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Translation

MEMORY AND ADAPTATION

By

R. Yu. Il'yuchenok

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[Annotation, introduction, chapters 2 and 3, conclusion, sections 2, 3 and 4 of the appendix, bibliography and table of contents from book by Rostislav Yul'yanovich Il'yuchenok, "Memory and Adaptation," edited by Aleksandr Feodorovich Nikiforov, Izdatel'stvo "Nauka" (Siberian Division), 4,500 copies, 192 pages, UDC 612.821.2+612.821.6]

CONTENTS

[Text] In the monograph the physiological mechanisms of adaptation are analyzed as a function of the effectiveness of work of the central regulatory systems and memory. An analysis of the data obtained during the adaptation of man to various climatic-geographical conditions (Pamiro-Alay, Altay, Kuril Islands) allowed us to separate three phases of the adaptational process, at the base of which lie various physiological mechanisms. Particular attention has been devoted to processes of memory and the functional asymetry of the brain in different phases of adaptation.

The book is designed for physiologists, psychologists, psychiatrists, neurologists, and therapists as well as students of universities and medical institutes.

Introduction

Up to the present time we have amassed extensive data about changes in different systems of the organism, basically during adaptation to extreme and near-extreme conditions. All this rich factual data has promoted an understanding of many particular mechanisms characteristic for concrete types of adaptation to defined conditions of the climatic-geographical and production environment. However on the basis of the material we have it is difficult to give an interpretation of the universal general mechanisms of individual adaptation.

Three expeditions (1975-1977) carried out by the Department of Central Regulatory Mechanisms of the Institute of Physiology, Siberian Branch of the Academy of Medical Sciences USSR with analogous programs of research into the adaptation of man to contrasting climatic-geographical conditions allowed us to compare the dynamics of a large number of reactions occurring in parallel and to show up those of them which were present both during adaptation to mountainous conditions with different climatic regimes and during a time shift after transmeridional flight, that is, allowed us to show up those reactions of the organism which are probably universal for the process of adaptation.

The investigations were carried out in mountainous conditions of Central Asia and Siberia (Pamiro-Alay, Altay) in points located roughly at an identical elevation, but differing in climate, and in conditions of a shift in the time zone by four hours (Southern Kuril Islands).

The expedition of 1975 on Pamiro-Alay (settlement of Konchech, elevation 2,500 m above sea level, a hot and dry climate) pursued the goal of clarifying adaptation to mountainous conditions with an elevated temperature.

In 1977 in Altay (the Aktash mine, at an elevation of 2,600 m above sea level with a markedly continental climate, similar in characteristics to the climate of Novosibirsk) "purer" adaptation to mountainous conditions was studied since inhabitants of the Academy City (Novosibirsk) and adjacent places comprised the group of experimental subjects. On the Kunashir Island (a Southern Kuril settlement, time shift of four hours, a monsoon climate) in 1966 scientists observed a predominance of desynchronization elicited by the transmeridional displacement, and adaptation in conditions of a monsoon climate.

The choice of geographical places with subextreme climatic conditions was dictated on the one hand by a desire to follow the clear cut process of adaptation but without the superimposition of pathological syndromes and on the other hand by a desire to compare the shifts of different functions in contrasting conditions while attempting to show up the presence of several common changes. Although the main problem of the investigations was a study of memory processes during adapation, a series of other psychological and psychophysiological tests were carried out paralleling this study. These investigations allowed us not only to evaluate the background on which one or the other process of memory took place, but also to follow the course of the process of adaptation through many parameters, and as was clarified later, to follow its phaselike quality with the physiological mechanisms intrinsic to each phase.

Therefore it seems expedient before examining the memory processes to give a description of the adaptational restructuring of the neurological status of the vestibular, statokinetic, psychological, and psychophysiological reactions; then one can show the significance of memory during adaptation, with the help of whose regulation one may predetermine the paths of intervention in the process of adaptation.

The first successful efforts to change the course of memory trace formation and reproduction by pharmacological substances introduce the hope that this path will furnish real approaches to the control of memory. Undoubtedly even by the end of this book the role of memory in different phases of the adaptational process will not be revealed because of an insufficiency of data. However, if we succeed in informing the reader that memory in its widest sense takes part in the process of adaptation and can compose the basis of the formation of adaptive programs which allow the organism to adjust its activity to the changing conditions of the environment, if we can succeed in informing the reader that memory is the foundation of physiological mechanisms providing for the individual adaptation of the organism, then we may consider that we attained our goal.

The collective of coworkers of the Department of Central Regulatory Mechanisms of the Institute of Physiology, Siberian Branch of the Academy of Medical Sciences USSR took part in the work. V. P. Leutin, I. V. Vol'f, S. B Tsvetovskiy, and E. I. Nikolayeva investigated the change of bioelectrical activity of the brain and vegetative shifts in people during the formation and reproduction of the memory trace. L. A. Konstantinovskaya and N. I. Dubrovina carried out psychological examinations of memory, attention, and functional state (in the first expedition N. K. Kiyashchenko and S. R. Chaplygina examined these). M. A. Gilinskiy, I. A. Korsakov, and V. L. Plyashkevich investigated the activity of the human operator during the adapation of man to mountainous conditions (Pamiro-Alay, Altay) and on Kunashir. The head of the faculty of the Belorussian Institute of Advanced Medical Studies, professor, doctor of medical sciences L. S. Gitkina and the head of the laboratory of the Institute of Neurology, Physiotherapy, and Neurosurgery of the Ministry of Public Health of the Belorussian SSR, professor, doctor of medical sciences I. A. Sklyut took part in the expedition. L. S. Gitkina carried out the neurological status examination and I. A. Sklyut carried out the examinations of static and dynamic coordination and vestibular reactions.

In experimental investigations L. V. Loskutova, I. M. Vinnitskiy, N. V. Vol'f, and S. B. Tsvetovskiy studied the role of different structures of the brain in the mechanisms of one session learning. N.I. Dubrovina studied the neuronal mechanisms of the interaction of these structures, and M. A. Gilinskiy, G. V. Abuladze, V. I. Masycheva, and I. A. Pukhov studied the significance of various structures of the brain in the mechanisms of regulation of memory tract formation and reproduction. The author expresses gratitude to all coworkers of the department and participants of the expeditions who took an active part in the research which lies at the basis of this book.

Chapter 2. General Physiological Mechanisms which are the Basis for Individual Adaptation and which Define the Phasic Nature of the Process

Adaptation is the universal property of the living. The individual life of an organism is the process of continual adaptation to a changing environment with the goal of achieving an adequate relationship with the external world. Without such individual adaptation life would be difficult and almost impossible.

The genetic programs formulated during the process of evolution ensure adapation to constantly operating factors.

The creation of morphofunctional and biochemical constructions are conditioned by genetic apparatus and all innovations in these constructions can arise only gradually by means of random mutations and natural selection, enabling adaptation by the species to very gradual changes in the environment. These acquired adaptations, built into morphological and functional systems, are relevant to the external world only within the boundaries of a given geographic range. The animal organism is adapted highly only in a given ecological niche (Shmal'gauzen, 1946).

The "creative" role of natural selection does not imply retention of genotypes which could be useful in the future given an expansion of the habitation range; individuals are selected which possess characteristics of increased viability in concrete climato-geographic conditions. The retention of what is useful and elimination of what is hazardous is accomplished not in expectation of advantage but in expectation of harmony with the real conditions of existence (Timiryazev, 1895).

If the new ecological zones are markedly distinct in their climato-geographic parameters and if migration occurs rapidly, then adaptationogenesis is possible (in particular, this is characteristic when people of one generation relocate, when the organism encounters repeating but intermittently operative factors or constantly operative ones, but for not so prolonged an exposure which might alter the genotype, for example, changes in temperature, pressure, social conditions, etc.). Then, in what fashion do living beings adapt to altered conditions of existence? A genetic program within the defined limits could be beneficial in the process of migration and assimilation of new ranges; but responses, constructed on the basis of these changes, make it possible to interact with the external world, but not always in an optimal fashion. Such reactions must either match, optimize, or reconstruct the same programs.

During the process of evolution of the animal world, we could expect the appearance of some universal mechanisms which could have enabled adaptation of the living being to the continually changing conditions of its existence. "Examples of adaptation which acquired universal significance in the evolution of animals and which determined group aromorphosis, are the development of the reproductive process and diploidy, multicellularity and differentiation of tissues and organs, transformation from roe to the ovum of viviparity, transformation from an independently formed larva to development inside a maternal organism (embryonization), increased protection of the embryo, nourishment of the young with milk, activation of hormones and more effective use of food, intensification of the oxidizing processes, improvement in thermoregulation, development of organs for higher nervous activity and improvement in reflex and motor apparatus, use of individual experience for protection and training of the young, adaptation to new situations by individual changes in behavior and development of behavior of the cognitive type" (Zavadskiy, Kolchinskiy, 1977, pp 14-24).

Data from the I. P. Pavlov school attest to the special role of higher nervous activity in ensuring balance of the organism with the external environment. As A. N. Severtsov wrote as early as 1922, it is necessary to point out that in higher animals and especially in man, there is a strong ability for behavioral adaptation to the surrounding environment. When confronted with rapidly approaching changes in surrounding conditions, the animal responds with a defined behavioral reaction without reconstruction of its organization and, in the majority of cases, adapts to new conditions. Behavior is one of the most effective means for individual adaptation. Behavior provides the organism with additional possibilities, which can not only expand, but also alter autonomic reflex reactions.

A. D. Slonim (1976) examined certain forms of homeostatic behavior, that is, behavior directed at supporting a stable internal environment of the organism; preference, active regulation of surrounding environmental conditions and specialized forms of activity, directed at creating the optimal conditions of existence in nature. Examples include behavior thermoregulation (Milner, 1973), construction of nests, search for shelter and wetting of the fur with saliva when it is hot. The ability of animals to adapt to new conditions solely by means of behavior is shown graphically in training of rats by subjecting them to cold, thermal lamps, activated by depression of a lever, (Wiess, Laties, 1961), cold showers, or moving them into a heated cage (Epstein, Milestone, 1968). Similar analysis of work on the homeostatic behavior of organisms is provided in the studies of A. D. Slonim and his co-workers (Slonim, 1976).

In man, the development of higher nervous activity achieved such a high level that behavior became a determining factor in his adaptation. Adaptation of man to different conditions in the external environment is based primarily on distinct forms of behavior, including artistic and technical abilities, by which he is able to exist in conditions which are unsupportable for other organisms (Hensel, Hilderbradt, 1964). This fact suggests that "adaptation, in the broad sense, is a process of adaptation by man to conditions in his living environment which, to a large extent, he creates by transformation of nature, directed at the preservation, development and achievement of his main goal: human progress" (Kazancheyev, Lozovoy, 1974, p 4).

Thus, man is adapted not only to conditions of habitation, but also, to a larger extent, he adapts the external environment to his biological abilities, creating an artificial environment--an environment of culture and civilization, by which he adapts to any conditions of existence. Of all living beings, man possesses the greatest ability for adaptation (Sevetsov, 1942; Deryapa, et al., 1975; and others). However, examination of the social aspects of adaptation by man falls outside the focus of this book, in which a detailed analysis of only the physiological mechanisms of adaptation is presented.

The ability of different systems in an organism, which guarantee homeostasis, to adapt effectively its activity to changing conditions of the surrounding environment is determined primarily by the function of central regulatory mechanisms. Creation, in the process of evolution, of the regulatory systems with the corresponding morphofunctional substratum led to the appearance of a potential for more precise reaction to the external environment, an increase in the range of adaptability without radical morphological and biochemical reconstruction of tissues, adaptation of physiological mechanisms by means of changes in function--that is, "adjustment" or optimization of responses.

All normal processes of life activity have an adaptive character, that is, all physiological reactions can be either adaptive to concrete "stationary" conditions of the environment, that is previous processes of adaptation, or nonadaptive ones, found in the process of adaptation. Consequently, both during the process of adapation and in the final stage of adaptation, it is important to represent the degree of participation of various physiological mechanisms and the role which they play in the creation of optimal interaction of the organism with the external environment. The basic burden in certain phases of the adaptational process fall on these mechanisms.

The process of adaptation is a function of time. Consequently, at different stages of it different physiological mechanisms can be involved. We assume that at the outset of the process of adaptation, in special complex situations when the organism, because of indadequate information, can not adjust appropriately or completely adequately to specific forms of adaptational reactions nonspecific mechanisms deteriorate such as emotion and Selye's adaptation syndrome by which the organism, expending a large amount of energy, adapts its activity to specially changing conditions. The participation of this syndrome in the mechanism of adaptation is referred to by the author's name, G. Selye (Selye, 1973). He asserts that, without stress, life does not exist. He considers that peasants working intensely during harvest, administrators undertaking a difficult problem, sportsmen striving for victory, a man sitting in a vehicle with his dying wife--all experience stress. Stress, according to the definition formulated at the International Congress on Stress, is viewed as a nonspecific reaction to any influence brought to bear on an organism. This, as well as distress is "bad" stress but eustress is "good" stress. It is interesting that in both forms of stress, nonspecific sympatoadrenal reactions (increase in excretion of adrenalin) are similar (Levi, 1972). Thus, stress can be without suffering, without grief, without unpleasantness and disease; it can arise from any stress--physical, emotional or intellectual; essentially, the degree of stress also limits the potentials of an individual.

At the present time, in the literature and in natural phenomena there are sufficient data, obtained in expeditionary conditions, to explain the initial stages of the process of adaptation, including the special adaptive mechanisms, involved in the adaptation syndrome of Selye. Thus, data are cited on the significance of stress in responses of an organism to extreme cold (Slonim, 1964; Maustrakh, 1975; and others). For S. N. Kukishev (1972), the inversion of circadian rhythm with the phenomenon of decreased chronognosis is considered to be a stress reaction. The first period of adaptation to inversion of sleep rhythm--wakefulness--is viewed by these authors as a stage of fear. However, it is inappropriate in this sense to consider this period before 10 days time and furthermore, as an example of the first stage of stress according to Selye --an anxiety reaction is delayed for 24-48 hours. In this period, a decline in many functions is noted. These effects are not related to specific forms of activity--nervous emotional stress can impair the activity of various functions. Thus, as illustrations, A. D. Slonim (1964) points to the inhibition of autonomic reactions; salivation, gastric secretions, respiration, cardiac activity, etc.

On the 2nd-3rd day of residence in Southern Kuril we noted a decrease in accuracy and an increase in the number of errors in comparison with control standards in corrective tests; there was a sharp increase on these days in variability of indices for the number of errors (fig 24). On subsequent days, the indices for number of errors and accuracy were normalized. We noted on the 2nd-3rd day of the adaptation process a decrease in activity (fig 25) evaluated subjectively by the test subjects in experiments conducted by SAS [Siberian Academy of Sciences]. The subjects experienced an improvement in their sense of well-being and their test performances were within the highest level of control numbers. The number of errors in tracking, that is, operator activity declined. Disturbances in the work capacity of the test subjects became evident in analysis of productivity (the quantity of reviewed letters, accuracy of work) in the first and second 5 minutes in corrective tests before and after hourly experiments (fig 27) and of the level of stability of reproduction of words throughout the course of the experiment (fig 28).

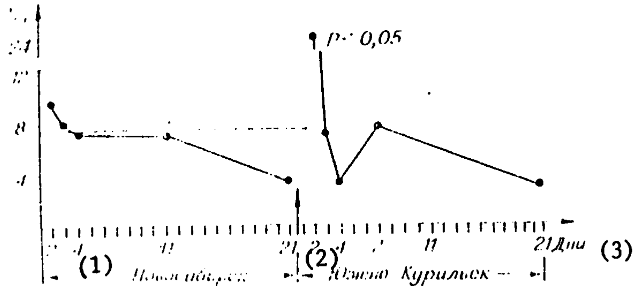

Рис. 24 Изменение дисперсии показателей числа ошибок в корректурной пробе.

Figure 24. Changes in Variability of Indices for the Number of Errors in Corrective Tests

Key:
1. Novosibirsk
2. Southern Kuril
3. Days

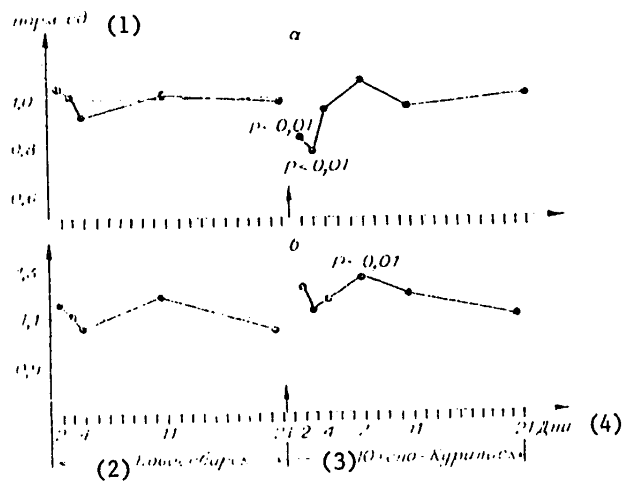

Рис. 25 Изменение показателей активности (а) и настроения (б).

Figure 25. Changes in Indices for Activity (a) and Adjustment (b)

Key:
1. Standard units
2. Novosibirsk
3. Southern Kuril
4. Days

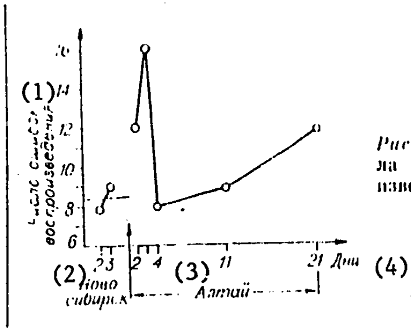

Рис. 26. Изменение числа ошибок при воспроизведении слов в процессе адаптации.

Figure 26. Changes in the Number of Errors in Reproduction of Words during the Process of Adaptation

Key:
1. Number of errors in reproduction
2. Novosibirsk
3. Altay
4. Days

Рис. 27. Корректурная проба. Гистограмма изменения стабильности работы при адаптации в горах Памиро-Алая — отношение числа просмотренных знаков второй половины пробы к первой.
1 — начало, 2 — конец опыта.

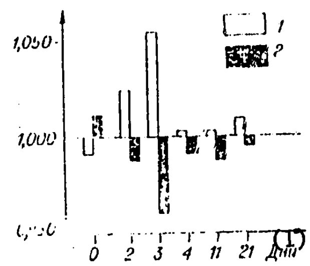

Figure 27. Corrective Tests. Histogram of Changes in Stability of Work given Adaptation to the Mountains of Pamiro-Alay--The Relationship of Numbers of Examined Indices during the Second Half of the Tests to the First Half. 1--Beginning 2--End of Experiment

Key:
1. Day

During these days in mountainous conditions, a decline in attention, disturbance in stability of work according to corrective tests and dynamic coordination of random indices occurred. On the 2nd day of residence in the mountains, we noted a worsening of the subjective condition, detected by the methods used by SAS; increase in variability of indices for motor memory of the right hand and maximum scatter of indices for motor memory of the left hand; a decline in reaction to moving objects and sensory-motor response, as well as an increase in the variability of their indices.

It is doubtful that a sudden contrasting change in climatic conditions causes a stress reaction without emotional overtones. But emotion, perhaps, should be viewed as an adaptive reaction to generalized nature. Even Charles Darwin (1872) assigned significance to the adaptational character of emotion. It is doubtful that this adaptive sign can be viewed as gradual loss in the process of evolution of its adaptational significance. On the contrary, and not inadvertently, the greater the degree of evolution that has occurred in an organism the richer it is, not only in number of reactions for expression of emotion but also, perhaps, in its ability for emotional survival. Man of all living beings possesses the greatest potential for adaptation to multiformed changes in the external environment and in man emotions are the most developed. It is difficult to verify that this is merely an apparent parallelism and not a fundamental relationship. The specific reactions can be depressed when man is introducted to new conditions. The majority of reactions turn out to be nonadaptational ones and only interfere with the interaction of the organism with the external environment. Ideally, reactions should be more generalized. Similar phenomena are observed at different phases in the development of the conditioned reflex when the absence of a specialized reaction is compensated for by the appearance of emotion and the animal is able to adequately achieve, at least in part, the required goal.

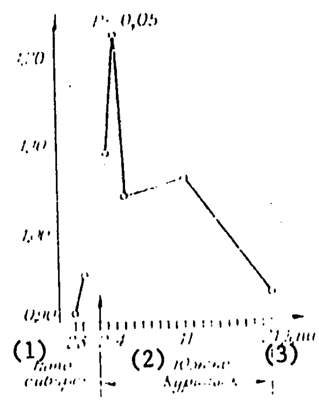

Рис. 28. Изменение стабильности воспроизведения слов в ходе эксперимента в процессе адаптации (отношения числа воспроизведений второй половины опыта к первой).

Figure 28. Changes in the Stability of Word Reproduction in the Course of the Experiment on the Adaptational Process (Relationship of Numbers of Words Reproduced during the Second Half of the Experiment to Numbers Reproduced during the First Half)

Key:
1. Novosibirsk
2. Southern Kuril
3. Days

However, it is doubtful that the role of emotion is limited merely to those external phenomena and mobilization of energetic reserves. The maximum output of power is achieved by mobilization of a wide range of adaptive programs in a short interval of time during critical situations for the organism with the aim of utilizing already existing programs for special adaptation. The physiological meaning of emtoions is explained well by the hypothesis of P. V. Simonov (1970) in which emotions are considered to be reflections of the dimensions of requirements and the likelihood of their satisfaction at a given moment. In particular, emotions can guarantee satisfaction of the needs of the organism in conditions of an information deficit that, undoubtedly, occur at the onset of residence by the organism in new conditions.

In recent years, the role of emotion in adaptive reactions of man and animals has been underscored by thorough analysis (Shingarov, 1971; Kruglikov, 1971; Khananashvili, 1972; Simonov, 1975; Fress, Piazhe, 1975; Ivanitskiy, 1976; Val'dman et al., 1976; and others). Some authors even give fundamental significance to the emotional state in the mechanisms of adaptation of man and animals (Banshchikov et al., 1975). Undoubtedly, emotion superimposes its own imprint on the subsequent processes for the formation of new adaptive programs as the perception of external signals is altered (Gerken, Neff, 1963; Hall, Mark, 1967; Gasanov, 1972; Kostandov, 1977) and the process of formation of their imprints (Whitly, 1962; Il'yuchenok, Yeliseyeva, 1966; Smythies, 1967; Beritashvili, 1968; Veyn, Kamenetskaya, 1968; Latash, 1968; Khananashvili, 1972; Il'yuchenok, 1972, 1977; Brady, 1975; Gromova, 1976) takes place.

After nervous emotional stress disappears masked signs of these states, characteristic for activation of the regulatory systems, are developed. Changes in external conditions require "adjustment" of physiologic reactions. On the basis of the existing program, genetically complicated during the process of evolution or created previously in the process of earlier adaptations, regulatory mechanisms are responsible for altering the level of regulation and switching over to another program. Although these programs for a new living environment are, on the whole, nonspecific, they are also fixed in their range of possible deviation, thus making their utilization feasible.

One can assume that the fundamental burden on regulatory mechanisms occurs at initial stages in the process of adaptation. The range of adaptation which is guaranteed by the central regulatory mechanisms depends on the limits of their potentials, reliability and reserves of resistance. Of special importance in a given situation is the degree of stress on the regulatory system (Kaznacheyev, 1973; Vasilevskiy, 1974; Kaznacheyev, Bayevskiy, 1974). A similar analysis of the resistance of the regulatory system in the process of adaptation was conducted by N. N. Vasilovskiy (1974, 1976) and S. I. Soroko (1975).

It is important to point out that the participation of the regulatory system is most apparent at the onset of the process of adaptation when the response is still based on old programs. This is illustrated by data, obtained in our laboratory, both for adaptation in mountains and in conditions of other zonal times. In this period, the resistance of function in different systems in the organism is decreased and the variability of indices for many physiological functions is increased. Changes in manifestation of orientational and cardiac reactions (fig 29), indices for dynamic coordination, reactions to moving objects (see fig 7b), sensory motor reactions and errors in evaluation of the proper time are increased. Reconstruction of the organism on a new level of function goes through a phase of destabilization (Miller, 1975; Bekhtereva et al., 1977).

Increase in variability leads to expansion of the range of response which improves the potential for correlation of important life-related information with the multiformed reactions of the organism. Change in the homeostatic regimes activate conditionally the regulatory systems. The fundamental task at this level of regulation is the search for the optimal regime for function (Breynes, Svechinskiy, 1963; citation from Kuritskiy, 1969; Kuritskiy, 1969). A higher level of regulation adds to the continuously active process of regulation of new "laws" and changes not only the limits of significance for parameters which characterize the regime for systemic function in the organism, but also the regime for this very search. It is unlikely that a new resistant state of function in the systems of the organism is achieved only when a switch over to a new program for interaction of the organism with the external environment occurs. Reconstruction of different systems in the organism occurs to accommodate a new regime for function, thereby the maximum level of reconstruction and the duration of it are dissimilar in different systems.

Рис. 29. Изменение дисперсии сердечных реакций в процессе адаптации.

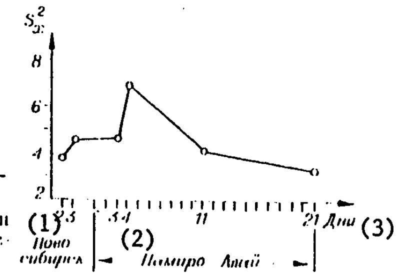

Figure 29. Changes in Variability of Cardiac Reactions in the Process of Adaptation

Key:
1. Novosibirsk
2. Pamiro-Alay
3. Days

The results obtained during three expeditions showed that in conditions at a height of 2,600 m and shifts in zonal time by 4 hours, reconstruction of the neurological (L. S. Gitkina), vestibular, statokinetic (I. A. Sklyut) and immunologic reactions (L. V. Devoyno, L. S. Eliseyeva, M. A. Cheydo et al.) resolved, on the whole, by the 2nd week of adaptation.

Autonomic guarantee of reactions by an organism given various forms of adaptation can vary; some are characteristic for a given form of adaptation with predominance of either parasympathetic or sympathetic components. We assume that stimulation of both systems occurs because of activation of the reticular formation in the brain stem. However, in this form of adaptation and in its different phases, one system predominates.

Thus, in adaptation to mountainous conditions, the activity of the sympathetic system predominated. This was characteristic also for the initial period of cosmic flight with a subsequent short-term strengthening in the tonus of the parasympathetic section of the nervous system (Vorob'ev et al., 1976). In adaptation to shifts in zonal time the activity of the parasympathetic system predominated.

In our experiments, the period of activation of the majority of regulatory systems occurred on the 3rd-7th day of adaptation. Total use of the existing program in an organism, given the need for future maintenance of activity in functional systems within the assigned limits, leads to stress of the regulatory system. In special conditions, this period is prolonged because for these conditions none of the adaptational programs can be optimal. However, the system functions within the limits of regulation and in the future in conditions of its disruption.

Given long term changes in external conditions stress on the regulatory system can be weakened or eliminated by including other, more adaptive programs for reaction, but given conditions where all program reserves are exhausted, this is possible only after formation of new programs on the basis of imprints of information concerning the changing surrounding environment; that is, use of memory. Those reactions, predetermined on the basis of genetic mechanisms, do not lend themselves well to "training" (they do not allow formation of fundamentally new programs for interaction with the external environment) because they either reached previously the limits of their retraining capacity or their adequateness in external conditions is ensured only in the course of the whole process of adaptation by maintenance of stress on the regulatory system, possibly, by transfer to other genetic programs for response. Recently, the process of adaptation for a number of functions can be viewed not as normalization of variability of indices, but as a decrease in them as we see, for example, in the dynamic coordination reaction to moving objects, the time of hand reaction given presentation of numbers and others.

Alleviation of the process of regulation with retention or even increase in the effectiveness of responses and decrease in expenditure of energy can be accomplished only by formation of new programs for adequate interaction of the organism with a changing external environment, and this ensures the possibility of registration and preservation of imprints of information regarding these changes. The more sharply distinct the dimensions of the parameters of the situation in which it is necessary to adapt, the greater the stress on the regulatory system; but the more diversity in the changing situation, the more need for time to completely fix all of its elements. With sharp differences and diverse factors in the new situation, inopportune and inadequate fixation of an imprint can not weaken the limited stress on the regulatory system and interruption of regulation in separate functional systems can set in before the completiong of the adaptational process. It is possible that, as a result of such dissociation experienced in high altitudes, in the first days of adaptation disturbances in higher nervous activity, diffuse general inhibition and a number of other pathological phenomenon (Sirotinin, 1957; and others) can occur. Shortening the transition period and the resulting stress on the regulatory system can enable a decrease in the probability of the onset of pathological symptoms. This occurs also with acceleration of fixation of imprints of changing external influences and the creation of new adaptive programs.

All the above mentioned considerations facilitate examination of the formation of adaptive states as a dynamic process with resulting transitory phases on which are built physiological mechanisms. It is likely that these principles must serve as the bases for a targeted program of study of the physiological mechanisms which lie at the foundation of the process of adaptation (see the program in the Appendix).

Chapter 3. Memory--The Basis for Individual Adaptation

Memory, arising at the earliest stages of evolutionary development, has universal significance for the living world: on its basis rudimentary progress became possible for the organization of responses in an ever more complex environment of habitation by the use of accumulated experience and creation of new programs on its basis. This characteristic not only retained its effectiveness in the most highly complex living systems, but also acquired more cardinal and universal significance for forms, existing at the highest levels of evolution because it consistuted the basis for individual behavior, attaining its more complete form in man in the form of behavior of the cognitive type.

The phenomenon of memory includes the process of transmission of information at the moment of its entry in the brain through selection for storage, the mechanisms for its retention and reproduction before return to the external world in the form of behavior of the animal or man. The essence of adaptation consists of the ability of an organism, after obtaining information from the external world, to respond adequately on the basis of formed adaptive programs of reaction to the environment.

Memory must be considered in the broadest sense as fixation of imprints to form programs for the most varied responses, both behaviorally and autonomically, and as the basis for all physiological reactions of biochemical transformation. However, the most important factor in individual adaptation of higher animals and man to changes in the external environment is the ability to register and retain information about these changes in order to alter behavior in relation to acquired experience (Il'yuchenok 1972).

Nevertheless, special study of the processes of memory in the conditions of adaptation has been devoted only to separate elements of function. Thus, in experiments on dogs subjected to prolonged residence at altitudes of 1,650 m above sea level (Avadkhara, the Caucusus), improvement in performance of extended dynamic stereotypes and acceleration of consolidation of temporal connections became apparent (Kipiani et al., 1974). Improvement in the formulation of memory imprints was noted here and in experiments on mice to observe performance of conditioned reflexes for active avoidance based on adaptation to an altitude of 3,200 m above sea level (the mountain pass of Tuya-Ashu) (Meyerson et al., 1971). Acceleration in the performance of positive conditioned reflexes in rats for adaptation to mountainous conditions (4,200 m, Minkush) was apparent also in the experiments of M. A. Aliyev and A. K. Kasymova (1970). In these studies, in contrast to others, an acceleration in performance of inhibitory conditioned reflexes was noted also. Interruption of the influence of hypoxia in conditions of a decompression chamber (daily for 5-6 hours at an altitude of 5,000-7,000 m above sea level) resulted in an improvement in rentention of the defensive conditioned reflexes of passive avoidance and an increase in resistance of the process of fixation of conditioned reflexes to the effect of electroshock given activation of nucleic acid and protein synthesis (Meyerson et al., 1970, 1976).

A smaller scale investigation of memory in conditions of adaptation was conducted in humans. Using psychological testing, scientists noted a worsening of memory in the first days of adaptation (Aydaraliyev et al., 1977) and an improvement in immediate word reproduction on a later date in the process of adaptation to high altitudes

(Mirrakhimov et al., 1975) and in the extreme North (Kust, 1974). However, these data on improvement of memory did not lead authors to assume that memory constitutes the basis for the process of individual adaptation.

Recently, the problem of interaction of memory and adaptation in the process of its formulation has attracted more attention (Il'yuchenok, 1972, 1977a; Kipiani et al., 1974; Mirrakhimov et al., 1975; Slonim, 1976; Vasilevskiy, Trubachev, 1977; Aliyev, 1977). The importance of a multifaceted approach to the study of this specific problem has been stressed (Bekhtereva, 1974) because memory ensures maintenance of the resistant state of health (homeostasis) and adaptive reconstruction (Bekhtereva, 1976).

Adaptation is a long-term process, making the role of memory at various stages of it ambiguous. Therefore, it is necessary to elucidate the character of changes in memory at different phases of the adaptational process. It would be incorrect to expect that these changes would be great in the collective sense, but, more correctly, they would be of long duration. In order that these changes would not be confused as pathological alteration in the function of different functional systems of the organism in extreme and close to extreme conditions, scientists found it advisable to analyze them given ambiguously expressed changes in the climato-geographic environment (altitude of 2,500 m and changes in zonal time by 4 hours).

V. P. Leutin, Ye. I. Nikolayeva, N. V. Vol'f and S. B. Tsvetovskiy conducted polygraphic recordings by electroencephalogram, electrocardiogram and dermo-galvanic reaction in expeditionary conditions.

The highly informative nature of electroencephalographic and autonomic indices was revealed during analysis of mechanisms for concentration of attention, perception, formulation of short-term and long-term memory (Pollen, Trachtenberg, 1972; Rusalov, Mekachchi, 1973; Klinger et al., 1973; Martidale, Armstrong, 1974). Using EEG methods, the complex regulation of space-time organization in brain processes in man in the normal state and in the pathological one, given formulation of associations and different forms of memory, was detected (Livanov, 1972; Voronin, Konovalov, 1976; and others). However, similar analysis was of no practical importance in understanding the effect of different climato-geographical conditions on these mechanisms.

With the completion of psychological tests, changes in the bioelectrical activity of the brain, dermo-galvanic reactions and the dynamics of cardiac rhythm occurred. Control studies at Novosibirsk showed that autonomic shifts are part of the phasic dermo-galvanic reaction which accompanies memorization and reproduction of words. Also seen was an increase in the frequency of cardiac contraction and the appearance of reactions for EEG activation (fig 30).

In the initial period of residence by the subjects in Southern Kuril (2nd-3rd day), against a background of increase in motor activity, spontaneous dermo-galvanic reaction and slowing of the cardiac rhythm, V. P. Leutin, N. V. Vol'f, S. B. Tsvetovskiy and Ye. I. Nikolayeva detected a decrease in the immediate reproduction of words given an increase in the manifestation of accompanying EEG activation and a decrease in the dimensions of recorded dermo-galvanic and cardiac reactions. A decline in word reproduction of the last words on the list occurred (fig 31). Immediately after passage to the mountains of Altay, testing showed that a decline in word reproduction did not occur but the number of errors increased (fig 32). In addition, an increase was noted in the manifestation of dermo-galvanic and cardiac reaction which accompanied word reproduction with retention of manifested EEG activation within normal limits (Fig 33). In the experiments of L. A. Konstantinovskiy, on the 2nd day of residence in Altay conditions, a decline in verbal and form-space memory was not noted. In Pamiro in this period, similar studies were not conducted. With regard to motor memory, by the 2nd day, the indices for left hand function showed an increase in the amount of deviation in the reproduced height from the preset one; in the indices for right hand function, no changes were observed on the 2nd day.

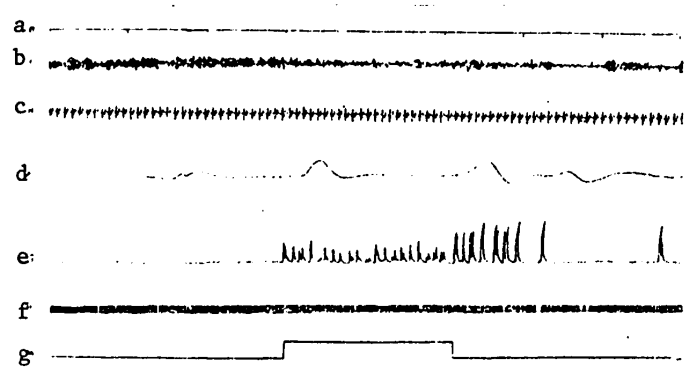

Рис. 30. Многоканальная регистрация физиологических функций испытуемого.

а — метки времени, 10 с; б — электроэнцефалограмма; в — электрокардиограмма; г — кожно-гальваническая реакция; д — фонограмма (всплески появляются в моменты воспроизведения слова магнитофоном и при устных ответах испытуемого); е — число пересечений «нуля» ЭЭГ; ж — отметки программы опыта.

Figure 30. Multichannel Recording of Physiological Function of Test Subjects. a--Time Markers, 10 s; b--Electroencephalogram; c--Electrocardiogram; d--Dermo-Galvanic Reaction; e--Phonogram (Spikes Appear at the Moment of Word Reproduction on Tape Recorder and given Oral Responses by Subject); f--Number of Intersections at "Zero" on EEG; g--Control Points of Experimental Program.

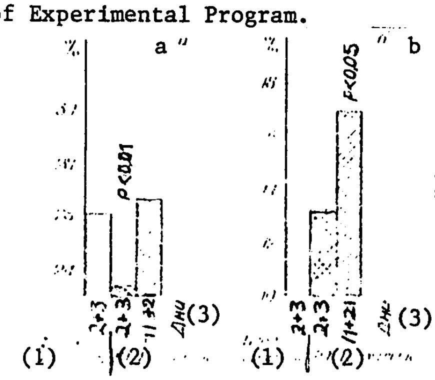

Рис. 31. Воспроизведение 10 последних (а) и 10 первых (б) слов списка.

Figure 31. Reproduction of Last 10 (a) and First 10 (b) Words on List

Key:

1. Novosibirsk
2. Southern Kuril
3. Days

Рис. 32. Изменение числа ошибок при воспроизведении слов в процессе адаптации.

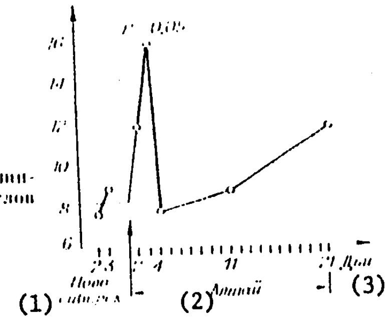

Figure 32. Changes in Number of Errors in Word Reproduction during the Process of Adaptation

Key:
1. Novosibirsk
2. Altay
3. Days

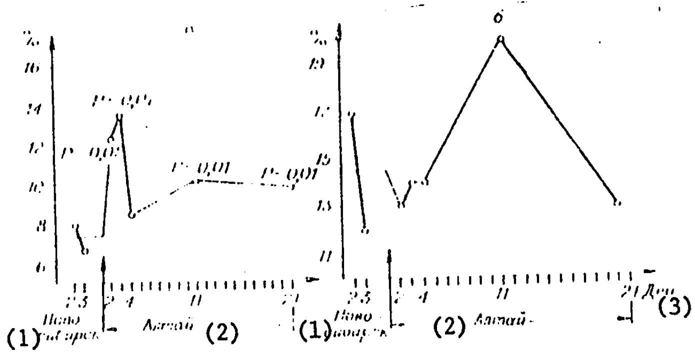

Рис. 33. Изменение выраженности сердечной реакции (а) и реакции ЭЭГ десинхронизации (б) при воспроизведении слов.

Figure 33. Changes in Manifestation of Cardiac Reaction (a) and EEG Desynchronization (b) during Word Reproduction

Key:
1. Novosibirsk
2. Altay
3. Days

In the next phase of the adaptation process (3rd-4th day), an increased level of spontaneous dermo-galvanic reaction continued; in Southern Kuril, cardiac rhythm slowed down; in the mountains, frequency of cardiac rhythm increased with a normal dermo-galvanic reaction; orientational reactions increased and motor activity was normalized.

In this period, memorization of words did not differ from control data for total memorization of the list. The number of test and control studies was the same. On the basis of a number of indices, on the 3rd day immediate reproduction decreased and by the 3rd-6th day, delayed word reproduction was noted in Southern Kuril. EEG activation reaction, accompanying word reproduction, diminished to the lower limits of the control. Dermo-galvanic and cardiac reactions remained below control levels although their increase had begun by the 4th day. In the mountains of Altay, on the 3rd-4th day, immediate and delayed word reproduction were somewhat lower than the control, but in another test, the indices exceeded the control. Levels of the accompanying EEG activation, dermo-galvanic and cardiac reactions were within the limits of normal. Verbal memory for syllables from the 4th day, and form-space memory from the 3rd day showed definite improvement (fig 34).

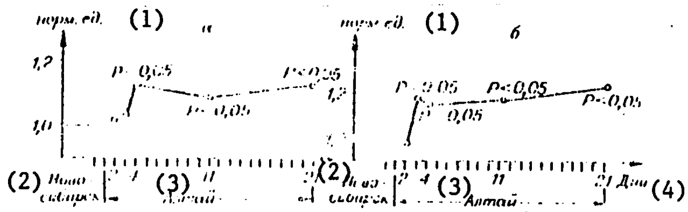

Рис. 34. Динамика кратковременной вербальной памяти на слоги (а) и образно-пространственной (б) памяти.

Figure 34. Dynamics of Short-Term Verbal Memory for Syllables (a) and Form-Space Memory (b)

Key:
1. Standard units
2. Novosibirsk
3. Altay
4. Days

With regard to motor-proprioceptive memory, in the first 11 days of adaptation, a distinction in the reproduction of a preset height by the right and left hands was noted: there was a definite "overestimation" of the preset height and as a result, increase in deviation of the reproduced height from the preset one during testing of left hand function. A reverse picture was noted in tests on right hand function: by the 3rd day of the adaptation process, a tendency towards decrease in deviation of the reproduced height from the preset one was noted, that is, "underestimation" of the preset height.

However, it is necessary to examine further the above described disturbance in motor coordination during this time. In the test of I. A. Sklyut, the "target" element of memory was very small, as seen in the lowering of the hand to shoulder level. The fact that disturbances in motor coordination were not related to the difference in reproduction of the preset height by the right or left hand points to the different roles of the brain hemispheres in the mechanisms for the adaptation process during this time. A more similar role of functional asymetry of the brain in adaptation will be examined below.

It is extremely significant that the variability in the number of reproduced words increased (fig 35). This was observed not only in a very low, but also in an unusually high level of word reproduction (fig 36), as well as in an increase in the individual scatter of indices for motor-proprioceptive memory.

Рис. 35. Изменение взвешенной дисперсии числа воспроизведенных слов.

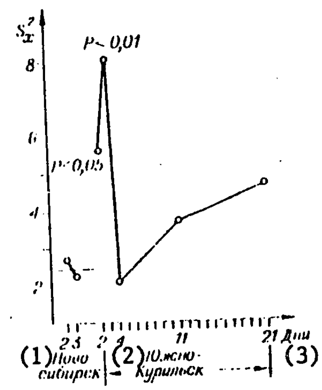

Figure 35. Changes in the Measured Variability in Number of Reproduced Words

Key:
1. Novosibirsk
2. Southern Kuril
3. Days

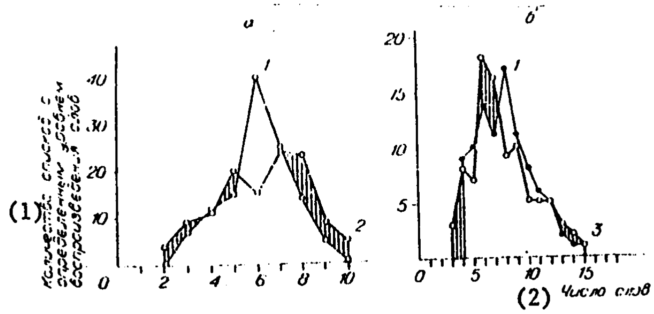

Рис. 36. Вариационная кривая числа воспроизведенных слов. а: Новосибирск, вторая и третья регистрации — 1; 2 — Памиро-Алай, 3-й и 4-й дни процесса адаптации; б: Южно-Курильск, второй и третий дни адаптации — 3.

Figure 36. Variability Curve for the Number of Reproduced Words. a: Novosibirsk, Second and Third Recordings--1; 2--Pamiro-Alay, 3rd and 4th Days of Adaptation Process; b: Southern Kuril, 2nd and 3rd Days of Adaptation--3

Key:
1. Number of list with defined level of reproduced words
2. Number of words

It was mentioned previously that there was an increase, in the intial period of the adaptation process, in the variability of indices for sensory-motor reactions, dynamic coordination, reaction to moving objects and orientational and cardiac reactions. The increase in the range of response increased the potential for adequate reactions to the changing external conditions of the environment.

Thus, the basic contribution of the processes of memory in this period is the function of mechanisms for reproduction: recovery and "playback" of the existing program or separate elements of it, on the basis of which response can be organized with the aid of the regulatory system. During the initial period, possibly, the reproduction of memory imprints was improved, thus facilitating the consideration of adaptive programs, determined genetically or derived in the process of previous adaptations. Unfortunately at the present time, there are no such data and special studies are needed.

In the initial period of residence of an organism in new conditions, the accumulation of imprints proceeds without significant activation of the processes of memory. In fact, the organism can not "know" how long these changing conditions will be maintained or whether it will be necessary to create new adaptive programs. Usually, in life, a short-term exposure to an ecological niche or not prolonged changes in conditions of that niche frequently occur rather than relocation with the goal of changing the range.

We assume that in the process of evolution, special mechanisms were formed which allowed the organism to adapt in a short period of time. Short-term adapation is achieved by inclusion and activation of the processes of regulation with the use of old programs and possibly, activation of mechanisms for reproduction of imprints. The creation of new adaptive programs for a short period of time is unnecessary.

Given prolonged residence by the organism in changing conditions, based on the accumulation of imprints of information obtained on the new factors in the environment, the long-term activation of function for the regulatory system can lead to overstrain. At such a stage, the stresses on the regulatory system are not known until the mechanisms cause activation of the processes of memory to accelerate the creation of new programs.

We suggest that the final period of individual adaptation is characterized by more rapid accumulation and utilization of imprints of new information concerning the environment, that is, by activation of the processes for memory involved in the creation and fixation of new programs. Actually, in our studies on adaptation, the maximum improvement in memory was noted on the 11th-21st days (fig 37).

Despite the fact that we selected subextreme conditions for testing, certain distinctions were noted in the effects of the influence of these conditions based on their duration. The least distinct improvement in the processes of memory during the psychophysiological studies was noted in adaptation of subjects to Altay. Whether this was related to less contrasting conditions of this region in comparison to the place of habitation of the subjects or was a consequence of repeated and intersecting adaptation (the expedition was conducted 3 years in succession), is difficult to determine at this time.

The distribution in time of reproduced words reached a maximum at the beginning of the interval for reproduction and subsequently, declined exponentially. In the first 15 s after presentation of the word lists to the subject, approximately 75 percent of all reproduced words were uttered (fig 38). Although word reproduction began later (fig 39) in Southern Kuril and by the 11th and 21st days of adaptation terminated earlier than in Novosibirsk, the general level of reproduction increased. In Altay, word reproduction was noted earlier than the rate seen in the control.

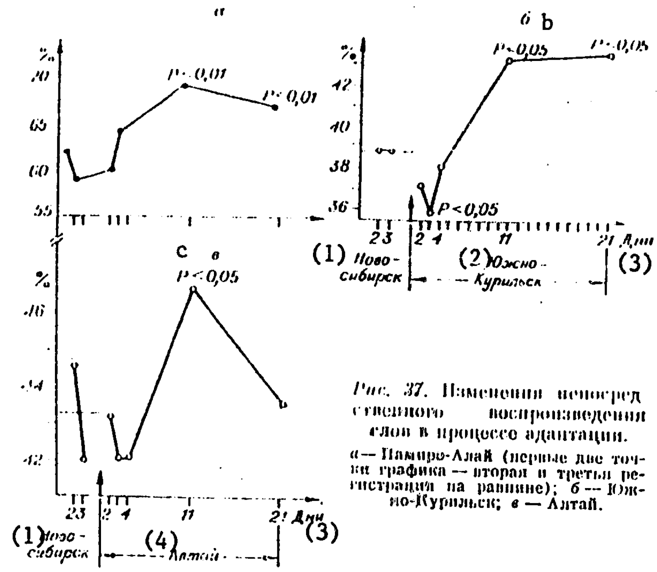

Figure 37. Changes in Immediate Word Reproduction in the Adaptation Process. a--Pamiro-Alay (First Two Points of the Graph--Second and Third Recordings for Comparison); b--Southern Kuril; c--Altay

Key:

1. Novosibirsk
2. Southern Kuril
3. Days
4. Altay

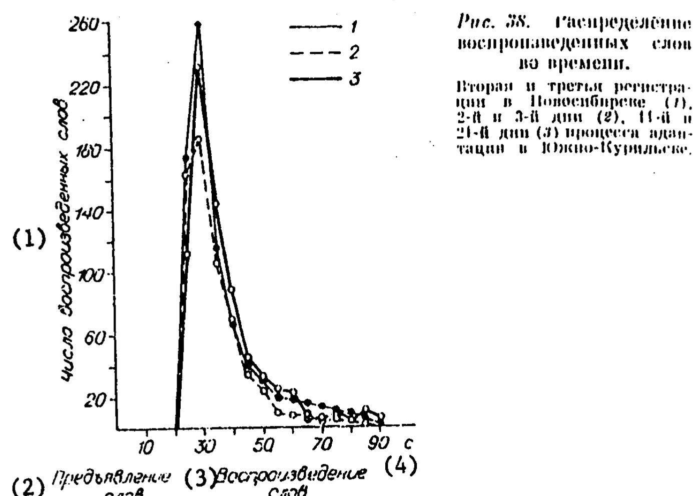

Figure 38. Distribution of Reproduced Words in Time, Second and Third Recordings at Novosibirsk (1), 2nd and 3rd Days (2), 11th and 21st Days (3) of the Adaptation Process in Southern Kuril

1. Number of reproduced words
2. Presentation of words
3. Reproduction of words
4. Seconds

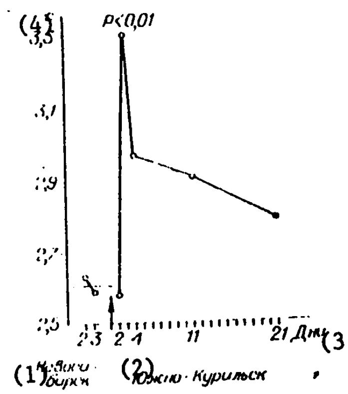

Рис. 39. Латентное время воспроизведения слов.

Figure 39. Latent Time for Word Reproduction

Key:
1. Novosibirsk
2. Southern Kuril
3. Days
4. Seconds

In this period, an improvement in memorization was observed: for complete memorization of words, fewer number of tests was needed than in control experiments (fig 40).

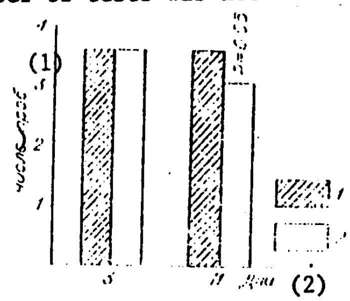

Рис. 40. Число проб заучивания для долговременного хранения. 1 — Новосибирск; 2 — Южно-Курильск.

Figure 40. Number of Memorization Tests for Long-Term Retention 1--Novosibirsk; 2--Southern Kuril

Key:
1. Number of Tests
2. Days

Analysis of the structures of the word lists showed that improvement in memory on the 11th-21st days occurred basically by the middle of the list when immediate and delayed reproduction and recognition of words took hold (figs 41, 42).

This "effect of the middle of the list of words" was seen in all three expeditions. In the 1977 expedition at Altay, analysis of "location on the list--reproduction" was carried out not only according to immediate reproduction of words but also for reproduction after intervals at 35 s and 2 min following the reading of the lists. In control and in test studies, comparison of data from all experiments for reproduction of words at the beginning, middle and end of the list revealed a definite improvement in the process of adaptation for word reproduction by the middle of the list. We consider that this effect was related to improvement in retention of long-term memory. However, in this period, changes in long-term memory studied in special tests were not detected: delayed reproduction after 24, 48 and 72 hours was close to the control values (figs 43, 44). Recognition after 72 hours also did not differ essentially from the control values.

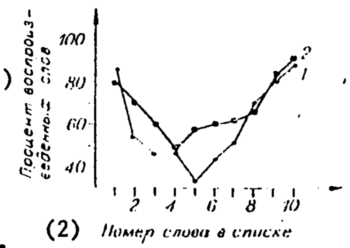

Рис. 41. Изменение эффективности воспроизведения слов в зависимости от места в списке. 1 — Новосибирск, второй и третьей регистрации; 2 — Памиро-Алай, 11-й и 21-й дни процесса адаптации.

Figure 41. Changes in Effectiveness of Word Reproduction in Relation to Location of Word on List
1--Novosibirsk, Second and Third Recording; 2--Pamiro-Alay, 11th and 21st Days of the Process of Adaptation

Key:
1. Percent of reproduced words
2. Number of word on list

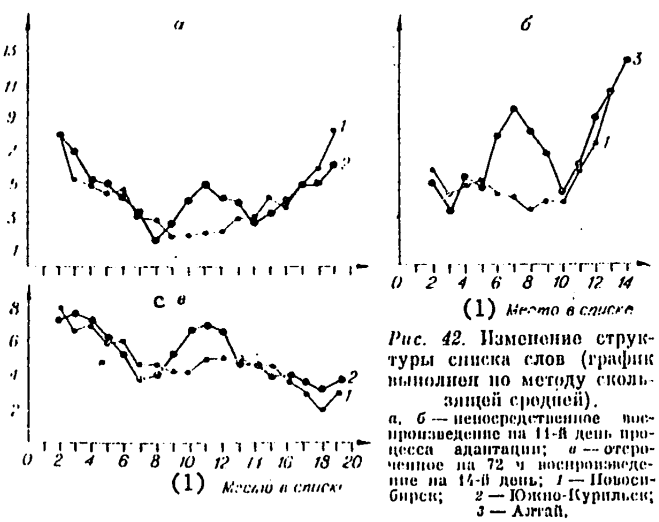

Рис. 42. Изменение структуры списка слов (график выполнен по методу скользящей средней). а, б — непосредственное воспроизведение на 11-й день процесса адаптации; в — отсроченное на 72 ч воспроизведение на 14-й день; 1 — Новосибирск; 2 — Южно-Курильск; 3 — Алтай.

Figure 42. Change in Structure of Word List (Graphing Done according to Nonlocalized Average)
a,b--Immediate Reproduction on 11th Day of Adaptation Process; c--Delayed Reproduction at 72 hours on 14th Day; 1--Novosibirsk 2--Southern Kuril; 3--Altay

Key:
1. Location on List

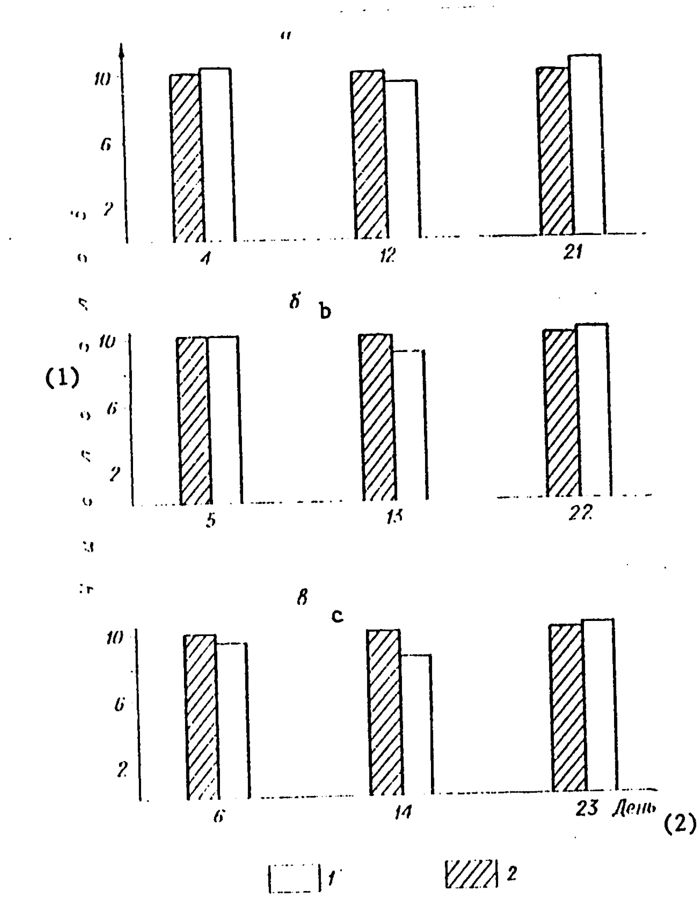

Рис. 43. Изменение долговременной памяти (отсроченное воспроизведение).
Через: а — 24 ч, б — 48 ч, в — 72 ч; 1 — Алтай, 2 — Новосибирск.

Figure 43. Change in Long-Term Memory (Delayed Reproduction) After: a--24 Hours, b--48 Hours, c--72 Hours; 1--Altay, 2--Novosibirsk

Key:
1. Number of Words
2. Day

A distinct level of reproduction of elements in relation to their location on the list was determined either by the time structure of fixation of the imprint, that is, by the mechanisms for short-term and long-term retention of imprints or by the condition of the imrprint at the moment of its readout, by the mechanisms for reproduction.

Reproduction of elements found in the middle of the memorized series can reflect the extraction of information, given a fixed imprint which, in the literature, is described as "auxiliary" memory (Messenger, 1971; Sanders, Barlow, 1971; Kruglikov, 1972). However, we think that this is determined not by the temporal structural fixation of the imprint, not a separate form of memory but rather reflects the process of reproduction in relation to the state of the fixed imprint.

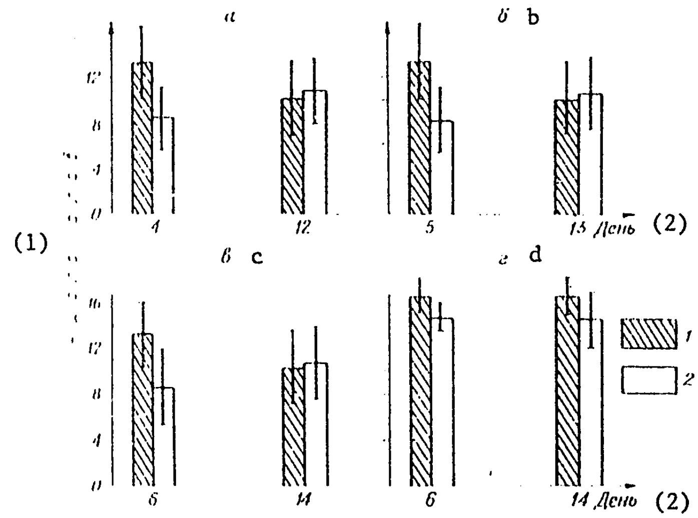

Рис. 44. Отсроченное воспроизведение и узнавание. Воспроизведение через: а — 24 ч, б — 48 ч, в — 72 ч, г — узнавание через 72 ч; 1 — Новосибирск, 2 — Южно-Курильск.

Figure 44. Delayed Reproduction and Learning
Reproduction after: a--24 Hours, b--48 Hours, c--72 Hours, d--Learning after 72 hours; 1--Novosibirsk, 2--Southern Kuril

Key:
1. Number of Words
2. Day

It seems that the form of memory is determined not by the nature of the fixation of the imprint, but by the potential for access to information for its readout. We assume that in the so-called short-term memory, its short duration is determined by the fact that the imprint is converted rapidly to a subliminal state and this makes its reproduction difficult. Thus, speech may represent not the disappearance of the imprint in short-term memory, but a rapid conversion of it to a subliminal state. A number of factors may be the cause of it: retroactive inhibition which occurs with the interfering influence of subsequent signals or inadequately intensive reinforcement. Concentration of attention, purpose, degree of emotional accompaniment and other factors are essential. With a one-time presentation of a signal, not accompanied by a manifested emotional reaction, after a short intervening time a loss of information for the organism occurs by the mechanism of omission. In "intermediate" memory, retention of imprints at the threshold of the state is expanded, but this is just a quantitative distinction given changes in the degree of influence of some of the enumerated factors. Perhaps these time intervals can be subdivided into shorter ones to obtain instantaneous, ultrashort, operative and many other "forms" of memory. It becomes clear why, in different investigations, this so-called short-term memory lasts from 10 s to several hours.

Given repeated exposure to these signals, each subsequent signal can strengthen the previous resulting process, making its duration permanent. It is possible that this enables retention of the imprint in the subliminal state and the potential for its readout after a large interval of time, thus suggesting that this state is long-term memory. Long-term retention of the imprint is possible given a single exposure to it with the presence of a manifested emotional reaction. This question is examined below in a similar fashion.

Improvement in the process of adaptation and memory of elements which are found in the middle of word lists can explain the weakening of proactive and retroactive inhibition (in subsequent statements, material will be presented on the weakening of proactive and retroactive interference during adaptation). There are data which show that proactive and retroactive interference is more marked in relation to memorization of elements found in the middle of the list because, in this location, the effect is conditioned by a one-time interfering effect of previous and subsequent elements of the memorized word series (Fress, Piazhe, 1973). When a weakening of both forms of inhibition occurs, then this is most marked at the middle of the list.

For the most part, during the course of the whole period of adaptation both to changes in zonal time and to mountainous conditions (2nd-4th and 21st days), a decrease in the average level of omission and strengthening of reminiscence on the 4th-11th days was observed (Fig 45a,b); by the 20th day, reminiscence returned to normal. In the course of the whole period of adaptation, for those subjects in whom was noted an increase in reminiscence from 7 percent (in the control) to 63 percent (see fig 45b), this process proceeds very actively in the initial period of adaptation. It is very interesting to compare the processes of omission and reminiscence in the period when these subjects undergo the greatest change in the initial period of the adaptation process, on the 2nd-4th days. In this period, the level of omission is decreased, but the number of test subjects in whom reminiscence is observed increases, even immediate reproduction in these days either does not change or declines somewhat.

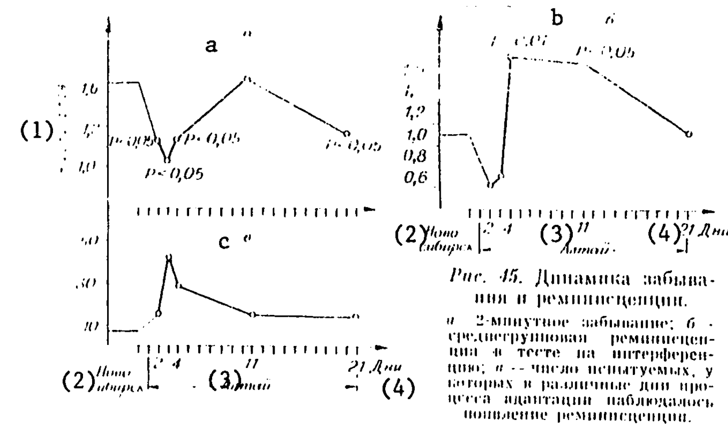

Figure 45. Dynamics of Omission and Reminiscence
a--2 Minute Omission; b--Average Group Reminiscence in a Test for Interference; c--Number of Subjects for whom on Different Days of the Process of Adaptation the Phenomenon of Reminiscence was Observed

It goes without saying that the decrease in omission and the increase in reminiscence attests to the fundamental changes in the processes of word reproduction during adaptation.

As for improvement of memory in the adaptation process, the manifestation and duration of EEG activation at the time of word reproduction shows that the imprint becomes stronger (see figs 31, 46). On the 11th-21st day of the adaptation process, EEG activation during word reproduction increased by 50-60 percent (fig 47a). Fixation and word reproduction of the imprint in memory occurs at a lower level in the dermo-galvanic reaction than in the control (see fig 47b). By the 21st day, the decrease in the average level of the amplitude indices for dermo-galvanic reaction was 42 percent. In comparison with Novosibirsk and with the first days of the adaptation process, a shift in the extremum of the dermo-galvanic reaction was detected in rėlation to the phase of effective word reproduction with an increase in its duration (fig 48). This points to the fact that the dermo-galvanic reaction, which is less distinct in magnitude, overlaps more fully with the phase of word reproduction.

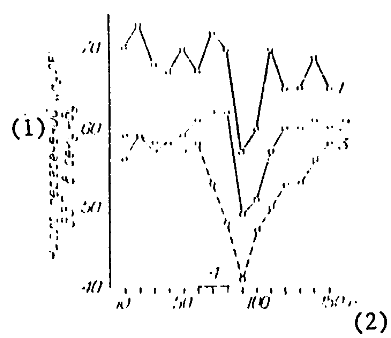

Рис. 46. Изменение числа пересечений «нуля» электроэнцефалограммы при запоминании и воспроизведении слов.
1 — Новосибирск; 2 — Южно-Курильск, 4-й день адаптации; 3 — 21-й день; 4 — момент предъявления слов.

Figure 46. Change in Number of Intersecting "Zero" Electroencephalograms during Memorization and Reproduction of Words
1--Novosibirsk; 2-- Southern Kuril, 4th Day of Adaptation; 3--21st Day; 4--Moment of Word Presentation

Key:
1. Number of intersecting "zero" EEG in seconds
2. Seconds

It is significant that on the 11th-21st days of the adaptation process the manifestation of cardiac reaction, given fixation and word reproduction, is only slightly different from normal. In this same period, the different electrocardiographic pictures (tachycardia in the mountains and bradycardia in Southern Kuril) actually determined the different characteristics of the accompanying fixation and word reproduction during the intial period of adaptation: in the Kurils, cardiac reaction was close to normal (fig 49), in the mountains of Pamiro-Alay and Altay, changes were more marked (fig 50a, b).

Classification of all word reproduction into two groups--by the number of reproduced words from the list greater than average for the experiment and those lower than average--allows detection of a shift in the extremum of dermo-galvanic reaction in

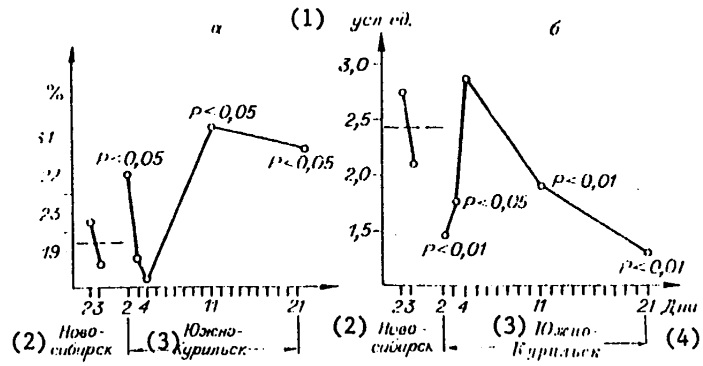

Рис. 47. Изменение выраженности ЭЭГ десинхронизации (а) и кожно-гальванической реакции (б) при воспроизведении слов в процессе адаптации.

Figure 47. Changes in Manifestation of EEG Desynchronization (a) and Dermo-Galvanic Reaction (b) during Word Reproduction in the Adaptation Process

Key:
1. Arbitrary units
2. Novosibirsk
3. Southern Kuril
4. Days

Рис. 48. Изменение кожно-гальванической реакции в процессе адаптации при запоминании и воспроизведении слов.
1 — третья регистрация в Новосибирске; 2 — 4-й день адаптации; 3 — 21-й день; 4 — момент предъявления слов.

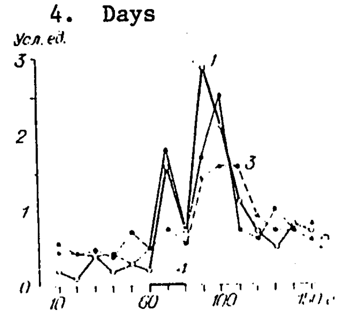

Figure 48. Change in Dermo-Galvanic Reaction in the Adaptation Process during Memorization and Word Reproduction
1--Third Recording in Novosibirsk; 2--4th Day of Adaptation; 3--21st Day; 4--Moment of Word Presentation

Key:
1. Arbitrary units
2. Seconds

the earlier period (4th day) of the adaptation process (fig 51). Data obtained at Novosibirsk and during adaptation to a monsoon climate showed that greater shifts in the dynamics of cardiac rhythm corresponded to more effective word reproduction (fig 52). Weighted variability of the dermo-galvanic reaction given word reproduction reached a maximum on the 11th day, remaining higher than the initial level during all the days of the adaptation process (fig 53).

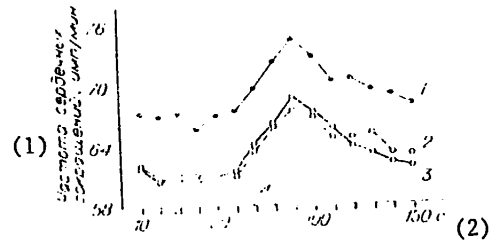

Рис. 49. Изменение динамики сердечного ритма в процессе адаптации при запоминании и воспроизведении слов.
1 — Новосибирск, вторая и третья регистрации; Южно-Курильск: 2 — 2-й и 3-й дни, 3 — 11-й и 21-й дни процесса адаптации, 4 — момент предъявления слов

Figure 49. Change in the Dynamics of Cardiac Rhythm in the Adaptation Process during Memorization and Reproduction of Words 1--Novosibirsk, Second and Third Recordings; Southern Kuril: 2--2nd and 3rd Days, 3--11th and 21st Days of Adaptation Process, 4--Moment of Word Presentation

Key:
1. Frequency of cardiac contraction beats/minute
2. Seconds

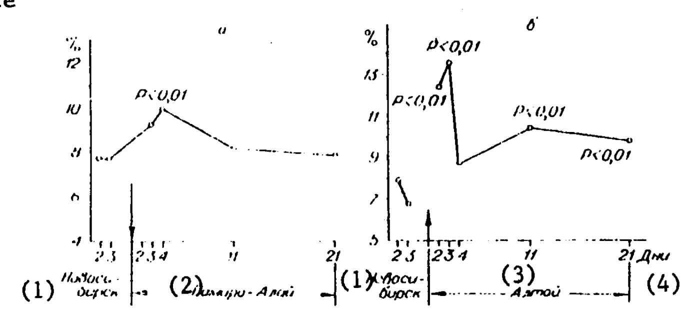

Рис. 50. Изменение выраженности сердечной реакции при адаптации в горах Памиро-Алая (а) и Алтая (б). Отношение частоты сердечных сокращений за минуту после предъявления списка слов к частоте сердечных сокращений за минуту фона (в процентах).

Figure 50. Change in Manifestation of Cardiac Reaction during Adaptation in the Mountains of Pamiro-Alay (a) and Altay (b). Relationship of Frequency of Cardiac Contraction from the Moment of Word Presentation to the Frequency of Cardiac Contraction from the Moment of Recording (in Percentages)

Key:
1. Novosibirsk
2. Pamiro-Alay
3. Altay
4. Days

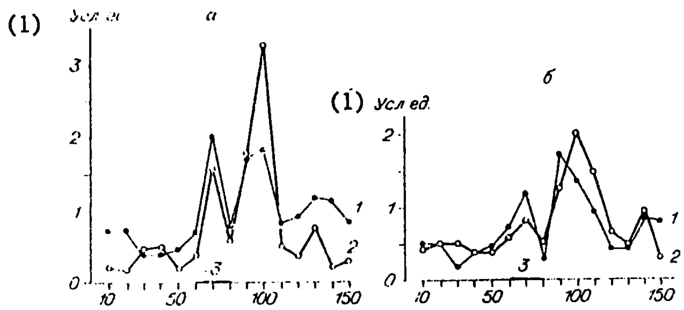

Рис. 51. Кожно-гальваническая реакция в процессе адаптации в Южно-Курильске при воспроизведении слов ниже (*1*) и выше (*2*) среднего значения.

а — 4-й день процесса адаптации; б — 11-й день; 3 — момент предъявления слов.

Figure 51. Dermo-Galvanic Reaction in the Adaptation Process in Southern Kuril during Word Reproduction, Lower (1) and Higher (2) than Average Values
a--4th Day of the Adaptation Process, b--11th Day; 3--Moment of Word Presentation

Key:
1. Arbitrary Units

By the 11th-21st days of the adaptation process, we continued to note an improvement in the form-space and verbal memory for syllables (see fig 34). From analysis of the motor-proprioceptive memory (fig 54), it was evident that the indices for left hand function were close to the control values, but in the indices for the right hand, a definite decrease in deviation from the preset height of the reproduced one was noted Thus, in this period, all disturbances in motor coordination (see fig 12b) disappeared, with such similar lateralization attesting to the significance of functional asymetry of the brain in changes in functional memory during the adaptation process.

During adaptation, the process of interference undergoes very interesting changes which are similar both for relocation in another time zone and in the mountains. Studies by L. A. Konstantinovskaya showed that in the intial period of adaptation (2nd-3rd days) the effect of retroactive interference on retention and reproduction of memory imprints increased, but then, from the 4th-11th days, retroactive interference decreased and by the 21st day, the manifestation of this influence increased to the level of control values (fig 55). The nature of changes in proactive interference was somewhat different (see fig 55b) and during the initial period, a noticeable strengthening of these changes was not observed. Beginning on the 4th day, during the whole subsequent period, decrease in proactive interference occurred. However, by the 21st day, manifestation of proactive interference in contrast to retroactive intereference did not increase, but remained essentially smaller than the control values.

Actually, these differences in the dynamics for manifestations of retroactive and proactive interference play a determining role in the physiological mechanisms of

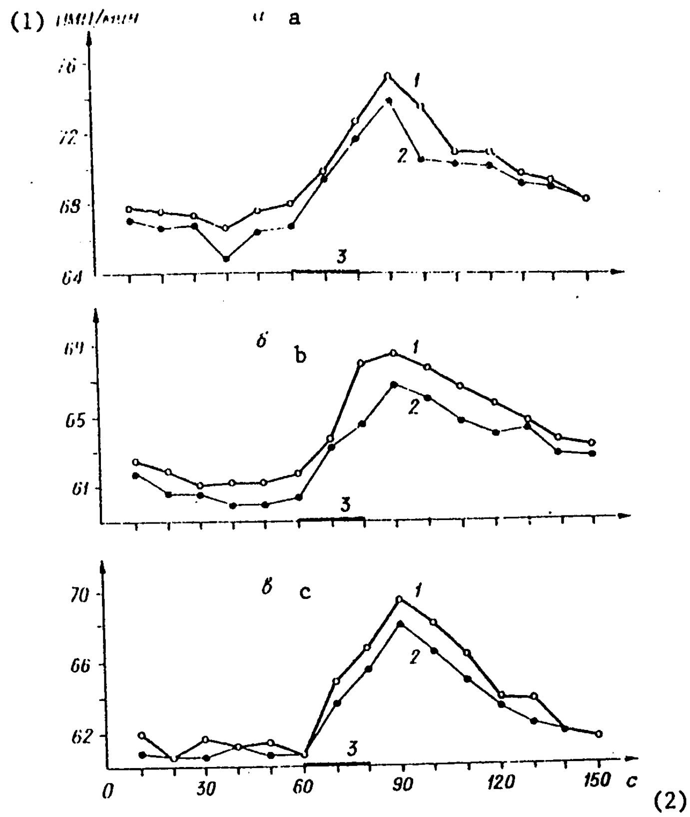

Рис. 52. Сердечная реакция в процессе адаптации при воспроизведении слов ниже среднего (2) и выше среднего (1) значения.
а — Новосибирск, вторая и третья регистрации; Южно-Курильск: б — 2-й и 3-й дни, в — 11-й и 21-й дни адаптации; 3 — момент предъявления слов.

Figure 52. Cardiac Reaction in the Adaptation Process during Word Reproduction at Lower than Average (2) and Higher than Average (1) Levels
a--Novosibirsk, Second and Third Recordings; Southern Kuril; b--2nd and 3rd Days, c--11th and 21st Days of Adaptation; 3--Moment of Word Presentation

Key:
1. Beats/minute
2. Seconds

individual adaptation. Whether they enable similar changes in the promotion of formation of new adaptive programs is difficult to say at the present time because these are the first data showing the role of the process of interference in the mechanisms of adaptation. Until this time, there have been no studies reported in the international literature which analyze interference in the process of individual adaptation of man to various climato-geographic conditions.

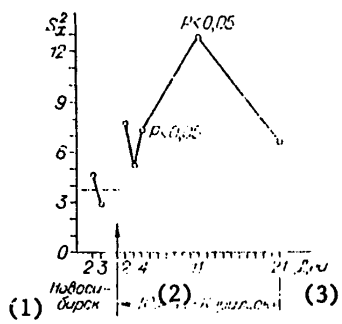

Рис. 53. Изменение взвешенной дисперсии кожно-гальванических реакций при воспроизведении слов.

Figure 53. Change in Weighted Deviation of Dermo-Galvanic Reaction during Word Reproduction

Key:
1. Novosibirsk
2. Southern Kuril
3. Days

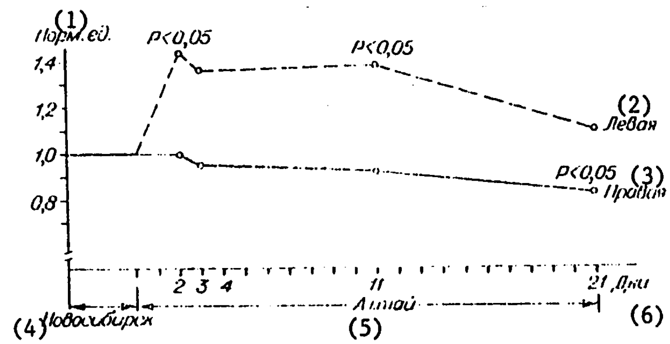

Рис. 54. Динамика двигательно-проприоцептивной памяти (по среднему отклонению от заданной высоты).

Figure 54. Dynamics of Motor-Proprioceptive Memory Based on Average Deviation from Preset Height

Key:
1. Standard units
2. Left
3. Right
4. Novosibirsk
5. Altay
6. Days

We assume that in the process of adaptation, because of weakening in lateral inhibition (as seen in a decrease in interference), the amount of information perceived and processed by the brain increases. Thus, there is evidence for an increase in sensory information in the sensory systems during the process of adaptation (Keydel et al., 1964).

The inhibitory interaction of nervous elements represents one of the basic mechanisms for many sensory modalities and for the level of integration (Brooks, 1959; Yung, 1964)

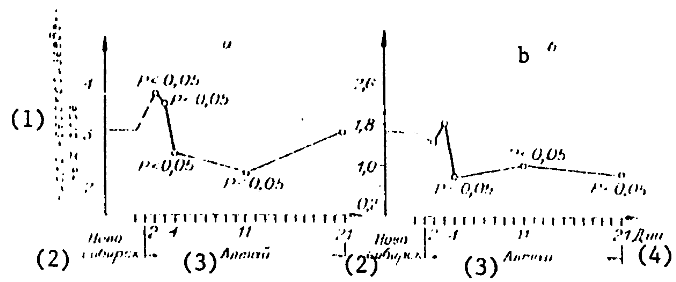

Рис. 55. Динамика ретроактивной (а) и проактивной (б) интерференции.

Figure 55. Dynamics of Retroactive (a) and Proactive (b) Interference

Key:

1. Number of words not reproduced
2. Novosibirsk
3. Altay
4. Days

It is of interest that lateral inhibition is suppressed in the reticular structure during dark adaptation and can even alternate with lateral irradiating stimulation (Barlow et al., 1957). Lateral inhibition is extremely wide spread throughout the central nervous system (Fessar, 1964; Konorskiy, 1973), in particular, in the cortex of the greater hemispheres and in the cortex of the cerebellum (Baumgartner, 1961; Mountcastle et al., 1957; Hubel, Wiesel, 1959; Pribram, 1975; Sentagotai, Arbib, 1976). The constant inhibitory reactions at the boundaries of a zone subjected to the effects of a separate electrical stimulus were recorded in the cortex (Jung, Tônnies, 1950; Creutzfeldt et al., 1956). This is one of the most important mechanisms for reprocessing sensory information (Lindsay, Norman, 1972).

Stimulation of nerve cells involves active inhibition of neighboring ones through inhibitory interneurons. Lateral inhibition, actually is a general principle for afferent connection of different modalities and it is directed at strengthening sensory distinctions with the aid of contrast (Jung, 1964). Lateral inhibition is necessary for spatial limitation of the zone of cells which activate peripheral stimulation (Mountcastle, 1964).

Thus, the nervous system is supplied with mechanisms which expose specific forms of excess information coming from the surrounding environment, and which regulate the amount of perceived information. Lateral inhibition can be viewed as one of the mechanisms which decreases the excess of information on the sensory-perceptive level.

Scientists have established that by transmission in the most advanced sections of the central nervous system (CNS), the general amount of information which is contained in the sensory impulse gradually decreases (Lindsay, Norman, 1972). It is possible that the weakening of lateral inhibition decreases the loss of information which occurs in sensory analysis.

The weakening of interference not only increases the amount of perceived information, but possibly, also the duration of rentention of memory imprints in the subliminal state and thus, promotes its reproduction. Conditions are created for retention of a large volume of information for a prolonged period of time.

It is likely that the imprints from a new multifactoral situation determine the neuronal elements of memory (the morphofunctional substratum). When a situation is repeated, the neuronal elements can again be combined with sensory inputs and interact with analytical mechanisms for correction and reinforcement of detailed fixed information. During the process of adaptation, certain loci of stimulation in the central nervous system, related to the selection of the most essential factors of change in the external environment, can acquire a dominant character. Dominance, as V. S. Rusinov suggests (1969) is a temporary predominant reflexive system which directs the function of the nerve centers at a given moment, unites functionally the nerve centers of the cortical, autonomic and humoral components. Prolonged uniform stimulation enables aggregation which leads to changes in the functional state of separate neuronal constellations and reconstruction of stimulation loci occurs on a new level of stationary stimulation. Increase in the capability of neurons for polysensoral reactions (Rabinovich, 1975) is extremely significant. All of this promotes aggregation of incoming stimuli from the external environment in the central nervous system. The loci acquire a dominant character and this is one of the initial stages of formation of memory imprints. If dominance is considered a system of opposite connections (Rusinov, 1969) where inhibition of sensory procedure can occur, then the potential weakening of direct and counter inhibition in the process of adaptation has great significance.

Finding biological significance in information acquired in the process of adaptation enables multiple repetition of stimuli, facilitating the separation of useful information from noise. An expanded range of perceived information allows the organism to detect changes in the characteristics of a large number of external signals, but with a decrease in the ability to distinguish and separate details. A worsening of the quality of analysis given the prolonged effect of new external conditions is compensated for by the potential, after separation of noise, to analyze repeatedly this signal. Increase in the amount of processed and fixed information, because of the accumulation, allows increase in the amount of significant information. The observable improvement in memory becomes adequate for facilitation of the accumulation of imprints given multiple repetition of the situation. The imprints are stabilized because of an enormous number of repetitions in the course of a long period.

Thus, the speed and accuracy of imprint fixation determines the process of adaptation and constitutes the fundamentals of the state of adaptation. The state of adaptation is determined by not only the firmness of imprint fixation, given activation of the processes of memory for strengthening new adaptive programs, but also by the completeness of reproduction. Consequently, the durability of imprint fixation and the completeness of its reproduction is the basis for formation and retention of new adaptive programs given individual adaptation. These mechanisms can ensure creation and retention of formed adaptive programs, which, in turn, facilitate repeated and intersecting adaptation.

Based on these concepts, we think it suitable to present a program for study of memory during the process of adaptation

Program--Memory and Adaptation

1. Adaptation--the result of formation of memory imprints and the completeness of their reproduction.
1.1. Mechanisms of memory in the creation of new programs.
1.1.1. Changes in memory during the process of adaptation.
1.1.1.1. Dynamics of different forms of memory in different phases of the processes of adaptation, reminiscence and omission.
1.1.1.2. Dependence of the amount of perceived information on changes in attention and interference in the adaptation process.
1.1.1.3. The adaptability of reactions as a function of the completeness of reproduction of different components of the imprint.
1.1.1.4. Analysis of functional asymmetry in the brain for detection of emotional and logical components given formation of new adaptive programs.
1.1.1.5. Role of retention of memory imprints in the mechanisms for readaptation and cross-over adaptation.
1.1.2. Participation of mechanisms in the brain in the creation and optimization of new adaptive programs.
1.1.2.1. Convergent properties of neurons and the significance of dominant loci of stimulation in the adaptation process.
1.1.2.2. Different forms of inhibition as an apparatus to stabilize the activity of neuronal constellations for separation and retention of signals, intended for memorization.
1.1.2.3. Interaction of sympathetic and intracellular systems which determine the potential for formation of memory imprints.
1.1.2.4. Memory as the basis for reconstruction in higher nervous activity of man in the adaptation process. The second signal system.
1.1.3. Formation of memory in relation to stress, emotional stress and the activity of the regulatory systems.
1.1.3.1. Memory against a background of different degress of stress.
1.1.3.2. The role of emotion in the regulatory mechanisms for formation and reproduction of memory imprints.
1.1.3.3. Role of stress on regulatory systems in the creation of new adaptive programs, based on the formation of memory imprints.
1.1.3.4. Autonomic guarantee of formulation of imprints in various phases of adaptation.
1.2. Search for, classification of and selection of adaptive programs which are acquired in phylo- and ontogenesis. Role of regulatory mechanisms of memory.
1.2.1. Structural-functional and neurochemical organization of the systems which regulate memory.
1.2.2. Neuronal mechanisms of action of the regulatory system in the formation and reproduction of imprints.
1.2.3. Activity of the regulatory systems in different phases of adaptation.
1.2.4. Stability and dependability of regulation.
1.2.5. Significance of the original functional state of the brain.
1.3. Immunologic memory in guaranteeing adaptive construction of immune response.
1.3.1. Neurohumoral and cellular mechanisms of immunologic memory.
1.3.2. The potential for reconstruction of the structure of immune response on the basis of immunologic memory.

1.3.3. Interrelationship of different clases of immunoglobulins: T- and B-cell systems.
1.3.4. Potentials and limits of regulation of immunogenesis.
2. Regulation of memory processes by means of changes in activity of the regulatory system.
2.1. Prediction of the effectiveness of formation of memory imprints according to informational indices for activity in the regulatory system.
2.1.1. Detection of the features of macropotentials which reflect the process for adoption of solutions (differentiation of signals) and selection of signals for memorization.
2.1.1. Evaluation of the time-phasic correlational relationships which make up the spectrum of latent potentials in the structures of the regulatory system according to the criteria of imprint reproduction.
2.1.3. Selection of informational indices for correct and incorrect reactions of reproduction by means of mechanical elaboration of an accumulated mass of responses in different formations of the regulatory systems.
2.1.4. Evaluation of the effectiveness of function of the regulatory systems of memory according to the informational characteristics of biopotentials.
2.1.5. Dyanamics of changes in the characteristic signs for evoked potentials in various stages of formation and reproduction of memory imprints.
2.1.6. Determination of a priori probability of the appearance of conditioned responses given detection of a complex of signs for changes in evoked potentials.
2.1.7. Construction of a dynamic model for an optimal regulatory system.
2.2. Development of physical and chemical capabilities for regulation of memory with the goal of acceleration and facilitation of adaptation.
2.2.1. Character and limits of possibilities for formation of memory imprints given activation, shutoff of nuclear formations and disturbance of connections in the regulatory systems.
2.2.2. Evaluation of the potentials of physical capabilities for action in a multi-structural regulatory system for facilitation of formation of memory imprints.
2.2.3. Formation of separate components of adaptive programs by means of preliminary psychological adjustments, special forms of learning, preliminary and cross-over adaptation.
2.2.4. Pharmacological means for regulation of memory. Creation of conditions for optimal formation and reproduction of memory imprints.
2.2.5. Development of chemical means to recover memory imprints based on the specifics of disturbances in reproduction during the performance of adaptive reactions.

Conclusion

Analysis of data, obtained during adaptation to different climato-geographic conditions suggests that, along with specific reactions, general mechanisms are in operation. Despite the varied character of the autonomic background in various adaptive conditions (predominance of the sympathetic tonus in mountains and of the parasympathetic in relocation to another time zone), general function of the regulatory systems and memory are very similar. Inclusion of thesephysiologial mechanisms in a specific time regime also determines the phasic nature of the process of individual adaptation.

Detection of mechanisms for regulation of the development of the adaptation process even today requires the development of a working hypothesis for the physiological mechanisms of this process which could serve as an instrument of analysis.

In view of the fact that the process of adaptation is a function of time, we assume that various physiological mechanisms are included in each stage. Given a rapid change in external conditions, special adaptation is accomplished with the aid of emotional mechanisms and the Selye adaptational syndrome. In these conditions, the responses, constructed on the basis of such nonspecific mechanisms, replace the more specific forms of adaptation because the later could not be accomplished with an absence of corresponding adaptive programs, the creation of which would be impossible with inadequate information. Given a short-term residence of the organism in new conditions, similar nonspecific mechanisms function efficiently without any kind of preparation and allow the organism to adapt rapidly to these conditions. This interrelationship of the organism and external environment can not be sustained for long because on the one hand, a large amount of energy is expended, and on the other, the range of responses exceeds considerably the amount which is required. Moreover, among all these responses, there are no completely adequate forms of adaptive reactions.

The development, given different forms of adaptational mechanisms, of engaged emotions and the Selye adaptational syndrome is determined by the sharp contrast between rapidly changing conditions and the psychological equipment of man. Given an insigificant contrast, such as the one found in the conditions of Altay, nervous-emotional stress is almost nonevident and regulatory systems can be included then and there. With manifested nervous-emotional stress in the first days of the process of adaptation, the indications for activation of the regulatory system are masked, although in a given situation, it is likely that a parallel search for adequate reactions by means of including regulatory mechanisms is absent.

The existing genetic programs or those formulated in the process of previous adaptations can reflect inaccurately the outside world given changes in ecological conditions. It is necessary to build on them for trial of the obtained adaptive reaction. Probably, in the first days of residence by the organism in the new conditions, a fundamental stress is placed on the regulatory systems. Physiological mechanisms, in the initial period of the process of adaptation, can be activated by the regulatory system for adaptation of responses to changed conditions with the use of the already existing programs.

Data obtained during adaptation of man at Pamiro-Alay, at Southern Kuril and at Altay showed that at the beginning of residence in new climato-geographic conditions, variability in indices for dynamic coordination, reactions to moving objects, sensory-motor reactions, errors in evaluation of time, fluctuations in manifestation of orientational and cardiac reactions, variation in the number of reproduced words and indices for motor-proprioceptive memory all increased (fig 97). A search proceeds for the optimal reactions because the range of response expands. The resulting decrease in resistance of separate systems in the organism and the increase in variability of responses possibly is related to a weakening of the processes of inhibition during this period.

During this period, gradual stress on the regulatory system increased, variability in indices for the most varied functions decreased, maximum improvement in memory was observed, transition to the next phase in the process of adaptation proceeded with the inclusion of new physiological mechanisms.

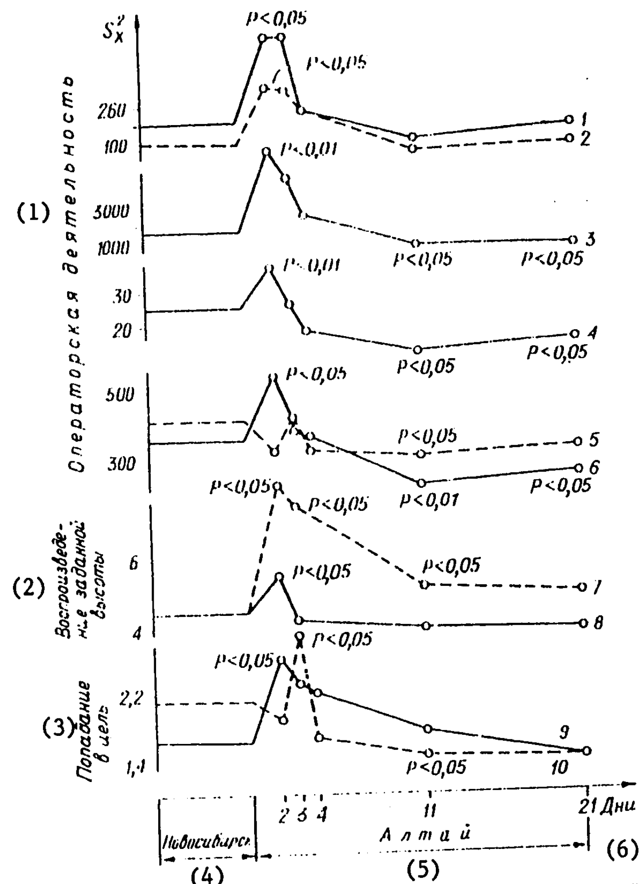

Рис. 97. Возрастание индивидуальной дисперсии показателей различных функций в первые дни адаптации.

Дисперсия времени реакции: *1* — правой, *2* — левой руки, *3* — на движущийся объект; *4* — дисперсия ошибки собственного времени; дисперсия времени вербальной реакции при предъявлении цифр: *5* — в левое, *6* — в правое поле зрения; дисперсия отклонения от заданной высоты: *7* — левой руки; *8* — правой руки; дисперсия отклонения от цели: *9* — правой руки, *10* — левой руки.

Figure 97. Increase in Individual Dispersion of Indices for Various Functions in the First Days of Adaptation
Variation in Time Reactions: 1--Right, 2--Left Hand, 3--to a Moving Object; 4--Variation in Errors of Judging Time; Variation in Time of Verbal Reaction given Presentation of the List: 5--in the Left, 6--in the Right Field of Vision; Variation in Deviation from the Preset Height: 7--Left Hand; 8--Right Hand; Variation in Deviation from the Preset Goal: 9--Right Hand, 10--Left Hand

Key:
1. Operator activity
2. Reproduction of preset height
3. Proximity of performance to test goal
4. Novosibirsk
5. Altay
6. Day

In the concluding period of individual adaptation, the basic physiological mechanisms which guarantee adaptation of the organism to a new environment is the activation of memory--the acceleration of accumulation and utilization of imprints of information in order to construct new adaptive programs for interaction with the surrounding environment and activation of the processes of memory for strengthening of formulated programs.

Initially, changes in formulation and direct reproduction of imprints of verbal, form-space and motor memory was noted in different periods of residence of the test subject in new climato-geographic conditions but the maximum improvement was observed on the 11th-21st days of the adaptation process (fig 98)

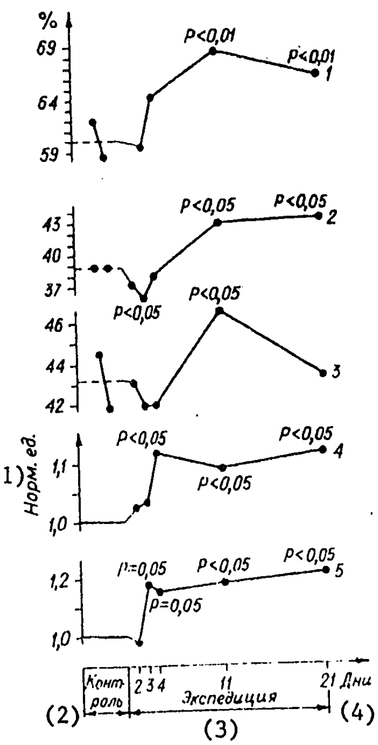

Рис. 98. Улучшение памяти в процессе адаптации.
Непосредственное воспроизведение: 1, 2, 3 — слов, 4 — слогов, 5 — образно-пространственных символов; 1 — Памир, 2 — Южно-Курильск, 3 — 5 — Алтай.

Figure 98. Improvement in Memory in the Adaptation Process
Direct reproduction: 1, 2, 3--Words, 4--Syllables, 5--Form-Space Symbols; 1--Pamir, 2--Southern Kuril, 3-5--Altay

Key:

1. Standard units
2. Control
3. Expedition
4. Days

Improvement of memory is accompanied by increase in EEG activation, retention of cardiac reaction, increase in duration and disturbance in the extremum of dermo-galvanic reaction, reflected particularly in the level of effectiveness of word reproduction. During this period of the adaptation process a significant functional asymmetry of the brain is very evident.

We observed in various phases of the process of adaptation that a decrease in proactive and retroactive inhibition (conditioned interference reaction), which is lateral weakening and retrogressive inhibition, actually increases the number of channels which transmit information. This leads to an increase in the volume of perceived information and allows detection of changes in characteristics of a large number of external signals. Improvement in memory, given a decrease in the interfering interaction between successive imprints of information, ensures facilitation of an accumulation of imprints of classified information and , given multiple repetition, it is fixed securely in a convenient form for its consideration. This is very significant both for attainment of the maximum adaptation effect in ordinary conditions in the environment and in very complex situations where the necessary conditions are not only resistan to fixation of memory imprints but also to the normal function of the program for reproduction. Response in highly organized animals and man is comprised of many components. However, during the performance of habitual responses, the components are not all reproduced and expression of them varies. It is probable that the magnitude of adaptation reaction is as important as are the structure and time construction of responses.

This pertains both to "nerve" and other forms of memory. An inadequately accurate fixation of a memory imprint or a nonoperative program for reproduction leads to disturbance in the reactions of the organism.

Thus, individual adaptation is determined by: 1) the process of adaptation when new adaptive programs are created on the basis of accumulation and utilization of information on the changes in the external environment and activation of memory takes place for strengthening these programs, and 2) the state of adaptation after completion of the process of adaptation. The process is ensured by the presence of developed programs which are maintained for a long time, mechanisms for their active search and selection, on the basis of which an optimal response is attained by the organism given the aid of the regulatory system. Thus, the most effective interaction of the organism with the new external environment, given a minimal energy output, is achieved.

Consequently, individual adaptation is accomplished on the basis of new adaptive programs maintained for a long time, and regulation of the physiological reactions in new conditions occurs also on the basis of the formed programs. The extensive morphofunctional potentials of man for adaptation to the most varied changes in the external environment probably are the result of functional asymmetry of the brain acquired in the process of evolution.

F. Z. Meyerson (1973) proposed that the general mechanisms of adaptation, including the initial deficit of macroergogenic phosphates, the increase in the potential for phosphorescence and mobilization of glycolysis with the consequent activation of genetic apparatus in cells and increase in synthesis of nucleic acids and proteins (which ensure an increase in the strength of the mitochondria) bear the entire weight for ensuring and regulating energy in the effector systems. We do not agree with the author that imprints, organized on the basis of long-term adaptation, are formed in the very same organs, even if they are formed by a unified functional system determining a given adaptive reaction.

V. V. Khaskin (1975) presents very convincing data on the fact that formation of structural imprints can not occur in the mitochondria of muscle, because in the interval between the first and second freezing of tissue in the experiment, the balance of adenylic acid and the relationship of oxidation and phosphorylation was not altered in the muscular mitochondria. He showed that imprints are not conditioned by either mobilization of nonesterified fatty acids or metabolsim of inductors in this system, that is catecholamines. Following productive discussions, V. V. Khaskin proposed that the nature of imprints probably lies on the level in memory of higher centers for regulation of metabolism. The author considers the increase in potential for phosphorylation as the signal impulse for adaptive changes in energy. A similar treatise explains more convincingly the participation of mechanisms for regulation of metabolism in the process of adaptation and does not contradict concepts on the significance of the brain, particularly in higher animals in the interaction of the organism with the external environment.

However, the proposed hypothesis on the whole, pertains only to the mechanisms for energy whereas this is a result of but not the mechanism for the process of adaptation.

Changes in metabolism and its regulation, on any level, can not determine the form of interaction of the organism or the structure and temporal construction of responses for adaptation of the organism to changing external conditions.

In our view, we give primary significance to the informational role of mechanisms which ensure the process of adaptation and the role of memory in the creation of programs for realization of the potentials of an organism given interaction of it with the external environment. It seems that the development of an informational theory of adaptation is close to our understanding of the significance of afferent reconstruction, maintenance and recovery of information and combines a unified program for ensuring the regulatory and functional systems of an organism. There still remains the open question of the concrete morphofunctional systems of the brain which determine the participation of the regulatory system and memory in the process of adaptation.

We previously stated our position on the participation of the amygdaloid complex in the process of comparison in neuronal network and in the mechanisms of interference (Il'yuchenok, 1973). K. Pribram (1975) suggests that normally functioning amygdaloid complex promotes suppression of action produced by the new stimuli which cause significant unbalance in an organism.

We assume that the change in activity of the system of the amygdaloid complex-central gray matter can lead to a decrease in contrast of the neuronal picture, a weakening of the mechanisms for lateral inhibition and a strengthening of the effect of unbalance which arises as a result of rapid change in the situation. It is the collection of these changes that we observed in different stages of the process of adaptation.

At the present time, data exist which allow us to examine the participation of brainstem structures of the reticular formation in the physiological mechanisms of adaptation. Actually, the changes in background EEG, the increase in time of stimulation and spontaneous dermo-galvanic reaction, the tendinous-periosteal reflexes of reflector nystagmus, the increase in manifestation and deviation of EEG activation during reproduction and improvment in the formation of memory can explain the strengthening of the activity of the brainstem reticular formation. However, in order to recognize the leading role of the brainstem reticular formation in changes of the psychophysiological status in the process of adaptation, scientists would like to have direct evidence to that effect. While no firm evidence exists, its participation is without doubt.

Recognition of the role of the regulatory systems of the brain and memory in physiological mechanisms which determine the process of adaptation provides many approaches to an investigation of ways to control these processes.

The data presented shows the potential for directed management of the processes of memory. Regulation of memory can be accomplished by the emotionogenic morphofunctional system which includes the amygdaloid complex, the preoptic field, the peri- and paraventricular nuclei of the hypothalamus and even the central gray matter of the midbrain. The involvement of the structures of the emotionogenic regulatory system precludes a single learning session because stimulation accelerates training by 5-10 times and allows recovery of reproduced imprints found in the lower threshold of sensation (readout).

Analysis of experimental data allows us to explain the role of separate structures of the system in the creation of space-time organization of the brain nucleus formations. Such an organization is necessary for adequate development of conditioned reflexes.

Given the establishment of separate components of a conditioned reflex, a single activation of the emotionogenic regulatory system leads to stabilization of reproduction of absent components. The potential for short-term reproduction of conditioned reflexes has been demonstrated given the presence of a subliminal imprint, pharmacologic facilitation of the synaptic processes and activation of the mesencephalic reticular formation.

Presently, it is possible to describe the neurochemical mechanisms of the emotionogenic system which regulates memory. Pharmacological analysis showed that, given an optimal level of activity of the serotoninergic structures, the normal cholinergic mechanisms determine the normal course of memory processes. Analysis of changes in neuronal reactions and conditioned evoked potentials, given a generalized effect on cholinoreceptors of the brain, local and microionophoretic supply of substances, the presence of cholinergic mechanisms which ensure the participation of these mechanisms in the regulation of memory was revealed. Data were obtained on the participation of cortical cholinergic structures in the genesis of conditioned evoked potentials which reflect the function of mechanisms for counting time and also the formation and reproduction of imprints of memory in various areas of the brain. The regulatory influence of cortical structures on the reproduction of memory imprints in the reticulatr formation was detected. A potential for "chemical" recovery of reproduction of memory imprints was also noted. Adaptation is seen as a function of the effectiveness of central regulatory systems and memory function which determine the direction of searches for ways to control the process of adaptation by means of changes in the activity of the neurochemical systems which regulate the formation and reproduction of imprints.

Analysis of mechanisms of adaptation and the potential for pharmacologic influence on the neurochemical regulatory systems of the brain points to the need to find ways for differentiated action on separate phases of the process of adaptation, each of which has its own characteristic physiological mechanisms.

Until recently, many questions remained unsolved: whether it is necessary to retain all phases of the process of adaptation, whether or not each previous phase includes a triggering mechanism for the next one, to what degree is there a required direction for the regulatory systems in the sense that prevention of overstrain of the regulatory mechanisms hinders the development of pathological conditions. This complicates the selection of a fixed period for use of pharmacologic substances in order to obtain a positive effect and not a disturbance of the adaptation process. Therefore, a thorough experimental trial of all proposed recommendations is necessary.

Appendix

Section 2.

Method for Study of the Activity of the Human Operator in a System of Compensatory Tracking (the method for expeditionary conditions was developed by M. A. Gilinskiy)

The technique for study of the activity of the human operator in a system of tracking moving objects allows investigators to use some of the concrete variants of experimentation according to their own experimental needs. Coinciding or compensatory types of tracking for regulated or random motion of an object in one or two dimensions is suitable for lab purposes.

We selected a simple methodology of compensatory tracking for an object moving in one dimension. The subject was required to contain a straight beam on an oscilloscope within the ranges of the sighting zone. The vertical coordinate of the beam was altered randomly in time. A portable apparatus, developed for the experiment was an analog accumulator of antiphasic directions. One of them consisted of a filter for low frequency given differences in direction, randomly distributed in time. The second (compensatory) one was activated by movement of the lever by the operator. In the experiments, the source of the signal was a minature radioisotopic generator for random impulses (SAIP, France), patterned in time, according to Puasson's law (fig 99). Each of these impulses was translated into a new state by the trigger Tr (fig 100), developed in a computer system. Originating in the discharge of the trigger, the randomly timed result of differences in directions (see the graphic representations in fig 99) was filtered further in the composite filter for low frequencies (see fig 100), gathered on the basis of integrated microcircuits KIUT402A. The maximum duration time of the circuits in the filter was 2.75 s. The level of current in the output of the filter for each moment determined the verticle coordinate of the straight beam on the oscilloscope SI-19. The threshold values for a random noncompensatory signal reached ±1,300 mV and beams moved out to the limits of the screen. The maximum speed of changes in the signal was 2.8 V/s. The diapason of amplitudinal values of the signal for which the beam was found in the "field of regulation" was ±100 mV.

The task of the subject involved maintenance of the straight beam of the oscilloscope within the limits of the central zone of the oscilloscopic receiver-- the "field of regulation"--with dimensions according to the verticals of 2 cm. This was achieved by shifting the lever of the apparatus, as a result of which the running current of the filter for low frequencies (random signal) was compensated for in the output of the integrating amplifier A_3 (see fig 100).

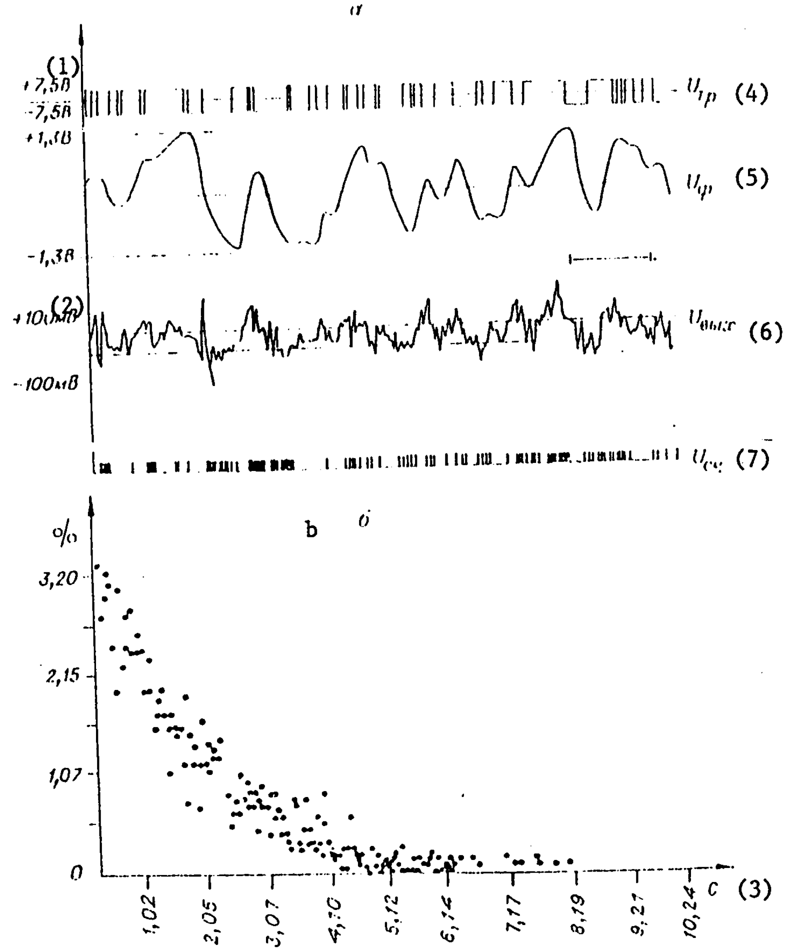

Рис. 99. Амплитудно-временные характеристики сигналов в устройстве слежения.

а — $U_{тр}$ — перепады напряжения на выходе счетного триггера; $U_ф$ — аналоговый случайный сигнал на выходе фильтра нижних частот; $U_{вых}$ — выходной сигнал устройства — результат компенсации случайного сигнала оператором; $U_{сч}$ — таймерные импульсы на входе СЧ, при превышении сигналом $U_{вых}$ пределов области регулирования; б — гистограмма сигналов генератора случайных импульсов: по оси абсцисс — длительность межимпульсных интервалов, с; по оси ординат — вероятность поступления импульса с соответствующим межимпульсным интервалом, %.

Figure 99. Amplitudinal-temporal Characteristics of Signals in a System for Tracking (R. Yu. Il'yuchenok)

a--U_{tr}--surges in current from discharge of measuring electronic trigger; U_{filter}--analogous random signal for discharge of filter for low frequencies; U_{output}--output signal of resistance--result of compensation for random signal by the operator; $U_{decimal\ calculator}$--timed impulses for the input of decimal calculator$_2$ when the signal of U_{output} exceeds the limits of the field of regulation; b--histogram of signals from the generator of random impulses: based on axi for the x-coordinate--duration of interimpulse intervals, s; based on the axi of the ordinate--the probability of intake of impulse with corresponding interimpulse interval, percent

Key (fig 99):

1. V
2. mV
3. s
4. $U_{trigger}$
5. U_{filter}
6. U_{output}
7. $U_{decimal\ calculator}$

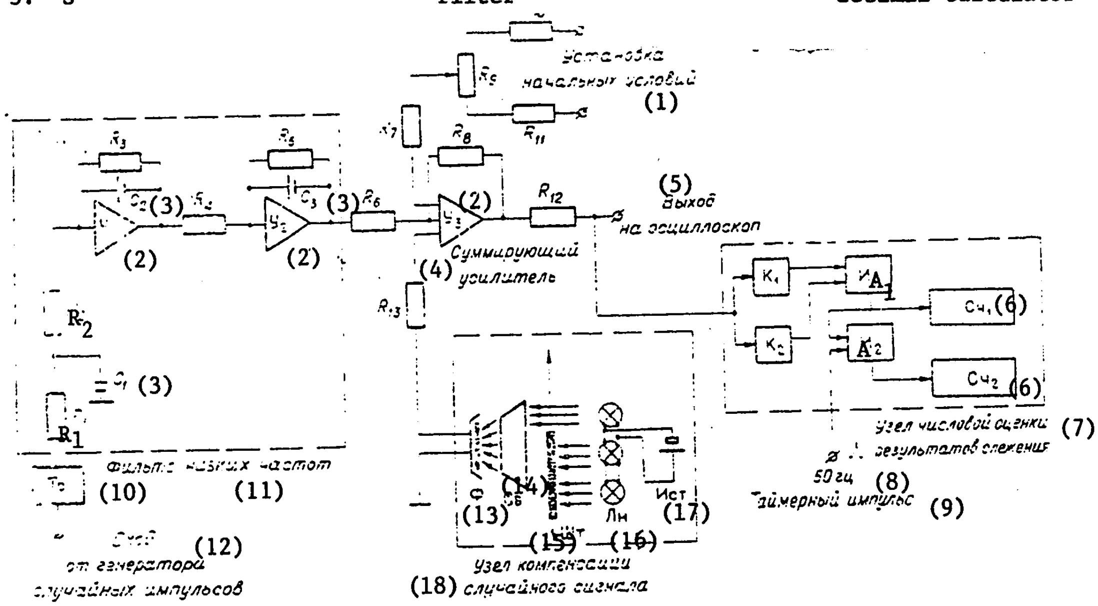

Рис. 100. Схема устройства для оценки характеристик слежения человеком-оператором случайно перемещающегося объекта.

Электронный узел: Тр — счетный триггер, $У_1$—$У_3$ — операционные усилители К1УТ402А; R_1, R_4, R_5=2,2 М; R_2=1 М; R_3=2,6 М; R_6, R_7, R_8=0,1 М; R_9=12 К; R_{10}, R_{11}=5,6 К; R_{12}=500 Ом; R_{13}=3,7 К; C_1, C_2=0,25, C_3=1,25 мФ. Узел компенсации случайного сигнала: Ф — селеновый фотоэлемент К20; Св — плексиглазовый световод переменного сечения; Шт — шторка, перемещаемая рычагом оператора; Лн — лампочки накаливания 6,3 В×0,28 А; Ист — стабилизированный источник накальных напряжений. Узел числовой оценки: $К_1$, $К_2$ — пороговые устройства с пределами ±100 мВ; $И_1$, $И_2$ — схемы совпадения; $Сч_1$, $Сч_2$ — декадные счетчики.

Figure 100. Scheme of System for Evaluation of the Characteristics of Tracking of a Randomly Moving Object by a Human Operator
Electronic units: Tr--measuring trigger, A_1--A_3--operational amplifier KIUT402A; R_1, R_4, R_5 = 2.2 m; R_2 = 1 m; R_3 = 2.6 m; R_6, R_7, R_8 = 0.1 m; R_9 = 12 C; R_{10}, R_{11} = 5.6 C; R_{12} = 500 Ω; R_{13} = 3.7 C; CRS_1, CRS_2 = 0.25, CRS_3 = 1.25 mF units of compensatory random signals: PE--selenium photoelement K20; LG--plexiglass light guide of variable diameter; Sh--shutter, movable by the operator's lever; IL--small incandescent lamp, 6.3 V x 0.28 A; SS--stabilizing source of incandescent current. Unit of numeral evaluation: K_1, K_2--threshold resistance with limits of ± 100 mV; I_1, I_2--schemes of congruence; DC_1, DC_2--decimal calculators

Key:

1. Apparatus for initial conditions
2. Amplifier
3. Compensatory random signal
4. Cumulative amplifier
5. Output for oscilloscope
6. Decimal calculators
7. Units of numeral evaluation for tracking results
8. 50 Hz
9. Time impulse
10. Measuring trigger
11. Filter for low frequencies
12. Intake from generator of random impulse
13. Photoelement
14. Light guide

Key (fig 100) continued:
15. Shutter
16. Incandescent lamp
17. Stabilizing source of incandescent current
18. Unit of compensatory random signal

In the initial variants of the apparatus for formation of compensatory current, we used precision potentiometers or rheochords, the sliding contacts of which were connected to the operator's lever. These elements were shown to be inadequately reliable and, moreover, they transmitted irregular impulse interference. For the final variant of the unit for compensatory random signals, we used a selenium photoelement, the illumination factor of which depended on the position of the operator's lever. Light from three supply lamps, stabilized by constant current, reached the photoelement through a plexiglass light guide of variable dimensions. The illumination factor of the rectangular output surface of the light guide was controlled by shutter movement, connected to the operator's lever in a pantographic transmission. Thus, adequate linearity of the EDS [expansion unknown] connections of the photoelement and the position of the lever was ensured. The requisite value of compensatory current was selected by changes in rated value R_{13} and a coefficient of transmission, based on the corresponding input of the integrating amplifier A_3.

The algebraic sum of random and contrasting, according to sign of compensatory current (U_{output}) which was fed into the input of the amplifier, was seen in the verticle deviation of the oscilloscope S1-19. The optimal variant of operator activity was the maintenance of integrated current at the level of zero. Given this, the rays of the oscilloscope remained in a middle position within the limits of the field of regulation.

When deviation of integrated current was greater than 100 mV in one or another side, this led to an output of rays at the limits of the 2 cm finder on the screen. One of two threshold elements was selected for recording when current exceeded the boundaries. The selection of any of the elements was fixed by meter 1 as "output for the limits of the regulation field." In a parallel fashion, meter 2 was calibrated for "time of residence within the lmits of the field." In the capacity of timed impulses, we used impulses of a frequency of 50/s, formed on the basis of sinusoidal light lines of current. The timed impulses were derived from meter 2 through a system of congruence which was controlled by the threshold elements at a moment in time which corresponded to the output of data on total current of the random signal and compensation for the limits of the regulation field.

Thus, we evaluated two characteristics of non-tracking: output of rays in the limits of the viewfinder zone, or "the regulation field", calculated for consecutive intervals at 30 s, and the time of residence of the ray (in the course of every 30 s) within the limits of the viewfinder. The equipment was utilized successfully during the expeditions of 1975-1977 to study the dynamics of adaptive transformation of function by the human operator.

The individual index for tracking in i-minutes of j-day of adaptation was expressed as

$$T_i^j = \frac{t_i^j}{t_\Sigma},$$

where t_j^i is the time of loss of control for i-minutes of j-day, and t_Σ is the average time of loss of control for 10 test minutes for experiments in lowland conditions. Correspondingly, the index for errors in tracking of the test subject is represented as

$$Q_j = \frac{\sum_{i=1}^{10} t_i^j}{t_\Sigma}.$$

Data on the characteristics of non-tracking of objects by individual test subjects warrants attention. A quantitative analysis of the data was not conducted because the sample of numbers was small. Nevertheless, these observations are of interest primarily for special cases of professional selection. The group of test subjects who demonstrated an inability to track objects can be referred to conditionally as a third category. Some of the operators did not show significant changes in the quality of their tracking within the limits of a 10 minute interval (according to information from evaluations conducted in lowland conditions). Others showed the need for "training sessions" with subsequent gradual improvement in results, despite the fact that initially, they viewed this time as a chance for assimilation of the tracking method. There were, finally, subjects who demonstrated a precise and mobile non-tracking in the first minutes of the experiemnt. For this group, there was a steady decrease in indices for lapse during some minutes of work. In our group of subjects, these categories appeared to be approximately uniform.

Section 3.
Psychological Methods for Study of Memory in the Adaptation Process (methods for expeditionary conditions were developed by L. A. Konstantinovskaya)

For study of the role of memory in the adaptation process, we used, in a modified variant, a number of methods, developed by native and foreign psychologists. Modification of the method was necessary because, until the present time, studies had not been conducted on a psychological level to establish the participation of memory in the organization of adaptive behavior of man in new conditions (changes in climatogeographic conditions, of time zone, etc.).

After a three-year study of the stated problem, in the course of which were developed not only methodological approaches to the problem, but also the methodologic component, the laboratory established a number of methods which could be used for the purposes of studying adaptive processes.

Methods for Study of Form-Space Short-Term Memory

In the test, the subject was presented (tachistoscopically or by the investigator) a series of pictures: the time of exposition and the timed interval between presentations was 1 s. Each picture (the dimensions were not greater than 20 x 20 cm represented a traced field in equal quadrants of 5 x 5 cm with some contrastingly shaded quadrants. All five pictures were issued in one series and were shown in succession. The shaded quadrants were located in different places.

After presentation of the last picture, the subject was asked to mark the location of the shaded quadrants on a page of the experimental protocol (all five quadrants were noted in one field of uniformly sized pictures, that is, with 5 x 5 cm quadrants).

The experiment consisted of three such series, conducted at two minute intervals, allowing for rest time. It is important to consider that, for this variant, corner quadrants were excluded and the central one did not represent a challenge for memory. The number of correctly designated quadrants, given a three-time presentation of 5 pictures (the maximum quantity of correct responses was equal to 15), was divided in 3 and taken as the index for form-space short-term memory (SM) for a given individual or group. The test provided sufficiently exact indices for short-term memory (SM). The grouped dispersion of indices varied in a small range (0.4-0.6). The sensitivity of the test was sufficiently high: we obtained statistically significant changes in the grouped indices for form-space SM in the adaptation period.

The extent of learning by the test subjects in a given test was not disclosed, that is, we did not obtain an improvement in results from test to test in the series of control experiments. The test can be conducted collectively.

Methods for Study of Short-Term Motor Memory

In the experiment, the subject reproduced a preset height using the right and left hands separately. He reproduced 10 new heights at levels of 95-140 cm (95, 100, 105, 110 etc.). The sequence of height was determined each time by a table of random numbers but the average height of reproduction for all test subjects in all control and expeditionary experiments remained the same--112.5 cm.

The inclusion of the visual component in memorization of height was excluded: the gaze of the test subject was fixed directly at the reference on which the subject's hand marked the height, located to the right (for the right hand) and to the left (for the left hand) of the subject.

Comparison of results of a given test with results obtained using the "target" method proposed by I. S. Sklyut (1973) allows differentiation of changes in motor memory from disturbances in the dynamics of coordination.

Methods for Study of Verbal Short-Term Memory

Using a tape recorder, the subject was presented a number of syllables, read successivel at a rate of 1 syllable per 1 s; immediately after listening, the subject was asked to read and reproduce the memorized syllables on a page of the experimental protocol. Afte reproduction of the syllables, a 2 minute rest interval was provided. Then, the second series of syllables was read, and so forth.

In all, in one experiment for verbal SM 3 series comprised of 10 syllables each were used. The series were reproduced by writing on separate sheets of the protocol.

Given a selection of syllables, it was necessary to avoid interconnection of meaning in a series of syllables and naturally, the repetition of one and the same syllable in one experiment or a series of experiments conducted in a small time interval.

As our experiments demonstrated, the test provided reliable indices for verbal short-term memory with an inexact scattering of grouped data in a series of control experiments. The test had adequate flexibility for indices. We obtained reliable changes in group indices for verbal SM in the adaptive process. The test can be conducted collectively.

Methods for Study of Interference

In tests for pro- and retroactive interference, we used the Flores scheme (Fress, Piazhe, 1973) in a modified variant. The modification of the method allowed study of the changes in influence of pro- and retroactive interference in the formation of memory imprints.

Using a tape recorder, lists of words were presented to the subject in a definite order. The lists were comprised of 15 single composite syllables encountered frequently in the Russian language. The formation of direct association in one list was reduced to the minimum. The test can be conducted collectively.

Study of Proactive Interference

A control series was conducted at the beginning of the experiment. The subject listened to a tape recording of a list of words, read at a rate of 1 word per 1 s and then reproduced the memorized words in writing on a page of the protocol. The time allotted for reproduction was 1 minute. The test series was conducted after the control and a 2 minute rest break.

The scheme for the test series was: to be read series A and then reproduce series A (20 s)--to be read series B and then reproduce series B (1 min).

In one experiment for proactive interference (PA), three test series were conducted, each followed by a 2 minute rest break.

The difference in reproduced words in the control series and series B in the test series was used as the index for PA interference (in absolute values). The index for PA in the three test series in one experiment averaged out.

Study of Retroactive Interference

A control series was conducted at the beginning of the experiment. The scheme for the control series was: to be read a series, pause for 35 s and reproduce the series in writing. The pause between reading and reproduction was constructed in a manner so that the process of natural omission did not distort the results of the interference influence.

The test series was: to be read series B--reproduce series B (20 s)--reproduce series A (1 min). The time alloted for reading of the series was 15 s, the time between reading through series A and reproduction of it was 35 s (therefore, in the control series, a time interval between memorization and reproduction was introduced).

In one experiment for retroactive interference (RA), three test series were conducted, each followed by a 2 minute rest break.

The lists of words were based on the same requirements as those used in tests for PA interference. The indices for RA were considered to be analogous to indices for PA.

Reproduction of each series was recorded by writing the words on separate pages of the experimental protocol. The experiment can be conducted collectively.

Study of Omission and Reminiscence

The scheme developed for test series to measure PA and RA allowed us to conduct simultaneously analysis of changes in omission and reminiscence.

The indices for omission were derived from reproduction of lists after pauses of 35 s in the control series for RA. At the same time, we conducted test series on RA and PA in each experiment, that is, on the same day after a break of not less than 10-15 min. During the control series for PA, we also carried out tests on immediate reproduction of identical word lists. The difference in these indices is characterized by 35 s of omission by an individual or group.

For the reminiscence index, we used the number of words which exceeded the level of word reproduction in the control series for a given individual or group. In other words, if in the control series, the individual reproduced seven words, and after interference, the perception of the information by him was not offset, but on the contrary, his ability to reproduce the words increased (for example, there were not five or six, but rather, nine reproduced words from the list), then the index for reminiscence in a given case was equal to 2, but the interference was absent in general, that is, was equal to 0. As our experiments showed, the process of omission and the process of reminiscence are subject to significant changes during the adaptation period.

Methods for Study of Long-Term Memory

We studied long-term memory in 24, 48 and 72 hour delayed time intervals between memorization of the word list (up to the first correct repetition of 75 percent of the words on the list) and its oral reproduction. Thus, we were able to determine not only the quantity of reproduced words, but also the order of their reproduction. This approach aided in the study of the structure of the word list both for memorization and for delayed reproduction and allowed analysis of the relationship of "location on the list to recollection."

The test was conducted in the following fashion. The investigator read the list of words to the subject according to the experimental protocol, then the subject repeated out loud the memorized list; the investigator next noted in the experimental protocol opposite the corresponding words, the order of their reproduction. This was repeated up to the initial correct repeating of 75 percent of the word list. The test was conducted individually.

After the second and third days, the investigator asked the subject to recall a word from the memorized list, noting on the protocol the order of reproduction. It is necessary to point out that for a given variant (with multiple repetitions of the test), it was not possible to avoid formation of tendencies for subsequent reproduction. But because this tendency was in both the control and tests during the adaptation period, then, in terms of comparative analysis of data, it did not exert a significant influence on results.

During the same test we also studied the process of delayed memorization: the subject (after examination at 72 hours following the test) was asked to learn familiar words from the memorized list of words among nonfamiliar words on the list--1:3. The subject noted those words which he memorized. The lists of words in a given test consisted of 20 adjectival words, selected according to frequency of encountering them in the Russian language.

To avoid the interference influence of words appearing next to each other on different lists, which were constructed on verbal information, we used: a) syllables to study short-term memory; b) those essential for study of pro- and retroactive interference; and c) adjectival ones for study of long-term memory.

Section 4.
Psychophysiological Methods for the Study of Human Adaptation (the methods for expeditionary conditions were developed by V. P. Leutin, I. V. Vol'f, S. B. Tsvetovskiy and Ye. I. Nikolayeva)

Experiments were conducted on essentially healthy subjects in various climato-geographic conditions. The subjects were placed in a shielded, almost soundproof dark room. The subjects were positioned comfortably, lying with closed eyes, in conditions of temperature comfort. In the course of the test, electroencephalogram (EEG), electrocardiogram (ECG), dermo-galvanic reaction (DGR), seismoactogram (SAG) and phonogram (PG) were recorded to allow comparison of changes in physiological function with programmed psychological tests and verbal responses of the subjects.

For EEG recording, we used sheet-like electrodes of stainless steel of an eliptical form with an axis of 10 and 7 mm, on which were soldered thin, flexible leads for attachment to the inlet of the amplifier. The electrodes were fixed to the subject in a "forehead--occiput" direction using collodion to guarantee firm contact with small (less than 5 kOm) resistance and not disturb the subject by a long recording session. ECG was recorded by attaching electrodes in a "left hand--right leg" position. The skin was wiped with alcohol and covered with an electroconducting paste. Steel-plated electrodes (40 x 30 mm) were secured with elastic bandages. The electroskin potentials were recorded using electrodes, placed on both sides of the wrist of the left hand of the subject. DGR recording was conducted using alternating current (constant time of 1.8 s).

To record EEG, the number of intersections of "zero" EEG, ECG, DGR and seismoactograms, we utilized a complex of electrophysiologic apparatus, consisting of an amplifier for biopotentials ABP2-03, an inductor to determine the stage of narcosis ISNP-1, an electrostimulator ESL-2, a recorder (Cometa-209) and a 5-channel tracer N-3020-5.

Preparation of the subject for the experiment took 10-15 min. Before the first test, the subject listened to instructions, previously written down by the investigator. In subsequent experiments, the instructions were not read before the test. During preparation for and the actual conducting of the investigation, we observed thoroughly the stereotypic aspects of and uniformity of the equipment. Te tests were conducted during the daytime for 50 minutes.

The experiment consisted of two parts. In the first part of the examination, the subject was read 20 two-syllable, nonrelated in meaning and sound, words. The subject was requested to reproduce the memorized words orally in any order. The test was repeated six times using a tape recording of new words. The rate of reading was 1 word per 1 s and the intervals between list presentation was 4 min.

A diagram of the experiments was put together so that on every experimental day, a fixed series of programs was used for a group of subjects. However, a new program was used for each subject according to the sequential number of the investigation. Thus, the program for study was always the same according to the group and was never repeated for one subject.

The programmed conduction of psychophysiological experiments, using tape recorded lists, provided the potential for exact reproduction of experimental conditions, accuracy and immutability in reproduction of instructions. This was especially important to the study of the process of adaptation in subextreme and extreme conditions, when the functional state of not only the subjects but also the investigators was altered.

In the second part of the experiment, we asked the subject, at his own rate, to tap the seismodevise with his right forefinger. During a 20 minute recording of sound track function, which was necessary for a detailed analysis of changes in the functional state of the subjects, the test subjects developed drowsiness (according to electrophysiological indices) and sometimes passed into light sleep. Once during the experiment the subject was presented with an undifferentiated auditory stimulus of a 3 s duration.

In order to detect in all subjects the essential and general shifts in physiological indices for function of the state of the central nervous system and the statistically significant deviation in the effectiveness of their performance of psychological tests, we calculated the average group results for each day of the investigation. The statistical significance of the differences in relation to the initial data obtained at Novosibirsk, was determined by use of paired nonparametric criteria in data analysis.

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Table of Contents

9139
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