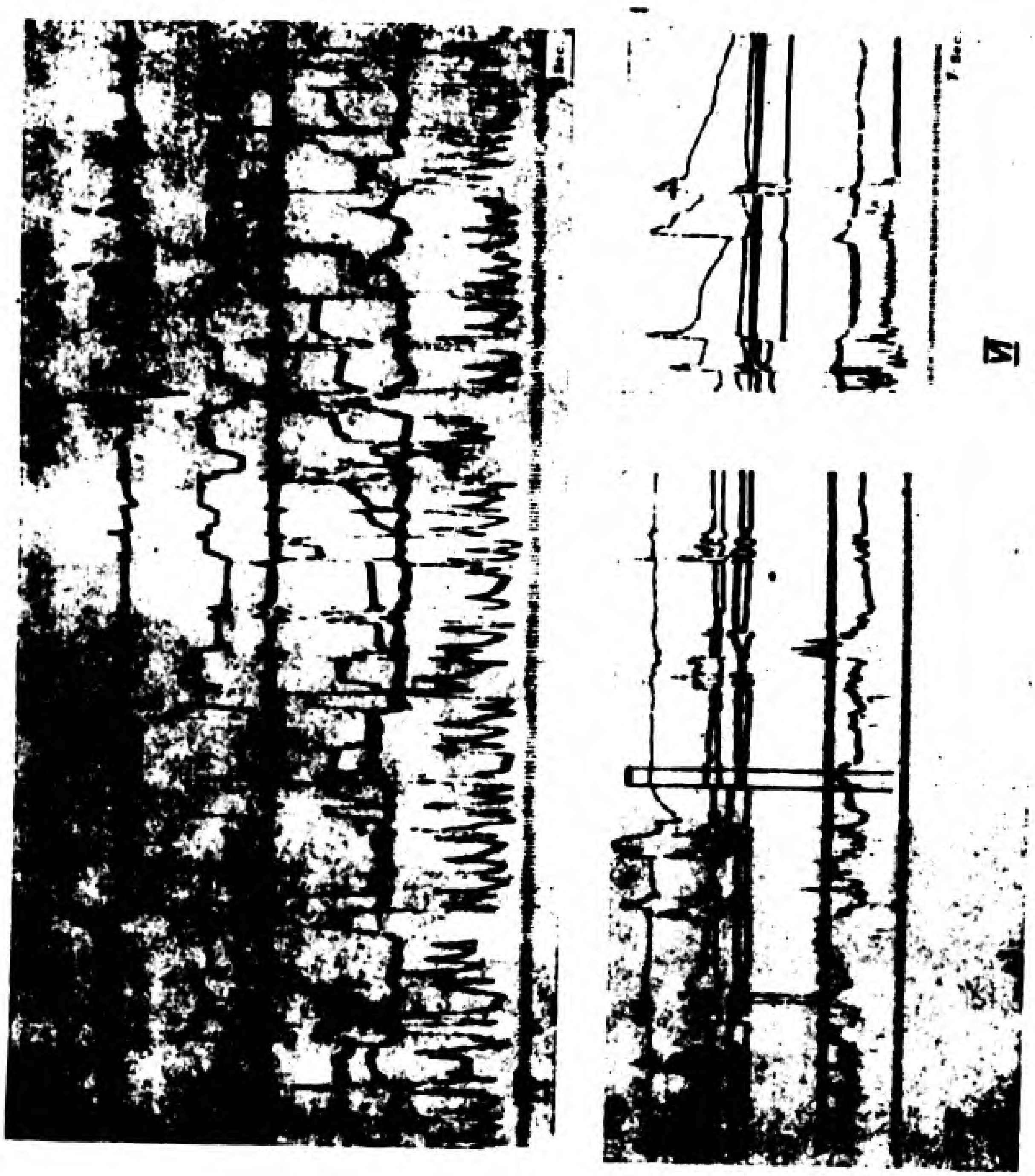
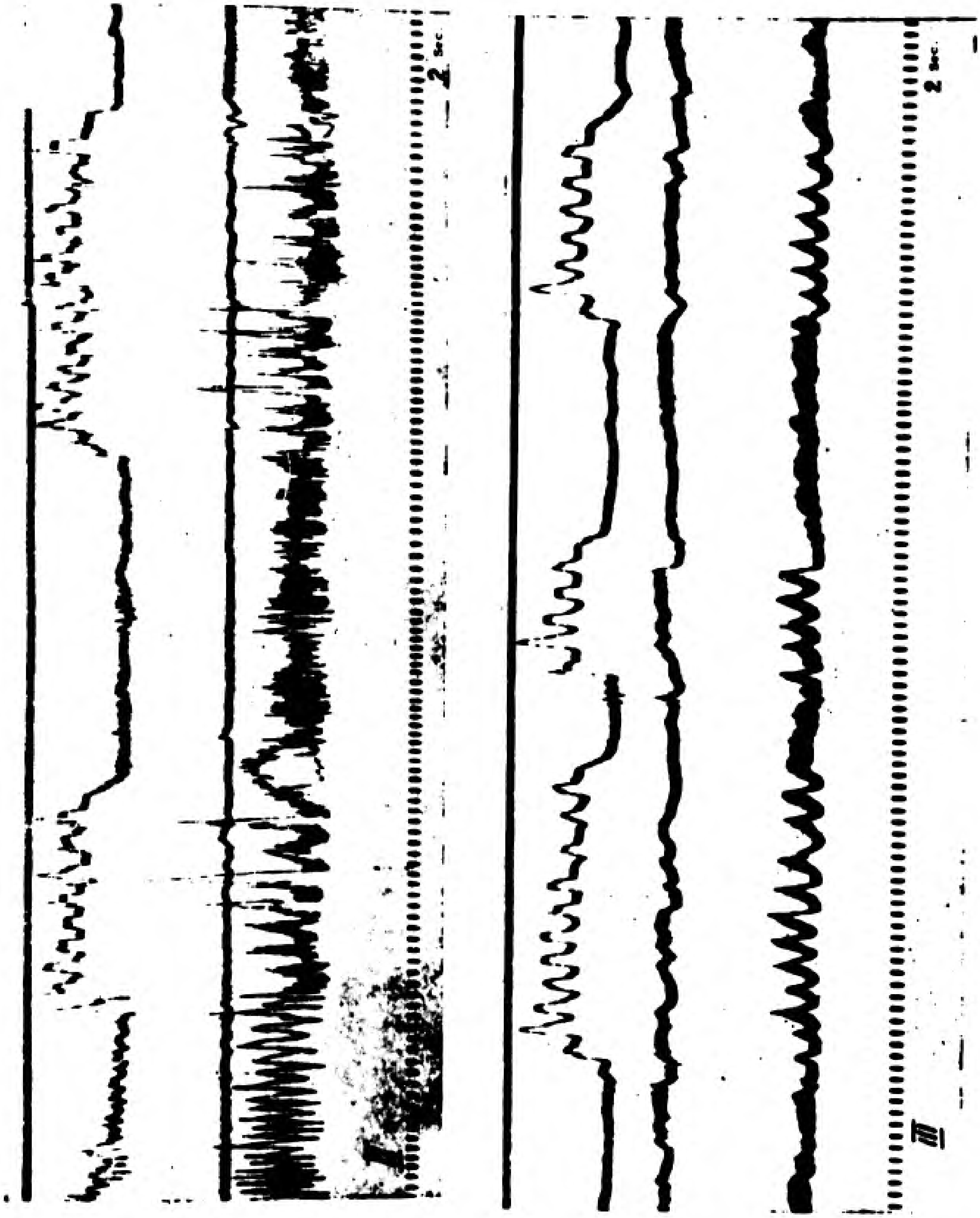


Fig. 89 continued



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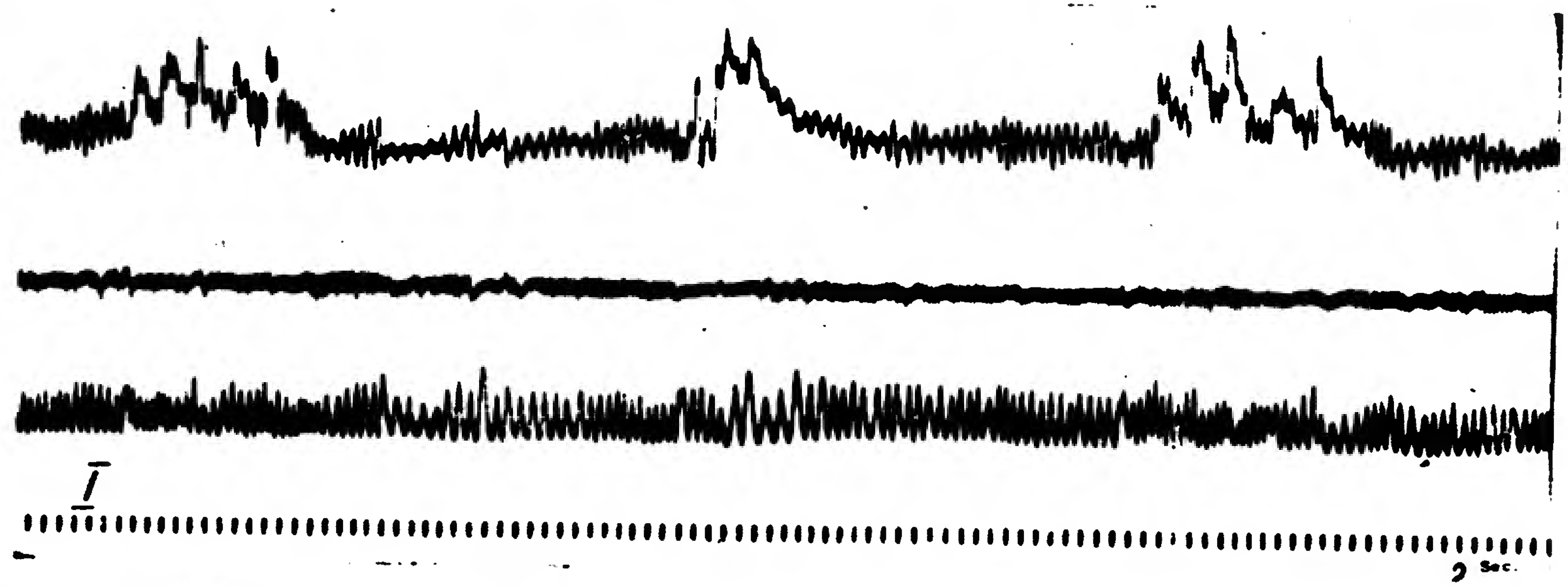


Fig. 89. Phases of the development of a difficult state of nervous activity during the development of nonspecific general preparatory conditioned reactions on the basis of electrical skin and strong sound (pistol shot) stimuli in the dog Dzhek. Three fragments of kymograms are presented which were recorded in the intervals between stimuli at the end of the experiment (in different experiments) at different functional states of the nervous system. First fragment (I) – experimental animal's reaction to experimental situation at the beginning of series of experiments; second (II) – after 5-6 experiments in response to experimental situation the most severe difficult state develops, as a rule, which continues during the entire experiment and is expressed in the animal's "freezing" in a position characteristic of a passive-defensive reaction, in tachypnea with periodic secondary variations in inspiratory tonus, in an increase in arterial pressure, sharp intensification in irregular contractions of the stomach, in intensification of salivation. Notation same as in Fig. 73.

which the external manifestations of the state of anxiety and emotional tension are more or less inhibited or are expressed in the animal's closing "within itself," in shaking, in tucking in of the tail, etc., and almost all the nervous activity evoked by the anxiety situation which cannot be retained and equilibrated in the brain (and the brain after overstrain of its higher sections is incapable of retaining any considerable part of the impulses generated in it) goes out of the brain through the respiratory center and visceral effector fibers, causing as compensatory reactions the most severe tachypnea, increased pulse rate, sometimes an increase (more infrequently – a decrease) in arterial pressure, intensification and change in the motor activity of the stomach, secretion of saliva and gastric juice.

It should be mentioned that the episodic development of various of the reactions indicated above is still not a sign of the onset of a difficult state of the nervous system. For example, in experiments on white rats a phenomenon is frequently observed when the use of inhibitory signals causes a severe reaction of washing and scratching which ceases after cessation of the signal (Krauklis, 1952, 1955, 1962). If the violent washing movements or other forms of the reaction on itself continue in the intervals between stimuli, and sometimes do not cease during the entire experiment, or are replaced by reactions of an even lower level of integration, for example, running into a corner of the cage and passive closing "within itself," then this undoubtedly is a sign of the beginning of a difficult state of the nervous system.

In experimental animals a difficult state which develops under certain experimental conditions is very frequently reproduced by an experimental situation promoting conditioned reflex reinforcement of those mechanisms of self-regulation (for example, pessimal cycles) which lie at the basis of the development of a difficult state of the nervous system. As a result, an experimental "situation neurosis" is formed.

If cessation of the difficult situation involves rapid extinguishing of the pessimal cycles of self-regulation, subsequent optimalization of the conditions, an increase in the level of integration and the development, that is, the restoration, of strong bio logically positive dominants, then the "situation neurosis" is reproduced only in the experimental situation. During the extinguishing by the experimenter of the nociceptive signal significance of the experimental situation which "traumatizes" the nervous system, the "situation neurosis" more or less quickly disappears without special treatment.

If, for various reasons, the pessimal cycles ("vicious circles") of self-regulation are not inhibited after the experiment, that is, not replaced by optimal cycles, the experimental animal's neurotic state can continue outside of the experimental situation and under certain conditions can change into a chronic neurosis.

Kymogram fragments illustrating the phases of development of a difficult state of nervous activity in experimental animals are presented below (Figs. 88 and 89).

§3. A true difficult state of nervous activity develops rarely in a healthy adult human subject in an observation session. It is easily manifested in children at the end of a fatiguing session, and especially in neurasthenic children, and sometimes also in adults with neurasthenia (Krauklis, 1956, 1958, 1960a). The development of a difficult state is connected with a decrease in cortical tonus and considerable relaxation in the subject of the leading positive intellectual and emotional dominants.

A sufficiently strong dominant of the second signal system which controls the afferentation entering the higher sections of the brain, intracentral coordination, as well as the outgoing efferentation, is usually maintained in a healthy human subject with the help of the third type of self-regulation, promoting thereby the maintenance both of optimal conditions and level of integration of higher nervous activity.

In a healthy, unfatigued subject there are always great possibilities of retaining with the help of the third type of self-regulation a large number of impulses of nervous activity in closed systems of the brain, of reworking and equilibrating them there, while not resorting to the mobilization of the first type of self-regulation and thereby avoiding the possible development of inadequately strong or qualitatively inadequate compensatory reactions.

If during the observation session a slight decrease in cortical tonus and weakening of the adequate dominant which regulates the conditions and level of the brain's operation develops in the subject as a result of intensified strain of higher nervous activity, then usually the second type of self-regulation is mobilized (the contraction and tension of the skeletal musculature and the functions of the respiratory apparatus are intensified) and the third type of self-regulation is activated (the person consciously evokes through the conditioned links new, and intensifies the available, dominants of the second signal system).

With further strain of nervous activity, and especially with the development of an anxiety reaction with an expressed limbic (emotional) component, the first type of self-regulationis also mobilized which nevertheless is under control of the leading dominant and of the third type of self-regulation.

With a further decrease in cortical tonus, weakening of the cortical dominants and a decrease in the effectiveness of the third type of self-regulation, the second and first types of self-regulation are intensified – a large number of inadequate compensatory reactions mainly on the part of the skeletal musculature and respiratory apparatus is displayed.

This is most frequently observed with stimuli which cause a severe anxiety reaction and strong exertion of internal (conditioned reflex) inhibition in the subject, or immediately after cessation of such stimuli.

However, in healthy, unfatigued adult subjects, the above-mentioned inadequate compensatory reactions are variable and the subject is usually able to eliminate them easily.

Sometimes it is only necessary to draw the subject's attention to the existence of his inadequate reactions (for example, excessive tension of the musculature, deep breaths, increased frequency and intensification of respiration, inadequate motor reactions) and the subject without special instructions suppresses them. This indicates that sufficiently high cortical tonus is usually retained in a healthy adult subject during the observations, and if tonus is temporarily decreased, then the subject is capable of voluntarily (by concentration of attention and mobilization of verbal motivation through the third type of self-regulation) increasing it to the necessary level.

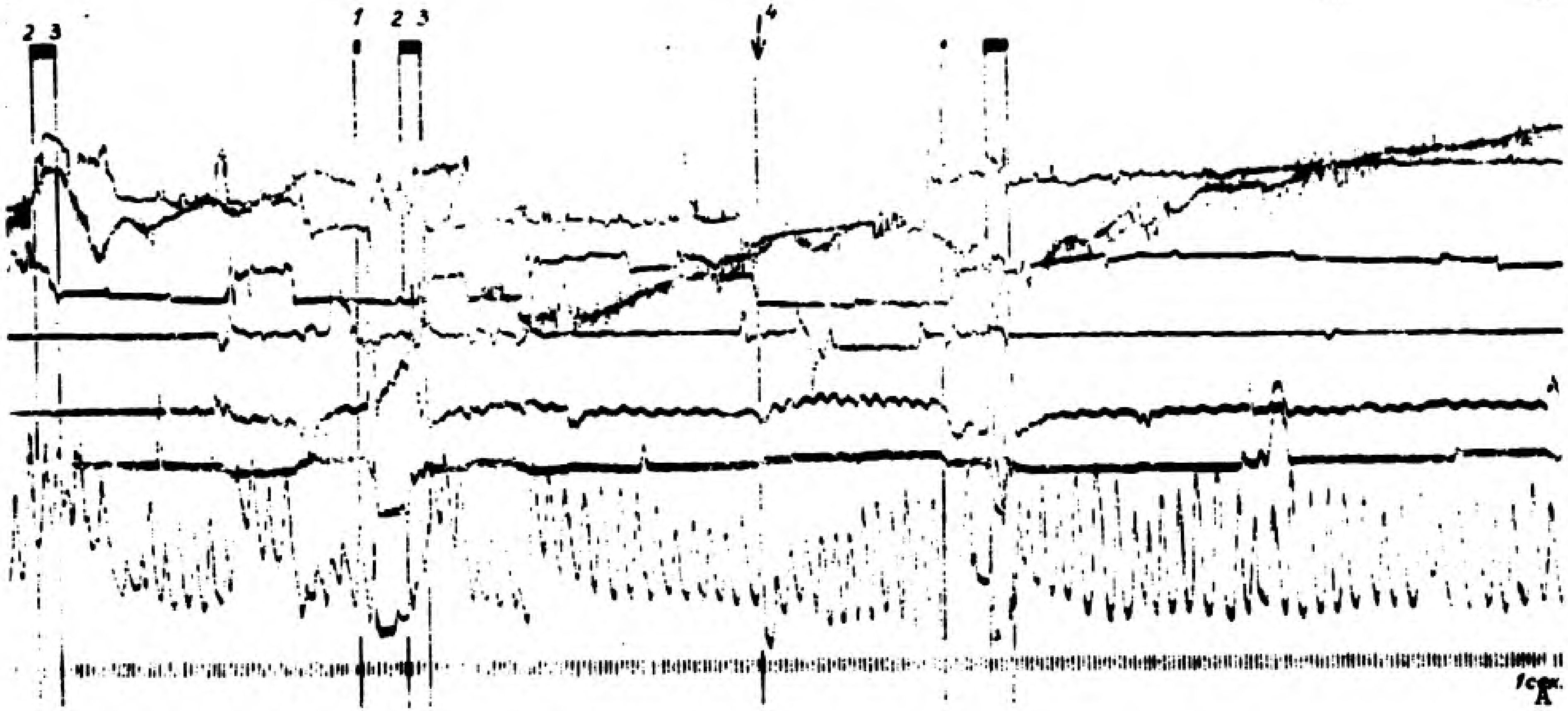


Fig. 90. Decrease in the length and cessation of an anxiety reaction as a result of verbal quieting of the subject O.Z. on the part of the physician conducting the observations. 1) Conditioned (sound) signal; 2,3) electrical skin stimulation of moderate strength; 4) verbal report to the subject: "The examination of your nervous system will soon be ended. Everything is in order, you are healthy. Two to three brief stimuli will still be applied which are weaker than the preceding." From top to bottom: contraction of the circular muscle of the eye and blinking movements; sphygmogram of the radial artery; raising of the eyebrows; movements of the lower jar; contraction of the flexors and extensors of the knee joint; pneumogram. A) sec.

If the initial level of cortical tonus is already decreased in subjects as a result of fatigue, overs-rain or neurotic disorders of higher nervous activity, then from the effect of the stimuli applied in the observation session a further decrease in tonus and level of integration, pessimalization of the conditions of self-regulation and the appearance of a large number of inadequate compensatory reactions develop relatively easily.

However, in such cases also voluntary self-regulation by the subject of stimulating verbal (thought) motivation (or approving verbal signaling on the part of the leader of the session) is capable of quickly increasing the tonus and of optimalizing the subject's self-regulation (Figs. 90 and 91).

In connection with this we should mention the work of Trofimov (1961) who, in studying the dynamics of blinking conditioned reflexes in healthy subjects and in patients with a slight degree of oligophrenia under different light and sound conditions, including in complete darkness and sound isolation, established that the subjects's normal central nervous system is capable of retaining the necessary functional level of cortical activity, in spite of changes in the conditions of the surrounding environment both in the direction of a decrease in the inflow of impulses and in the direction of its increase.

At the same time, in oligophrenics the change to decreased light and to complete darkness caused a decrease in blinking conditioned reflexes and a disturbance in respiratory rhythm with the periodic appearance of deep inspirations.

It is interesting to note that even in oligophrenics activation of the second signal system — with the help of speech stimuli in the form of simple questions — immediately led to the restoration of conditioned reflexes which were extinguished in the dark and to normalization of respiration. It is necessary to agree with the author's conclusion that "in man principal significance in the regulation of the overall tonus of the cortex of the large hemispheres belongs to the "extreme increase" in the form of the second signal system which in its nature is a purely conditioned reflex mechanism."

The strongly expressed and primarily inadequate compensatory reactions developing in the observation session in neurotic patients, and particularly in neurotic children (Krauklis, 1956), most frequently is the expression of ineffective mechanisms of the first and second types of self-regulation of nervous activity. Usually, arythmic respiration with frequent deep inspirations and prolonged lags in respiration, frequently at high inspiratory tonus of the respiratory musculature, sometimes periodic respiration, postural-tonic contractions of the skeletal musculature, tonic contraction of the sphincters, chewing muscles, muscles at the bottom of the oral cavity, lips, tongue, mimetic musculature, sharp increased rate of blinking movements, of the swallowing,etc. etc., are observed. Frequently tachycardia, strongly expressed retional vascular reactions and third and higher order waves, lability of arterial pressure, intensification of stomach's motor activity are noted. Inadequate speech reactions are not usually

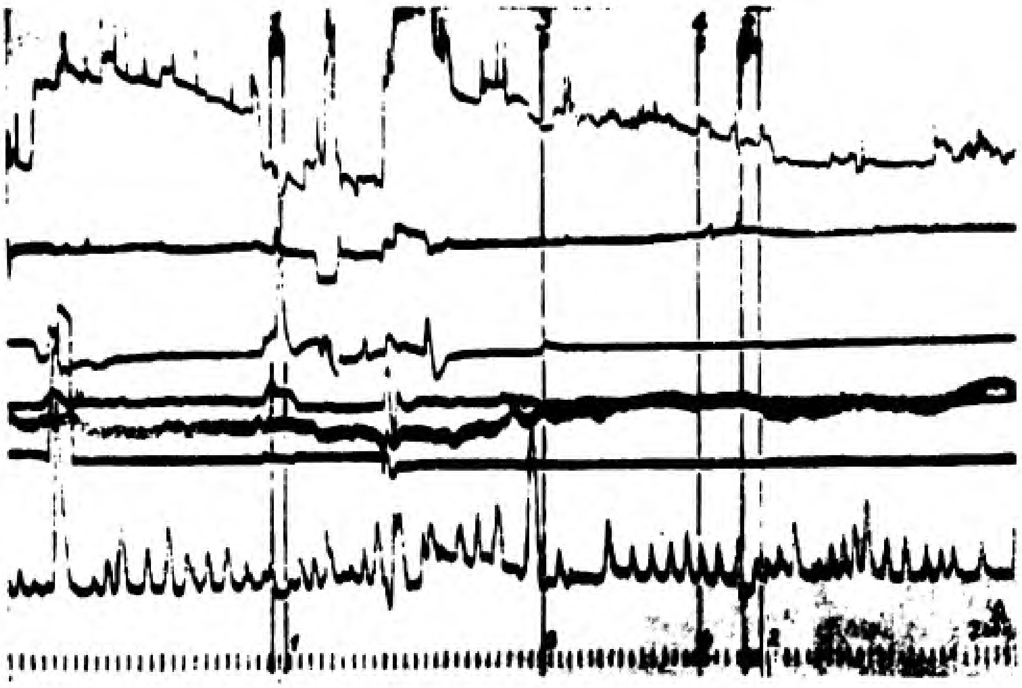


Fig. 91. Cessation of anxiety reaction as a result of verbal report to subject that in the future before the use of any stimulus a verbal warning will be given about the next stimulus. A general preparatory conditioned reaction to time was developed in the subject Ya.E. 1,2) Electrical skin stimulation of forehead; 3) verbal report: "At future examinations any stimulus will be preceded by a verbal warning. Surprise stimuli will no longer be used"; 4) oral signal: "Attention, there will be the usual stimulus!" Notation same as in Fig. 88 (only in place of sphygmogram, plethysmogram of the finger was recorded which is found between the curves of the contraction of the extensors and curves of the flexors of the knee joint). A) sec.

found.

In cases in which the above-noted inadequate reactions become prolonged, filling the intervals between stimuli, it is possible to speak of the presence of a true difficult state of the nervous system in the subjects.

Usov and Trofimov observed that during the development in elderly people, middle-aged people with senile psychosis and in patients with oligophrenia of motor conditioned reflexes, any strong exertion of the subjects' higher nervous activity easily leads to the development or intensification of speech, behavioral and respiratory reaction which are inadequate for the concrete situation (Usov, 1952, 1955a,b,c, 1951: Trofimov, 1952, 1955a,b, 1961, 1962).

Judging by these authors' data, it is possible to assume that in middle-aged people and people with organic defects of the higher sections of the brain, self-regulation of higher nervous activity is ineffective and that the third type of self-regulation has lost to a greater or lesser degree its leading, organizing significance.

SIGNIFICANCE OF INADEQUATE DOMINATION OF REACTION OF EMOTIONAL (LIMBIC) AWAKENING IN THE STRUCTURE OF THE ANXIETY REACTION IN THE ORIGIN OF DIFFICULT STATES OF THE NERVOUS SYSTEM

§4. The conditioned reflex fixation and reproduction of inadequate behavioral, respiratory and visceral reactions is a very frequent phenomenon both in experimental animals and in man. The conditioned reflex reproduction and fixation of ineffective or pessimal variants of self-regulation of higher nervous activity which characterize a difficult state of the nervous system and "situation neuroses" are rarely observed in healthy individuals, however, they are not a rarity.

Usually the episodic reproduction of various "situation neuroses" does not lead to the development of a true neurosis.

At the same time, observations show that the development of chronic neuroses both in experimental animals and in man often begins with various "situation neuroses."

As already noted in the second section of this chapter, one of the leading factors in the development, and especially in the maintenance and deepening of a difficult state of the nervous system or "situation neurosis" in experimental animals, is an inadequately strong anxiety reaction, particularly, its inadequately strong emotional components.

The effectiveness of the mechanisms of self-regulation of nervous activity in many respects is determined precisely by to what degree they are capable of preventing the development or of limiting and inhibiting the further development of the emotional components of the anxiety reaction.

In connection with this, it is necessary to indicate that in neurophysiology and morphology data has been accumulated in recent years which speak of the fact that the activity of the reticular formation of the brain is under the continuous control not only of the new, but also of the old (the so-called "olfactory" or "visceral") cortex, or of the limbic system.

On the basis of the experimental data of a number of authors (see below) it can be assumed that the visceral cortex, or limbic system, participates in the organization of the reaction of emotional awakening.

The limbic system send projections to the reticular formation at the level of the intermediate brain and central gray matter of the middle brain which is, as is well known, the most important switching station on the neuron paths which participate in reactions of affects and emotions. At these levels the limbic ring, and especially the amygdaloid body, and entorenal cortex can have a strong influence on the current of activity ascending along the reticular formation.

Thus, the limbic system modulates (through the reticular formation and hypothalamus) both sensory feelings and automatic acts of behavior connected with emotions, with prospecting, alerting, olfactory, sexual, flying, etc., activity, in accordance with the organism's actual requirements (Papez, Hunsper er, 1956, Eydi, 1962, Green, 1962; Glor, 1962).

According to Glor's ideas, the limbic system, by using data stored in it (mainly in the hippocampus) facilitates or inhibits, depending on the organism's needs, various types of behavior integrated in the gray matter of the subcortical structures. The limbic system is thereby connected with mechanisms of motivational reinforcement.

Green and Arduini (1954) established the presence of inverse relationships between types of electrical activity of the new and old cortex. In an animal who is awake large regular waves (5-7 cps) in the hippocampus are combined with low and frequent waves in the new cortex. And vice versa, in a dozing animal, rapid asynchronous activity in the hippocampus is combined with outbursts of the spindles in the cortex.

There are indications that the hippocampus has an inhibitory effect on the orienting reaction and has reciprocal relations with the reticular formation of the brain stem (Lissak et al, 1957).

Magoun (1958) assumes that the low-voltage rapid discharges in the new cortex and its projections are connected with the process of perception and the establishment of links during the mobilization of attention, whereas the large slow waves of the old cortex and its projections - with affective and emotional activity.

By analyzing our observations of the conditions determining the effector functional structure and the dynamics of different forms of the anxiety reaction in animals and man in the light of the above-mentioned literature data, we came to the following hypothesis.

Both the higher dominating formations of the brain - the new and old cortex of the forebrain - use the reticular formation (and structures of the stem and intermediate brain closely connected with it) for purposes of organizing different aspects of afferent and effector integration of nervous activity, that is, of the actual dominant of the individual's nervous activity and behavior.

The old cortex (limbic system) with the help of structures of the reticular formation organizes and carries out the reaction of emotional awakening which mobilizes the nervous system, behavior and vegetative functions of the organism directed toward the satisfaction of the organism's actual needs and creating the complete emotional directedness (and simultaneously the criterion) of all the afferent and effector functions of the brain, while the new cortex through the reticular formation organizes the reaction of cortical awakening which provides for a differentiated reflection by the brain of the changing conditions of the external world and dominant corticofugal control of afferent and effector integration of nervous activity.

With optimal conditions of higher nervous activity, limbic control of afferentation and efferentation is regulated by corticofugal effects (through the cortico-hypothalamic links), while cortical activity is modulated with the help of the action of the limbic system (through the zonal convolution and field 32) (Murphy, Gellhorn, 1945; Meyer, Beck, McCardy, 1947; Ward, McCullock, 1947; Clark Le Gro, 1950).

During an anxiety reaction, depending on the signal significance of the stimuli causing it and the actual requirements of the organism, sometimes primarily cortical, at others limbic (emotional) awakening is activated as the intracentral components.

In difficult states of animals and man, all the components of the anxiety reaction, including emotional awakening, are mobilized. If the latter becomes inadequately strong and dominating (in connection with weakening of the dominant cortical effects), it is capable of becoming the source of extreme emotional excitation, and consequently, of extremely massive compensatory effector switching of the brain's activity to the periphery, causing violent primarily inadequate and secondarily ineffective behavioral and visceral compensatory reactions.

The latter are the source of secondary afferent and humoral effects on the brain which signal the organism's inability to resolve the difficult situation with the help of effector activity and provoking a further intensification of the activity of the corresponding subcortical structures and cortical-subcortical cycles circulating around the closed systems.

Thus, a reaction of anxiety and emotional strain which is inadequate in intensity and functional structure can be an important link in the origin and maintenance of difficult states of the nervous system and "situation neuroses." Since the development of chronic neuroses often is connected with more and more frequent and continuous reproduction in the individual of various difficult states and "situation neuroses," an inadequate anxiety reaction acquires important significance in the origin of chronic psychoneuroses and visceral neuroses.

Considering the data of observations which we obtained in a study of higher nervous activity, including the anxiety reaction and neuroses, in animals and man, as well as clinical observations and literature data on the physiology of the limbic system, we suggest as a working hypothesis the following diagram of the origin of "situation neuroses" (Fig. 92).

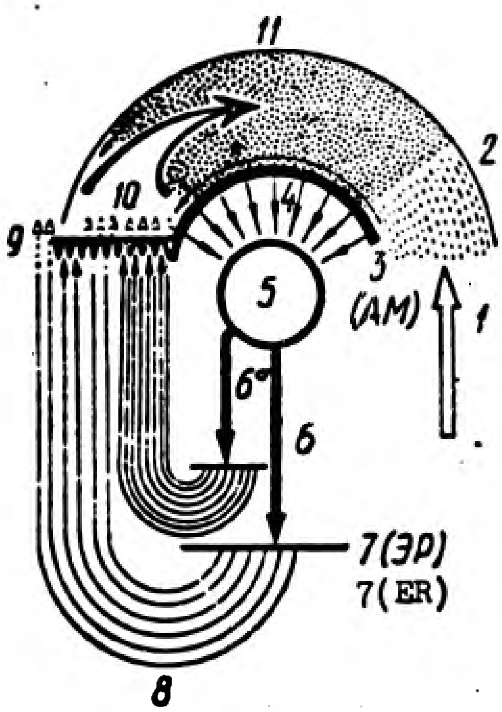


Fig. 92. Diagram of the origin of difficult states of the nervous system and "situation neuroses" on the basis of closing of a "vicious circle" which supports an inadequate anxiety reaction with the prevalence of emotional excitation. Notation same as in Figs. 48 and 49.

CERTAIN ASPECTS OF THE PATHOGENESIS OF PSYCHONEUROSES AND VISCERAL NEUROSES

§5. The central links of the diagram presented above of the origin of difficult states of the nervous system are, on the one hand, sharp weakening of the adequate cortical dominant of the individual's nervous activity (i.e., of the dominant afferent model of effector activity) (see Chapter 5, §3), on the other -- the development of an affective-emotional dominant which is inadequate or of slight adequacy for the situation as a result of an extremely severe and qualitatively distorted anxiety reaction.

The absence of an adequate cortical dominant promotes the development of an inadequate limbic dominant and the replacement of effective variants of self-regulation with less effective or even pessimal variants.

In man the third type of self-regulation loses its leading and organizing role and the dominating variants become ineffective or pessimal variants of the first and second types of self-regulation.

Therefore, in man in difficult states of the nervous system there develop both diverse speech, behavioral and visceral reactions inadequate for the situation which are an expression of compensatory switching of extremely strong activity of the brain to the periphery and strong monotonous tonic contraction and tension of the skeletal musculature (that is, muscular hypertension) which are an expression of compensatory generation of a proprioceptive inflow for purposes of increasing cortical tonus and conjugate inhibition of functional systems of the brain which are disadvantageous for the conditions of the brain's operation.

However, both those and other compensatory reactions during a difficult state of an individual's nervous system are of slight effectiveness or ineffective, and frequently even promote the development of pessimal cycles of self-regulation and cause further pessimalization of the conditions of higher nervous activity (see Chapter 5, §3).

The process of the development of a chronic neurosis is connected with the conditioned reflex fixation and more and more frequent reproduction of pathological functional systems of neural links developed during difficult states and "situation neuroses." Reproduction develops in different situations which cause in the individual more or less expressed tension of higher nervous activity and which acquire the significance of a signal which disinhibits the pathological systems.

A progressive increase in the number of stimuli of the organism's external and internal environment which acquire signal significance, that is, the ability to reproduce in a conditioned reflex manner difficult states and a "situation neurosis," can be explained by the internal development of pathological systems of neural links and by the progressive functional joining of these systems with previously developed and newly developed systems of conditioned links.

The existence of internal dynamics of neurotic disorders is well-known to clinicians. It was first noted in experimental neuroses by I.P. Pavlov's school. The American physiologist Gantt thoroughly studied and described cases in which an experimental neurosis develops in manifest form during a long latent period after the infliction of a single psychotrauma on the experimental animal.

Gantt (1944, 1953, 1958) believes that there are neural mechanisms of the internal development of those traces of neural processes which were once caused by conflict situations or stress-situations. The process of the latent development of neurotic disorders Gantt calls "negative autokinesthesis." The process of the latent development of the changes which optimalize nervous activity which develop as a result of one therapeutic action, Gantt calls "positive autokinesthesis."

Gantt assumes that latent changes (of a pathological nature) in the relations between the nerve centers involve changes in those response reactions of the nervous system which develop during stimulation of the peripheral receptors and of these same nerve centers. As a result, the normal relations of the functions of the organs and tissues in the entire organism are changed, in connection with which the afferentation entering from the acting organs changes.

In the final analysis continuous changes develop in the synapsis of the corresponding nerve paths and centers. As a result, the neurotic disorders are deepened and fixed. Gantt assumes the participation of self-exciting neural cycles in the process of autokinesthesis.

In Viner's opinion (1958), the excitation circulating around the closed systems of neural links has great significance in the origin of chronic mental diseases. Viner believes that new pathological systems of conditioned links can be formed both through direct interaction with the external environment and through conversion of previously accumulated information and the inclusion of this information in the newly developing pathological links.

The fact that the pathological systems of neural links involve newer and newer neural elements in the pathological process leads to the inclusion of normal relations with the external environment, to the switching off of the selection of reliable information and to the development of conditioned links after one combination and to the absence of extinguishing from their systematic nonreinforcement.

Thus, the process of development of chronic neuroses represents a process of the development of those functional systems of pathological significance which are developed in difficult situations and continue to organize around themselves neural connections even after the cessation of the difficult situations and in the intervals between them.

As a result of the progressive widening of the range of functional links and effects of the pathological complex, a difficultly resolvable lack of correspondence between the desired effect of the individual's nervous activity and the actual effect develops more and more easily in situations requiring intensified exertion of higher nervous activity, and consequently, the reproduction of an inadequately strong and distorted anxiety reaction which is expressed in the provocation of strong emotional excitation which is disadvantageous for the organism and the mobilization of the organism's functional and energetic resources.

A sort of "battle readiness" of the nervous system and the entire organism unnecessary in the given situation is thereby created which requires great expenditures of nervous energy which, however, as a rule, is not realized in behavioral acts adequate for the situation capable of eliminating the difficult situation. In connection with this, in man an inadequate state of anxiety and "battle readiness" requires great expenditures of functional and energetic reserves of the nervous system in order to inhibit external manifestations of the anxiety state which are inadequate for the situation.

The frequent development of an inadequate emotional dominant, its conflict relations with a dominant which is adequate for the situation and the most severe stress of higher nervous activity caused by this involves a chronic decrease in cortical tonus, critical weakening of adequate and optimal dominant systems of neural links, a decrease in the level of integration and pessimalization of the conditions of higher nervous activity.

As a result only relatively ineffective variants of self-regulation of nervous activity can be mobilized for compensation of the disorders of nervous activity. For example, in man, instead of tonic, encouraging verbal (idea) motivations, emotionally exciting idea motivations often develop (anger, pain, malice, aggressiveness, overevaluation of the significance of a conflict situation, egotistical offense, etc.).

The first type of self-regulation which is expressed in massive compensatory switching of the inadequately strong activity of the brain to peripheral effectors becomes leading.

Frequently, the least effective variant of the second type of self-regulation also becomes strongly expressed – the monotonous continuous isometric contraction of the skeletal musculature for purposes of compensatory generation of proprioceptive inflow.

In cases in which in man cortical tonus is chronically decreased and optimal intellectual and emotional dominants which adequately reflect the difficult situations in which the person with a developing neurosis is found are weakened, continual readiness of the nervous system for massive compensatory "abreaction" of excessive emotional excitation (which is not equalized in the closed systems of the brain) is created through various, usually more or less inadequate ideomotor, behavioral and visceral reactions.

In some cases compensatory "abreaction" of extreme excitation occurs primarily through subjective experiences, discussions, forms of fantasy (the person, for example, attempts in place of real resolution of a difficult situation – actual or expected – "to resolve" it in his fantasy).

However, thoughts and subjective experiences are an extremely ineffective "channel" of the first type of self-regulation of higher nervous activity in cases in which a biologically and psychologically positive and adequate for the situation intellectual and emotional dominant which is capable through the third type of self-regulation of organizing and controlling the other types of self-regulation is absent. Therefore, compensatory "abreaction" is usually not restricted to the ideomotor level, but is also carried out through contraction and tension of the skeletal musculature, stereotyped motor reactions, respiratory apparatus, etc.

Frequently, compensatory "abreaction" of excessive excitation occurs through behavioral and speech acts which are inadequate for the situation.

If compensatory "abreaction" is carried out through behavioral acts which are adequate for the situation then this means that the first type of self-regulation is controlled by the third type, that is, by adequate intellectual and emotional motivation and that the person is capable of actively counteracting the development and maintenance of an inadequate emotional dominant.

However, the capacity of a neurotic person to control "abreaction" of emotional excitation through behavior and speech usually is restricted by the capacity to voluntarily suppress external manifestations of a state of anxiety and emotional strain, whereas the capacity for active elimination of the source of anxiety is usually absent or insignificantly expressed.

As a result of voluntary inhibition of the "behavioral channels" of nervous activity, compensatory effector switching is carried out mainly through subjective experiences, skeletal musculature, respiratory apparatus and visceral organs.

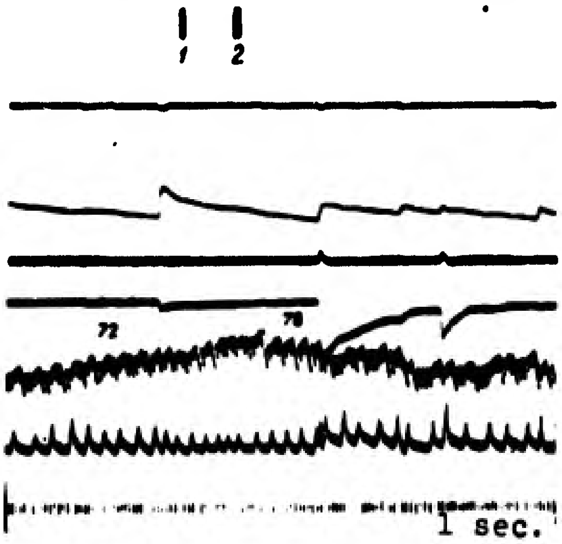
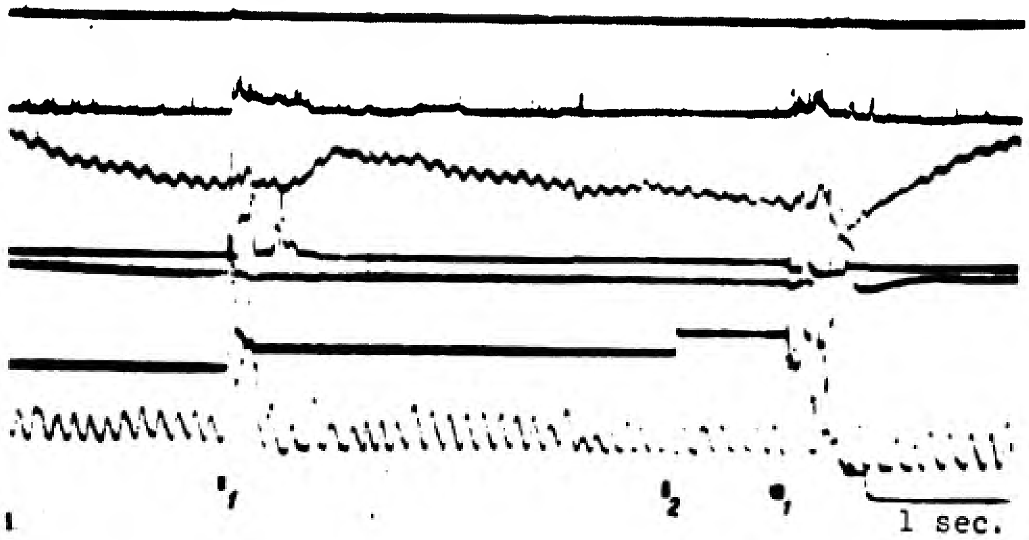


Fig. 93. Compensatory switching of brain's nerve activity to vasomotor centers in healthy individuals (during normal functional state of corresponding visceral effectors) as a result of conditioned reflex inhibition of the activity of the somatic effectors (including the respiratory apparatus). First fragment – compensatory increase in arterial pressure in the experimental dog Dzhek at a differentiated signal (1,2) against the background of conditioned reflex inhibition of the remaining components of a conditioned defensive-motor reaction [see Fig. 19, 20, 88 (3)]; second fragment – compensatory increase in arterial pressure and rise in plethysmographic curve of finger against a background of attempt at voluntary inhibition by subject V.K. (quiet, balanced and disciplined) of motor and respiratory reactions at a strong sound stimulus (pistol shot) (1 – shot; 2 – instructions: "At the next shot suppress any reactions to the shot!"). Notation same as in Figs. 70 and 81.

In experimental animals sharply expressed involvement of the visceral organs in the effector manifestations of the anxiety reaction is observed in difficult states and experimental neuroses in those cases in which cortical tonus is strongly decreased and the higher sections of the brain which organize the animal's active behavior are more or less inhibited.

In a neurotic person sharply expressed compensatory visceral

Fig. 93 continued



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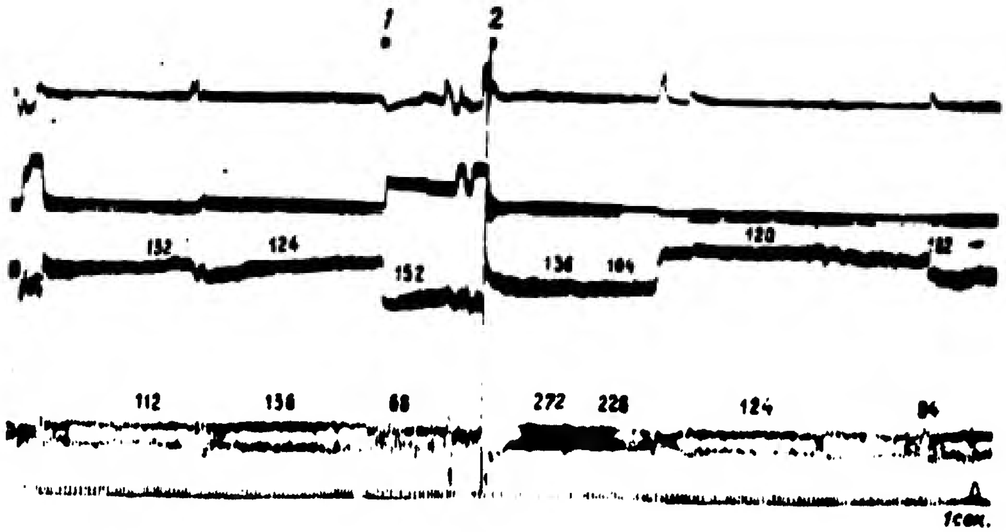


Fig. 94. Compensatory switching of brain's nervous activity to peripheral centers of respiration and coronary activity against a background of complete mechanical blocking of movements of the extremities, femurs, tail and brachial belt in the dog Dzheris (experiments of Yu. Briyedis). *1* – Preparation of experimenter for application of sound stimulus (pistol shot); *2* – shot. From top to bottom: movements of lower jaw; head movements; sphygmogram of carotid artery; pneumogram. A) sec.

reactions can develop both as a result of too strong overexertion of nervous activity of the higher sections of the brain, primarily the cortex of the large hemispheres, and as a result of voluntary systematic inhibition of the behavioral manifestations of the emotional dominant.

It should be noted that intensified involvement of the effectors of the organism's internal environment in self-regulation of higher nervous activity, particularly in the compensatory switching of emotional excitation to the periphery is still not a sign of the development of so-called visceral neuroses.

As clinical observations show, the development of visceral neuroses takes place in the presence of such conditions as: 1) The development, conditioned reflex fixation, internal development and more and more frequent and strong reproduction of those pathological systems of neural links which cause the development of a prolonged, inadequately severe state of anxiety and emotional tension with the prevalence of emotional awakening over cortical awakening; 2) retention of relatively high cortical tonus and level of integration of the person's mental and behavioral activity and in connection with this retention of the capacity through the second signal system to control and suppress subjectively and objectively undesirable external manifestations (in behavior and speech) of the anxiety reaction; 3) inability through second signal system to organize those mental, speech and behavioral acts which could eliminate the difficult situation, that is, the source of the inadequate anxiety reaction; 4) special predisposi-

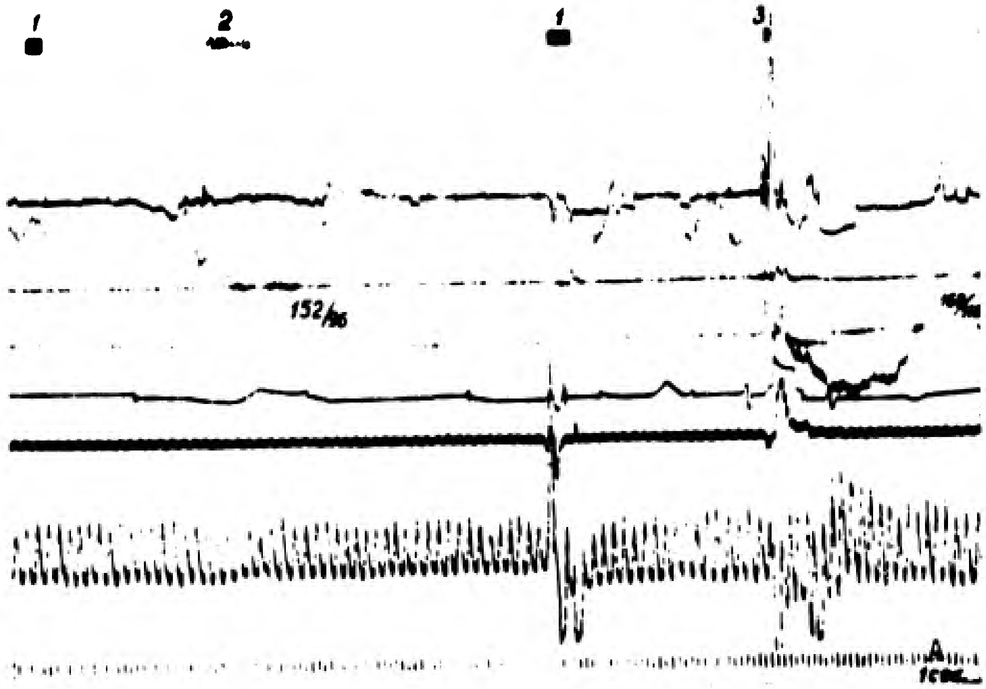


Fig. 95. Intensified switching of brain's nervous activity to vasomotor centers as a result of the development of an anxiety reaction in the subject I.N., a patient with hypertension (at the initial stage of the illness). Subject is distinguished by stable, balanced nervous system, very restrained. First fragment - subject's reaction to first half of observation, second - at the end of the observation after many applications of electrical skin stimulus unpleasant to the subject. 1) Conditioned signal; 2) stimulation of skin of the forehead with direct current impulses; 3) the same as 2, only the stimulation is continued only for half a second in order not to traumatize the subject. Notation same as in Figs. 44 and 90. A) sec.

tion of various central vegetative structures of the brain for their involvement in pathological systems of neural links.

There exists the opinion among clinicians that organs and organ systems whose functions and anatomical structures for various reasons are already disturbed have a predisposition for neurotic disorders. It is also assumed that here innate "weak places" in various tissues and organ systems also have significance.

It was shown in the experiments of Saragea and Foni (1962) that if in dogs which have had experimental gastritis or inflammation of the gall bladder, in the period after recovery, a disruption of higher nervous activity is caused, then as a result of the neurotic state the original illness - gastritis or colecystitis - resumes. On the basis of these, as well as other experiments similar in content, the authors draw a conclusion concerning the leading role of the organism's "pathological history" and functional state of the corresponding higher nervous centers in the localization of visceral neuroses.

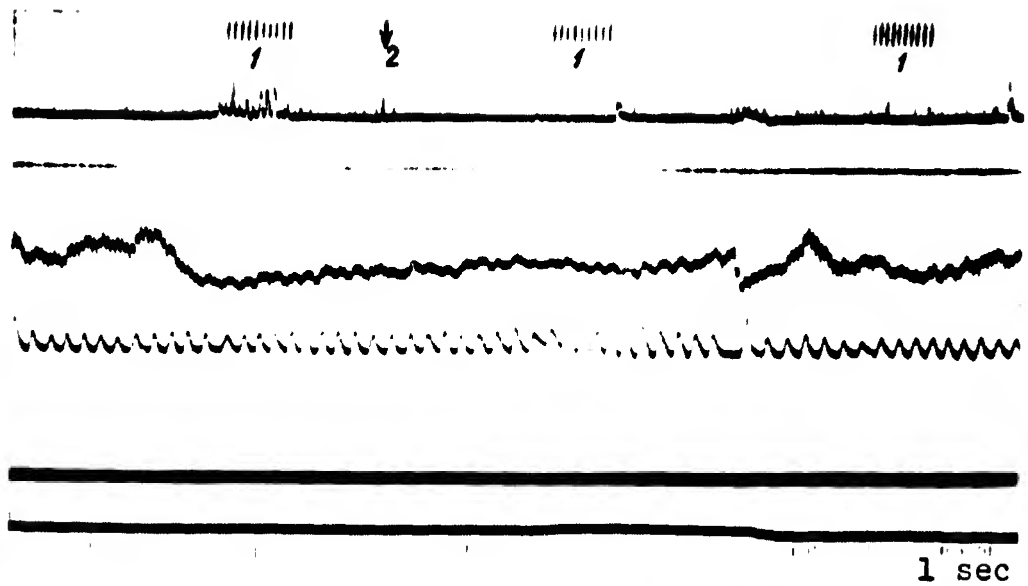


Fig. 96. Intensified switching of brain's nervous activity to the vasomotor centers, increase in arterial pressure and decrease in pulse pressure from the use of a nociceptive stimulus, especially against a background of voluntary suppression of the activity of the comatic components of the reaction in subject Ya. Ya., having a tendency toward hypotension and vertigo. During the observation the subjects sit very quietly, try to be maximally "disciplined." *1)* Ten stimulations of the cornea with a jet of air; *2)* instructions: "Suppress blinking movements during stimulation of eye mucosa!". Notation same as in Figs. 95 and 12, only in place of plethysmogram, sphygmogram of radial artery was recorded.

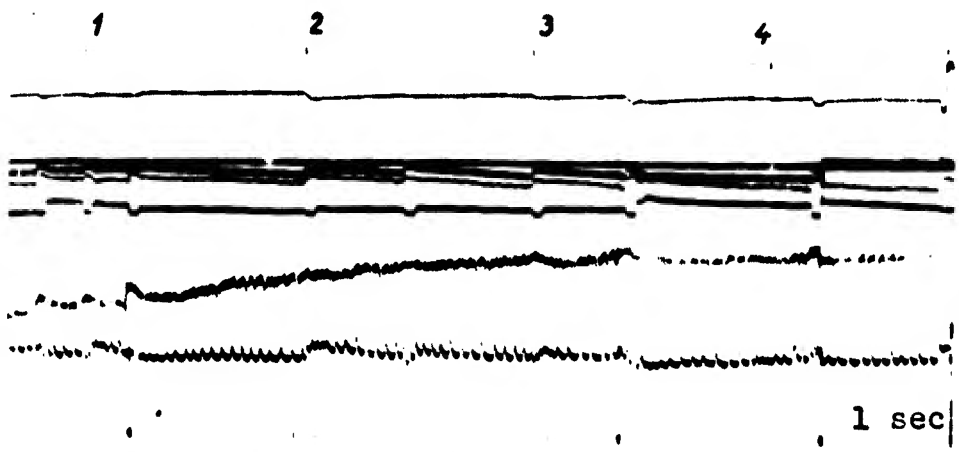


Fig. 97. Intensified switching of nervous activity to vasomotor centers and progressive increase in arterial pressure during extinguishing of stereotype of stimuli and motor conditioned reaction developed by Petropavlovskiy method in the dog Viltsinysh with arterial hypertension, very obedient and equable in behavior. 1-4) Times of applied electrical skin stimuli which ceased several minutes ago. Notation same as in Figs. 51 (3), 78, 85 (2).

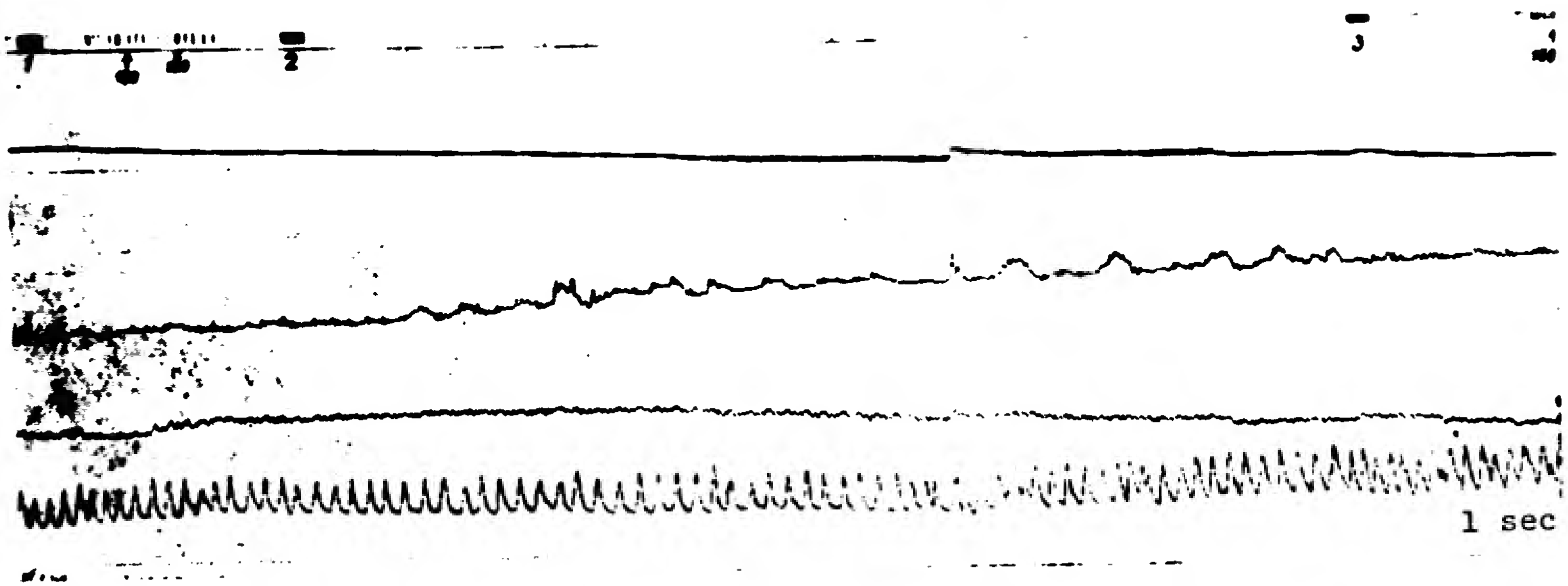
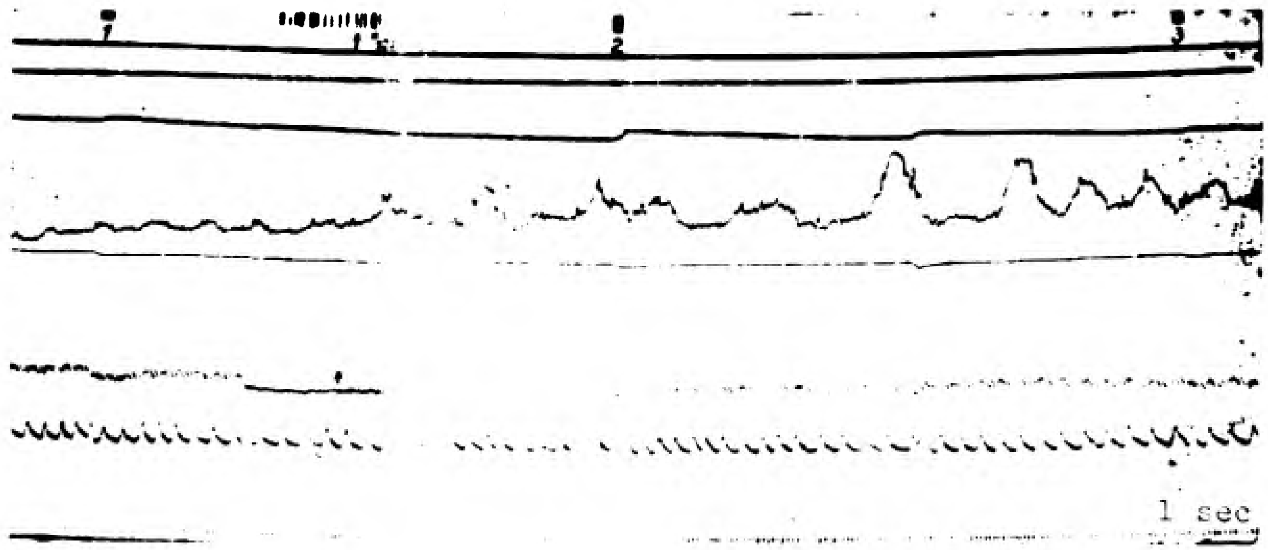


Fig. 98. Intensified switching of nervous activity of the brain, caused by stimuli used and experimental situation, to motor centers of the stomach as a result of stretching the stomach walls with a Kurtsin-Bykov balloon probe (volume of baloon 100 cm^3) in the dog Zigfried. First fragment – temporary cessation of application after a one-minute interval of electrical skin stimulation of the back; second – the development of a new stereotype of stimuli – with a two-minute interval. In all the experiments the dog behaved very quietly. The dog belongs to the I.P. Pavlov strong equable type. 1-3) Electrical stimulation of the back. From top to bottom: secretion of saliva; movements of the lower jaw, head and extremities; stomach contractions; sphygmogram of carotid artery, pneumogram.

Our laboratory observations on practically healthy people, patients, as well as experimental animals, showed that diseased organs or organs whose functions are experimentally changed react to situations of anxiety and emotional strain differently than intact organs. In this case the reactions of the diseased organs to the conditioned stimuli used and the circumstances of the observation session are much more inert, that is, have a longer aftereffect period in comparison with the reaction of normal organs (Figs. 93-101).

In cases in which in the initial period of the neurosis (we have in mind the most common neurosis – neurasthenia, common within certain limits in man and animals) the



internal organs still do not display a tendency toward involvement in chronic neurotic disorders (that is, when the various changes in the functions of the internal organs which develop during an anxiety reaction have a rapidly ascending, episodic character), such a tendency can develop in a later period of the neuroses' development. However, as is well known, in a majority of cases in neurasthenics severe visceral neuroses do not develop even over the course of an illness of many years.

Fig. 99 continued

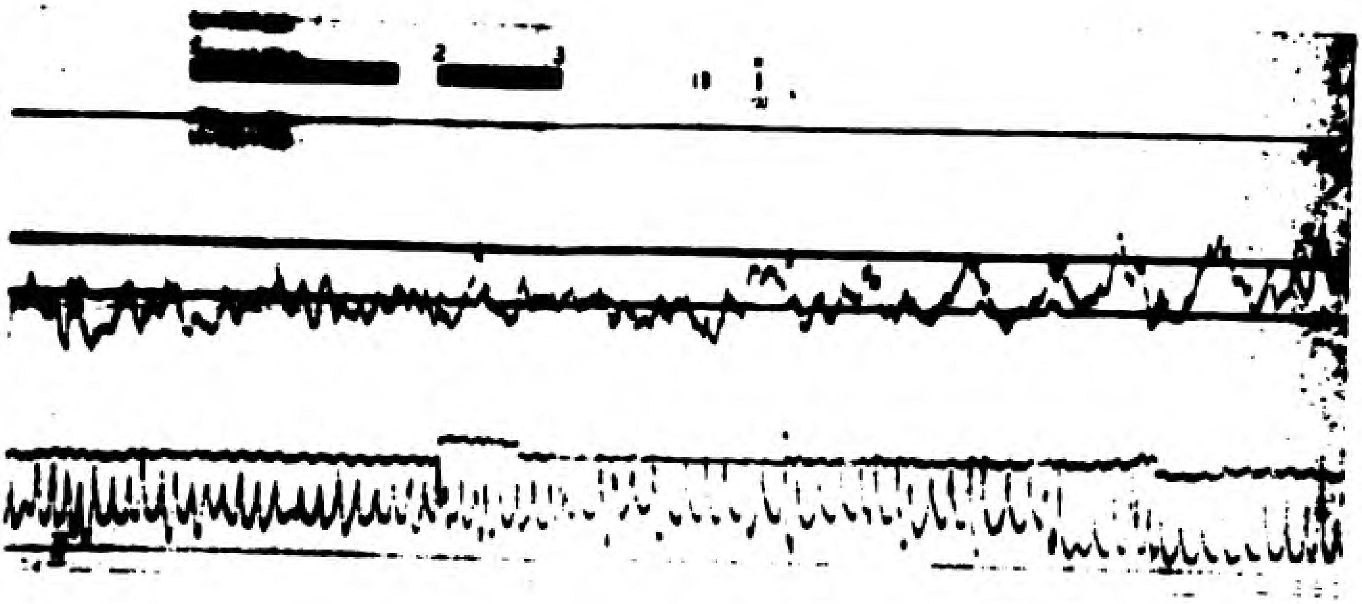


Fig. 99. Intensified switching of nervous activity, caused by conditioned stimuli used and experimental situation, to motor centers of the stomach as the result of stretching the stomach walls with a balloon of a volume of 100 and 250 cm^3 in the dog Margarita (experiments of I. Rotsen-Krauklis) during extinguishing of food conditioned reflexes. First fragment — volume of balloon of Kurtsin-Bykov probe — 100 cm^3; second —250 cm^3. 1) Start of conditioned signal; 2) start of showing of empty feeder; 3) end of signal and showing of feeder. Notation same as in Fig. 98, only without record of movements of lower jaw.

It is possible that neuro-humoral regulation plays a decisive role in this respect. If humoral disorders capable of closing a "vicious circle" of neuro-humoral regulation of the internal organs do not develop during neurasthenia, disease of the internal organs does not develop.

If, as a result of a chronic state of anxiety and of adequately "unabreated" emotional tension, chronic hypermobilization of the adrenosympathetic system, for example, develops, the prerequisites are created for systemic disease of various organs, for example, for the development of hypertension (Kennon, 1937).

Evidently, visceral neuroses are developed primarily in those patients who retain during the illness relatively high cortical tonus and a chronic "battle" takes place between two strong competing dominants — the adequate, chiefly intellectual dominant and the inadequate affective-emotional dominant and when the result of this "battle" is suppression by the person of the external manifestations of the emotional dominant which leads to compensatory intensification of its visceral manifestations.

Thus, visceral neuroses are as if the result of an unresolved chronic battle between two variants of the third type of self-regulation, one of which promotes generation through the second signal system of an inadequately strong and distorted reaction

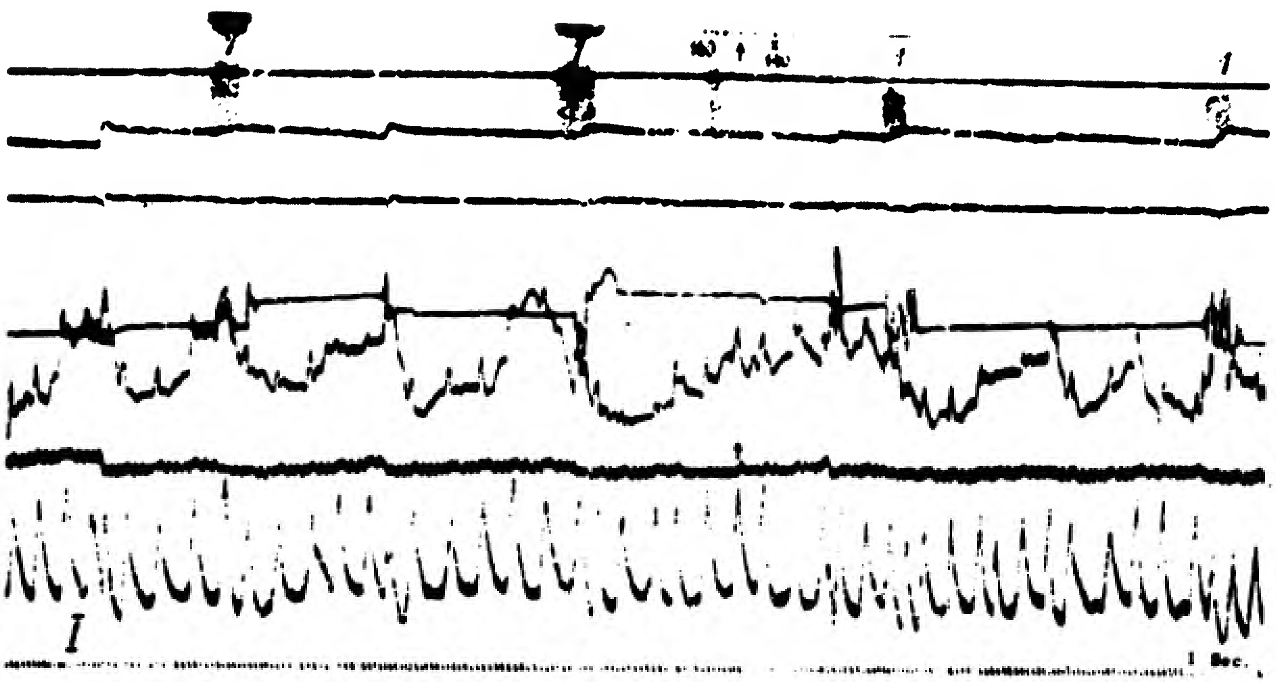


Fig. 100. Intensified switching of neural acticity caused by stimuli used and experimental situation to motor centers of the stomach as a result of stretching the stomach walls with a balloon of a volume of 100 or 250 cm^3 in the dog Margarita during the development of defensive-motor conditioned reactions by the Bekhterev-Protopopov method. First (I) and third (III) fragments – volume of Kurtsin-Beykov probe balloon 100 cm^3; second (II) and fourth (IV) – 250 cm^3; fifth (V) – 50 cm^3. Experiments with mechanical blocking of the stimulated extremity are reflected in the third and fourth fragments. 1) Electrical skin stimulation of the right hind leg; 2) beginning of blocking of movements of the stimulated extremity; 3) cessation of blocking; 4) absence of next stimulus and beginning of extinguishing of developed stereotype. From top to bottom: recordings of arterial pressure; secretion of saliva; movements of head, extremities (total) and right hind leg; contraction of stomach; sphygmogram of carotid artery; pneumogram.

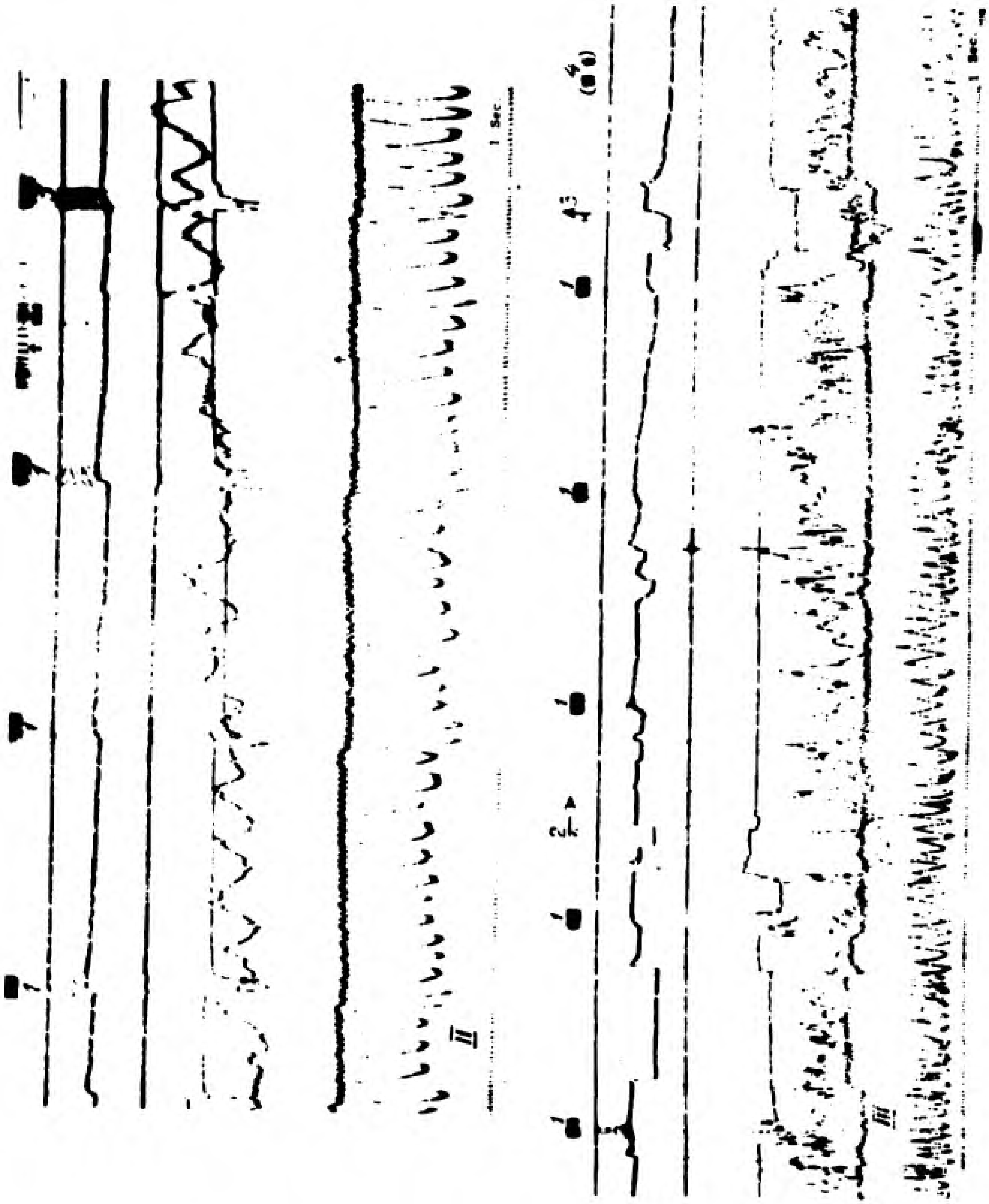


Fig. 100 continued

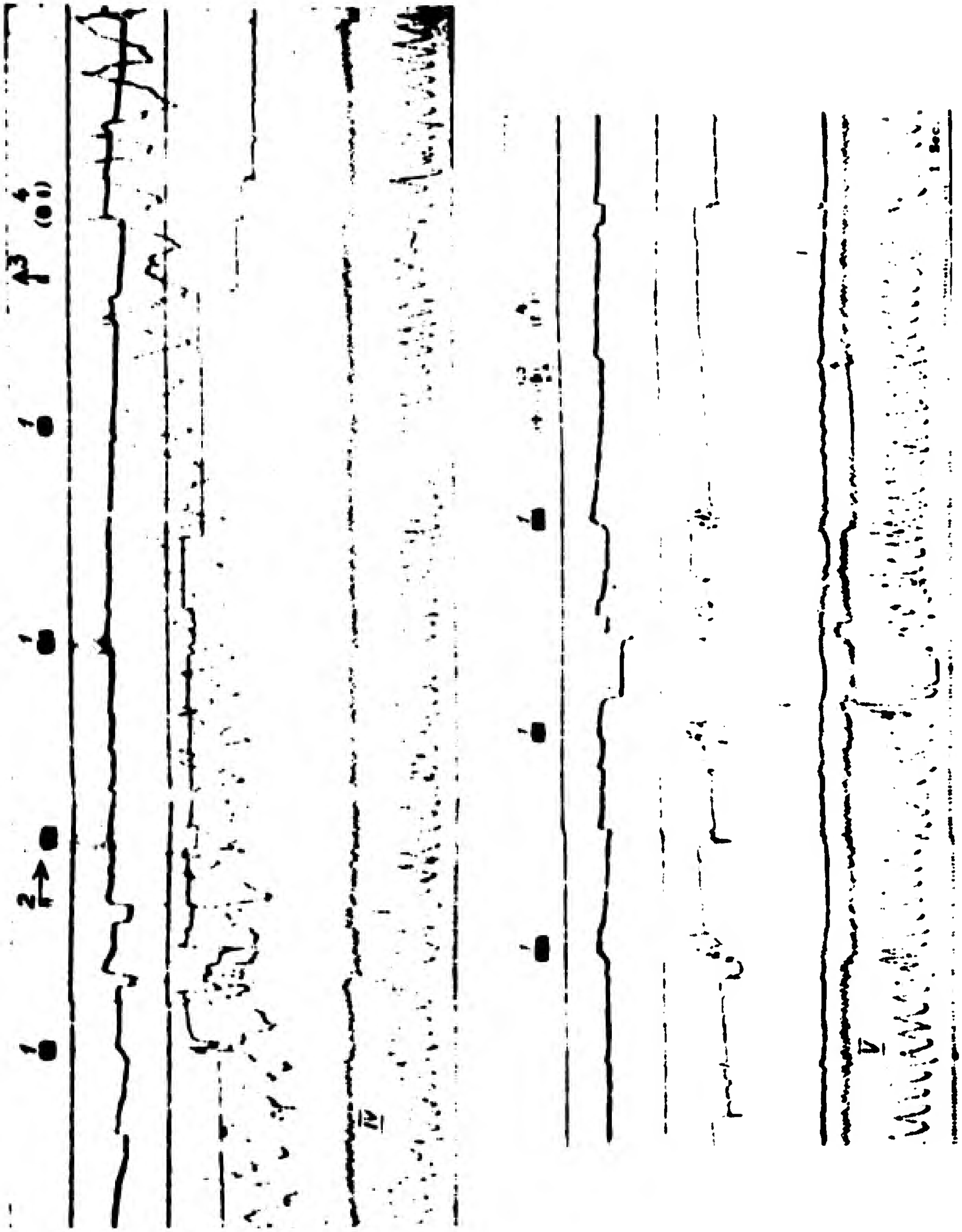


Fig. 100 continued

of anxiety and emotional awakening, while the second promotes generation of the reaction of cortical awakening and verbal (thought) motivation capable of inhibiting the external manifestations of the anxiety reaction.

Neither the first nor the second of these variants of the third type of self-regulation is effective since they do not promote elimination of the difficult situation and optimalization of the conditions of higher nervous activity. Therefore, the result of the "battle" between both variants (that is, dominants), as a rule, is the prevalence of an ineffective and even pathogenic variant of the first type of self-regulation which compensatorily switches the brain's activity through any effector channels, including visceral, which are free of inhibition.

In those neurasthenic patients in whom cortical tonus and level of integration of higher nervous activity are decreased to such a degree that a prolonged "battle" between the above-mentioned dominants cannot develop, and consequently, the emotional dominant cannot obtain the intensity and concentration to involve in its pathological system of neural links various vegetative central structures, a visceral neurosis rarely develops.

In children and adult neurasthenics reactions of the respiratory apparatus and skeletal musculature (movements, or muscular hypertension) prevail during a severe anxiety reaction, whereas in patients with hypertension (in the neurogenic stage), reactions of the cardiovascular system prevail under the same conditions (Figs. 102 and 103).

It is possible that the relatively frequent development in experimental dogs who undergo chronic overexertion of higher nervous activity of experimental hypertension is the result of the development of an extremely severe state of anxiety and emotional tension against a background of systematic inhibition by the animal of behavioral reactions in connection with the fact that these reactions under experimental conditions cannot have any adaptive effect.

The diagrams presented below can serve as an illustration of the role of mechanisms of self-regulation in the origin of psychoneuroses and visceral neuroses (Fig. 104).

The significance of emotional stress in the origin of neurotic disorders of internal organ functions in animals and man has been shown by many investigators and clinicians over the whole world (Pavlov, 1932; Cannon, 1929, 1939; Dunbar, 1938; Alexander, 1939, 1941, 1950; Saul, 1939, 1944; Petrova, 1946; Bykov, 1947; Alvarez, 1951; Bykov, Kurtsin, 1960 and many others).

The role of systematic voluntary blocking by a person of the higher manifestations of severe emotional strain (in speech and behavior) in the origin of visceral neuroses has also been emphasized many times in world literature (Cannon, 1929, 1939; Guthrie, 1938; Saul, 1939; Wolf, 1943; Liddell, 1944; Freeman, 1948a,b; Lang, 1950; Anokhin, 1955, 1958; Myasishchev, 1960 and others).

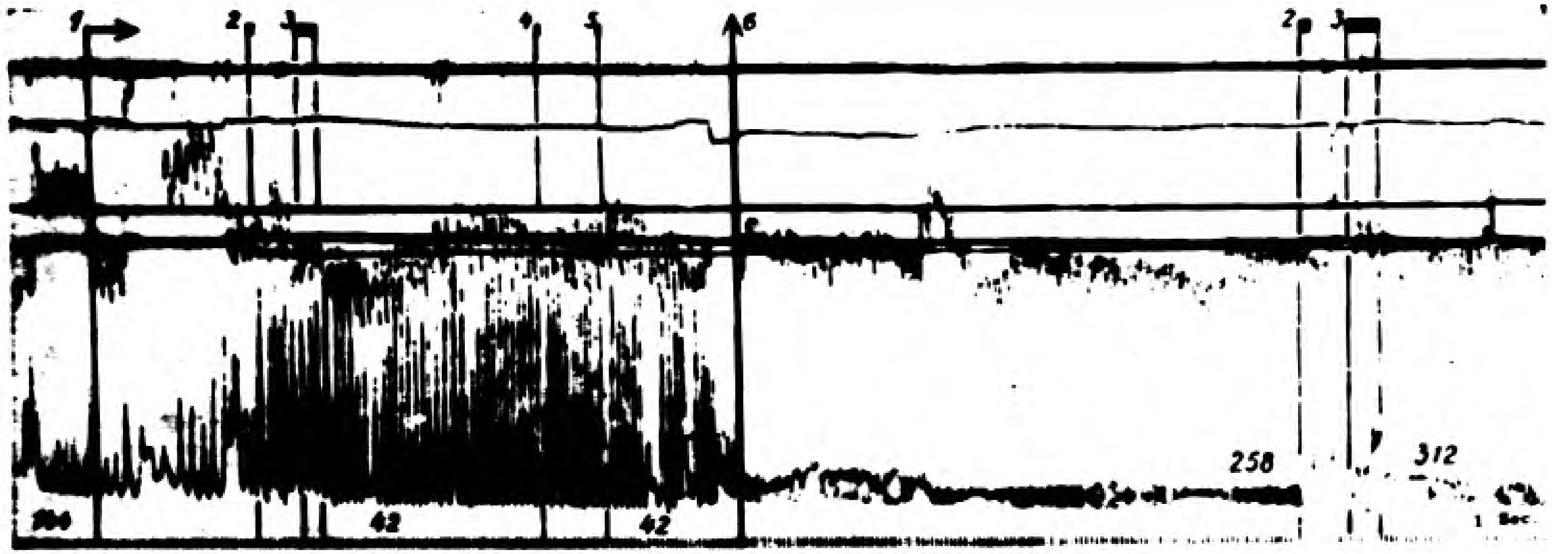


Fig. 101. Changes in respiratory reactions to conditioned and unconditioned stimuli depending on experimental effect on the conditions of respiration by means of decreasing or increasing the diameter of a tube introduced into the trachea in tracheotomized dog (experiments of Yu. Briyedis). 1) Decrease in diameter of trachea tube; 2) conditioned signal; 3) electrical stimulation of left hind leg; 4 and 5) differentiated signal; 6) restoration of optimal diameter of trachea tube. Notation same as in Fig. 23.

We believe that the origin of visceral neuroses is directly connected with disorders in the self-regulation of higher human nervous activity, which are:

1) the absence of effective variants of the third type of self-regulation capable by means of the individual's "self-generation" of positive intellectual and emotional dominants of preventing the development of a state of anxiety which is inadequate and pessimalizes nervous activity, of limbic dominants of fear, anger and "battle readiness;"

2) the persistent prevalence of only one variant of the third type of self-regulation – one-sided inhibition of the external manifestations of a limbic dominant (in speech and behavior) which promotes intensified visceral switching of impulses and maintenance of the emotional dominant;

3) the presence of changed (usually intensified) a-ferent and humoral signaling of one or another region of the organism's internal environment which promotes the development of chronic disturbances in the functions of various organ systems as a result of frequent, strong and continuous involvement of the visceral effectors in the carrying out of the first type of self-regulation.

From what has been stated above the following conclusions pertaining to the prevention and treatment of visceral neuroses follow.

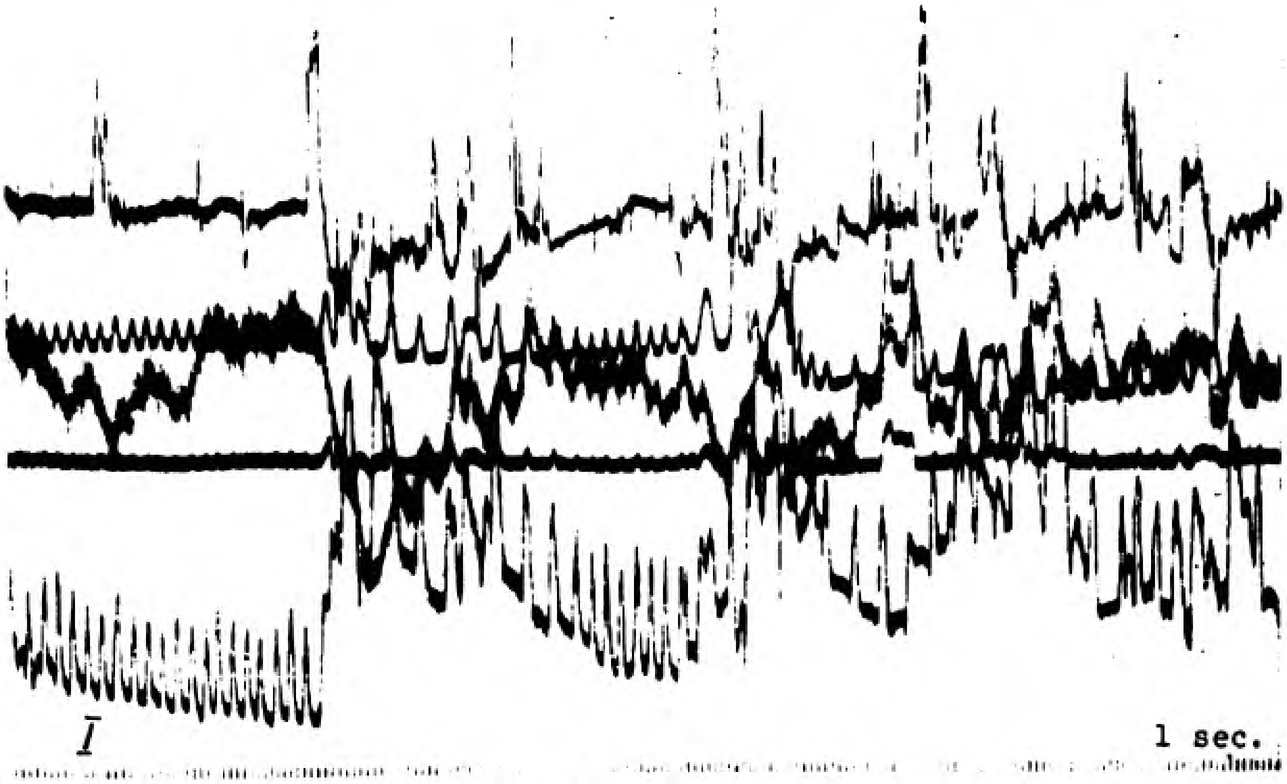
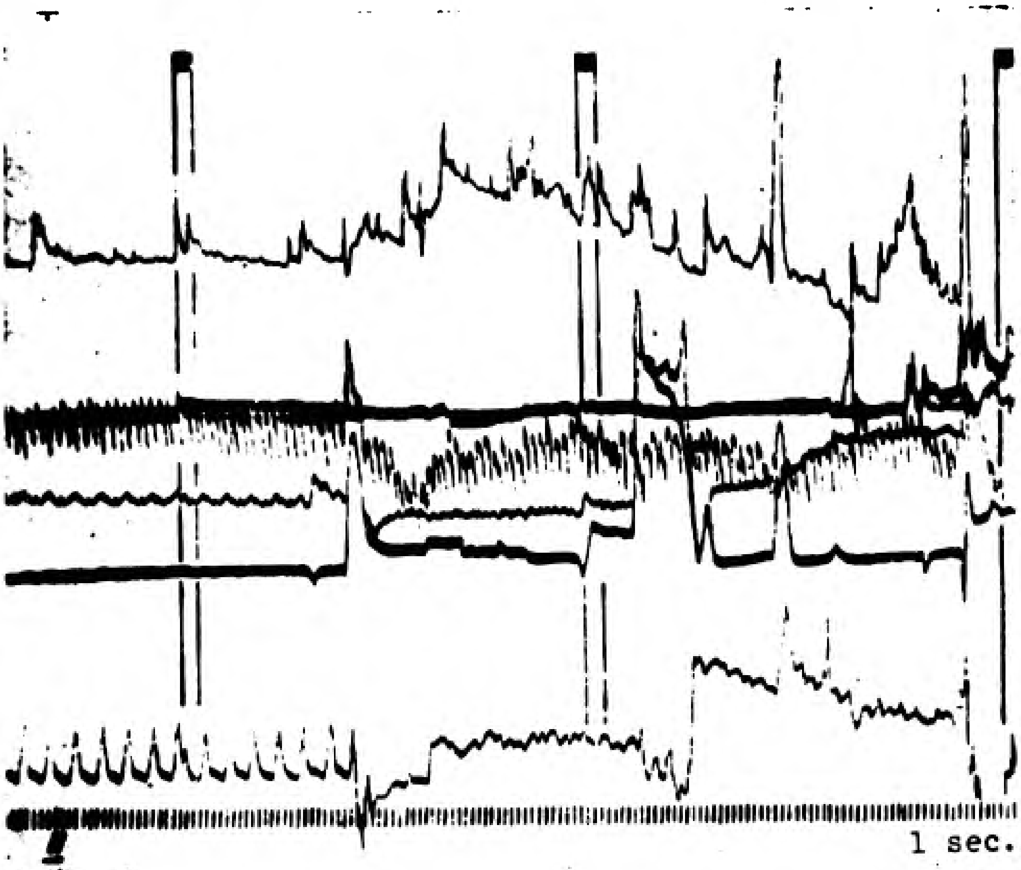


Fig. 102. Primary inadequate intensification of activity of motor effectors and respiratory apparatus during an anxiety reaction and difficult states of nervous activity in patients with neurasthenia (see first three fragments) and primary inadequate intensification of activity of various visceral effectors under the same conditions in patients with visceral neurosis (see fourth fragment). First (I) fragment – neurotic reaction (difficult state) in second half of observations during the development of a blinking reaction to time as a result of a change (shortening) of stereotyped intervals between stimuli in subject E.O., a patient with neurasthenia (stage of increased excitability). Top to bottom: blinking movements; contraction of extensors of knee joint; plethysmogram of finger; contraction of flexors of knee joint; pneumogram. Second (II) fragment – difficult state at end of observation session in neurasthenic subject L.M. during the development of a nonspecific general preparatory reaction on the basis of electrical skin stimulation of the forehead (see Figs. 32 and 43). Third (III) fragment – neurotic respiratory reactions in the dog Zity against a background of chronic overexertion of the animal's higher nervous activity during the development of a nonspecific general preparatory reaction on the basis of electrical skin stimulation of the right hind leg (see Fig. 51(3) and 79). Fourth (IV) fragment – increase in arterial pressure during session in the subject N.N., very reserved (with hypertension) (see Figs. 32 and 43).

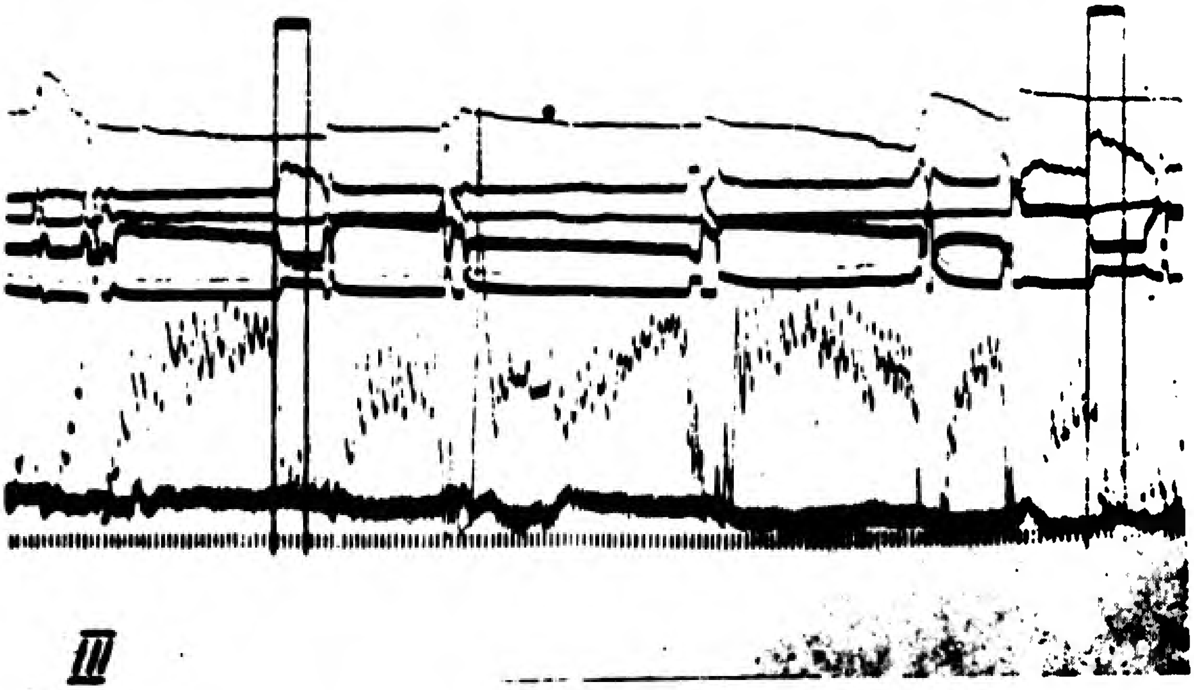
The widespread opinion that the best "means" against the development of neurogenic disorders of internal organ functions is "retraining" of the person's habits of behavior in such a way that the person "learns" to systematically and effectively "abreact" severe nervous tension and emotions can be considered as one-sided.

Considering the fact that the principal cause of the development of visceral neuroses is the more and more frequent reproduc-

Fig. 102 continued

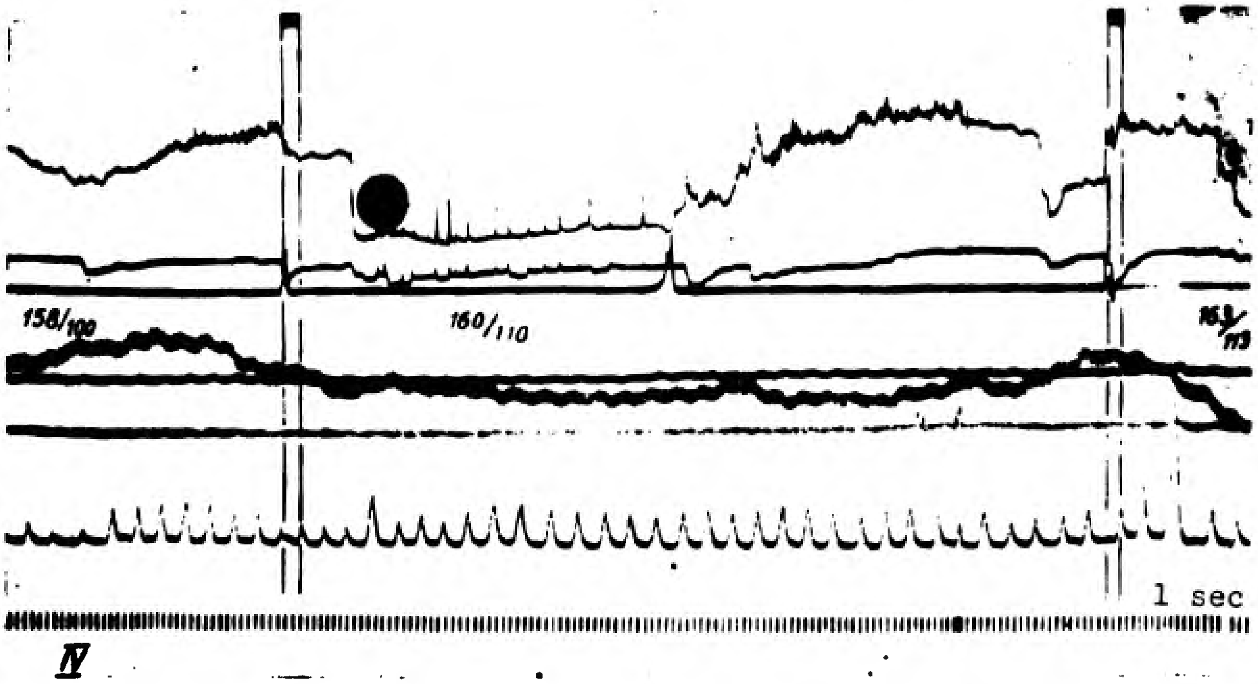


II



III

Fig. 102 continued



tion by life situations and by the individual's second signal system of an inadequately strong and qualitatively distorted reaction of anxiety and emotional tension (that is, of a reaction of limbic awakening), it should be recognized that the preventive measures must be directed first of all toward an increase in cortical tonus and functional reserves of the nervous system and to retraining the person in such a way that in appropriate difficult situations of life sufficiently strong, adequate and positive intellectual and emotional dominants capable of preventing the development of an inadequate state of anxiety and negative emotional dominants are always reproduced in the person.

This means that the individual must "learn" to reflect both intellectually and emotionally more adequately social attitudes and the genesis of difficult situations of life, to better know "himself," to overcome sterile apprehension in the face of possible future failures and misfortunes, as well as an egotistical, frequently painful sensitivity to "personal insults and offenses," to insufficient consideration of the individual's "personal interests" on the part of other members of society, etc.

Fig. 103. Preparatory reaction and aftereffect reaction in the neurasthenic subject V.V. [first (I) fragment] and in subject P.N., patient with hypertension (first stage) [second (II) fragment] during use of strong sound stimulus – pistol shot. Third (III) fragment – dynamics of mean values (from 5 observations) of terminal systolic pressure and rate of respiration in subjects V.V. (black columns) and P.N. (white columns). I) Before preparation;II) during preparation for stimulus;III)1 min after stimulus;IV) 3 min after stimulus. 1) Verbal warning of subsequent shot; 2) shot. From top to bottom: blinking movements; raising of eyebrows (rise in curve) or wrinkling of forehead (drop in curve); contraction of knee joint extensors and flexors; plethysmogram of finger of left hand; arterial oscillogram recorded from right shoulder P_s – systolic lateral, P_m – middle, P_d – diastolic pressure, OI – oscillographic index in mm). Oscillogram (IV) shows principles of the determination of arterial pressure (RR – terminal pressure).

Fig. 103 continued

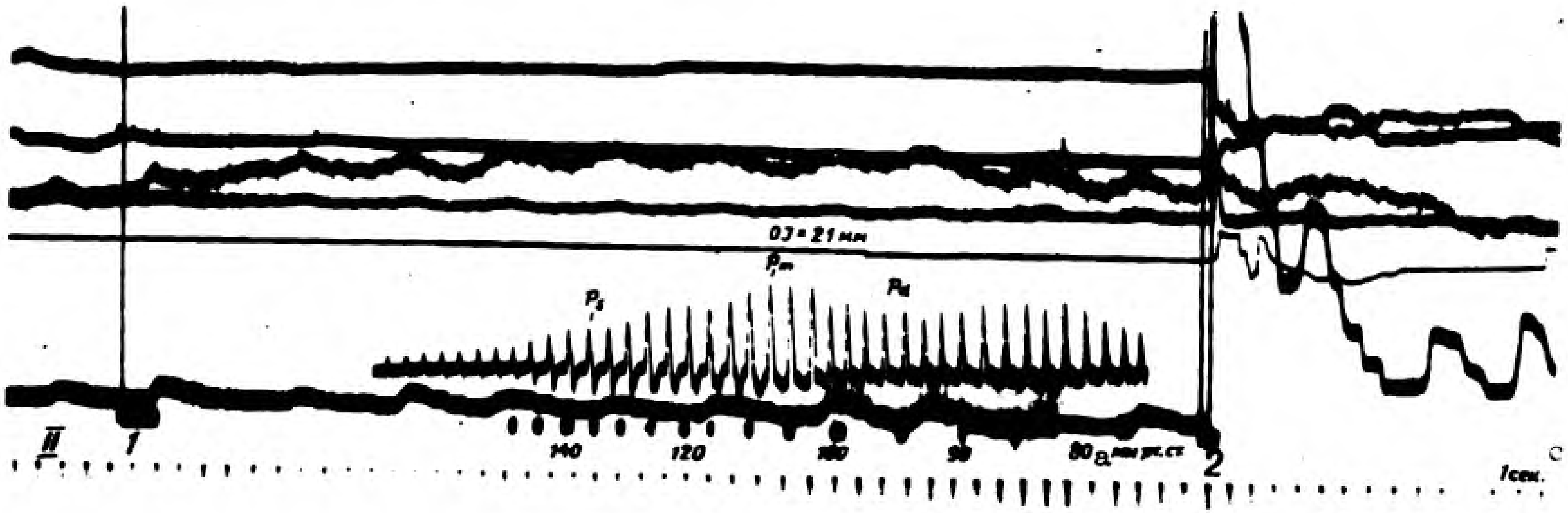
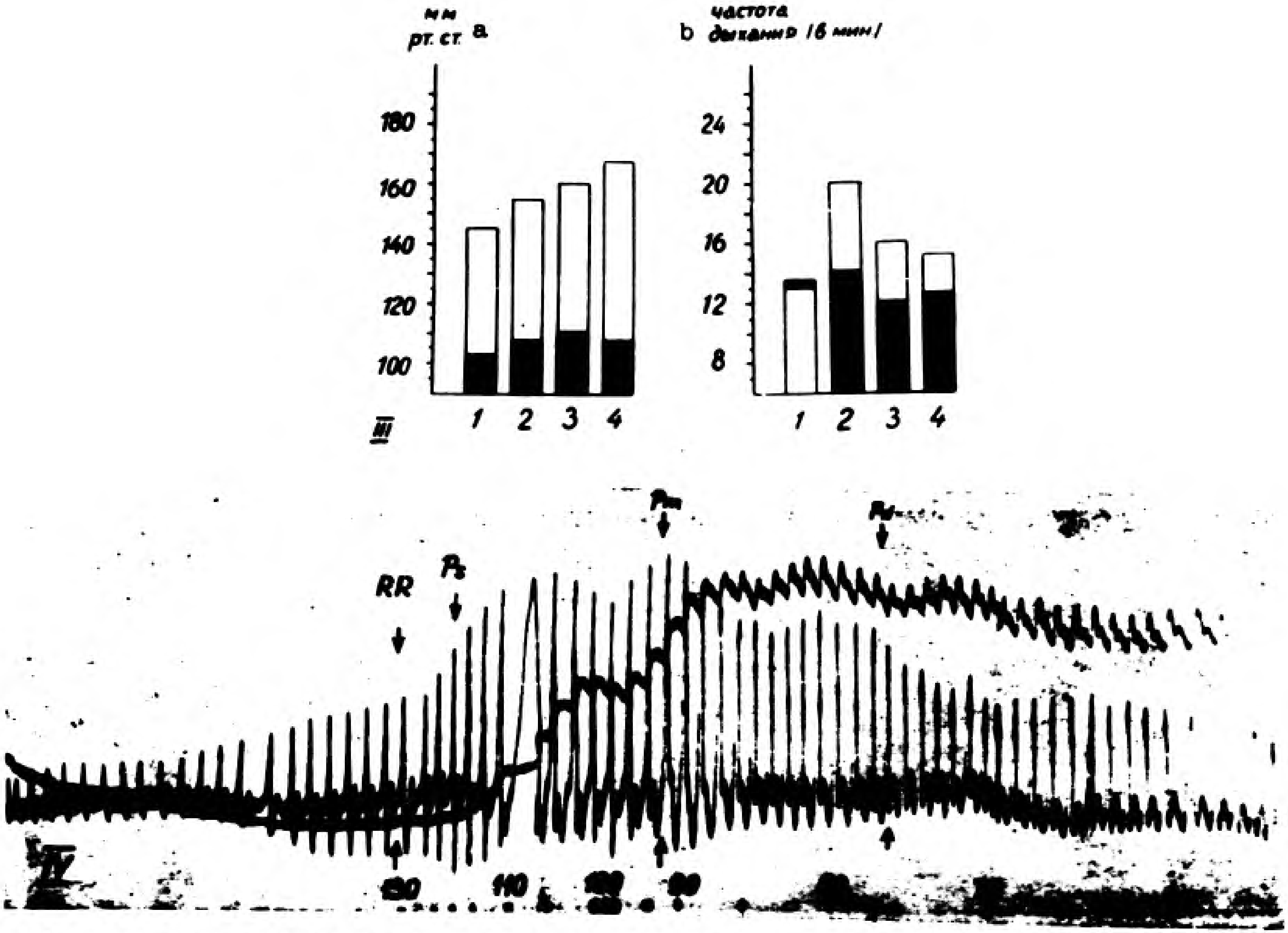


Fig. 103 continued



a) mm of mercury; b) respiratory rate (in min); c) sec.

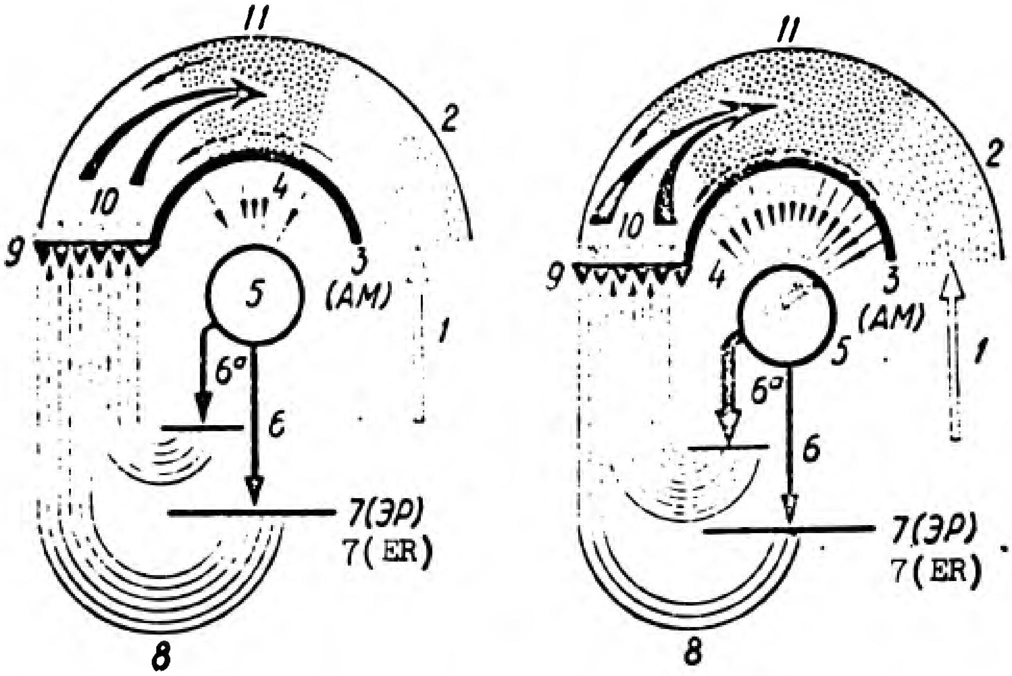


Fig. 104. Diagrams of origin of psychoneuroses and visceral neuroses. Notation same as in Figs. 48 and 49.

At the same time it is very important to instill socially adequate and physiologically and psychologically effective forms of "abreaction" of that excessive emotional strain which may arise in spite of the individual's attempts to prevent its development.

It is necessary to take into consideration that socially inadequate abreacting of emotions, as a rule, in the final analysis only deepens conflict and other difficult situations of life.

Of course, the principal form of adequate and effective "abreacting" of emotional tension in man is interesting, absorbing creative work and fruitful social activity.

The communist education of Soviet people is directed toward developing in the individual adequate forms of creative work and social activity, and the development of socialist society provides in an ever increasing measure the material and social conditions for free manifestation of all the positive intellectual and emotional potentials of people. Therefore, the most favorable conditions are being created in our socialist society for social and personal mental hygiene and mental prophylaxis and thereby for the struggle with neuroses.

At the same time it should be mentioned that these possibilities are still being used insufficiently and in a very unorganized way since mental hygiene as a science has still not been properly developed by physicians and teachers. In connection with this widespread propaganda of scientifically based practical effective measures of mental hygiene and "mental techniques" cannot be carried out among the population.

However, prevention of the development of visceral neuroses cannot be limited to the provision of optimal conditions of a high level of human mental activity. The provision and strengthening of the health of the entire organism, including optimum neurohumoral regulation of internal organs also has the greatest importance since disorders of the latter are an important factor which promotes repeated, and with time, even continual inadequate involvement of various organ systems in the reaction of anxiety and emotional tension.

Therefore, in the prevention and treatment of visceral neuroses, as of any other forms of neuroses, optimal conditions of work and rest, mental and physical load and nourishment plays a large and sometimes decisive role.

It should be noted that the systematic development of inadequate massive compensatory switching in visceral neuroses (primary switching to the organism's internal environment), in the hyperstenic form of neurasthenia (switching to different effector channels) and phychasthenia (switching occurs in the sphere of the second signal system), as a rule, plays an important role in the strengthening and maintenance of pessimal stereotypes (that is, of "vicious circles") of self-regulation. At the same time, in hysteria free compensatory "abreaction" of extreme emotional stress sometimes can lead to temporary optimalization of the conditions of higher nervous activity. However, in this case a sharp decrease in the level of integration is noted since hysterical fits or their equivalents usually have a socially clearly inadequate character which degrades the person and causes conflict relations of the patient with the people around him. This gives rise to new difficult states of the patient, to new hysterical attacks, and so forth.

CHAPTER 8

SELF-REGULATION OF HIGHER NERVOUS ACTIVITY AND CERTAIN QUESTIONS OF MENTAL HYGIENE AND PERSONAL TRAINING. TYPE CHARACTERISTICS OF SELF-REGULATION

THE PROBLEM OF SIMULTANEOUS PROVISION OF OPTIMAL CONDITIONS AND SOCIALLY ADEQUATE LEVEL OF HUMAN HIGHER NERVOUS ACTIVITY

§1. As we have emphasized many times, self-regulation of higher nervous activity of animals and man is directed toward the simultaneous establishment of optimal conditions and a level of afferent and effector integration of nervous activity adequate for the situation. It was also noted that a more or less expressed lack of correspondence between both aspects of self-regulation frequently develops.

In animals, lack of correspondence between the level of integration and conditions develops as a result of the reproduction and maintenance by stimuli of the organism's external and internal environment of a level of integration and exertion of higher nervous activity, and involves more or less expressed pessimalization of the conditions.

In man conscious reproduction of one or another thought motivation (of a domant of the second signal system) capable of causing or maintaining a level of integration of brain operation which is too high for the actual energetic and functional resources of the brain or, on the other hand, of consciously avoiding situations requiring a considerable increase in level for the purpose of providing "at any cost" optimal, that is economical and stable, conditions of nervous activity has the greatest importance in the origin of this lack of correspondence.

The mechanisms of self-regulation of the higher nervous system of animals and man are directed toward provision of a stable (and at the same time economical) balance of the brain's neural processes in such a way that the brain's activity, in its turn, can provide a stable balance of the organism with changing conditions of the external environment.

It follows from this that the highest adaptive effectiveness is provided by those mechanisms of self-regulation which promote the establishment of a level of integration which is adequate for the situation with the help of the nervous activity which takes place within the limits of the optimal conditions.

However, in difficult situations requiring considerable exertion and overexertion of an individual's higher nervous activity, frequently the mechanisms of self-regulation are not in a condition to provide both these indices of adaptive effectiveness — level and conditions of nervous activity — to the same degree.

In such cases, the person's higher nervous activity is faced with a dilemma: whether to sacrifice the level of integration of nervous activity and thereby the quality of the brain's operation in order to stably maintain economical conditions of the brain's operation or, on the other hand, to sacrifice economical conditions of operation and the energetic and functional resources of the brain in order to provide a level of integration adequate for the situation.

In order to resolve this dilemma adequately, the person's brain must adequately reflect not only the biological, psychological and social importance of the actual situation, but also the importance of probable subsequent situations, that is, extrapolate to the future. However, for such a detailed and adequate reflection of the conditions of the external environment, the brain must operate (that is, convert actual and previously accumulated information) at a sufficiently high level of activity.

This means that equilibration of the system "individual-environment," or, more accurately, "individual-society," always requires the establishment of a sufficiently high level of the individual's nervous activity and that the very conditions of the person's life are already resolving the dilemma introduced to a certain degree.

A person cannot develop and improve his work and social activity, his personality and relations with other people, without sacrificing more or less systematically economical conditions of his nervous activity in favor of an increase in the level of mental and behavioral activity.

The above-mentioned dilemma has the nature of a dialectical contradiction. All of a person's work and social activity is an indication of the person's more or less tenacious struggle for creative resolution of the dialectical contradiction between the desired high level of intellectual-emotional and behavioral activity (that is, appropriate to the interests of society and growth in the individual's personality) and the actually possible levels accomplishable with retention of optimal conditions of nervous activity.

This contradiction proceeds from the fact of the person's existence as a member of a continually developing society, as a person who must develop together with the society.

It is a source of progressive improvement of higher nervous activity and of mechanisms of its self-regulation. At the same time, it is a source of constant efforts and exertions of the person's higher nervous activity.

The dialectical contradiction under discussion is resolved in such a way that high, that is, adequate, levels of the person's reaction (if they reflect sufficiently adequately the principal features of the world around the person) in the final analysis promote the development of a dominant of the second signal system, that is, of an effective variant of the third type of self-regulation, which is capable of organizing other effective variants (of the first and second type) of self-regulation and of providing the establishment of optimal conditions of self-regulation for the highest levels of integration of higher nervous activity and of also maintaining the optimal conditions and level in difficult situations of life.

A person who thoroughly understands life and the interests of society and who is accustomed under any conditions of life to carry out his work and other social obligations at a high creative level is able even in very difficult situations to mobilize optimal variants of the third type of self-regulation, that is, powerful thought motivations, capable of effectively organizing and controlling all the other variants of self-regulation and in the final analysis of preserving optimal or close to optimal conditions of higher nervous activity.

The life of veterans of the revolution, civil war and the difficult years of the building of socialism in our country who, in spite of incredibly difficult conditions of work and battle, were able to preserve a joy of living, a fighting and creative spirit and high working capacity until old age can serve as a clear example of this.

Thus, a person's capacity to maintain one or another level of integration of higher nervous activity, while preserving optimal conditions of the latter, or on the other hand, of temporarily "sacrificing" optimal conditions in favor of the level of nervous activity, depends a great deal on the quality (that is, social, psychological and biological content) and intensity of the thought dominants which are mobilized by the person's nervous system through the third type of self-regulation, that is, through conscious reproduction ("self-generation") of signal reactions, that is, of thought motivations which organize all forms of self-regulation of higher nervous activity.

As is seen, the third type of self-regulation in man is the principal link both in the establishment of the level of integration and in the establishment of the conditions of nervous activity.

On the person's education, on the social, psychological (including emotional) and biological directedness and adaptive effectiveness of various variants of the third type of self-regulation depends to what degree priority of the level of integration over the conditions of higher nervous activity is provided in the person, or in other words, the individual characteristics, dynamics and resolution of the dialectical contradiction between the priority of the level and the priority of the conditions of higher nervous activity.

The third type of self-regulation in man is first of all self-establishment by the nervous system of the level and conditions of its activity by means of a conscious purposeful volitional act of the individual. In spite of the principal (organizing) role of the intracentral components of the third type of self-regulation, the effector components of self-regulation which provide the subjective feeling and emotional directedness of the self-regulation also have considerable importance in the provision of a secondary adaptive effect.

The first, and especially the second types of self-regulation which are organized by the third type and accompany, as a rule, in a more or less expressed form the latter, act as "instruments" of the third type of self-regulation, providing compensatory adjustment of the afferent inflow and effector switching of nervous activity by means of compensatory effector reactions.

The second type of self-regulation of nervous activity (through the establishment of optimal conditions of afferent inflow) can serve as an effective means of providing all aspects of self-regulation if it is organized and controlled by the third type of self-regulation.

The first type of self-regulation mainly provides maintenance of optimal conditions of nervous activity through establishment of the conditions of the effector current. It is incapable of establishing a level of integration of nervous activity which is adequate for a situation. Therefore, the effector manifestations of the first type of self-regulation, that is, the compensatory reactions, depend entirely on the level of effector integration which is provided by the second and especially, the the third type of self-regulation.

§2. As follows from the above, the mechanisms of the third type of self-regulation of higher nervous activity are connected in the closest way with the process of conscious establishment of a goal for the individual's mental and behavioral activity.

The person, with the help of conscious reproduction of various dominants of thought motives, is capable of directing his higher nervous activity toward maintenance of the priority of high and socially adequate levels of integration even in those cases in which this causes deviation of the conditions from the optimum, or, on the other hand, toward the maintenance only of such levels of integration which can be accomplished under optimal conditions of higher nervous activity.

Every person can find himself in a situation in which he mobilizes creative and socially effective variants of self-regulation, as well as in a situation in which he mobilizes variants which provide primarily optimal conditions of nervous activity. Everything depends on the social and psychological specifics and significance of the specific situation.

As life's experience shows, there are people who in a y socially significant situations try to mobilize the most effective of the available variants of self-regulation in order to resolve the actual problems at a high creative level of afferent and efferent integration of nervous activity.

At the same time, there are people who even in very responsible and socially significant situations are guided by outdated standard stereotypes developed long ago, trying to circumvent fundamental questions, to avoid difficulties and creative searches and thereby an "excessive" strain and load on their nervous systems. Self-regulation of higher nervous activity in such individuals is directed first of all toward the provision in any situations of life of optimal, economical and stable conditions of nervous activity, ignoring a possible decrease and inadequacy of the level of integration of the latter.

In every person at a specific stage of his life, depending on social environment, life experience, education, state of health, particularly of the nervous system, and other factors, there exists a specific "range" of work and social activity and nervous "load" within whose limits he is capable of maintaining simultaneously a sufficiently high, that is, socially adequate, level, as well as optimal conditions of higher nervous activity.

Outside of this range a more or less expressed lack of correspondence between the desired high level and the limited opportunities of self-regulation of the nervous system to provide at this level optimal, that is, economical and stable, conditions of nervous activity can easily develop in the person.

The more frequently and the further the person goes beyond the limits of this range, the more and more frequently and clearly he is faced with the dilemma mentioned in the preceding section – whether to sacrifice temporarily optimal conditions in favor of a high level of nervous activity or, on the other hand, to sacrifice the level of nervous activity in favor of the conditions, that is, of economy and stability of the brain's functions.

Man's ability always to find in the changing conditions of life that sphere of work and social activity, as well as that size load within whose limits he is capable of stably maintaining both a sufficiently high level and also optimal conditions of his higher nervous activity, that is, of maintaining the highest adaptive effectiveness of higher nervous activity is extremely important and valuable.

At the same time, this ability, or "art of living" must be supplemented by the person's aspiration to improve his mental activity and to temper his nervous system and character in order to continually broaden that range of creative activity within whose limits he can retain high adaptive effectiveness of his nervous activity both actually, and also in prospect.

This means that the person must aspire to the accomplishment of more and more complex and socially significant tasks and to find the most creative ways of resolving them, proceeding always from his actual capacities, from those levels of activity which have already been "mastered" by him. In other words, the person must systematically "train" and perfect his higher nervous activity and its self-regulation, while constantly testing in practice the supposed potential capacities of the nervous system and adjusting the set goals and methods of their attainment in accordance with its actual capacities.

It goes without saying that always when we are talking about high socially significant goals whose attainment may require from members of society efforts and exertions of nervous activity going beyond the limits of the above-mentioned optimal ranges of activity, the person must fulfill his debt to society and temporarily sacrifice, if necessary, optimal conditions, economy and stability of his higher nervous activity in favor of a difficultly maintainable, but socially necessary high level of nervous activity. However, if progressive pessimalization of the conditions of nervous activity occurs, it is difficult to continuously "impose" on the nervous system an excessive level of integration. Therefore, in optimalizing the conditions of an individual's nervous activity a positive influence of the surrounding social situation on them acquires decisive importance.

It is well known that in difficult life situations, and particularly in people's struggles for high social goals and ideals, the most effective means of maintaining high tonus of the individual's nervous system, working capacity and joy of life is a mobilizing, progressive ideology (thought motivation), a positive example and the help of comrades.

These factors, by acting on the individual's brain through the second signal system, promote the development of effective thought dominants capable of organizing effective variants of self-regulation of higher nervous activity, which optimalize the latter's conditions.

Thus, the potential capacities of self-regulation, more accurately, of the third type of self-regulation, are determined to a considerable degree by the person's ideological training, by his moral "reserves" and by the ideological and other social factors of the external environment which act on him.

Of course, the above-described range of the load on mental activity within whose limits the individual is capable of maintaining optimal conditions of higher nervous activity depends not only on the person's ideological training but also on the type capacities of his higher nervous activity, acquired stereotypes of behavioral reactions, general state of health, ability to employ systematically effective physical exercises and general hygienic measures for purposes of hygiene of the nervous system and many other factors.

Of these factors, two groups require individual examination: first, all those factors which are connected with the hygiene of higher nervous activity and, second, the type characteristics of self-regulation of higher nervous activity.

THE EFFECTIVENESS OF SELF-REGULATION OF HIGHER NERVOUS ACTIVITY — THE PHYSIOLOGICAL BASIS OF MENTAL HYGIENE

§3. In the preceding chapters we attempted to show that effective self-regulation of higher nervous activity has the greatest importance in providing high adaptive effectiveness and prevention of disorders of a person's mental activity.

As has been emphasized many times, the principal type of self-regulation in man is the reproduction of adequate and optimalizing dominants of the second signal system capable of organizing all the types and variants of self-regulation for provision of high efficiency of mental activity. The reproduction of these dominants is carried out by a person more or less consciously, however, far from everyone has an idea of the physiological mechanisms of self-regulation.

There can be no doubt that knowledge of the fundamental principles of self-regulation of nervous activity can significantly broaden the possibilities of a person's conscious direction of his mental activity.

By knowing of the existence of self-regulation of nervous activity and its subjective and objective manifestations, a person is capable of recognizing, knowing himself and other people more deeply,and thereby of reflecting and transforming the external world more adequately, particularly relations between people.

By knowing, taking into account and carrying out in everyday life effective variants of self-regulation of nervous activity, a person carries out hygiene of his own higher nervous activity.

Hygiene of higher nervous activity, or mental hygiene, as a medical and psychological science has still not been properly developed. In the future it undoubtedly will become the most important link in the general hygiene of man.

It is well known that a person's mental activity has a tremendous influence on all the functions of the organism. Medical practice and a person's everyday life confirm that optimal and adequate mental activity acts as a powerful protective factor which counteracts the harmful influence on the organism of various nociceptive agents — climatic, toxic, traumatic (including mental traumas), physical and mental overfatigue, etc.

Therefore, mental hygiene, that is, mental prophylaxis, when it is scientifically developed and widely popularized among the population will acquire great importance in the provision of health, high efficiency of mental activity and growth of the person's personality.

Many branches of the biological and social sciences, first of all, neurophysiology, neurocybernetics, psychology, the physiology and psychology of labor and physical culture, pedagogical science, medicine (particularly, the prevention of disturbances in nervous activity and neuro-humoral regulation) and others united by a theory of the self-regulation of mental activity from our point of view must be the theoretical basis of mental hygiene as a scientific discipline.

The physiological content of mental hygiene is more and more stable maintenance by the individual's nervous system of optimal conditions at higher and higher levels of integration of nervous activity in any socially significant, including difficult, situations.

Evidently, a person's capacities to develop more and more effective means and methods of mental hygiene are unlimited in principle, but actually are limited by the specific social conditions and external environment in which the individual finds himself.

Scientifically based mental hygiene only in our time is obtaining a firm foundation for successful development. At the same time, in the history of human society on the basis of empirical observations the most diverse methods and systems of measures directed toward the provision of stability and equilibrium of a person's mental activity in any, even the most difficult conditions of life have already been developed and tested.

In connection with the fact that a person's voluntary regulation of his higher nervous activity can be carried out by three principal methods: by means of an influence on the external world and by means of the reproduction of various dominants of the second signal system, that is, ideological motivations, the specific means or methods of mental hygiene use primarily one of these methods of a secondary effect on nervous activity.

Since the specific expressions of self-regulation of higher nervous activity in many, if not all, respects are determined by the social structure and ideology prevailing in the given era and in the given country, in our day – in Soviet society – of all the numerous and diverse methods and means of mental hygiene empirically developed by past generations, we can use mainly those at whose basis lie the secondary influences of the individual on his mental activity through physical exercises.

Therefore, from the whole tremendous "arsenal" of methods of empirical mental techniques of the past, we are interested first of all in methods of self-regulation of nervous activity through a person's rational change in the functioning of the respiratory apparatus, skeletal musculature, cardiovascular system, sensory organs, digestive tract, etc. The experience of past centuries must be used in the development of scientifically based recommendations for present day man on how, for purposes of mental hygiene, to regulate most effectively conditions of respiration, muscular activity, extero-, proprio- and interoception, work and leisure conditions, conditions of intellectual and physical work.

It should be considered that various methods of mental techniques, for example, respiratory gymnastics, physical, dynamic or postural-tonic exercises, tension or relaxation of the musculature, a change in the system of sensory organ stimuli, concentration of attention on various subjective sensations and organ functions, etc., promote only steady provision of optimal conditions of nervous activity necessary for economical and stable maintenance of the desired level of integration of nervous activity. The establishment itself of a specific (desired) level and specific type of integration of nervous activity occurs through the person's reproduction of various dominants of the second signal system, that is, ideological motives. Therefore, the selection of specific forms of mental techniques is determined by those ideological motives and desired levels of integration of the person's higher nervous activity by which and for the sake of which mental hygiene is organized.

Many of the empirical systems of mental techniques developed in the past, for example, various methods of asceticism, physical and respiratory exercises of Indian and Tibetan yogas and Buddhist monks, etc., are directed toward the provision of those levels and types of integration of nervous activity which promote closing of the person in his own "inner world," rejection of creative labor and social activity, realization of religious reflections, experiences and effective auto-suggestion of various ideological motivations which usually reflect in a distorted way the world around the person, the purpose and meaning of human life.

Therefore, in reviewing from the viewpoint of modern achievements of science the "traditional arsenal" of mental techniques, it is necessary to proceed from the interests of our socialist society, from the interests of the communist education of Soviet people, taking into account that many empirical methods of mental hygiene developed in social structures of the past may prove to be very inadequate for members of today's most progressive social structure — socialism.

In developing effective methods of mental hygiene, it should be taken into consideration that all the measures must promote improvement in the creative functions of mental activity and the provision of a socially adequate dynamic form of human life.

A person's systematic use of mental techniques which ignore the necessity for provision of socially adequate levels of integration of nervous activity, that is, of adequate reflection of the surrounding social environment and adequate social activity, promotes degradation of the personality and runs counter to the interests of socialist society.

In connection with this it is necessary to consider the following very important fact. Sometimes the tenacity of various prejudices, outdated or reactionary opinions, as well as illusory ideas, dreams, belief in God, etc., which take place in one or another person is explained not only by social and gnosiological roots, but also by the fact that these prejudices, opinions or ideas have important significance in the stereotypes of the regulation of the person's mental activity.

Any attempt to alter these stereotypes requires from the individual the strongest exertion of mental activity and involves a sharp deviation of the latter's conditions from optimum. As a res' .. ,se variants of the third type of self-regulation are mobilise_ in the person which intensify to an even greater degree the old dominant systems of ideological motivation for the purpose of inhibiting the new conflicting dominants.

Therefore, it is very important that any adult, conscientious member of our society know and understand in general outline the physiological mechanisms of self-regulation of mental activity. This understanding can help him considerably in the difficult process of overcoming prejudices and incorrect opinions, and most important - to mobilize in good time effective and optimal variants of self-regulation in order to prevent the development and strengthening of inadequate and distorted forms of ideological mental hygiene among which, for example, various religious convictions, a tendency toward mysticism, irrationalism, as well as the ideology of fascism, racism, militarism, etc., belong.

The experience of the historical development of society and its scientific generalization - the theory of Marxism-Leninism - shows that the leading factor providing the development, distribution and maintenance of different forms of reactionary ideology is the objective social interest in these forms of ideology of various ruling circles of the dominant class.

At the same time, those physiological and psychological mechanisms of the self-regulation of higher nervous activity of man which determine the individual's tendency toward the provision of optimal conditions of nervous activity at any stereotyped levels of integration (which are determined, for example, by previously acquired reactionary opinions and prejudices) also play a certain role in the strengthening and inert maintenance of reactionary and anti-scientific opinions, and particularly, religious opinions.

In studying the physiological and psychological side of a person's sometimes very inert maintenance of opinions which are very inadequate for social activity, it should be considered that the intellectual and emotional directedness of the person's mental activity is determined, first, by the leading factor - the person's social environment and external situation, and second, by the person's inner environment, among which previously acquired and fixed stereotypes of the reflection of the world and self-regulation of the conditions of mental activity also belong.

Therefore, the effectiveness of the ideological struggle with prejudices and outdated opinions can be increased if not only the inconsistency of their opinions (which is undoubtedly most important)is demonstrated to the appropriate people but also those causes, including the above-noted mechanisms of self-regulation of mental activity which promote the strengthening and reproduction of inadequate opinions are shown.

Conditions for social mental hygiene which encompasses all members of a society can be created only by socialism and communism, that is, by a social structure where there is no class antagonism, objective antagonism between the individual's interests and society's interests, in connection with which the broad development of personal mental hygiene of all members of society is only possible under socialism and communism.

Personal and social mental hygiene are inseparably linked and mutually dependent. Personal mental hygiene can be successful only when the surrounding social environment, that is, the social relations between people at work, at home, in institutions, etc., is friendly and comradely. And on the other hand, there can be such relations between people only when the individual, in trying to accomplish his own personal mental hygiene, at the same time actively helps in carrying out the mental hygiene of his comrades.

An egotistical, individualistic "mental hygiene" can prove to be very harmful for the people around and, in the final analysis, harmful for the individual himself.

In having a specific social foundation, the above-mentioned antiscientific, reactionary and antihuman ideologies are "fixed" in the brain of one or another person with the participation of mechanisms of self-regulation of higher nervous activity and themselves become components of this self-regulation.

The task of true scientific and humane mental hygiene is to prevent the possibility of the accomplishment of such "ideological diversion" in the mind of man.

It is clear that individual, or personal, mental hygiene alone does not have the power to provide for all aspects of the creative development of the personality. Individual mental hygiene can be properly humane and successful only when it is realized against a background of social mental hygiene and when each individual considers the interests not only of personal, but also of social mental hygiene.

TYPE CHARACTERISTICS OF THE SELF-REGULATION OF HIGHER NERVOUS ACTIVITY

§4. It was shown in the preceding chapters that the different types and variants of self-regulation of higher nervous activity which we examined are compensatory mechanisms which promote the provision of as high as possible general adaptive effectiveness of higher nervous activity.

The most rational and simple characterization of self-regulation undoubtedly is characterization of self-regulation according to the degree of its adaptive effectiveness which determines self-regulation, proceeding from the most objective and most important social aspects of the individual's activity – from the socially significant actual result of his nervous activity.

Of course, the degree of the adaptive effectiveness of the mechanisms of self-regulation do not reflect the type characteristics of these mechanisms. It is determined by the training, education (general and specific), social and particular working experience of the person, by the specific social and psycholcgical situation and interests of the person in fulfilling those tasks by which the effectiveness of his higher nervous activity is evaluated, as well as by the general state of health, by the functional state of the nervous system and by other changing factors of the organism's external and internal environment.

It is impossible to determine the adaptive effectiveness of the higher nervous system "in general," it can be determined only concretely for a specific situation and a specific area of knowledge and working habits of the person. For example, it is possible with the help of special tests, as well as of daily observations of the specific working activity of a specific person to characterize the effectiveness of his nervous activity in resolving specific tasks under specific conditions.

In order to obtain a more thorough notion of the effect veness of an individual's nervous activity in different life situations and during the resolution of various tasks and assignments, it is necessary to know this individual's life experience well, as well as to carry out extensive and many laboratory investigations of his nervous system. And even in that case, it will be possible to speak not about the effectiveness of nervous activity "in general," but only about its effectiveness under specific conditions.

As is seen, a characterization of a person's self-regulation by degree of its effectiveness can produce very valuable data for labor practice, however it cannot give an idea of the type characteristics of self-regulation.

In order to characterize the type characteristics of self-regulation of higher nervous activity of animals and man, it is necessary to determine those more or less constant stereotypes of the compensatory equilibration of nervous activity with whose help the individual usually carries out self-regulation.

These stereotypes change and are perfected depending on the person's life experience. In order to determine the hereditary characteristics of self-regulation it would be necessary to study stereotypes of the individual's self-regulation over the course of many years. In connection with this, that which we will call type characteristics of self-regulation are the stereotypes of self-regulation which dominate under given conditions and in a given period of the individual's life.

An analysis of these stereotypes shows which deviations of the conditions of nervous activity prevail in the given individual, for example, during severe intellectual strain of the nervous system, during severe emotional excitation of positive or negative significance, during states of anxiety and expectation of the development of potentially nociceptive stimuli, etc.

Does deviation of the conditions in the direction of inadequate predominance of incoming and circulating nervous activity which requires mobilization of mechanisms of prophylactic and compensatory switching of the brain's activity to the periphery develop easily? Is the brain capable of retaining a large number of activity impulses in closed systems? Does the brain require a regular compensatory increase in afferent inflow? Is this compensatory inflow provided primarily through stimuli of the external world or with the help of an increase in proprio- and interoceptive inflow? Does compensatory generation or compensatory "abreaction" of nervous activity take place through a second signal system or primarily through behavioral or visceral reactions?

All these, as well as many other questions of the same order are extremely important, however it is necessary to systematize them. The answers to them are capable of characterizing very exactly the type differences not only of mechanisms of self-regulation, but also of a person's entire higher nervous activity.

As is seen, this type of physiological and adaptive characterization of higher nervous activity and its self-regulation makes it possible to judge the character of a person (and of animals), that is, how adaptive effectiveness of an individual's nervous activity is provided, for which levels of integration the optimum of nervous activity is maintained and how various deviations from the optimum are compensated.

§5. The types of higher nervous activity of animals and man described by I.P. Pavlov characterize the dynamic equilibrium between the activating and inhibiting (of the reflex act being studied) effects of the brain, and in connection with this, the relative intensity and mobility of these effects.

The Pavlovian typology makes it possible to judge the temperament of a person or of animals, as well as the relative significance of intellectual and emotional activity in the organization of the person's behavior.

Thus, by combining a study of the indices of higher nervous activity worked out by I.P. Pavlov with a study of the stereotypes of self-regulation of higher nervous activity, it is possible to obtain data permitting one to give a physiological basis to the psychological characteristics of personality — temperament and character.

Of course, determination of the type characteristics of self-regulation of a person's higher nervous activity can have practical significance for psychology, pedology, medicine, physiology and labor hygiene, etc., only if it is combined with a determination of the adaptive effectiveness of the person's higher nervous activity under the conditions in which determination of the types takes place.

It follows from this that there must be reliable methods available to the physiologist, psychologist and doctor which make it possible objectively to characterize qualitatively and quantitatively both the fundamental plan (formal model) of the stereotypes (mechanisms) typical of the individual, the self-regulation of the person's higher nervous activity and the adaptive effectiveness attainable with these stereotypes. As is well known, such methods still do not exist.

At the same time, there can be no doubt that progress in the physiology and pathology of the higher nervous activity of man depends in many respects precisely on more or less successful and timely resolution of the question of adequate methods for an objective study of the most important aspects of higher human nervous activity.

We believe that in developing these methods it is necessary to compare data of laboratory investigations with data from objective observations of the human subject's behavior in situations of everyday life, as well as with data from the person's self-observation. This means that the data which was obtained in the observations and which determined the mechanisms of self-regulation should be generalized into concepts which reflect both the psychological and physiological aspects of the observations. These concepts should reflect both the fundamental or formal plans of the self-regulation and also its psychological and social content.

It is evident that mathematical and cybernetic methods of analyzing the complex self-regulating systems should play a large role in the development of such concepts and terms.

We still cannot suggest developed, ready methods for an objective study of the typology of higher nervous activity in man. On the basis of our observations it is only possible to state certain considerations in regard to the direction in which it is expedient to concentrate attention in the development of appropriate methods.

It seems to us that it is necessary to develop two fundamental variants of the laboratory study of type characteristics of self-regulation of higher nervous activity.

1. One variant should be adapted to well-known psychophysiological tests of the characteristics of the professional efficiency of human higher nervous activity. In addition to indices characterizing the primary adaptive effect of the subject's mental activity (for example, the number of correct and incorrect resolutions of the mental tasks applied, time for the resolution of the tasks, etc.), it is necessary to take into account those "secondary" effector reactions (somatic and visceral) which can characterize the first and second types of self-regulation.

In addition, it is necessary to develop a system of measured increases in the subject's intellectual and emotional tension which would make it possible to judge the subject's capacity to mobilize effective variants of the third type of self-regulation which are capable through a second signal system of counteracting the development of an inadequate anxiety reaction with expressed emotional components (whose presence can be found by observation of the dynamics of the indices of the functions of the skeletal musculature, respiratory a-paratus, cardiovascular system and other internal organs).

Data characterizing the properties of self-regulation of higher nervous activity should not count less than the results which characterize the primary adaptive effect of the subject's nervous activity.

If in the subject a correct reaction to the test assignments used is accompanied by relatively slight effector reactions of secondary significance (for example, slight intensification of tonic contraction of the skeletal musculature and intensification of respiration) or if these reactions are absent, it can be concluded that for the given mental load the general adaptive effectiveness of the higher nervous activity is high. If these indices also do not change essentially with a considerable increase in the subject's intellectual and emotional tension, this indicates the individual's capacity to mobilize (through the third type of self-regulation) sufficiently effective dominants of a second signal system capable of preventing the development of a severe and inadequate anxiety reaction and thereby of not allowing deviation of the conditions of higher nervous activity from the optimum.

In cases in which the subject's correct reaction to the test task is accompanied by strongly expressed somatic, and particularly, visceral compensatory reactions, it can be concluded that with the given mental load the adaptive effectiveness of the higher nervous activity requires the mobilization of such compensatory mechanisms which cause an uneconomical expenditure of energy and inadequate intensification of the activity of those organs which do not have a direct relation to the task being resolved.

In cases in which the subject resolves the test task with many errors or too slowly, but at the same time effector reactions of secondary significance are absent or weakly expressed, the conclusion can be drawn that the subject has retained unused relatively large reserves of energy and functional capacities of the nervous system and that the small primary adaptive effect accomplished by the subject during resolution of the test task is explained by the absence of the individual's professional interest, lack of skill or little interest in accurately performing the task.

If an erroneous reaction to the test assignment is combined with sharply expressed compensatory reactions of secondary significance, the subject's adaptive effectiveness in the specific situation is very low.

Data obtained by the above-mentioned method can be compared only among subjects of the same professional group (for example, pilots). They have immediate importance for the evaluation of the adaptive effectiveness of certain aspects of higher nervous activity only within the limits of the test assignments used and with consideration of the specifics of the laboratory circumstances. Data which characterize certain properties of self-regulation of a subject's nervous activity in no case can be used for characterizing types of self-regulation.

In order to study a person's type characteristics with the help of laboratory methods it would be necessary to use a large number of different tests on the subject making it possible to thoroughly characterize self-regulation in different socially, psychologically and biologically significant situations. In this case, it is necessary to carry out observations several times on different days in order to exclude to a certain degree the chance factor. Evidently such methods will be developed in the future, when as a result of the wide introduction into physiological and psychological observations of mathematical methods of treating the material, as well as of principles of cybernetic analysis it becomes possible on the basis of a tremendous amount of individual data to determine strictly objectively and accurately the basic, typical features and tendencies of an individual's higher nervous activity and its self-regulation.

At this stage of physiology's development, it seems to us still impossible to somehow convincingly determine by laboratory methods the type of higher nervous activity and thereby the type of its self-regulation in man.

2. In order to obtain in laboratory observations data permitting one to compare to a certain degree the characteristics of the self-regulation of higher nervous activity in different subjects independently of their profession, education and habits acquired in life, it is necessary to develop a second methodological variant – simple tests which do not have any professional specifics. It is clear that such tests as the solution by a subject of complex arithmetical problems "in his head," etc., are little suited for the above mentioned purposes.

The second fundamental variant of the method of studying self-regulation in man must be as simple and unspecialized as possible.

Our experience shows that tests which cause sufficiently strong unspecific intellectual and emotional tension of the subject's nervous system are very suitable for obtaining comparable data characterizing self-regulation. In this case, progressive tension must be achieved not by progressive complication of the mental tasks being solved, but by accelerating the rate of solving the tasks and by the use in the observation session of signal and nociceptive stimuli which are turned on at an erroneous reaction of the subject.

Some systems of studying self-regulation of nervous activity based on the principles of the above-mentioned second methodological variant and used in our observations are presented below.

PRELIMINARY ATTEMPTS AT AN OBJECTIVE CHARACTERIZATION OF SELF-REGULATION OF HUMAN HIGHER NERVOUS ACTIVITY

§6. One of the orienting systems of studying the type of characteristics of self-regulation which we used consisted of showing to the subject on a screen for several seconds (2-10) a series of numbers (for example, 5, 8, 19, 2, 95) which the subject had to remember and mentally arrange in increasing order (in our example: 2, 5, 8, 19, 95), as well as to find them in the same order in a special table placed in front of the subject and which contained 100 identical squares (that is, 10 x 10) each of which was designated by a number. In all, numbers from 1 to 100 were placed in the table, however, they were not arranged in order. The subject, in attempting to orient himself quickly in the table and not to forget the numbers and their order, had to find and point with a finger (or by pressing the appropriate button) all the squares with the appropriate number in correct order (that is, 2, 5, 8, 19, 95).

After solution of this problem, a new series of numbers was shown on the screen, etc.

When the subject mastered the task, the rate of his solution was accelerated. If the task was beyond the subject's powers, it was simplified: only a small number of figures was shown on the screen and, on the other hand, if the subject resolved the problem rapidly and easily, it was quantitatively made more complicated.

In order to increase the subject's intellectual and emotional tension, after specific intervals of time, a loud electric bell was turned on which signaled the subject that he has "overexpended" the time provided for resolution of the task and that he has to "hurry up" with the resolution of the task.

When there was an erroneous solution of the task or repeated lag in the time set for performing the task, the subject received a "strict warning" – electrical skin stimulation with an induction current.

A correct solution was accompanied by lighting a green light placed in front of the subject.

At the end of the observation session the index of the efficiency of the individual's mental activity which took place during the performance of the tasks was calculated from the number of correct and incorrect answers taking into account the answers solved in the set time as well as those with a delay.

According to a different system of investigation, the subject was shown a large number of numbers on a screen with which the subject, according to instructions, had to carry out simple arithmetical operations (addition and subtraction), and the result – usually a two digit number – had to be pointed out in the above mentioned table (with squares and numbers from 1 to 100).

We used one other system which was the simplest: the subject was shown on a screen for short intervals of time (whose length was established depending on the subject's degree of reaction) one or another number (from 1 to 100) which the subject had to find as quickly as possible and point out (or, after finding it, press the appropriate button) in the table. This variant of the investigations in combination with a periodic warning to the subject that he is not keeping within the time set for performing the task (by means of turning on a loud bell and lighting a red light of a powerful lamp, and with repeated delays – by the use of electrical skin stimulation) in many cases, particularly in children, proved to be a very effective method of provoking a reaction of anxiety and emotional tension which increases in intensity. The latter, depending on the characteristics of the individual's self-regulation of higher nervous activity is accompanied by more or less expressed compensatory reactions - components of the first or second type of self-regulation.

The systems of investigations in which the associative speech motor method developed by Ivanov-Smolenskiy (1952) was combined with the above mentioned warning of the subject by a loud bell and electrical skin stimulation, as well as with the recording of the principal specific and nonspecific components of the subject's behavior gave comparatively good results.

Each of the indicated systems of observations has its own shortcomings. The absence of adequate tests and criteria of evaluating the higher nervous activity of an adult human with whose help sufficiently strong measured tension of higher nervous activity could be experimentally caused, as well as the absence of test assignments whose performance would be associated with the mobilization of different conditions of the activity of the skeletal musculature (for example, static and dynamic work), respiration, cardiovascular system, exteroception, etc., are common shortcomings.

During the entire observation session (before the beginning of solution of the problems, during their solution, as well as some time after cessation of solution of the problems) the following somatic and visceral reactions of the subject were recorded:

1) contraction and tension of the skeletal musculature of the extremities and torso;
2) blinking movements;
3) movements of the lower jaw;
4) respiratory excursions (sometimes abdominal and thoracic respiration separately);
5) pulse rate and regional vascular reactions;
6) arterial pressure.

In cases in which the investigations were conducted on patients with a disease of the digestive tract, the motor activity of the stomach and sometimes also the secretion and acidity of the gastric juice were also recorded.

Of course, it is necessary to modify the "assortment" of recorded components in accordance with the group of patients being studied, including in it the appropriate visceral effectors.

The absence of indices of the dynamics of the metabolism and hormonal changes during the test assignments, as well as after their cessation is an important shortcoming. This shortcoming is due to methodological and technical reasons.

It should be noted that a study by means of psychophysiological tests of the activity of an affected organ or system of organs in patients with certain internal illnesses can give indications of the specifics of the possible participation of these organs in intellectual and emotional tension and anxiety reactions and thereby indicate the importance of disturbances in cortico-visceral relations in the origin or maintenance of the given organ's pathology.

On the basis of 1) the indicated psycho-physiological observations; 2) of observations conducted with the help of methods of developing motor, respiratory, vascular and general preparatory conditioned react-ons and different types of internal inhibition and 3) clinical observations, an orienting classification of the type characteristics of self-regulation of higher nervous activity in man was drawn up. It should be emphasized that by type characteristics we mean not innate or acquired types of self-regulation, but those characteristics of self-regulation which occur in a subject during repeated investigations under given observation conditions and in a given period of life. The following four type variants were distinguished.

The first type variant of self-regulation of an individual's higher nervous activity is carried out primarily by means of the intracentral components of the third type of self-regulation, that is, through the reproduction of dominants of the second signal system which establish optimal conditions of afferent inflow and effector current, as well as an adequate level of integration of nervous activity.

Optimal variants of the second type of self-regulation are used as auxiliary mechanisms, that is, adjustment of the conditions of the afferent inflow by means of changing the activity of the skeletal musculature, respiratory apparatus and exteroception.

The first type of self-regulation, that is, prophylactic and compensatory switching of the brain's activity to the periphery, usually is expressed relatively weakly and is carried out mainly with the help of primarily adequate reactions of behavior and speech, as well as with the help of reactions which are reproduced for purposes of the second type of self-regulation.

Under laboratory conditions of observation a minimal number of inadequate compensatory reactions is noted in a subject both during the application of various stimuli and in the aftereffect period and the intervals between stimuli. The subject's specialized response reactions to the test stimuli or the test-assignments are adequate in form, however, they can be both correct and erroneous in content.

Under conditions of everyday life people who belong to this type variant usually are equable, composed and mentally stable.

People of the given type variant use speech, mimicry, gestures and other dynamic forms of behavior very little for purposes of prophylactic and compensatory switching of nervous activity to the peripheral effectors.

The second type variant. In contrast to the first variant, representatives of this group widely use somatic and respiratory effectors in the self-regulation of nervous activity. In them the third type of self-regulation, as a rule, is maintained by effective forms of the first and second types of self-regulation.

For purposes of compensatory switching of the brain's activity to the periphery, as well as for compensatory generation of secondary afferentation, people of this type intensively use speech and all forms of behavior adequate for the situation in self-regulation.

Under conditions of everyday life these people usually are active, more or less temperamental, but at the same time, equable and mentally stable.

In observation sessions they display nonspecific general motor reactions, sometimes reacts with sharp changes in conditions of respiration, however, upon the appropriate instructions to sit quietly, etc., is capable of observing exactly the "discipline" of the observations.

Inadequate visceral reactions are usually absent, the aftereffect reaction is slight.

The third type variant. In members of this group, both in the observation session and under conditions of everyday life, compensatory isometric contractions of the skeletal musculature, including respiratory, mimetic, chewing, swallowing, sphincters, etc., are frequently extremely strongly expressed.

The third type of self-regulation of nervous activity in these individuals is not capable of preventing, through intracentral components and ideological motivations, but rather, on the contrary, provokes the frequent development of a strong reaction of anxiety and emotional excitation. However, at the same time, people belonging to this group are capable of inhibiting both adequate and inadequate behavioral manifestations of the emotional dominants.

They easily develop inadequate compensatory reactions of the respiratory apparatus and visceral effectors. They tend toward visceral neuroses, as well as toward psychasthenia.

The fourth type variant. In members of this group, somatic and visceral reactions are intensively involved in self-regulation, they frequently develop the most severe inadequate compensatory reactions which are a result of reactions of anxiety and emotional tension which are frequently caused even by stimuli and situations of little significance.

Effective forms of the third and second types of self-regulation usually do not play a leading role in self-regulation, but ineffective or pessimal forms frequently only provoke or deepen difficult situations and difficult states of the nervous system which are accompanied by massive compensatory "abreaction" of emotional excitation which is excessively severe for the nervous system.

Members of this group are inclined toward neurasthenia or hysteria.

As seen from this orienting classification, the type characterization of self-regulation of human higher nervous activity has a certain correlation with the types of nervous systems developed by I.P. Pavlov. However, it demonstrates not the temperament, but the character of a person, showing by which methods of self-regulation the person is accustomed to establish and maintain optimal conditions and an adequate level of higher nervous activity, in what way he is accustomed to use for these purposes relations with other people, to what degree social methods of self-regulation of his nervous activity are in accord with the interests of society or conflict with them.

An objective characterization of the properties of effector integration of nervous activity in "difficult states" or during strong measured tension of the subject's higher nervous activity has great practical importance for demonstrating the presence and degree of neurogenic disturbances in the functions of the corresponding organs in one or another visceral pathology.

With the help of a study of changes in internal organ functions which develop during an anxiety reaction and emotional tension under laboratory conditions, it is possible to judge to what degree the organs being studied (that is, the corresponding vegetative centers) became in the pathological process those compensatory effector channels through which by means of fixed conditioned links inadequate prophylactic and compensatory "abreaction" of nervous activity takes place.

It should be noted that the nervous system's tendency toward inadequate compensatory switching of activity to various visceral organs sometimes can be very clearly demonstrated through the following methodological procedure.

During an observation session, the respiratory excursions of the chest cage and abdomen, the total contraction of the large muscle groups of the extremities, and sometimes even blinking movements are projected on a screen in front of the subject with the help of a moving light "spot" or other technical methods.

For purposes of observation these projections can be quantitatively or qualitatively modified by the physician conducting the observations.

In cases in which during more or less strong exertion of mental activity compensatory intensification of the activity of the skeletal musculature and respiration, and to suppress any motor reactions of the body, including contractions and tensions of the musculature.

Visually observing the dynamics of the above mentioned projections on the screen, the subject and the physician conducting the observations watch for exact fulfillment of the instructions.

As a result of the effective suppression of external manifestations of somatic reactions against a background of an anxiety reaction and emotional tension, compensatory switching of the brain's activity to visceral effectors, primarily to those organs which are involved in the pathological process, particularly if the latter has the nature of a visceral neurosis, frequently develops in the patient.

By comparing the data of repeated observations of the dynamics of the visceral components with data on the dynamics of the somatic components and the subjective sensations of the patient during the session, it is possible to obtain a characterization of those type characteristics of self-regulation of higher nervous activity which occur in the patient at a specific stage of the illness.

By interpreting the data of medical practice from the viewpoint of the concept of self-regulation of nervous activity stated in the present book, it can be assumed that qualitatively and quantitatively inadequate involvment of various organs in different intellectual, emotional and behavioral reactions, including in reactions providing self-regulation of higher nervous activity, has definite significance in the pathogenesis of many internal diseases.

One of the factors determining the nature of this inadequate involvement undoubtedly is the type characteristics of a person's self-regulation of higher nervous activity.

The more sharply expressed the tendency of an individual's higher nervous activity in situations of intensified exertion of mental activity to maintain optimal conditions of the brain's operation through rapid compensatory switching of nervous activity impulses to the peripheral effectors, the more likely it becomes that in situations which are difficult for the nervous system various internal organs can use systematically mechanisms of self-regulation of nervous activity as additional effector channels for providing compensatory switching ("abreaction") of excessively strong nervous activity of the brain. Such a danger is particularly great in those cases in which prevalence of the first type of self-regulation is combined with a person's tendency to suppress systematically external (somatic) expressions of intellectual and emotional excitation and strain.

Our experiences show that a convenient and sufficiently adequate method of objectively examining the participation of internal organs in mental activity, including in its self-regulation, is laboratory reproduction in the subject (through a second signal system) of an anxiety reaction with objective recording of the dynamics of the leading somatic and visceral components of the reaction, with particular consideration of the possible participation of pathologically changed organs in the anxiety re tion. As was shown in the preceding chapters (particularly in the sixth chapter), various forms of the anxiety reaction are widely used by the nervous system for purposes of self-regulation of higher nervous activity.

Normally – under optimal conditions and with an adequate level of the individual's higher nervous activity – the biological directedness and intensity of the visceral components of the anxiety reaction correspond to the actual (or probable in the near future) requirements of the organism's metabolism and neurohumoral regulation. Those internal effectors whose activity provides for the above mentioned needs of the organism chiefly enter into the functional structure of the anxiety reaction.

In pathology — with disturbed functions of various internal organs — the participation of these organs in the effector structure of an anxiety reaction is determined rather by stereotyped mechanisms of self-regulation of higher nervous activity than by the actual needs of the organism's metabolism and neuro-humoral regulation.

Those internal organs which normally are a constant component of the anxiety reaction, for example, the cardiovascular and respiratory systems, during pathological disorders often react quantitatively and qualitatively inadequately in situations of anxiety. Other organs which normally do not participate in an anxiety reaction, for example, the digestive tract, during their pathology begin to be involved more and more frequently and intensively in the anxiety reaction.

If, for example, an anxiety reaction is evoked in patients with a lesion of the myocardium under laboratory conditions (for example, by means of combining the observations with the use of different, potentially nociceptive stimuli or by means of the subject's strained resolution of a mental problem suggested by the physician) and the dynamics of the somatic and visceral components of the anxiety reaction are recorded, it is possible to establish that in the patients the anxiety reaction is frequently accompanied by a much more considerable and prolonged, than normally, increased rate (and sometimes intensified in comparison with the initial state) of coronary activity.

In patients with decreased respiratory surface of the lungs (as a result of tuberculosis) during an anxiety reaction a more expressed, than normally, increase in the rate of respiratory excursions of the chest cage and an inadequate increase in pulmonary ventilation (which exceeds the value of the average increase in ventilation observed in healthy subjects) are frequently observed.

In patients with a disease of the stomach (gastritis or ulcers) the anxiety reaction is accompanied by expressed changes in the stomach's motor activity and secretion. For example, against a background of standard stretching of the stomach wall by means of a Kurtsin-Bykov probe balloon, during an anxiety reaction either intensification and lengthening of the periodic contractions of the stomach musculature or, on the other hand, sharp active inhibition of the periodic contractions (see Chapte 7, §2 and 5) develops. Similar changes are also observed with respect to secretion of gastric juice. Whereas normally an anxiety reaction, if it is not very severe, usually is not accompanied by considerable and prolonged changes in the secretion of gastric juice (in response to standard background stimulation, for example, stretching of the stomach wall or stimulation with a 5% alcohol solution), during pathology of the stomach either an expressed increase in secretion or its inhibition is frequently observed.

It should be emphasized that the mentioned increased and frequently inadequate participation of the heart, lungs and stomach in the anxiety reaction is observed not only with local pathological changes in the structure and functions of these organs, but also during illnesses connected with general disturbances in the organism's neuro-humoral regulation, for example, in neurasthenia, thyrotoxicosis, hypertension or hypotension, etc., even in cases in which pathological changes in the indicated organs are weakly expressed or absent (for example, in neurasthenia).

For example, in the hyperstenic form of neurasthenia the anxiety reaction is frequently associated with sharp changes in the conditions of respiration and blood circulation: respiration is intensified, becomes irregular, deep inspirations and a delay in respiration are frequently noted, inspiratory tonus is increased, etc., the pulse rate increases, respiratory arhythmia of the pulse is intensified, more expressed than normally, changes in vascular tonus, arterial pressure, etc, develop, the digestive tract is involved in the reaction, spastic states or, on the other hand, atonia of the sphincters, changes in the stomach's motor activity and secretion, in the secretion of the salivary glands develop, etc.

During thyrotoxicosis, the anxiety reaction is accompanied by a sharp increase in pulse rate, by an increase in minute volume, a rise in systolic arterial pressure (of 10-20 mm mercury) and by an increase in lung ventilation.

In hypertension (in the first and first to second stages) during an anxiety reaction an increase in coronary activity and a more expressed, than normally, increase in systolic and diastolic arterial pressure are noted. In hypotension considerable variations in arterial pressure occur.

The above-mentioned changes in the respiratory, cardiovascular and digestive systems which occur in patients with neurasthenia, thyrotoxicosis or hypertension, during an anxiety reaction are more or less inadequate for the specific (that is, laboratory) situation and the stimuli used since they do not increase the adaptive effectiveness of the anxiety reaction, that is, the individual's mental and behavioral activity.

Experience shows that inadequate involvement of functionally or structurally affected organs in the anxiety reaction develops most frequently from a combination of intensified introception from the affected organ with severe emotional excitation.

It is well known that during a therapeutic procedure by a dentist as a result of a combination of intensified stimulation of the receptors of the oral cavity with emotional tension the patient frequently develops very intensive salivation which continues from the effect of the situation even during manipulations of the dentist which are practically painless for the patient. A decrease in emotional tension leads to some decrease in salivation, however, it is normalized only after elimination of both inducing factors — severe emotional tension and intensified or continuous interoception from the oral cavity.

The nervous regulation's tendency toward constant inadequate involvement of the diseased organs in the anxiety reaction (or in another strong mental and behavioral reaction) evidently is determined by chronic changes in interoceptive signaling, chronic weakening of corticofugal control of the limbic system and subcortical formations, by distrubances in afferent and efferent, that is, effector, integration of the brain's nervous activity and by pessimalization of self-regulation of the individual's higher nervous activity.

The relation between the type characteristics of self-regulation of the higher nervous activity of man and animals, on the one hand, and the intensity of the internal organs' inadequate involvement in the anxiety reaction, on the other, is of fundamental interest to the present work.

According to our observations, the inadequate involvement of diseased organs in the anxiety reaction is observed most frequently and in most expressed form in patients in whom there is a tendency of the nervous system toward inadequately frequent, strong and continuous emotional excitation, and predominance of mechanisms of the first type of self-regulation (see Chapter 2), particularly if they are combined with systematic voluntary suppression of external, including speech, manifestations of emotional excitation and a state of anxiety (see §6, third type variant).

The inadequate involvement is weakly expressed in patients with highly effective self-regulation of higher nervous activity.

In connection with this, it is appropriate to mention the following. In our experiments on animals it was established that the most expressed disturbances in the organism's visceral and trophic functions develop in an experimental situation in which multiple application of nociceptive stimuli is combined with sharp restriction of the experimental animal's motor activity and in which, according to the conditions of the experiment, the animal in no way can avoid these nociceptive stimuli which cause a more and more expressed difficult state of the nervous system.

SUMMARY

This book has been devoted to an examination of the problem of self-regulation of the conditions and level of higher nervous activity of animals and man.

The position that a person's intellectual and emotional motives, speech and behavior acts, as a rule, have two principal adaptive effects - primary and secondary is substantiated and developed.

The primary effect is the individual's adaptation to changing conditions of the external world, that is, equilibration of the system "individual-external environment." The secondary effect is establishment of the functional state of the brain necessary for the realization of the primary effect and equilibration of the functions of the nervous system itself.

Self-regulation of higher nervous activity is in essence conditioned reflex organization of an individual's intracentral coordination, behavior and visceral reactions for purposes of providing the secondary adaptive effect desirable for the situation. In connection with this, the conditions for the development of effector reactions (somatic and visceral) which are reproduced by the nervous system mainly or exclusively for purposes of achieving one or another secondary adaptive effect, that is, for purposes of self-regulation of nervous activity, are analyzed in the work.

The possible physiological mechanisms of self-regulation of the functioning of the higher sections of the brain through conditioned reflex control of the incoming, retained (circulating) and outgoing nervous activity, that is, through control of the conditions of higher nervous activity, are examined.

As a result of an objective study of the higher nervous activity of animals and man three principal types, or variants, of self-regulation of higher nervous activity have been demonstrated.

The first type of self-regulation is conditioned reflex regulation by the brain of the conditions of the outgoing impulsation, that is, of the intensity and paths of switching nervous impulses from the brain to the peripheral effectors for purposes of maintaining optimal intensity of the intracentral (circulating in the brain) nervous activity. As a result of intensification or weakening of the outgoing impulsation, the exertion of nervous processes is accordingly decreased or increased and the tonus of the new and old cortex of the brain changes. Since intensification of the impulsation coming out of the brain for purposes of self-regulation of nervous activity is of a compensatory nature, we call the ef-

fector reactions evoked in this case compensatory reactions.

The second type of self-regulation is conditioned reflex regulation by the brain of the conditions of the incoming impulsation and humoral influences on the brain. Control of the incoming impulsation and its centripetal passage is provided: first, by appropriate establishment of intracentral, particularly cortico-subcortical, effects which determine the selective passage of the afferent impulses and, second by the establishment of conditions of the individual's effector activity which determine the conditions of the generation, and consequently, the quantitative and qualitative characteristics of the secondary afferent inflow (the so-called "inverse afferentation") and of the humoral effects on the brain through the blood.

The third type of self-regulation is conditioned reflex reproduction of behavioral acts and visceral reactions, and in man also intellectual and emotional motives and speech acts, during whose realization secondary conditioned signalling of extero- and introceptive, as well as of intramental, origin which acts "inversely" on the brain and reproduces secondary changes in the functional state of the brain which are capable of maintaining optimal conditions of higher nervous activity.

The mechanisms of self-regulation are interconnected and interdependent. During a person's life experience, as well as during onto- and phylogenesis of animals, various complexes, or stereotypes, characteristic of the individual, of the mechanisms of self-regulation are developed. In man they are characterized by inexhaustible diversity and social directedness.

Normally, the stereotypes of self-regulation promote maintenance of optimal conditions of higher nervous activity, that is, rapid optimalization of the conditions when they deviate from the optimum.

In difficult states and during overexertion of an individual's higher nervous activity stereotypes inadequate for the situation which deepen the already present deviation of the conditions of higher nervous activity from the optimum are sometimes reproduced.

If, for example, in an athlete with extreme prestarting agitation, as a result of mobilization of mechanisms of self-regulation, compensatory "abreaction" of the agitation develops through peripheral effectors which are adequate for the situation, for example, in the form of rational, preparatory physical exercises (so-called limbering up), and in the process of carrying out the compensatory effector reactions secondary effects, particularly proprioceptive inflow, are generated which inhibit the brain, the athlete's extreme agitation can be decreased and the conditions of higher nervous activity return to or approach the optimum. If the extreme prestarting agitation obtains a compensatory outlet from the brain through effectors which are inadequate for the situation, causing, for example, generalized excessive tension of the skeletal musculature, inadequate intellectual, emotional, speech and ideomotor reactions or extreme visceral reactions, which secondarily intensify to an even greater degree the athlete's state of anxiety, the mechanisms of self-regulation cause not optimalization, but further pessimalization of the conditions of higher nervous activity.

The conditions of higher nervous activity (that is, the ratio per unit time of the incoming, circulating and outgoing impulsation and the interrelations of the facilitating and inhibiting dominants of the systems of neural links) must be considered as optimal if, with an economical expenditure of energy and functional reserves of the brain, a level of integration of nervous activity, that is, a level of the brain's reflection of the conditions of the external environment, adequate for the situation (in man – socially adequate) is stably provided.

The conditions are pessimal if even with a considerable expenditure of nervous energy only a relatively low, that is, undifferentiated, level of integration – or level of reflection – is provided.

In healthy people pessimalizing stereotypes of self-regulation of higher nervous activity are reproduced only episodically during expressed difficult states of nervous activity. At the same time, in patients with psychoneuroses and to a lesser degree in patients with visceral neuroses, pessimalizing stereotypes of self-regulation are systematically mobilized during any more or less difficult states.

The development of ineffective pessimal forms of self-regulation is often associated with the development of an inadequately strong anxiety reaction.

In a healthy person the following stereotype of self-regulation has great importance in the maintenance of optimal work of the brain in situations of anxiety: a strong, stable and adequate intellectual and emotional dominant → effective corticofugal control (in case of the leading participation of a second signal system) of the activity of the subcortical levels of the brain and afferent inflow → the provision of an adequate and highly differentiated reaction of cortical and limbic awakening → the eventual compensatory increase in the outgoing impulsation through adequate effectors → the development of primarily and secondarily adequate effector reactions of the organism → the generation during the carrying out of effector reactions of beneficial secondary afferent and humoral effects which act "inversely" on the higher sections of the brain → the maintenance of a primary adequate intellectual and emotional dominant, etc.

Thus, a kind of "optimal (or optimalizing) cycle" of self-regulation of the nervous system is present.

In patients with neuroses a "pessimal cycle" of self-regulation develops in place of an "optimal cycle": the absence of a strong intellectual-emotional dominant → ineffective corticofugal control → the development of an inadequately strong and inert anxiety reaction → the massive compensatory "abreaction" of extreme excitement through any effectors which are relatively free of inhibition → the development of primarily, and frequently also secondarily, slightly adequate or inadequate effector reactions →

the generation of extreme excessive secondary afferent and humoral inflow → further weakening of the adequate dominant and so on.

In patients with hysteria inability for effective self-regulation of higher nervous activity is expressed:

1) in the inability to mobilize in difficult situations of life (with the help of the third type of self-regulation) a socially adequate intellectual and emotional dominant of nervous activity and behavioral and speech signal reactions which establish adequate relations between the individual and the surrounding social environment;

2) in the reproduction of socially inadequate affective signal reactions – hysterical fits, dramatic mimic and speech acts, etc., which secondarily generate emotional response reactions on the part of the people present which are subjectively desirable for the patient;

3) in the massive, unrestrained compensatory "abreaction" of excessive central excitement through the above-noted affective reactions.

In patients with psychasthenia, ineffectiveness of the third type of self-regulation (that is, the inability for reproduction in difficult situations of a sufficiently strong intellectual and emotional dominant which provides completeness and single-mindedness of higher nervous activity) is combined with primary compensatory "abreaction" of the state of anxiety and mental stress in the sphere of the second signal system – through slightly adequate or inadequate reflections which do not bring the individual to an active change in the situation, to creative action on the surrounding external world.

In patients with the hyperstenic form of neurasthenia similar ineffectiveness of the third, that is, leading in man, type of self-regulation is combined with generalized compensatory switching of excessive central excitement (caused by an inadequate anxiety reaction) to various somatic and visceral effectors. The compensatory behavioral and visceral reactions which develop in this case frequently are the source of an inadequate secondary afferent inflow which provokes further intensification of the anxiety reaction and overexertion of higher nervous activity.

In patients with the hypostenic form of neurasthenia, compensatory effector switching (that is, "abreaction") of the excitement is relatively weak.

In patients with visceral neuroses the third type of self-regulation and, consequently, the actual intellectual and emotional dominant is strong enough to control the compensatory switching of the excitement to the somatic effectors and to inhibit the development of inadequate speech and behavioral reactions. At the same time, the actual dominant is not strong enough to prevent the development in difficult situations of an excessive anxiety reactions and compensatory "abreaction" of the "excessive" emotional excitement through visceral channels. The inadequate visceral reactions evoked in this case, when they are systematically repeated, can play a definite role in the pathogenesis of various internal diseases of the organism.

The first type of self-regulation, that is, compensatory effector switching of excitement, is the link which determines in many respects the form and adaptive effectiveness of the other links of self-regulation. Both in healthy people and in patients with neuroses the compensatory switching has individual pecularities depending on whether it is carried out primarily through somatic or visceral effector channels or through channels which provide highly differentiated, adequate effector reactions or through channels which provide undifferentiated and primarily inadequate compensatory reactions.

The individual and type characteristics of self-regulation of higher nervous activity of man together with the type characteristics of the strength, mobility and balance of the interdependent and interacting (facilitating and inhibiting) dominants (studied by the I.P. Pavlov school) are the physiological basis of the entire manifestations of the personality which are defined by psychologists as a person's character and temperament.

If temperament is determined in large measure by the formal dynamics of the "competing" dominants of higher nervous activity, character is chiefly determined by the actual social result which develops in a stereotyped way in case of the predominance in the individual of various forms of self-regulation, various methods of the practical resolution (in society) of the "battle" of the "rival" intellectual and emotional dominants of mental activity.

In the present work the necessity of developing a new discipline of medical and pedagogical sciences – hygiene of higher nervous activity, or mental hygiene – is emphasized. The hypothesis is expressed that the physiological basis of mental hygiene must be the principles of self-regulation of human higher nervous activity.

The physiological content of mental hygiene is the provision by the nervous system (through mechanisms of self-regulation) of stably optimal conditions and an adequate level of integration of higher nervous activity.

The social content of mental hygiene is instilling in a person the capacity for more and more effective conscious control and improvement of the self-regulation of one's own mental activity for the purpose of accomplishing with a more and more economical expenditure of nervous energy higher and higher socially adequate levels of the reflection and creative transformation of the external world.

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