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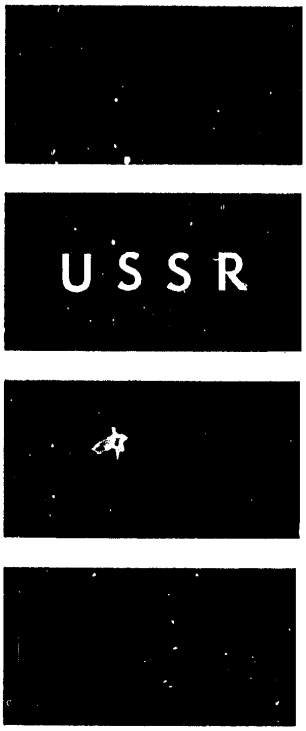
29 May 1979



TRANSLATIONS ON USSR SCIENCE AND TECHNOLOGY

BIOMEDICAL AND BEHAVIORAL SCIENCES

(FOUO 18/79)

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TRANSLATIONS ON USSR SCIENCE AND TECHNOLOGY

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BIOCHEMISTRY

EFFECT OF CADMIUM ON THE HUMAN BODY AND ITS DISTRIBUTION IN THE BIOSPHERE

Moscow FIZIOLOGIYA CHELOVEKA in Russian No 2, 1979 pp 370-371

[Report by V. P. Drebitskas on the International Cadmium Conference, 1-3 August 1977, GDR]

[Text] Cadmium compounds are enjoying increasingly greater use in industry; this is why metallurgy, especially nonferrous metallurgy, is producing continually larger amounts of wastes containing cadmium. All of this is leading to accumulation of cadmium in the biosphere.

However, the problem of saturating the biosphere with cadmium and the mechanism of cadmium's action on the human body have not been studied sufficiently as yet, and thus the International Cadmium Conference was extremely important.

The International Cadmium Conference, which was organized by Karl Marx University in Leipzig and Friedrich Schiller University in Jena, was held in Jena (GDR) from 1 to 3 August 1977.

The conference proceedings were attended by 142 scientists from 18 countries, and 60 reports were given.

The following problems were examined at the conference: Research on the biological significance of cadmium; cadmium biochemistry; the cadmium load in the biosphere; the harmful action of cadmium on the human and animal body.

The reports discussed the dynamics of cadmium accumulation by the body depending on various external and internal factors. Observed data showed that the cadmium concentration grows gradually with age. More cadmium accumulates in men than in women (M. Anke, GDR, and others). Cadmium is concentrated mostly in the kidneys and liver, but it can also be found in the lungs, heart, muscles, bones, blood, hair, pancreas, spleen, thyroid, adrenal glands, and the brain (M. Anke and I. Shneyder, GDR; G. Makhata, Austria, and others). When identical quantities of zinc and cadmium are taken up by the body, more cadmium than zinc is accumulated in the kidneys

and liver. Irrespective of the pathway by which cadmium enters the body (through the lungs, with food or water, as an injection), within a short time it is deposited in the liver and kidneys.

Cadmium is absorbed in the digestive tract and in the lungs very quickly, since the body's barrier membranes are fully permeable to it.

The reports emphasized physiological interaction of cadmium with other bio-elements in the body (with zinc and copper). It was found that cadmium accumulation by the body leads to insignificant disturbance of the metabolism of iron, phosphorus, and calcium, and to more-pronounced changes in zinc metabolism. Changes in copper metabolism are very dangerous to life. An organism poisoned by cadmium suffers from a lack of copper elicited by cadmium uptake, and it may die from this lack. Cadmium blocks the action of zinc and copper. Large cadmium doses inactivate zinc-containing enzymes. Cadmium also reduces iron absorption in the digestive tract (V. Groppel, A. Hennig, and M. Anke, GDR; S. Elinder, and M. Piskator, Sweden, and others).

The possibility of cadmium poisoning increases when there is a copper deficiency in the ration.

Addition of cadmium salts to the rations of laboratory and agricultural animals elicits a large number of disturbances in their bodies. Cadmium alters the activity of alanine-aspartate aminotransferase, alkaline phosphatase, aldolase, and succinate oxidase. Cadmium elicits redistribution of zinc, followed by impoverishment of the body's zinc, copper, and iron supply; it reduces zinc absorption and causes disturbances in mineral metabolism of zinc, iron, copper, calcium, and phosphorus.. Enzymatic systems participating in digestion are impaired by cadmium. Cadmium has a negative action on immunobiological reactions and erythropoiesis (A. Hennig, GDR; V. Drebitskas, USSR, and others).

Cadmium is eliminated from the body with urine. Small quantities are eliminated with chyle and milk. A good criterion for determining the cadmium load in a given territory is its concentration in animal kidneys.

A discussion was conducted on the way (and from where) cadmium enters the animal and human body. Date were presented on its concentration in food, drinking water, air, and so on in different areas. Interesting data were presented on the concentration of cadmium in the biosphere of the GDR, Czechoslovakia, Romania, and other countries (A. Rippel', Czechoslovakia; V. Kharland, USA, A. Regyus, Hungary, and others). There is more cadmium in food in certain industrial regions. It is found in cigarettes, and it enters the smoker's body. It is inhaled with air at enterprises working with substances rich in cadmium. Air is enriched by cadmium from coal smoke as well as smoke from metallurgical plants. Cadmium precipitated from the air enters the soil, plants, vegetables, and fruits, and subsequently the human and animal body.

It has been established that cadmium has a negative influence mainly on kidney and liver function, and that it causes development of anemia, headache, chronic pneumonia and pulmonary emphysema, chronic kidney inflammation, chronic gastritis, hypertension, and so on.. Long contact with cadmium causes disappearance of the sense of taste and smell. There is a certain dependence between human mortality caused by hypertension and atherosclerotic damage to the heart, and the concentration of cadmium in the air. It is still not clear whether or not cadmium is carcinogenic. But people dying of cancer have a high cadmium concentration in their bodies.

When birds were fed cadmium salts, it was found that cadmium has a negative effect on egg laying, that it causes atrophy of sex organs, and that it has negative action on the growth and development of subsequent generations (A. Khennig, GDR; N. Khardebek, FRG, and others).

Thus it was demonstrated in the conference reports that cadmium is a microelement that is toxic to the human body.

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INSTRUMENTS AND EQUIPMENT

UDC 615.014.83.014.45

HEAT STERILIZATION USING LAMINAR FLOW OF AIR

Moscow KHIMIKO-FARMATSEVTICHESKIY ZHURNAL in Russian No 3, 1979 pp 92-97

/Article by L. Gail, "Babcock-BSK" Company, Federal Republic of Germany/

/Text/ There is great interest in special fields of use of technology for creation of ultra-clean compartments when the air-current, in addition to its function of purification, also fulfills the function of heat exchange. These systems are widely used to carry on various scientific investigations and in industrial production.

For several years now, to achieve continuous sterilization of open, uncontaminated, glass vessels more and more use has been made of tunnels in which the process of sterilization has employed infrared and heated air. While all working operations connected with filling of vessels has been accomplished in working zones on assemblies which operate on the principle of laminar flow, the process of sterilization itself has been carried out under conditions where the concentration of particles, 0.5 mcm in size, has reached up to 10^4 in 1 l of air. These particles appear due to formation of scale from the heating elements, wear from a transporter belt and, also, by introduction with disturbed air.

The high degree of purity of the air in the assemblies which work on the principle of laminar flow, giving an air current with weak manifestation of turbulence, suggested use of the principle of laminar flow for the sterilization process. The highly purified air current fulfills in this case, along with the heat-exchange function, the function of protecting (screening) the product being sterilized from unpurified air entering from outside.

Figure 1 presents in cross-section a tunnel for sterilization by a heated laminar flow of air. Glass vessels on a transporter belt are moved through the zone of heating, being rapidly and uniformly heated hereby with purified hot air (temperature 350°C, speed 0.7 m/s). Creation of such a sterilization set-up was preceded by extensive research to resolve a number of technical questions such as, for example, the stability of the current at

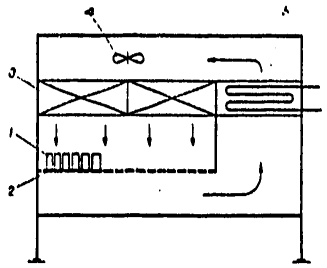


Fig. 1. Sterilized tunnel with laminar flow of heated air

1-product being sterilized; 2-belt transporter; 3-tissue filter; 4-air blower; 5-heater

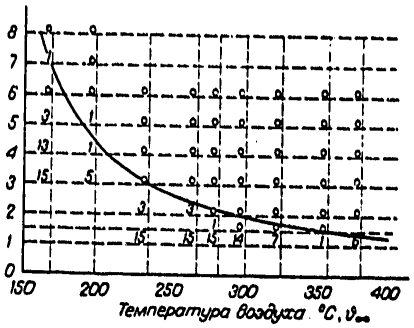
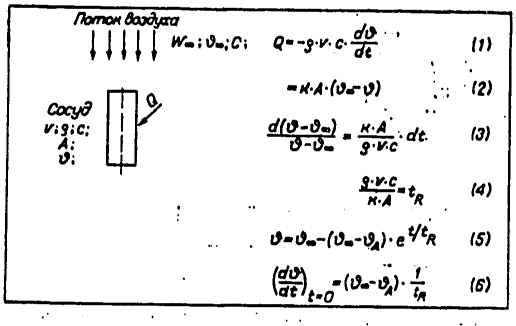


Fig. 2. Results of biological tests. abscissa: temperature of air (in °C); ordinate: duration of exposure (in min). Ampules, 25 ml; speed of air flow 0.7 m/s

Fig. 3. Formulas to calculate heating of a vessel. Parameters of air flow: W_∞ -speed; Θ_∞ -temperature; C-heat capacity; Parameters of the vessel: V-volume; p-density; C-heat capacity; A-surface; Θ -temperature; Q-amount of heat transferred to vessel; K-heat exchange coefficient; t_R-time to heat to a constant temperature
Words at top: air flow
Word at bottom: vessel



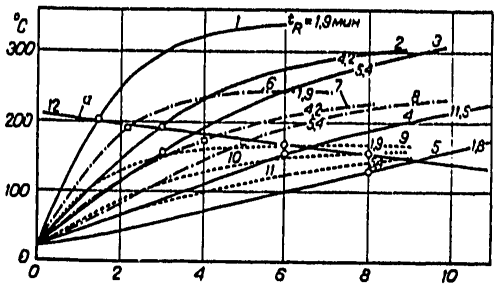
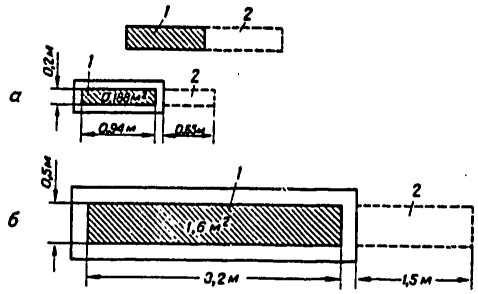


Fig. 4. Heating of vessel at different temperatures of air and value of t_R, assuming sterility (a). abscissa: time of heating (in min); ordinate: temperature of vessel (in °C). Velocity of air 0.7 m/s, temperature of air assuring sterility:
1-5--350°C at t_R=1.9-18 min;
6-8--260°C " "=2.9-5.4 min;
9-11--170°C " "=5.4 min;
12--temperature of glass
v_{st}=210-7t

Fig. 5. Comparison of space required for usual sterilization and laminar air flow sterilization.
1—heated zone; 2--cold zone;
a--tunnel with laminar air flow (θ_∞ =350°C in 3.5 min);
b--usual sterilization tunnel (θ_{ST} =280°C in 20 min)



high, varied temperatures and selection of high temperature-resistant materials for filters,hermetization and construction of the assembly, with due regard for the work of the air-circulation system. At the center of attention was the question of development of optimal conditions for sterilization, i.e., should there be interlinkage of such factors as the non-stationary character of the heating process, assurance of maximally low temperature of the object being sterilized and provision of conditions for sterilization. It was found that, thanks to the system which works under the laminar flow principle, it was possible to create maximally-favorable, uniform and powerful conditions for heat exchange cited earlier, which lead to very rapid and controlled sterilization. The filter for suspended particles plays here--as for any assembly for ultra-fine purification of air--a dual role: it serves for sterilizing-filtration of air and for rectification of the air current. Since, in this case, the heating of the object is a function of the velocity of the air, a uniform air velocity is of especial importance here.

Fig. 2 shows the results obtained in sterilization of 25-ml ampules. Taking into account the large number of factors affecting the process, a calculated model was created (Fig. 3). Among these factors must be mentioned, for example, such things as the ratio of surface to mass, geometry of the object, temperature of the air, velocity of flow of the air current; the process of heating of each glass object is shown as the time of relaxation (achievement of constant temperature; t_R) (Fig. 4).

Results of our studies can be briefly summarized in this way: we achieve the process of sterilization in the shortest interval of time; the degree of purity is $\sim$1 particle, size more than 0.5 mcm, in 1 l of air.

The short time needed for sterilization (for example, it amounts to several minutes for ampules) requires even substantially less time depending on the volume of the sterilization apparatus. The high degree of purity of air completely excludes the possibility of contamination of the ampule by extraneous particles in the process of sterilization.

A decrease in duration of processing the ampules in the sterilizer lowers the probability of contamination of the purified ampules and less production space is required for setting up the sterilizer (Fig. 5).

Further shortening of the time the ampules are in the sterilizer can be achieved by raising the temperature of the gas for heating. In this case, the filter for catching the suspended particles should not be located in the heating zone. In stationing it, as shown in Fig. 6, it appeared that here, too, the process of sterilization takes place in a medium practically cleansed of suspended particles.

In heated-air sterilization of large vessels the duration of their presence in the sterilizer and, also, in small number, plays an even greater role.

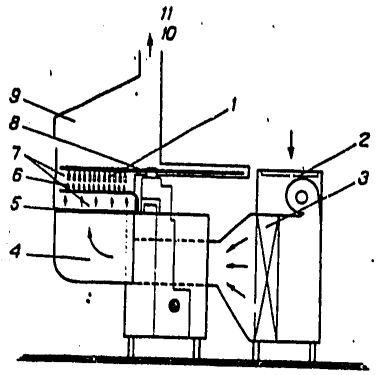


Fig. 6. High-temperature sterilization with fire heating and zone of laminar flow.
1-sterilizing product; 2-pre-filter; 3-main filter; 4-directing canal; 5-support device; 6-burning without cinders; 7-zone of laminar flow; 8-transport system; 9-suction housing; 10-regulating exhaust; 11-sterilizing gases exit

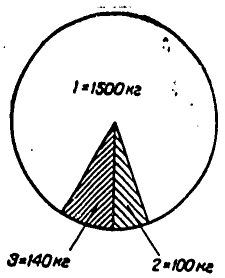


Fig. 7. Ratio of masses in the chamber sterilizer
1-heating chamber (1500 kg); 2-sterilizing product; 3-transport belt and tare

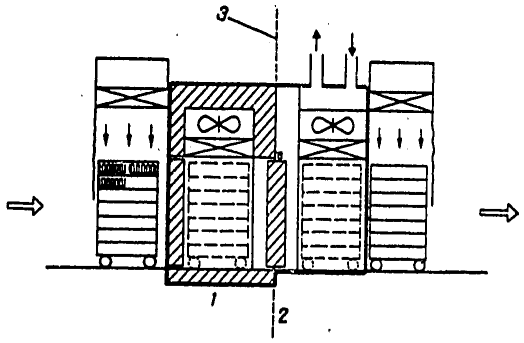


Fig. 8. Double-chamber sterilizer with laminar flow of heated air
1-heating part; 2-cooling part; 3-partitioning glass

Since the work is conducted in a cyclically-determined rhythm, then, in addition to the product being sterilized, ¼ of the mass of the loaded belt and the mass of the heating room--larger by a factor of 15--is being heated (Fig. 7); this means that, here, extremely little use of the space occurs. For 8 hr work in the usual sterilizer, 1 m^3 in volume, only 1 cycle--including heating and cooling--can be realized. In addition, the product of the sterilization is, during this time, under most unfavorable conditions, from the point of view of purity of the surrounding air. If the zone of heating is united with the zone of cooling, then the mass of the heating chamber is no longer pertinent (Fig. 8). In both zones there is established the required constant temperature to reach which a substantially shorter time is needed. As a result, there is no longer any necessity for heating and cooling large "dead" masses and this substantially increases the coefficient of use of the working volume of the apparatus.

Fig. 9 shows the curve of change in temperature of one of the objects of sterilization at the stages of heating and cooling. Total duration of the process of sterilization is determined by the temperature curve in the coldest place in the sterilizer. For this case, this is the lowest level. With loading of the sterilizer with low-volume objects, the process is shorter in duration (Fig. 10). Intensive circulation of the air in the flow-through part of the double-chamber sterilizer promotes creation of constant and reproducible conditions of heat exchange. Heating of the product being sterilized proceeds evenly in a hot laminar current so that, despite the high rate of heating, internal stresses in the glass leading to cracking do not arise. The process of heating and the regimen of sterilization can be controlled by the temperature of the exiting air (see Fig. 10). As a result, the possibility has appeared, for the first time in practise, to accomplish the heating, in a chamber sterilizer, precisely by this regimen, necessary for neutralization of a given type of microorganism. By simplifying experimental conditions, it is possible to establish, by calculation, the temperature curve of the regimen in the process of heating.

Fig. 11 presents the parameters learned in a calculated model. Within the limits of the segment of time Δt for each place of location Δx which corresponds to a definite level of the load, calculation is made of the magnitude of heat transfer to the object being sterilized and to the interior wall of the sterilizer. Then, a balance is set up of the temperatures of the air, of the sterilized product (+ the loaded belt) and of the interior wall of the sterilizer for the following segment of time.

Temperature curves obtained by calculation, and experimentally, are brought into conformity. This method of calculation of the temperature regimen makes it possible to establish the relationship between the heat of isolation, mass of product and velocity of air and to calculate the dimensions of the apparatus for this cyclic regimen of work.

If, in a continuous regimen of work, the heating in the sterilization process depends on the form and size of each individual item, then, in the work in a cyclic regimen using a double-chamber method, the heating is

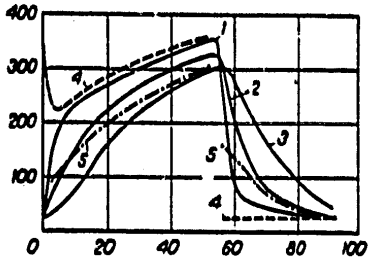


Fig. 9. Curves of temperature change in double-chamber sterilizer, with mass of glass 80 kg. abcissa-time (in min); ordinate-temperature of glass on surface (in °C): 1-upper; 2-middle; 3-lower; 4-entering air; 5-exiting air

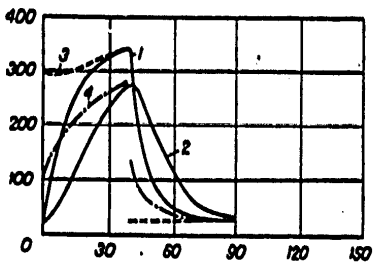


Fig. 10. Curves of temperature change in double-chamber sterilizer, with mass of glass 40 kg. abscissa-time (in min); ordinate-temperature of glass on surface (in °C): 1-upper; 2-lower; 3-entering air; 4-exiting air

determined only by the total mass of the sterilization products. The time of presence of the product in the sterilizer, needed for sterilization, is determined with the help of microbiological tests.

It appeared that, as also in the tunnel sterilization, maximum temperature of heating can be represented as a linear function of time of exposure. For sterilizers which work on the principle of laminar flow it is not required to determine the duration of presence of the sterilization product at this or that temperature level.

Results of tests are represented in Fig. 12. The maximum curve of sterilization develops at 140°C with expiration of approximately 40 min on a straight line running parallel to the abscissa axis; shown independently of the rate of heating and the temperature of the air fed, is the maximum point of temperature at longer exposure, in which the sterilization process is ended.

The process of sterilization of spores of microorganisms under the action of dry heat is represented by the Arrhenius equation:

$$\frac{d \ln K}{dt} = \frac{E_a}{RT^2}.$$

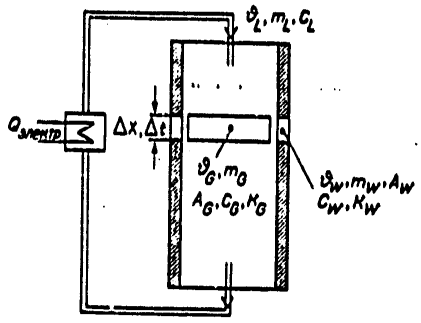


Fig. 11. Calculated parameters of change of temperature of glass
Parameters: -temperature; m-mass; C-specific heat capacity; Q-amount of heat.
Indices: L-air; G-glass; W-wall

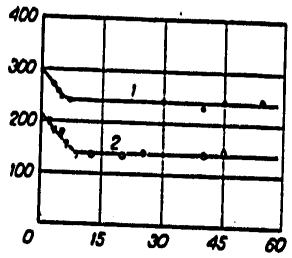
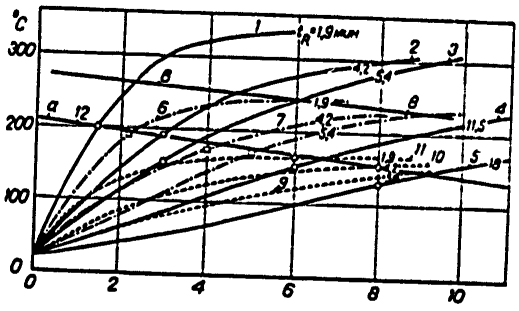


Fig. 12. Limiting curves of sterilization and of disruption of pyrogens.
abscissa-time (in min);
ordinate-temperature of object (in °C):
1-curve of disruption of pyrogen;
2-curve of sterilization constructed with use of literature data.

Fig. 13. Change in temperature of vessel with curves of temperatures of sterilization (a) and disruption of pyrogens (b)
abscissa-time of exposure (in min)
ordinate-temperature of vessel (in °C);
velocity of air 0.7 m/s;
air temperature assuring sterility (a) and disruption of pyrogens (b)
1-5--350°C at t_R=1.9+18 min;
6-8--260°C at t_R=1.9+5.4 min;
9-11--170°C at t_R=1.9+5.4 min.



Another empirical function was found by Bigelov:

$$\log N_U = \frac{U}{D} + \log N_D.$$

From this logarithmic relationship is derived time D needed for sterilizing spores in the course of which 90% of the spore population at a definite temperature is inactivated. The indices obtained are altogether distinct from each other and this led us to the conclusion that, here, a definite role is played by interference factors in the heat exchange process. These factors do not exist in sterilizers working on the principle of laminar flow thanks to the intensive movement of the air and the possibility of establishing strictly defined temperatures for the object of sterilization.

Thermal disruption of pyrogens is of great importance in production of infusion solutions. It was necessary to determine the oriented, but closely practical, indices for thermal processing of the product, contained in a glass vessel, in a sterilizer, which works on the principle of laminar flow. The first step to prevent formation of pyrogens has been already made thanks to circulation in the sterilizer of sterile-clean air which goes through the filters for the suspended particles. In measuring concentration of particles in a sterilizer under a loaded belt, 10-20 particles, 0.5 mcm in size, in 1 l of air were found. The index of concentration of particles at that place in the sterilizer is higher than directly under the filter but it is so small that the interior space of the sterilizer can be characterized as an ultra-clean zone.

The heat resistance of pyrogens is substantially higher than that of microorganisms. To break up pyrogens it is usually necessary to place the product of sterilization under the action of dry heat about 2 hr at a temperature of 300°C.

The obtained oriented indices were experimentally confirmed and gave results completely correlated with the process of sterilization (Fig. 13).

Recently, we attacked work on the task of cooling the products in the zone of flow-through cold air. After resolution of a number of questions, including selection of the material for filters and of regimens of flow, we hope to devise a promising method for preliminary handling of products of sublimation drying.

Relying on a directed current of air, purified of suspended particles and almost free of turbulence, we succeeded in devising more progressive methods of heat inactivation of microorganisms.

8586
CSO: 1870

INSTRUMENTS AND EQUIPMENT

UDC 615.453.6:661.122:62.867.8

PNEUMOCONVEYANCE OF TABLETS

Moscow KHIMIKO-FARMATSEVTICHESKIY ZHURNAL in Russian No 3,1979 pp 98-100
manuscript received 10 Jul 78

/Article by Ye. D. Novikov, O. I. Bespalov, L. M. Obrazhey and N. G. Tankayan, Leningrad Chemico-Pharmaceutical Institute/

/Text/ Use of pneumotransport for movement of tablets /I/ has a number of advantages, the main one being the absence of contact between man and tablets.

There are attendant difficulties that have to be met in setting up tablet pneumoconveyance, the basic one being assurance that the tablets remain intact during the conveyance. In addition, the weight of a tablet, which has passed through all of the equipment of the pneumoconveyer system, should be within the limits allowed by the GFKh.

In consonance with the traditional method of determining the hardness of tablets, it can be reckoned that the "safe" speed of impact of the tablets with a metal obstacle is equal approximately to 4.5 m/s (speed of a fall from a height of 1 m).

It is necessary to take into account that, according to the impact theory, the maximum stress upon collision of bodies arises not at the surface but at some depth. This situation can lead to the fact that the initial positive consequence will be a defective one--some time after the test, the tablets will disintegrate. Such has been the case in our preliminary tests (cyclone-separators, with diameter less than 290 mm, were used). Due to the collision of tablets moving at substantial speeds, internal cracks arose which also led, after some time, to disintegration of the surface of the tablets. It was especially necessary to be cautious in the ultimate decision on applicability of a pneumoconveyor if it is set up with a cover for tablets since the hardness of the cover, as a rule, is higher than the strength of the tablets and damage of the surface can ensue after a sufficiently large interval of time.

In setting up a pneumoconveyer of tablets it is necessary to select those dimensions of the cyclone-separator with which effective deceleration of the tablets is provided on the way into the cyclone. It is known that in cyclone chambers with a low relative area of entry ($f_{AE}/F_C = 4f_{AE}/D^2$, where f_{AE} is the area of entry, F_C is the area of the cyclone cross-section, D is the diameter of the cyclone-separator), due to redistribution of speeds in the jet entering the cyclone and due to local vortex formations, a substantial drop occurs in the speed level at the entrance. Especially substantial deceleration of tablets is to be expected when $f_{AE}/F_C \leqslant 0.02$ [27].

Reliable conveyance of tablets is assured at a sufficiently high level of speed of air in the material-pipe. According to calculation, the speed of the air should be no less than 17-20 m/s. At this output of the pneumoconveyance device, and, consequently, at this area of entry channel, the required ratio of f_{AE}/F_C is reached due to an increase in diameter of the cyclone-separator D.

Experimental Part.

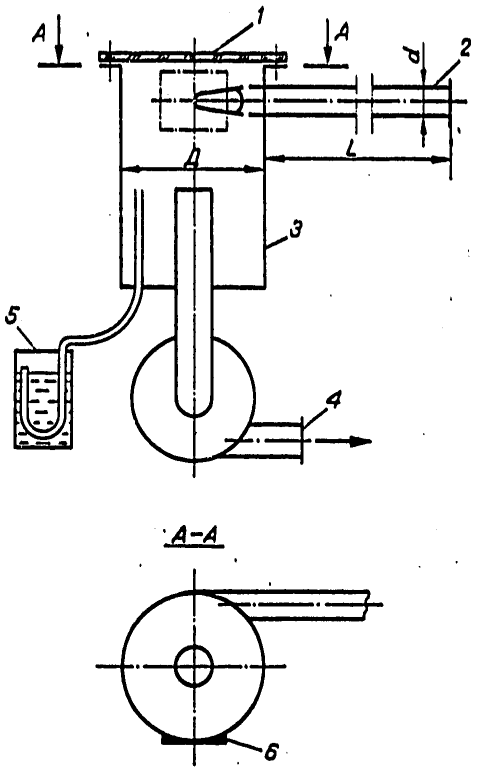
The laboratory equipment comprised (see drawing) a cyclone-separator (3) with a transparent removable lid (1), a material-pipe (2) with variable length L with inside diameter d = 26 mm, a vacuum pump (4) which sucks air from the cyclone, a system for monitoring air-vacuum inside the cyclone. The cyclone is equipped with a transparent hatch (6) through which picture-taking and visual observation were realized. Check on the speed of the air was accomplished with a Pitot tube (5) at a distance of 260 mm (10 gauges) from the entry section of the material-pipe. The inside surface of the cyclone was covered with a vacuum rubber.

A vacuum at the center of the cyclone at a sufficient distance from the entry aperture was measured with a differential manometer, speed of air at the entry into the material-pipe, with a Pitot tube and a differential manometer. The speed of the tablets upon entry into the cyclone was determined by accelerated photography. The character of the surface was established visually.

The last evaluation of the integrity of the tablets was carried out 3 years after the tests.

Experimental inspection of the work of the pneumosuction system was accomplished as appropriate for tablets of pentovit (coated tablets in the form of an ellipsoid with long axis 10 mm, short axis 4 mm).

The tests were carried out under the following conditions: diameter of the material-pipe 26 mm, diameter of hopper separator 460 mm, length of the material-pipe 85-8.7 m [sic], vacuum of air in the hopper 140-557 mm, water column, speed of air (V_A) at entry into the material-pipe (without addition of tablets) at a distance of 260 mm from the entry cut, 13.9-33 m/s.



Laboratory apparatus for pneumoconveyance of tablets

Explanation in text

Results and Discussion of Them.

Analysis of results indicates that, under the conditions of the experiment: 1) tablets with a coating are not damaged; 2) after extended storage (3 years) the tablets are also not damaged; 3) wear of tablets with a coating is slight (less than 1.8%); 4) tablets without a coating have a

weight loss related to knock-off of sharp edges, which amounts to 0.3-0.5%; 5) reliable conveyance of the pentovit tablets is assured at air speeds above 18 m/s, with a material-pipe about 10 m; 6) conditions of flow-around with the tablets differ substantially from conditions of flow-around with a sphere.

The tablet is close in form to an ellipsoid, having different coefficients of resistance along the axes, under movement in air. This leads to rapid rotation (up to 1 rotation/s) with frequent hits on the walls of the tube and, consequently, to large loss of energy. These impacts do not lead to disintegrations. In comparison with fine-grained materials under analogous conditions, the speed of the tablets is substantially less. In existing methods for various particles, it is recommended to take for their speed the value of 0.3-0.8 V_A. In our tests, the speed of a tablet did not exceed 3.5 m/s at an airspeed of 33 m/s, i.e., approximately 0.1 V_A. This circumstance has a decisive significance in reckoning pneumoconveyance of tablets.

Losses of energy should have minimum importance. This minimum in every concrete case (for this expense, the diameter of the tablets, too) must be found by choice of values for f_{AE}/F_C, V_A and d.

It is interesting to note that the movement of a tablet at exit from the material-pipe can be accelerated as long as the tablet is in the nucleus of the jet. For tablets falling out of the jet immediately after exit from the material-pipe, this is not observed.

In conclusion it must be noted that in the path of broad introduction of pneumoconveyance of tablets stands our ignorance of the mechanical properties of tablets and their coatings and of the conditions of movement of an air-tablet system. Required are broad laboratory research both on the actual process of conveying tablets in a stream of air and, also, on the mechanical properties of various tablet mixes in pressed form with and without a coating.

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CSO: 1870

INSTRUMENTS AND EQUIPMENT

UDC 615.453.62.012:/656.029.6:621.313.17.016.2

DETERMINATION OF THE POWER OF THE ELECTRIC MOTOR OF AN APPARATUS FOR PNEUMOCONVEYANCE OF TABLET MIXES AND TABLETS

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/Article by O. I. Bespalov, Ye. D. Novikov and L. M. Obrazhey, Leningrad Chemico-Pharmaceutical Institute/

/Text/ At the present time, basic technological operations for preparation of tablet mixes and the tabletting itself at national chemico-pharmaceutical plants are, generally, mechanized. However, feed-in of raw material, transfer of tablet mixes and of tablets, from some machines or automats to others is practically not mechanized as yet at many plants.

Pneumoconveyance is a prospective kind of mechanization of intra-plant movement of raw material, tablet mixes and tablets. Pneumoconveyance of bulk materials has a number of advantages as compared with mechanical forms of transporting them: hermeticity of the line, i.e., isolation of the material being transported from the environment, raises the quality of production, purity of the atmosphere of the shop and improves the quality of labor. Usually, a pneumoconveying setup consists of an electric motor, a compressor or vacuum pump, a sampler, a material-pipe, a cyclone and filters. Based on weight concentration of the mix being transported (μ), pneumoconveyance apparatus types can be divided into 3 groups: $\mu \leq 5$, $5 \leq \mu \leq 50$ and, $\mu > 50$.

With increase in weight concentration, the speed of feed-in decreases and the problem of assuring its stability arises. Considered below are pneumoconveyance apparatus of the first group (forced type). Analysis of the technological process and of conditions of production permits determination of the required hourly productivity Q_p and adjusted length of the line L of the pneumoconveyance setup. At given Q_p and $L_{пр}$, the power of the electric motor N is determined by the given concentration of the mix μ and speed of feed-in, V_B. Diameter of the pipeline d in this case is determined according to the values of Q_p, V_B, μ.

A devised method of calculation of basic parameters of a pneumoconveyance

setup was checked by comparison of losses of pressure on a line calculated by this method using experimental data, with data obtained by measurements of these losses on an actual pneumoconveyance setup at the "Farmakon" plant.

It was found that calculations by the chosen method agree well with experimental results. Based on the devised method, an algorithm and a program were composed for the "Mir-2" computer for computing the basic characteristics of the pneumoconveyance setup. The method of organized excess of parameters was used to calculate the required powers of the electric motor of the pneumoconveyance setup. The algorithm for calculation of the parameters of the pneumoconveyance setup is presented below.

Computer Algorithm.

Varying parameters:

Q_p is the productivity of the setup (250, 500 kg/h), V_B is the air speed (14,20,30,40 m/s), $L_{тр}$ is the adjusted length of the line (20,40,174,348 m) μ is the weight concentration of vanilin in air (1,2,3,4 kg/kg).

The order of calculation is as follows

$$Q_в = \frac{Q_p}{3600 \cdot \mu \cdot \gamma_в}, \qquad (1)$$

where Q_B is the flow-rate of air (in $нм^3/с$), γ_B is the specific mass of "normal" air (1.2 $кг/м^3$).

$$d_{тр} = \sqrt{\frac{4 \cdot Q_в}{\pi \cdot V_в}}, \qquad (2)$$

where d_{TP} is the diameter of the pipeline (in m)

$$R = \frac{100 \cdot d_{тр}}{V_в}, \qquad (3)$$

where R is the coefficient of resistance

$$R_e = \frac{V_в \cdot d_{тр}}{\nu}, \qquad (4)$$

where R_e is the Reynold's number; v is the coefficient of cinematic viscosity for "normal" air (14.9×10^{-6}, in m/s^2);

$$\lambda = 0{,}246 R_e^{-0{,}22}, \tag{5}$$

where λ is the coefficient of friction of pure air

$$\Delta P_в^* = \frac{\lambda \cdot V_в}{d_{гр} \cdot 2g} \gamma_в, \tag{6}$$

where $\triangle P_B^*$ is losses of pressure in movement of pure air over a 1 m path (in kg/m^2 per 1 m); g is the normal acceleration of the force of gravity ($9.81 m/s^2$)

$$\Delta P_{см}^* = \Delta P_в (1 + R\mu), \tag{7}$$

where $\triangle P_{cm}^*$ is losses of pressure in movement of a mix over a 1 m path (in kg/m^2 per 1 m)

$$P_п = \Delta P_{см}^* \cdot L_{пр}, \tag{8}$$

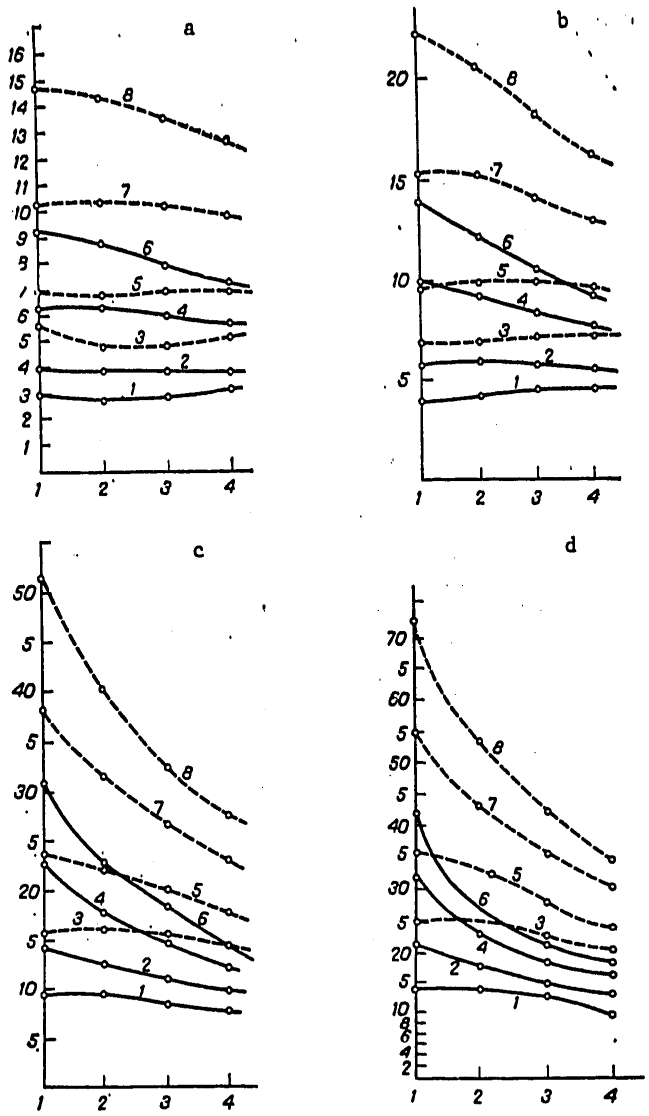
where P_n is the total losses of pressure on function (in kg/m^2)

$$\gamma_{вых} = 1{,}2 (1 + 1{,}1 P_п \cdot 10^{-4}), \tag{9}$$

where $\gamma_{ВВХ}$ is the specific mass of air at the start of the line (in kg/m^3)

$$P_{под} = \gamma_{в.вх} \cdot \mu \Sigma l_в, \tag{10}$$

where $P_{под}$ is the losses in pressure on elevation (in kg/m^2); $\sum l_в$ is the summary length of vertical sections of the pipeline (7.7 m)



Computation of the power of an electric motor of a pneumoconveyance set-up. abscissa- μ; ordinate-N(in kwt); solid line-Q = 250 kg/g; dotted line-Q = 500 kg/g; $\alpha_{\pi\rho}$20 (a), 40 (b), 174 (c), 348 (d); V_B = 14 (1 and 3), 20 (2 and 5), 30 (4 and 7), 40 (6 and 8) m/s

$$P_{дин} = \mu \frac{\gamma_{в.\,вх} \cdot V_в^2}{2g}, \qquad (11)$$

where $P_{дин}$ is losses of pressure on acceleration (in kg/m^2)

$$P_р = [\alpha + 1\,(P_п + P_{под} + P_{дин}) \cdot 10^{-4}], \qquad (12)$$

where $P_р$ is the pressure of air before the feeder (in kg/cm^2); α is the coefficient of losses in the loader apparatus, equal to 1.2

$$\Phi = 2{,}303 \cdot 10^4 \left(\lg \frac{P_р}{P_0}\right) P_0, \qquad (13)$$

where Φ is the theoretical work of the air-blower machine, referred to 1 m^3 of drawn-in air under isometric compression (in kg/m^3); P_0 is the pressure of the normal atmosphere (in kg/m^2)

$$N = \frac{\Phi Q_в}{102\eta}, \qquad (14)$$

where N is the required power of the motor of the air-blower machine (in kwt); η is the coefficient of useful activity of the air-blower machine, equal to 0.55.

Based on results of computation, graphs were constructed and are shown in the figures. Analysis of the results obtained showed that optimum values of μ and V_B^*--which assure the minimum power N_{min} of an electric motor in the studied range of hourly delivery ($250 \leqslant Q_р \leqslant 500$ kg/hr), with an adjusted length of material-pipe $L_{тр} > 40$ m—lie at the limit of the maximally permissible concentrations and minimally permissible speeds of feed-in V_{min}. At a corrected length of material-pipe L , the optimum indices of concentration are a function of the adopted speeds of feed-in. Thus, at V_B 20 m/s, the optimum values of concentration μ^* also lie at the limit of maximally permissible concentrations μ_{max}. At V_B 20 m/s the optimum values of concentration μ^* are in the area $1 < \mu^* < 4$. Hence, to each fixed value of $Q_р$, $L_{тр}$, V_B there correspond concentrations μ^* which assure minimum power of the electric motor of the pneumoconveyance setup. It can be found from the graphs obtained or determined by the developed algorithm.

Optimum agreements of the parameters μ^*, V_B^* at govem Q_p and $L_{\pi p}$ determine the minimally permissible power of the electromotor N. From analysis of computation results it follows also that there is need for theoretical and experimental studies of maximally permissible concentrations of tablet mixes μ_{min} and minimally permissible--at these concentrations--speeds of feed-in V_B for tablet mixes with various properties.

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INSTRUMENTS AND EQUIPMENT

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EXPERIENCE OF WORK IN FULFILLMENT OF THE PLAN OF ORGANIZATIONAL-TECHNICAL MEASURES FOR THE ZHDANOV PLANT FOR TECHNOLOGICAL EQUIPMENT

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/Article by Ye. A. Boyev, Zhdanov Plant for Technological Equipment/

/Text/ Fulfilling Decisions of the 25th Congress of the CPSU, directed toward raising the productivity of labor, the plant devised a complex plan for introduction of leading technology, mechanization and automation of production processes for the years 1976-1980; each year the plan is developed for organizational-technical measures, mechanization and automation for the current year. For this, the plant director issues an order, at the end of each year, proposing that all of the personnel collective of the enterprise take part in setting up such a plan for the following year. All plant units, knowing their own "tight spots" and shortcomings, project measures for their eradication. These measures are discussed in the active units and transmitted to the Department of Mechanization and Automation for entry into a common, combined plan which, in turn, is discussed in the Technical Council of the Scientific Technical Society where the question of expediency of introducing this or that measure is resolved. Into that particular yearly plan, measures are introduced designed for fulfillment in the combined Five-Year Plan.

Guided by the plans affirmed by the plant administration, the Department of Mechanization and Automation of Production Processes prepares the technical documentation which, depending on its readiness, it transmits to the Department of the Head Mechanic where there is a group of specialists who execute these developments in metal.

The plant has worked out an enterprise standard, STP 640428-196-77, which provides for the sequence of preparation of non-standardized technological instrumentation, mechanization and automation of production processes, starting with design and ending with handing over for exploitation. The plan of organizational-technical measures has 2 sections: 1) organizational-technical measures and preparation of non-standardized equipment and

2) mechanization and automation of production and auxiliary processes.

A special form has been worked out, provided for by the enterprise standard, wherein are established the time frames for fulfillment of design-construction jobs, times for their realization in metal, expenditures, source of financing, economic effect and number of freed working forces.

The Department of Mechanization works in close cooperation with the Bureau of Technical Information of the plant, from which it continuously receives information on achievements of science and technology at leading enterprises of the nation; field trips to these enterprises for exchange of experience are arranged.

In addition, the Department of Mechanization is occupied in development of projects for improvement of technology and betterment of labor conditions; measures are being worked out for protection of the atmosphere and water basins from contamination.

For improvement of work on mechanization and automation of production processes a competition is announced yearly at the plant with the input of successes of the year, in December. All of the plant personnel collective are included in this work. On the basis of suggestions received, a supplementary plan of measures is set up, the most pressing of these are selected and get priority realization.

A stimulus to the search for production reserves has been the result of work of the industrial enterprises of the Zaporozhe Oblast. The personnel collective of our plant also began to occupy itself with the question of certification of manual work based on the example of enterprises of the Zaporozhe Oblast.

At the present time organizational measures are projected and special forms developed. This work is scheduled for carrying out over a 2 year period.

Along with this, difficulties do exist. In the period of setting up the plan it is impossible to foresee all the work for the next years since in the course of a year new ideas manifest themselves, new measures arise which might not be taken care of by the initial plans and then, in consonance with the devised enterprise standard, they take the same path as that in creation of the basic plan. If realization of additional measures is expedient, it is entered into the common plan upon its revision. Fulfillment of work in mechanization and automation of production processes is often complicated due to absence of essential equipment and materials. Hence, it is expedient that equipment and materials for mechanization and automation of existing production and auxiliary processes be released just as it is for the basic production.

In the last Five-Year Plan at our enterprise a combined-mechanized sector

was created for preparation of an industrial mix in a foundry shop which gave the factory 6 thousand rubles saving and the release of 4 people from heavy manual labor; a continuous, mechanized line for preparation of a container from expanded polystyrene was put onstream, replacing the process of preparation of the container from wood, which was made by hand; the sectors for preparation of heavy matrices, assemblies, transport and loading of metal shavings on automatic machines, the preparation of rods, etc., were all mechanized.

Developed and introduced were a paint chamber with hydrofilters, special welding post for electric welders, a dust-catching device with washing action (a USD) for systems of exhaust ventilation which provide substantial improvement of labor conditions.

Much work has been executed in mechanization of load-lifting and transport jobs with development and introduction of a series of special devices and accomodations. Heavy manual labor is practically absent at the plant. As a result, the total economic effect of the measures in the Tenth Five-Year Plan amounted to about 100 thousand rubles.

The most important of 16 measures realized in 1978 are the centralized supply of emulsion for the machines located on the third floor; a special electric closet with automatic regulation of temperature for heating plates of organic glass under profile bending; a welding sector has been organized with effective ventilating and mechanization of setting the heavy parts being welded; a stand has been prepared for rolling reductors, and so on.

According to the complex plan for the Tenth Five-Year Plan, design is foreseen of a mechanized, continuous line for painting serial items in an electrostatic field with an anticipated yearly economic effect of about 30 thousand rubles; galvanic shops will be reconstructed in order to introduce leading experience of other plants; a cupola furnace which runs on fuel, will be replaced by an induction furnace, more productive; also a number of other measures whose introduction is technically and economically expedient for our enterprise are foreseen.

In the Department of Mechanization and Automation of production processes of our plant there is a special archives wherein are kept designs for mechanization, the preparation of a different sort of non-standardized equipment, including that for technological, foundry, welding, mechanical and other shops. These designs can be obtained by interested services of enterprises of the Ministry of Medical Industry to use at their own enterprises. This will facilitate betterment of work in the fulfillment of plans of organizational-technical measures and of socialist obligations in improving technological processes, mechanization and automation of production and auxiliary operations in mechanical repair shops of the chemical-pharmaceutical industry and manufacture of medical glass and of polymeric materials and,it will yield a definite economic effect.

PHARMACOLOGY

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MICROBIAL CONTAMINATION OF SOFT MEDICINALS

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/Article by G. Ya. Kivman and S. V. Denisova, State Scientific Research Institute for Standardization and Control of Medicinal Agents, USSR Ministry of Health/

/Text/ In the problem topic, microbial contamination of non-injection medicinal agents, a special place is occupied by questions of contamination of soft medicinal forms. This is related to conditions of survival of microorganisms in ointments due to the presence in the drugs, as a rule, of two phases and the inclusion of preservatives in the overwhelming majority of cases, (even if antibiotics, sulfanilamides and other similar substances are present as the primary nutrient) in the composition of the ointments. Both native and foreign research workers have found that the presence of antimicrobial agents does not always guarantee microbial purity of these medicinal forms.

The task of exposure of microbial contamination of ointments and of other soft medicinals should be resolved with due attention to their physical chemical properties and component makeup which, as a rule, hamper the separation of the microorganisms.

Necessity for Control of Microbial Contamination of Soft Medicinals.

In recent years much attention has been devoted to microbial contamination of non-injection medicinals. This problem is of great interest since it involves the undesirable consequences which ensued as a result of use of preparations contaminated by microorganisms, including pathogens. Descriptions exist of severe infections caused by presence, in medicinal preparations, of Pseudomonas aeruginosa, Staphylococcus aureus, Klebsiella pneumoniae, Salmonella typhi or Alcaligenes faecalis /1/

An incident is reported /1/ of the finding of an antibiotic-resistant strain of Ps. aeruginosa in an eye ointment into the composition of which neomycin

and amphocillin had been added. This same microorganism was isolated from a steroid cream prescribed for application on the skin. The preservative agent added to the cream was 0.1% chlorocresol which at this concentration has an inhibiting action on Ps. aeruginosa, in aqueous solutions. However, the presence of chlorocresol in the cream did not have such an effect. Analysis showed that the lowering of action of the antiseptic was caused by passage of it into the fatty phase and inactivation, by 90% [7]. The authors also found that the presence in the fatty phase of even 1% chlorocresol does not repel growth of Ps. aeruginosa.

Among the pathogenic microorganisms found in ointments, including cosmetics, the greatest attention, in addition to Pseudomonas, has to be devoted to Staph. aureus. Reports on its isolation are met quite often [3-97. Also found in skin ointments were Proteus vulgaris, Enterococcus, Streptococcus faecalis and other microorganisms [1,8,10].

Staphylococci, streptococci, various fungi, including the Candida family, can evoke severe diseases of the skin and mucous membranes, which, in a number of cases, are hard to cure.

Especially to be noted are the numerous cases (one of which we recalled above) of isolation, from ointments and other soft medicinals, of microorganisms, including pathogenic, which are resistant to antibiotics, sulfanilamides and the like. Thus, in eye ointment containing oxytetracyclin, a tetracyclin-resistant, hemolytic streptococcus was found [8]. The same author isolated--from some ointments for external use--other microorganisms, resistant to tetracyclin: an aerobic spore-forming rod, Str. faecalis and Staph. albus. Along with this, Ps. fluorescens was isolated, resistant to tetracyclin, streptomycin, neomycin and penicillin (minimum bacteriostatic concentration, respectively, 31,125,250 and over 500 mcg/ml).

In discussing the cited data, it must be noted that in the majority of cases the index of resistance of the microorganisms to antibiotics is significantly, at the least by an order of one, lower than the concentrations of these preparations in the ointments. Evidently, under these conditions, there are impediments to the manifestation of the antimicrobial action of the antibiotics. Confirmation of this is the result of analysis of microbial contamination of penicillin-and furacillin-ointments prepared in pharmacies [3]. Along with isolation from them of microorganisms resistant to the cited preparations, various gram-positive rods and cocci sensitive to them were isolated.

In addition to the danger of infection, the presence of microorganisms in medicinals can negatively affect their stability, therapeutic properties, and so on [11,12]. Under the influence of enzymes of the microorganisms, changes can occur in the initial consistency of the ointment base, and, also, it can turn rancid and unpleasant odors can appear, substantially lowering the quality of the ointment.

Survival of Microorganisms in Ointment Bases and Oils.

Reports on survival of microorganisms in ointment bases and oils, i.e., actually, in the auxiliary substances for soft medicinal forms, are contradictory, due, to a certain degree, to the methods of study used by different authors.

Staph. aureus has been found in yellow vaseline in the course of 10 days [13], 14 days [14] and 25 days [15] after contamination. In study of the influence of lanolin on Staph. aureus, it was found that, in this medium, it survived 2 days [15]; according to others, it was not seeded after a lapse of 7 days [16] and 10 days [13]. Comparison of the materials of the two latter reports permits the assumption that increase of temperature of incubation of the staphylococcus in lanolin from 4-20 up to 37°C leads to some decrease in the term of survival of the microorganism. In lard, Staph. aureus survived 28 days; in solid peanut oil, 18 days; in solid rapeseed oil, 25 days [15]; in eucerin, 10-30 days [13,15]; in white vaseline, 15 days at 4°C and 10 days at 20°C [13]; in lanolin-vaseline- and emulsified-bases, 7 days [17].

E. coli in white vaseline, lanolin and eucerin at 4°C died after 40 days, and in yellow vaseline, after 20 days. At the same time, in the bases maintained at 20°C, it died in some cases in shorter periods of time: in white vaseline, after 20 days; in yellow vaseline, after 15 days; in lanolin, after 30 days; and in eucerin, after 40 days [13]; in lanolin-vaseline base, it died after 7 days; in the emulsified base, after 14 days [17].

The hay bacillus (Bac. subtilis) survived, in lard, 40 days; in yellow vaseline and lanolin, 60 days; in solid peanut and solid rapeseed oil, over 60 days; and, in eucerin, over 90 days [15].

Mold and yeast fungi appeared, as a rule, to be quite resistant to the action of ointment bases; in vaseline, emulsified and hydrophilic bases and lanolin, they survived, in the majority of cases, from 6 months to 1 year [17,18].

Literature data indicate that survival of microorganisms, including one and the same species, varies in different ointment bases and oils. There is reason to think of the possibility of antimicrobial action of some of them; one can't exclude an autosterilization effect under certain conditions.

Research [19] carried out to resolve this question made it possible to establish the following. Maintenance at room temperature of non-sterile ointment bases and oils--pork fat, white and yellow vaseline, lanolin, rapeseed oil and fish oil--led to complete autosterilization of lanolin in the course of the very first days, whereas, in pork fat and in white vaseline, aerobic bacteria were found, and, in the remainder, aerobic, anaerobic bacteria and

molds. After 2½ months, the pork fat was sterile. In addition to this, slowed growth of aerobic bacteria was noted (their appearance on the 8th-14th day of incubation of the media) on seeding of white and yellow vaseline and, also, of oils. In analysis of an ointment with fish oil, and, also of boric acid and sulfathiazole ointment prepared from non-sterile bases and substances, bacteria were found. After 1 month of storage at room temperature, the boric acid ointment was sterile, and the others, after 3 months, were not sterile. The authors speak of complete and partial autosterilization of a number of ointment bases and ointments studied by them, which were contaminated by microorganisms from the environment.

Microbial Contamination of Medicinal Forms on an Ointment Base, Including Therapeutic Cosmetics.

We presented, above, descriptions of cases of severe injuries of the eyes evoked by use of ointment medicinals, contaminated by Ps. aeruginosa.

According to data of a number of authors, ointments are less contaminated than other non-injection forms [4,5,8,10,20,21] but studies are encountered [1,8,21-24] in which high indices are presented.

This testifies, primarily, to the great difference in microbial contamination of ointments, despite the difference in methods of performing the analysis.

Eye ointments prepared with observation of the rules of asepsis, all contain microorganisms in a certain percentage of cases. Of 79 examined pharmacy items of ointments and ointment bases, 16% contained bacteria and 6%, fungi [22]. In another case, of 83 eye ointments, contained in unopened tubes, 71 were non-sterile [26].

The number of microorganisms in eye ointments can be quite large. Thus, in 4 eye ointments of 13 studied, prepared in pharmacies, 180-900 microorganisms were found in 1 g [24]. Attention is attracted by a case described in Sweden, where, of 60 studied series of eye hydrocortisone ointment with antibiotics, 27 contained Ps. aeruginosa, and in large amounts--2000 microbial cells in 1 g [17]. In eye ointments prepared in pharmacies, staphylococci were also found, including Staph. aureus [3,24,25], Str. haemolyticus, capsule pneumococci [37], Bac. subtilis [1,24], Alcaligenes [17], individual species of microorganisms of the Micrococcus genera [24], yeast and mold fungi and saprophytic bacteria [3,24,25]. The majority of the isolated microorganisms were saprophytes. In eye ointments containing antibiotics, beta-hemolyzing streptococcus and mold fungi were found [8].

Among the other soft medicinals prepared in pharmacies, suppositories can be mentioned; in one case alone in a preparation with extract of belladona more than 1000 non-pathogenic microorganisms were found in 1 g [22].

According to data of a number of authors, industrially produced ointments,

which can be non-sterile, showed, generally, relatively low microbial contamination: 10-100, more rarely 300-400 microorganisms in 1 g [1,5,21]. A trial was made on sterility of 208 samples of various ointments, including medicinal cosmetics, with subsequent study of microbial contamination of preparations which appeared non-sterile. The majority of them (93%) were sterile; 6 samples showed up to 100 bacteria, 1, up to 1000, 2, up to 10,000, 1, up to 50,000 and 4, more than 50,000 bacteria in 1 ml. As for fungi, 98% of the samples had none, only 2 had up to 100 mold fungi, and 1, up to 1000 in 1 ml.

There are data on the basis of which, with respect to indicators of microbial contamination, soft medicinal forms containing antibiotics, in some cases can be regarded as close to the soft medicinal forms into whose composition antibiotics were not added. Of 15 series of examined dermatological ointments, 3 were non-sterile; of 5 series of granulates for emulsions and 5 series of emulsions, 9 were non-sterile. From dermatological ointments which appeared non-sterile, small amounts of microorganisms were isolated--2 to 68 from 1 g. A granulate for emulsions (Polfamucin-tetracyclin), 4 series in 5 which were non-sterile, contained from 12 to 2400 bacteria in 1 g, and an emulsion (Diaropect, 5 series of 5)—from 1160 to 50,750 bacteria and from 230 to 1780 yeast fungi in 1 g [8].

Other soft medicinal forms do not differ fundamentally from those cited, on the basis of indices of microbial contamination [1,4,22].

The species makeup of microflora found in industrially produced ointments is quite variegated.

Of the number of spore-forming aerobic bacteria in ointments, the most frequently found are non-pathogenic species--Bac. subtilis, Bac. cereus, Bac. megatherium [1,5,10,22]. Many investigators report finding fungi, predominantly non-pathogenic [1,5,10]. In the opinion of a number of authors [1,5,8,9,10], in the number of pathogenic microorganisms, staphylococci are found most often in the ointments. Also to be mentioned are Str. faecalis, gamma-Streptococcus, Pr. vulgaris, Gaffkya tetragena, Ps. fluorescens, representatives of the Enterococcus genus and Alcaligenes [1,8,10,22]. In industrially prepared suppositories, along with non-pathogenic species, including mold fungi [22], Bac. subtilis were found, Staph. albus, gamma-Streptococcus and Alcaligenes were also found [1]; in vaginal globules and beads, Staph. haemoliticus and Bac. subtilis [1,4].

A number of medicinal cosmetics are a good nutrient medium for microorganisms [6]. Thus, in a pediatric cream from 85 to 1000 bacteria and 110 fungi were found in 1 g; in cream for the face, skin, massage, vaseline camomile, 155-338 bacteria and 47-850 fungi in 1 g [1,7]. Isolated from cosmetic agents were yeast fungi, Bac. subtilis, gamma-Streptococcus, Alcaligenes, and, which needs special attention, Staph. aureus, Str. haemolyticus and Ps. aeruginosa [6,7,12].

Packaging can be viewed as a potential source of microbial contamination of a medicinal. However, in tubes for ointment, not in a single case were more than 10 saprophytic microorganisms found, and, in the majority of them, microorganisms were not found at all /22/.

Methods for Determination of Microbial Contamination of Soft Medicinals.

Control of sterility and of microbial contamination of ointments involves substantial difficulties since liberation of microorganisms from surrounding fatty layers with the aid of fat-dissolving organic substances can be accompanied by an effect of the latter on the microorganisms.

The simplest and, at the same time, according to data of some authors /107, a sufficiently exact method of finding aerobic microorganisms in ointments, is direct seeding of 0.01 g of a preliminarily prepared sample on the surface of an agar medium. Accuracy of the method is 70-80%. A method of definite interest is one where the ointment is emulsified in 0.25% agar, melted and cooled to 50°C, with subsequent seeding on solid and in liquid nutrient media /3/.

More often, soft medicinals are emulsified in warmed physiological solution while stirring with glass beads /27/ or without them /26/. Also used are buffer solution, peptone water and the like. Various emulsifiers are used --tween-80, span-80, paraffin oil, etc. The temperature at which emulsification is carried out is 37-45°C, time 5 min to 1 hr /4,5,22,28-31/. Cosmetic agents are treated likewise /12,32/. At the time of incubation of the studied substances, when the temperature exceeds 37°C, caution must be observed. There are data indicating that in emulsifying some ointments at 45°C for 20 min, substantial necrosis of staphylococci and E. coli occurs.

The membrane filtration method--which has a definite advantage in a number of cases, in comparison with the direct seeding method--found use in determination of sterility and of microbial contamination of soft medicinals.

At the present time, dissolving the ointments, ointment bases, oils, etc. frequently is done in isopropylmyristate usually heated to 47°C /34-40/. It is emphasized that the time between solution and filtration of the sample should be minimal since prolonged presence of microorganisms in the isopropylmyristate at 47°C promotes death of vegetative forms. To emulsify ointments before filtration , in order to study their sterility and microbial contamination, use is made--as in the case of direct seeding--of phosphate buffer solution, peptone water, tween-80 as the emulsifier and, also glass beads and heating /8/21/24,36,42/ Ointments containing

antibiotics are processed in the same way but, moreover, after filtration, the filter is washed three times with peptone water and tween-80 /8/.

The number of solvents and emulsifiers used in testing soft medicinals for sterility or microbial contamination is quite large at the present time. We have indicated the most-widely used. In addition to those can be mentioned n. hexane, dimethylsulfoxide, triton X-100, peanut oil, sesame oil, etc. /34,36,39,40,43-46/. There are data that preparations of tween /85, 80,60 and 40/ and triton are utilized by cells of microorganisms (47) i.e., they can be stimulators of their growth /48,49/; however, other authors report an antimicrobial effect of triton and a number of non-ionogenic detergents /48,50/. In study of the microbial contamination of cosmetics and of the use, for this purpose, of the isopropylmyristate and tween, authors /12/ prefer isopropylmyristate since it is a good solvent and has minimum effect on microorganisms.

Of essential interest is work which compares the various methods for determination of microbial contamination of soft medicinals. Thus, in comparison of two methods: emulsification of the ointment (1 g) in physiological solution (10 ml) with glass beads at 37°C and stirring for 1 hr with subsequent seeding of 0.1 ml of the emulsion on solid nutrient medium, and, direct seeding of 0.01 g of ointment, preference was given to the second method as the simplest, use of which gives sufficiently reliable results /23/. The method of direct seeding, at any rate in study of eye ointment,/25/ is defective and cannot be recommended. Carrying out a comparative study of microbial contamination of an ointment using three methods (membrane filtration, homogenization in aqueous solution of tween-80 and sequential dilution /38/) indicated that with the help of the first two methods it is possible to obtain good reproducible, reliable results. The third method is regarded as less acceptable by authors /21/. No essential difference was found in determination of microbial contamination of ointments which do not have antimicrobial action, in use of the method of membrane filtration and homogenization of samples in 1% solution of tween-80 in peptone water /9/. Other authors /15/ give preference to the last of the three methods of study of microbial contamination of ointment bases (use of aqueous extraction, direct seeding on agar medium or sugar bouillon, and membrane filtration).

Requirements and Norms Which Limit Microbial Contamination of Soft Medicinals.

Proceeding to direct description of normative requirements which limit microbial contamination of non-injection medicinals, it is necessary especially to separate preparations in respect to which there exists a requirement for sterility or the quite-close-to-it requirement for absence of microorganisms in 1 g or 1 ml of the preparation.

This refers first of all to eye agents. Question of their sterility is not a subject of discussion. One must speak just of sterility of eye agents, not distinguishing the medicinal forms.

It is stressed /24,42,51,52/ that many authors involved in study of microbial contamination of non-injection of medicinals are of one mind about the need of a requirement of sterility (or absence of microorganisms in 1 g or 1 ml of a preparation) for substances applied on the skin surface, and, also, introducible into a sterile cavity. Some authors /53-55/ consider it necessary to introduce the requirement for sterility with respect to preparations used to treat diseases of the eye and nose, and also for all drugs containing steroids.

Medicinals can be separated with respect to whether their requirement for sterility is unnecessary but the number of microorganisms in them should be sharply limited. This should include, evidently, preparations used to treat diseases of the ear and nose, those introduced into the vaginal cavity, those used to treat skin diseases and several others /42,51/. Most basic is the requirement to limit, in these drugs, the number of apathogenic microorganisms up to 100 in 1 g or 1 ml, but with full absence of pathogenic and conditionally pathogenic, which should include /34,51/ bacteria of the Enterobacteriaceae family, and, also Ps. aeruginosa and Staph. aureus. According to another opinion /42/, this list should be supplemented with Str. pyogenes and Dipl. pneumoniae.

Finally, there is a large group of medicinals with respect to which requirements limiting their microbial contamination can be minimal: up to 1000 bacteria and 100 fungi in 1 g or 1 ml in the absence of pathogenic and conditionally pathogenic microorganisms. Precisely these requirements with respect to microbial purity of industrially produced preparations are contained in the CSSR Pharmacopeia, Edition III /56/. However, as for drugs prepared in pharmacies, requirements on limitation of their microbial contamination are somewhat different: allowable is the presence, in 1g or 1 ml of the preparation, of up to 10,000 bacteria; none of the remaining criteria is different than that formulated for industrially produced agents.

On the basis of experimental data /22/ for ointments and suppositories, the following requirements are proposed: preparations should not contain, in 1 g, pathogenic microorganisms, indication of fecal contamination or more than 1000 non-pathogenic microorganisms, including 100 non-pathogenic fungi and yeasts. An exception is ointments for which requirements for sterility are broadened.

As for cosmetics, whose number includes therapeutic cosmetic agents, a number of authors /12,57/ are of the opinion that they cannot have more than 100 apathogenic microorganisms in 1 g or 1 ml. Along with this, it is stressed /12/ for example, that cosmetics and tooth paste should not contain pathogenic and conditionally pathogenic microorganisms, namely, Salmonella, E. coli, Ps. aeruginosa, A. aerogenes, Klebsiella, Staph. aureus, Streptococcus and several fungi. Some authors (Wallhaeuser, cited in /32/) divide cosmetics into two groups according to permissible amount of microorganisms in them: children's powder, tooth pomade, agents for

eye cosmetics, sun protectants, and the like, should have no more than 100 microorganisms in 1 g or 1 ml; others, no more than 1000, and some, even 10,000 microorganisms.

At the present time it is possible to isolate a number of directions in the problem topic, to which the review is devoted, warranting from our point of view, great attention.

Everything bearing on assurance of production of soft medicinal forms which guarantee their harmlessness on the basis of microbiological indices is very important. An indispensable condition here is control of raw material and observation of requirements of hygiene and sanitation at enterprises. The latter include /1/ regular control of personnel health at the enterprises and in the pharmacies, assurance of appropriate purity of equipment and site, including the storage.

No less important is prevention of increase of microbial contamination of soft medicinal forms in the process of their use. Great interest is warranted in the search for new preservatives and in study of the peculiarities of action of antimicrobial agents in respect to microorganisms which survive in ointments. Along with this, there is considerable promise in creation of packaging with a minimum amount of the preparation and—for eye agents—single dose packages.

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PHYSIOLOGY

UDC 613.693:612.84/88

EFFECT OF VESTIBULAR STIMULATION ON MYOELECTRIC ACTIVITY

Moscow FIZIOLOGIYA CHELOVEKA in Russian No 2, 1979 pp 270-275

[Article by E. V. Lapayev, V. I. Zorile, G. I. Pavlov, and F. B. Solodkov]

[Text] We know that when the human vestibular analyzer is stimulated, we observe sensory, autonomic, and somatic reactions which may be accompanied by a worsening of the general subjective sensation of health and by a decline in efficiency. In order to determine the suitability of an individual for occupations associated with the effect of adequate stimuli on the vestibular analyzer, various methods have been created for selecting and developing the criteria by which to assess individual vestibular stability. Nevertheless the problem of preventing unfavorable vestibular reactions in aviation and cosmonautics and during sea cruises continues to be one of the most pressing problems today.

Thus according to Markaryan et al. (1) 12.6 percent of the pilots, students, and flight school applicants exhibited instability in response to vestibular stimuli. This situation is explained in part by absence of sufficiently informative criteria by which to make an objective assessment of tolerance to vestibular stimuli, and in part by the fact that expert conclusions are made on the basis of a subjective means for evaluating autonomic vestibular reactions, suggested by Khilov in 1927 (2).

Research has shown that certain vestibular-autonomic and sensory reactions to vestibular stimuli are very variable (3-9). Because individual reactions are not informative enough to permit a judgment concerning resistance to motion sickness, Yuganov et al. (10) suggested using integral indices such as, for example, systolic and minute blood volume. In addition they suggested utilizing various vestibular-somatic reactions which, owing to an inadequate quantitative assessment, never saw practical use. In addition to this some authors (11-14) concede that motion sickness may have a latent course which would be even more difficult to diagnose.

The research that has been conducted indicates that the electromyographic method provides a certain amount of information on the influence of vestibular stimuli. It has been established in particular that impairment of labyrinth functions leads to change in muscle tone (15-25).

An increase in the electric activity of individual skeletal muscles of a healthy individual was revealed in response to opticokinetic and caloric stimulation (16, 23-26) at the time of action of high angular accelerations (27).

Utilizing the electromyographic method, Yemel'yanov (28) demonstrated that threshold and subthreshold vestibular stimuli cause arisal of vestibular-somatic reflexes in the absence of sensory reaction in man. But a quantitative assessment of changes in myoelectric activity in response to vestibular stimuli has not been published. Differences in the experimental data can apparently be explained by the fact that the authors employed different functional tests, they studied different muscles with the motor apparatus in different initial states, and they used procedures differing from one another. In addition authors studying changes in muscle electric activity in response to simulation of the vestibular analyzer do not cite data concerning individual sensitivity of their subjects to these stimuli.

Methods

The research was conducted with the objective of determining changes in the electric activity of human skeletal muscles in response to Coriolis accelerations. Electromyographic research methods were employed. Dosed static and rhythmic tensing of the muscles was used as the functional test. Static tensing of muscles to one-half of maximum effort, determined by wrist dynamometry, was achieved by pressing on a rubber balloon for 40 seconds. The effort exerted by the subject and experimenter was monitored on the basis of the position of the pointer of a pressure gauge connected to the rubber balloon. Skin electrodes secured in pairs to a textolite pad were used to pick off the biopotentials. Electric activity was picked off from muscles of the upper arm and from the flexor digitorum sublimis and the extensor digitorum communis of the right hand. The subject's hand was secured in a strictly identical position to the armrest of the vestibulometric chair. Muscle biopotentials were intensified with a Disa electromyograph and recorded synchronously on paper (Mingograph 42 B) and on magnetic tape with a two-channel Nagra-IV tape recorder. We automatically processed the EMG's with an electromyographic analyzer which we developed and tested, the AMG-1 (29,30).

We determined the mean frequency and integral (area) of the EMG for a 16 second interval, beginning 5 seconds after the functional test was started. Continuous accumulation of Coriolis accelerations (CACA) was achieved on the electrically operated swivel chair by the following procedures: The subjects were turned with their eyes closed while actively tilting the head 30° toward one shoulder and then the other. The time of head movement (from the right to the left and back) was 2 seconds. The time of exposure depended on the expressiveness of motion sickness symptoms (hyperhydrosis, paleness, nausea, vomiting), while when such symptoms did not occur the exposure time did not exceed 3 minutes in most cases. In some studies the CACA time was increased to 15 minutes. EMG's were recorded prior to the

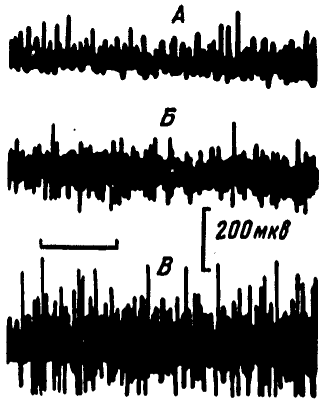
CACA test, immediately after the CACA, and 10-15 minutes after exposure to Coriolis accelerations.

In all we studied 249 healthy individuals (97 of them twice) from 18 to 25 years old. We obtained EMG's from both studied muscles in 296 experiments.

Research Results and Discussion

The research showed that the bioelectric activity of one or both muscles experiences significant changes as a rule in all subjects in response to Coriolis accelerations. On different days of no exposure to accelerations, the EMG parameters we studied varied by about ±10 percent. The integral (area) of the EMG changed most of all. In the presence of accelerations we observed both a decrease and an increase in muscle bioelectric activity, the expressiveness of which depended on the time of exposure to acceleration (Figure 1).

The research materials show that changes in electric activity of different muscles varied depending on the tolerance of the subjects to accelerations (see table).



(1)

Figure 1. Changes in Bioelectric Activity of the Triceps Extensor Cubiti in Response to Dosed Static Tensing (Subject S.): А--EMG prior to rotation, Б--EMG after 2 minutes of rotation, В--EMG after rotation but prior to arisal of motion sickness symptoms (6 minuntes); horizontal bracket indicates 1 second interval.

Key: 1. μv

Changes in EMG of the Flexor Digitorum Sublimis and the Extensor Digitorum Communis Depending on Tolerance of Up to 3 Minutes of the CACA (Average Data for 139 Tested Persons, %)

EMG Index	Muscle Group and Acceleration Tolerance			
	Flexor		Extensor	
	Good	Poor	Good	Poor
Integral (area)	19.0	33.2	24.3	40.3
Frequency	7.9	12.3	14.0	17.3

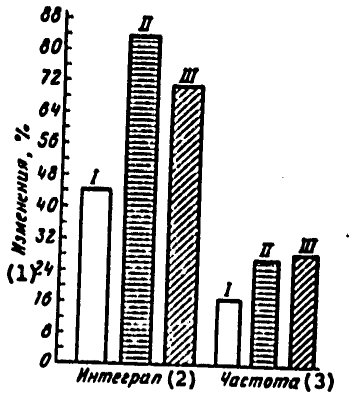


Figure 2. Integral and Frequency of EMG's From Tested Subjects Depending on Tolerance of Acceleration Operating for Up to 3 Minutes (Average Data for 60 Persons): *I, II, III*--Tolerance Groups

Key:
1. Changes, %
2. Integral
3. Frequency

We can see from the table that changes in bioelectric activity are more pronounced with the extensor, especially among persons exhibiting vestibular-autonomic and vestibular-sensory reactions (poor tolerance).

There is a certain amount of interest in analyzing the experimental materials depending on the grouping of subjects in relation to their tolerance of vestibular influence. With this purpose the subjects were subdivided into

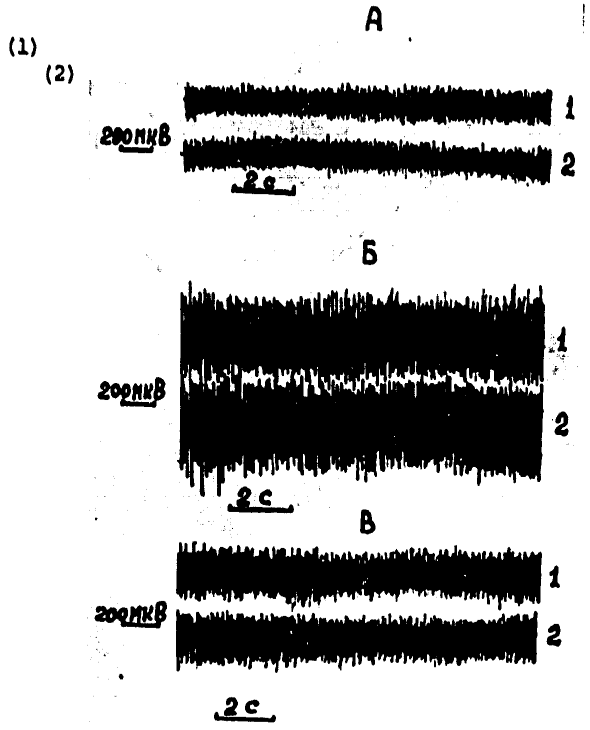


Figure 3. Changes in Response to Dosed Static Muscle Tensing in Different Conditions (Subject Ya.): А--Before CACA exposure, Б--2 minutes after a 10-minute CACA exposure, with motion sickness symptoms present; *1*--flexor digitorum sublimis, *2*--extensor digitorum communis

Key: 1. μv
2. sec

three groups depending on expressiveness of the vestibular-autonomic reactions in response to different times of CACA exposure. The first group contained subjects exhibiting no objective or subjective signs of motion sickness in response to 3 minutes of CACA exposure. The second group was made up of subjects who complained of unpleasant sensations (nausea, weakness, dizziness, warmth, heat) or exhibiting objective signs of motion sickness (paleness, hyperhydrosis of skin on the face, forehead, and wrists, and the urge to vomit) following 3 minutes of CACA exposure. The third group consisted of persons who developed signs of motion sickness in response to 1-2 minutes of CACA exposure.

The degree of change experienced in the frequency and, especially, the integral of the EMG's of subjects in the second and third groups was significantly higher ($p<0.05$) than that of subjects in the first group (Figure 2).

It should be noted that for some of the people the degree of changes occurring in the EMG differed to a certain extent from the group averages. An inconsistency between the degree of changes in the integral of the EMG and the vestibular-autonomic and sensory reactions was observed in 24.3 percent of the cases.

The results of studying bioelectric activity of muscles in different time intervals following exposure to a vestibular stimulus have certain prognostic significance. The research showed that after 10-15 minutes some persons exhibited a partial return of the EMG parameters to their initial values; others exhibited further intensification of the initial changes; still others did not reveal any significant changes. The most typical EMG changes occurring after CACA exposure are shown in Figure 3.

Beginning with Magnus (31), a number of authors (Il etc.) discovered presence of vestibular-somatic reflexes in animals in response to vestibular stimulation. We interpret the obtained data from the standpoint of the teaching on homeostasis (32-34), according to which relative constancy of internal environment and physiological functions is observed in man. Owing to sufficient development of homeostatic mechanisms persons resistant to vestibular stimuli experience elimination or limitation of the effects of acceleration operating as an unfavorable environmental factor, and they exhibit milder EMG changes than do persons that are vestibularly non-resistant.

The obtained data demonstrated the informativeness of the electromyographic method in relation to determining vestibular-somatic tolerance. This permits us to use it as a means for objectively assessing individual vestibular-somatic tolerance. The greater changes occurring in EMG's recorded from persons in the second group in comparison with those of the third group can apparently be explained by the greater time of exposure of persons in the second group to accelerations. This is confirmed by data indicating a dependence of EMG changes on acceleration time (35). Consequently the greater the vestibular-somatic tolerance of the subjects,

under otherwise equal conditions the smaller are the changes on the part of bioelectric activity of skeletal muscles in response to vestibular stimuli. The experimental materials permit the conclusion that the integral (area) of the EMG can be used as a criterion by which to objectively assess vestibular-somatic tolerance. The permissible degree of change of this index is determined depending on concrete conditions and requirements imposed on the occupational activities of the person examined.

Conclusion

The obtained experimental data show that the functional state of the motor apparatus experiences significant changes in response to vestibular stimulation (achieved with the CACA procedure), and that they can be used for diagnostic purposes.

Change in the bioelectric activity of human skeletal muscles in response to Coriolis accelerations depends on the individual vestibular tolerance of the examined individuals and the time of action. Significant changes in muscle bioelectric activity attest, irrespective of their direction, to low vestibular-somatic tolerance. In this aspect the EMG integral (area) is more informative than frequency. The permissible EMG changes in response to the vestibular test, offered in occupational selection, must be determined with a consideration for the working conditions and the requirements of the concrete occupations.

The method we developed for automatically analyzing EMG's with the help of the AMG-1 electromyographic analyzer can be used to efficiently determine quantitative changes in the bioelectric activity of human skeletal muscles in different conditions.

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NYSTAGMOGRAPHIC DESCRIPTION OF REACTIONS TO ROTATION BY PEOPLE WITH DIFFERENT DEGREES OF VESTIBULAR-AUTONOMIC STABILITY

Moscow FIZIOLOGIYA CHELOVEKA in Russian No 2, 1979 pp 276-280

[Article by B. I. Polyakov, M. I. Serebrennikov, Yu. V. Lysenko, Yu. P. Ozerov, and B. V. Permyakov]

[Text] Functional load tests making use of stimuli of significant magnitude have enjoyed the greatest acceptance in the practice of vestibulometric occupational selection. The criterion often employed in this regard is the time of arisal of pronounced vestibular-autonomic disturbances, which often make subjects reluctant to participate in repeat tests. Moreover in a number of cases it is in general impossible to use such loads, or their use presents a certain risk (for example presence in unusual ecological conditions, in a pressure suit, alteration of the body's reactivity, and so on). This is why we must obviously search for a merciful method which would permit us to evaluate vestibular-autonomic stability (VAS) without resorting to such intense stimuli.

Attempts have been made many times to study the correlation between VAS and the nature of nystagmus elicited by rotation at moderate speed. But in most studies the nature of nystagmus has not been assessed with sufficient completeness. Moreover although use of different and often incomparable experimental conditions and groups of subjects by different authors has promoted study of the problem from different sides, it has led to accumulation of contradictory information. Owing to this, despite the long time this problem has been studied a unified opinion as to the diagnostic value of nystagmometry to occupational selection has not evolved as yet (1-18).

Our objective was to make an integrated assessment and a comparison of electronystagmograms (ENG) obtained from people with different VAS's in response to one-time dosed angular accelerations of moderate magnitude. In this case we intended to assess not only static indices (averaged for each trial) describing the average intensity of the reactions, but also the dynamics behind changes in various parameters which have not as yet been the object of special study.

Methods

Seventy healthy men from 20 to 40 years old participated in the research. The subjects were subjected to the following influences: 1) Positive 15°/sec^2 acceleration for 6 sec (the final angular velocity was 90°/sec, and the velocity of rotation was constant for 1.5 min); 2) negative 90°/sec^2 acceleration for 1 sec (the stop stimulus). The subject's attention was actively distracted during the test by means of oral arithmetic (successive subtraction of the number 7 from a given number) (14,19). The subject was rotated in dim light, and his eyes were closed.

The resulting rotational and postrotational nystagmus were recorded with an NC-1000 electronystagmograph (the time constant of the recording channel was 1 sec and the tape advance rate was 5 mm/sec). According to our initial calibration, deviation of the optic axis of the eye by 10 degrees corresponded to a 10 mm deflection of the recorder's stylus.

We assessed the following nystagmus parameters: The amplitudes of the fast and slow components (AFC, ASC), the rates of the fast and slow components (RFC, RSC), their frequencies (FFC, FSC), reaction time (T_r), latent time (T_l), and the number of jerks (N). We studied both the averaged characteristics for each trial and the dynamics of each of the parameters over time. The VAS was assessed on the basis of the results of tests employing double rotation (in minutes)--the Coriolis acceleration accumulation (CAA) test as described by Bryanov (20).

Research Results and Discussion

All of the obtained ENG's were subdivided into three sets depending on the three levels of vestibular stability distinguished for the subjects: Low stability--tolerance of the CAA test for 1-3 min (29 persons), average stability--4-9 min (23 persons), and high stability--10-15 min (18 persons).

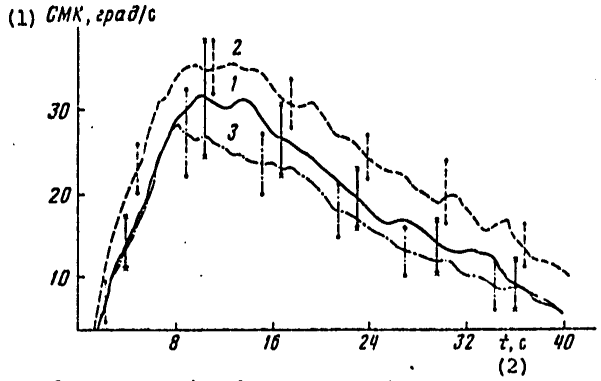
Absence of a single universally accepted criterion for subdividing people into groups depending on their tolerance of cumulative vestibulometric tests gave us the right to make such a distinction, on the basis of the peculiar features of the given experimental situation. In particular, isolation of the extreme groups (persons with low and high VAS) stemmed from the way the sample was distributed in relation to this characteristic. In this case there were two histograms with mode values of 1 and 15 minutes and variation intervals of 0.5-9 and 13.5-15 minutes respectively. The first histogram exhibited significant positive asymmetry.

Despite the fact that the measurements responsible for the first histogram were in a sense part of one statistical step, its further subdivision was found to be suitable because, from the standpoint of medical certification, persons with a VAS equal to 1-2 minutes are not equivalent to persons manifesting second-degree autonomic disturbances (AD-2) (22,23) after just 9 minutes or somewhat sooner. In terms of certification the latter require

a differentiated approach, and it would be just as incorrect to place them in the unstable category as it would be to place them in the conditionally stable category.

Subdivision of the set by the known statistical method of discarding the "strays" did not seem correct due to the asymmetry noted above for the distribution curve. This is why we based our determination of the boundary between the group with low VAS (up to 3 minutes) and the group with average VAS (from 4 to 9 minutes) on the fact that a 2-minute cumulative test is used in expert otorhinolaryngological certification to reveal persons with low stability. The possibility that the subject may exhibit volitional effort to withstand further rotation was taken into account by raising this boundary to 3 minutes, the limits of this effort being known to us from previous experiments.

The figure below shows RSC dynamic curves for postrotational nystagmus, averaged in relation to each set. Similar results were obtained for the other parameters as well. These data permit the conclusion that parameters reflecting nystagmus intensity contain information about vestibular-autonomic stability, while parameters reflecting the shape of the dynamic curves carry no information.



Dynamics of postrotational nystagmus in people with different levels of vestibular-autonomic stability: Symbols: *1*--RSC dynamics for the group with average stability, *2*--the same for the group with low stability, *3*--the same for the group with high stability; abscissa--time from the beginning of the stop stimulus, sec; ordinate--RFC, degrees/sec; solid line -- confidence intervals for average stability group, broken line-- the same for the low stability group, dot-dash line--the same for the high stability group.

Key: 1. RSC, degrees/sec 2. *t*, sec

Table 1. Indices of Rotational Nystagmus in People with Different Levels of Vestibular-Autonomic Stability (VAS)

Параметр (1)	Низкий УВУ $M_1 \pm \sigma_1$ (2)	Средний УВУ $M_2 \pm \sigma_2$ (3)	Высокий УВУ $M_3 \pm \sigma_3$ (4)	p		
				$M_1 = M_2$	$M_1 = M_3$	$M_2 = M_3$
АМК, град (5)	8,63±2,72	6,78±3,44	8,52±5,05	$>0,05$	$>0,05$	$>0,05$
АБК, град (6)	8,03±0,55	6,36±3,39	7,64±4,61	$>0,05$	$>0,05$	$>0,05$
ЧМК, 1/с (7)	0,13±0,55	0,10±0,05	0,10±0,04	$>0,05$	$>0,05$	$>0,05$
ЧБК, 1/с (8)	0,42±0,06	0,38±0,14	0,37±0,08	$>0,05$	$<0,05$	$>0,05$
СМК, град/с (9)	23,00±11,00	16,75±7,50	19,00±7,90	$<0,05$	$>0,05$	$>0,05$
СБК, град/с (10)	84,25±24,87	66,50±30,50	75,50±42,75	$<0,05$	$>0,05$	$>0,05$
$T_р$, с (11)	48,50±10,43	44,58±16,29	42,45±13,69	$>0,05$	$>0,05$	$>0,05$
Н, уд. (12)	89,00±19,77	75,00±24,25	76,00±25,11	$>0,05$	$>0,05$	$>0,05$
$T_{ла}$, с (13)	0,88±0,74	1,05±0,75	1,43±1,43	$>0,05$	$>0,05$	$>0,05$

Key:

1. Parameter
2. Low VAS
3. Average VAS
4. High VAS
5. ASC, degrees
6. AFC, degrees
7. FSC, 1/sec
8. FFC, 1/sec
9. RSC, degrees/sec
10. RFC, degrees/sec
11. T_r, sec
12. N, jerks
13. T_l, sec

Table 2. Indices of Postrotational Nystagmus in People with Different Levels of Vestibular-Autonomic Stability (VAS)

Параметр (1)	Низкий УВУ $M_1 \pm \sigma_1$ (2)	Средний УВУ $M_2 \pm \sigma_2$ (3)	Высокий УВУ $M_3 \pm \sigma_3$ (4)	p		
				$M_1 = M_2$	$M_1 = M_3$	$M_2 = M_3$
АМК, град (5)	7,41±2,56	6,45±2,89	5,09±2,62	$>0,05$	$<0,05$	$>0,05$
АБК, град (6)	6,56±3,42	6,12±2,78	4,67±2,33	$>0,05$	$<0,05$	$>0,05$
ЧМК, 1/с (7)	0,11±0,01	0,09±0,03	0,09±0,26	$<0,05$	$>0,05$	$>0,05$
ЧБК, 1/с (8)	0,42±0,10	0,38±1,20	0,33±0,12	$>0,05$	$<0,05$	$\approx 0,05$
СМК, град/с (9)	19,25±6,25	15,25±7,50	11,78±4,25	$\approx 0,05$	$<0,05$	$<0,05$
СБК, град/с (10)	72,85±21,94	63,75±29,75	46,00±22,00	$>0,05$	$<0,05$	$>0,05$
$T_р$, с (11)	39,13±9,14	42,22±18,64	29,78±8,23	$>0,05$	$<0,05$	$\approx 0,01$
Н, уд. (12)	80,00±22,88	68,00±21,70	64,00±21,81	$>0,05$	$>0,05$	$>0,05$
$T_{ла}$, с (13)	0,34±0,35	0,66±0,77	0,38±0,55	$>0,05$	$>0,05$	$>0,05$

Key: [See Key, Table 1]

Table 3. Correlation of the Parameters of Rotational and Postrotational Nystagmus with Vestibular-Autonomic Stability

Вид нистагма (1)	АМК (4)	СМК (5)	АБК (6)	СБК (7)	ЧМК (8)	ЧБК (9)	$T_{лп}$ (10)	T_p (11)	H (12)
Вращательный (2)	−0,00	−0,27	−0,13	−0,18	−0,16	−0,20	0,15	−0,20	−0,18
(3) Поствращательный	−0,36	−0,30	−0,38	−0,41	−0,18	−0,28	0,00	−0,27	−0,23

Key:

1. Type of nystagmus
2. Rotational
3. Postrotational
4. ASC
5. RSC
6. AFC
7. RFC
8. FSC
9. FFC
10. T_l
11. T_r
12. N

Tables 1 and 2 show the significance statistics for differences between the mean values of the parameters of rotational and postrotational nystagmus for groups with low, average, and high stability. As we can see from these tables significant differences ($p<0.05$) were found in the assessment of rotational nystagmus in relation to ASC, AFC, RSC, RFC, and N in groups with average and low stability, and in relation to FFC in groups with low and high stability. Assessing postrotational nystagmus, we found significant differences ($p<0.05$ and <0.01) in relation to the means of ASC, AFC, RSC, RFC, T_r, N, and FFC for groups with low and high stability, in relation to RSC and FSC for groups with low and average stability, and in relation to RFC and T_r for groups with average and high stability.

We can conclude on the whole that the means of the nystagmus parameters are more informative in relation to tolerance of the CAA test at the time of the stop stimulus than with longer positive angular acceleration.

Table 3 shows the coefficients of correlation of the parameters of rotational and postrotational nystagmus with vestibular-autonomic stability. As we can see from Table 3 the most significant correlation with motion sickness resistance is seen for RSC ($r= -0.39$) and RFC ($r= -0.41$); these coefficients are significantly different from zero at $p<0.05$. But this correlation measure should be treated as being only approximate, since the nature of the sample distribution in relation to VAS differed from normal.

The multiple correlation coefficient for the postnystagmus parameters and VAS was found to be equal to 0.47 (significantly different from zero at ($p<0.05$).

This research not only confirmed the data obtained earlier indicating shorter postnystagmus time for persons with high VAS (2,3, etc.), but it also deepened our ideas concerning the features of the ENG in relation to different levels of vestibular stability. It was demonstrated, first, that the difference in duration pertains only to postnystagmus and that it does not manifest itself in rotational nystagmus; second, that it does not materialize between people with low and average VAS; third, that the RFC, RSC, and FFC are more significant distinguishing characteristics than is postnystagmus time.

Also of interest was the fact that people with low stability were distinguished from highly stable persons (depending on the form of the testing stimulus) in relation to certain parameters while people with average stability were distinguished from them in relation to others. In this case the highly stable subjects were distinguished from the rest of the subjects by a lower frequency for the fast component, irrespective of the form of the stimulus, while differences did not exist in this regard between weak and average groups.

References to the informativeness of the RSC of nystagmus have been made in the literature. But different authors sometimes attach different meaning to this term. As an example work (14) concerned itself with the change in the RSC following a motion sickness test, in connection with which it was suggested that the RSC be used to monitor the subjects and make an objective assessment of their states. In contrast to this, we attach prognostic meaning to our definition of the informativeness of the RSC (as well as the RFC and the FFC): The implication is that the VAS can be predicted from ENG parameters.

Differences in the intensity of nystagmus exhibited by persons subjected and not subjected to motion sickness can be explained by data concerning the role of central cholinoreactive and adrenoreactive systems in regulation of the nystagmic reaction. Considering that pharmacological blockade of M- and N-cholinoreactive structures elicits a dramatic decline in nystagmus parameters while blockade of adrenoreactive structures causes them to increase (21), we can conclude that the activity of adrenergic structures dominates in people with high VAS. Meanwhile, cholinoreactive systems dominate in people with low and moderate stability.

Thus the greater or lesser intensity of nystagmus served in our experiment as one of the manifestations of the balance, between the divisions of the autonomic nervous system, typical of the given subjects. Consequently the reactivity of the vestibular system, evaluated on the basis of this characteristic, can hardly be interpreted as an independent factor with which VAS is in a causal relationship.

Conclusions

1. The higher the vestibular-autonomic stability, the lower is the intensity of postrotational nystagmus.

2. In relation to the succession of influences indicated in our procedure, the stop stimulis is a more informative testing influence than is positive angular acceleration.

3. The dynamics of ENG parameters pertaining to this testing influence do not bear information on the level of vestibular-autonomic stability.

4. The revealed ENG features of persons with different VAS's may serve as the basis for studying the possibilities for predicting vestibular stability from the results of more-tolerable (not unbearable) tests.

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PHYSIOLOGY

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FEATURES OF TACHISTOSCOPIC TEXTURE PERCEPTION

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[Article by V. M. Krol' and L. I. Tanengol'ts, USSR Academy of Sciences Institute of Control Problems]

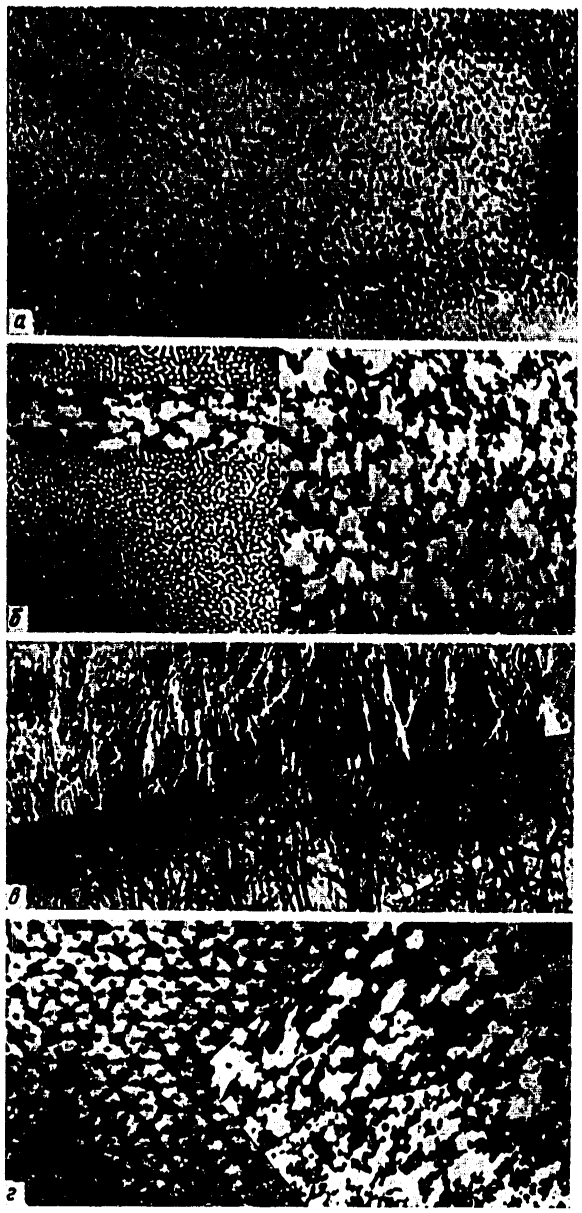
[Text] Texture analysis is apparently one of the most important means for subdividing a complex three-dimensional scene into areas containing numerous objects similar in relation to some particular characteristic. It would seem that the essence of texture analysis--isolation of areas which must subsequently be viewed as units of perception--dictates the method of texture analysis. This method must be implemented without the need for describing the small fragments out of which the texture area consists. Such approaches to the texture analysis problem are being developed in abundance in modeling studies employing spectral, integral, and autocorrelational methods (1-7).

However, this approach is not obvious from what we know about the structure of the visual system's receptive neuron fields. These neurons are well adapted to local processing of parts of an image. Such initial considerations led us to the objective of the present work--to reveal whether the visual system utilizes mechanisms associated with analysis of elementary fragments making up a texture, or mechanisms responsible for isolating areas but not analysis of these fragments when breaking down a three-dimensional scene into texture areas.

Methods

Ten practically healthy subjects from 25 to 35 years old participated in the experiments. The subjects were shown slides on which two texture areas were mounted together. In all, five slides were shown for set time intervals, each with different boundaries between the areas. Four examples of the slides are shown in the figure below. Minor variations in brightness may have been present within each texture area.

The slides were presented tachistoscopically with blackouts in between slides. The presentation time was varied with an interval of 2.5 msec. The



Examples of Slides Presented in the Experiments

brightness of the preexposure, exposure, and blackout fields was 7 lux. The angular dimension of the slide was 1.5-2.0°. The blackout pattern consisted of curve segments, and it was similar in execution (in thickness and density of lines) to that of the images being analyzed.

The subjects were given the following instructions: "Slides containing two or three texture areas will be shown to you for a short time. (Examples of such textures that were not used in the experiments were shown.) You must draw your impressions and provide written commentary on what you see. Turn your attention to two aspects--the course of the boundary between the texture areas and the elements of which each area is composed."

Research Results and Discussion

As the slide exposure time was increased the subjects passed through four stages: Isolation of zones of equal brightness; partial description of elementary texture fragments; approximate isolation of the "poles" of the texture areas; distinction of boundaries between texture areas.

Threshold Times of Texture Analysis Stages, msec

(1) Испытуемые	(2) № слайда	(3) Стадия выделения зон разной яркости	(4) Стадия частичной охарактеризации фрагментов	(5) Стадия приблизительного выделения «полюсов» текстурных областей	(6) Стадия полного выделения границ текстурных областей
O. D.	1	32	40	40	190
	2	32	40	40	158
S. K.	1	—	66	66	180
	2	32	66	72	220
V. K.	1	60	40	40	154
A. K.	2	60	40	66	228
	8	40	90	108	158
P. F.	1	—	54	54	160
Yu. Sh.	1	—	54	54	190
	5	27	71	120	142
L. T.	1	40	40	54	188
	2	32	60	60	160
Yu. M.	8	32	96	96	150
Zh. K.	1	—	35	35	200
N. P.	7	40	40	40	208
$M \pm m$		38,8±3,4	55,4±4,9	63,0±6,8	179,0±6,3

Key:
1. Subjects
2. Slide number
3. Stage of distinction of zones of different brightness
4. Stage of partial description of fragments
5. Stage of approximate distinction of "poles" of texture area
6. Stage of complete distinction of texture area boundaries

The stage of distinction of zones of different brightness had the lowest temporal threshold (see table). But what is extremely important is that the bright zones were not in areas having the same texture. Several zones of different brightness could be present in each texture area.

This stage is possibly close to the stages of amorphous perception distinguished in tachistoscopic experiments involving presentation of formalized untextured images in short time intervals (8).

It would be interesting to note that when the same slides were presented the stage of distinction of zones of varying brightness was not present in all cases. This apparently indicates that the importance of its role is lower, or that it is not mandatory to texture analysis.

The stage of partial description of elementary fragments and distinction of texture areas is texture analysis specifically. When the slide presentation time is increased, the brightness analysis stage begins to be followed by the stage of partial description of fragments making up the texture areas. The temporal threshold of this stage differs significantly (according to Student's test with p=0.5) from the threshold of the brightness analysis stage (see table).

The threshold of the next stage--approximate distinction of texture areas, where the subjects indicate only the "poles" of the areas, for example up and left--is statistically indistinguishable from the threshold of the stage of partial fragment description (see the second and third columns of the table).

However, it is important that in none of the cases did the subjects arrive at the "pole" stage before reaching the partial description stage, and in 25 percent of the cases the subjects had a higher threshold for the "pole" stage (see table).

The drawings and verbal reports of the subjects corresponded to each other in the stages of partial fragment description and approximate distinction of the "poles" of the texture areas; in this case the typical descriptions included "tangled ropes on top," "chessboard," "small kernels or granules on the left," and so on.

Irrespective of whether the subjects distinguished the areas roughly or more accurately, they always distinguished them as places occupied by fragments of a particular type. Perhaps this fact is the most significant of those we discovered. Subjects never distinguished the texture areas themselves without providing information as to what sort of fragments these areas contained.

We believe that this phenomenon is a significant argument in favor of the notion that the human visual system does not employ an autocorrelation mechanism or a spectral decomposition mechanism when distinguishing texture

areas in a scene. In fact, were such mechanisms operating the areas would have been distinguished before information about the fragments appeared, and we did not find this in the experiments.

The last stage of perception involved drawing borders between the texture areas. It was very difficult for the subjects to draw the boundaries, and therefore we treated the boundaries as correct when the subject indicated the orientation of the principal segments with an accuracy of 20-25°. The principal results of analyzing this stage was that its threshold significantly exceeded (by about a factor of 3) the threshold of the partial fragment description stage (see table).

We can hypothesize on the basis of these experiments that distinction of the texture areas occurs in association with gradually growing complexity of the description of fragments making up the content of texture areas, in which case growth in complexity of fragment description occurs before distinction of the texture areas themselves.

In light of this hypothesis we should not be surprised by the fact that in our experiments we encountered cases (about 25 percent) in which the stage of partial fragment description had a lower threshold than that of the stage of approximate distinction of the "poles" of texture areas (the second and third columns in the table). The phenomenon occurred when the elements making up both texture areas were most similar to one another in shape. It would be natural to suppose that the course of analysis in these cases included stages in which characteristics were found having identical significance to elements of both textures, while characteristics making the elements of the two textures different were not found. As an example there were two areas on slide No 8--grass and fibrous elements of another type (nerve cells and their branches). Subject A. K. first described this slide as a "fibrous structure" (threshold--90 msec), and it was not until later that he noted that the fibrous elements were of two subtypes forming different areas (threshold--108 msec).

It would be interesting to answer the question as to whether partial description of fragments making up textures takes significantly more time than their integral evaluation. It is clear from the verbal reports and the drawings that all subjects did not describe the fragments completely. Apparently the visual system makes use of a rich but nevertheless limited set of texture functions, and it is only with their participation that fragments making up textures are analyzed and areas are distinguished. The limited nature of the set of operations associated with texture analysis is what causes incomplete, "sketchy" description of textures.

Conclusions

1. The time threshold was the lowest (38.8±3.4 msec) for the stage of distinction of zones of different brightnesses within the texture areas. These zones were not consistent with particular texture areas.

2. The threshold time of the stage of partial description of elementary fragments making up the textures is 55.4±4.9 msec, and it is statistically indistinguishable from the threshold of the stage of approximate distinction of the "poles" of the texture areas (63.0±6.8 msec).

3. Subjects distinguished texture areas in all cases only as areas occupied by fragments with particular characteristics. The subjects never distinguished the texture areas themselves without providing information as to what sort of fragments they consist of.

4. The treshold of the stage of final distinction of borders between texture areas is 179±6.3 msec, which is significantly higher than the threshold of the stage of partial description of elementary fragments making up the textures.

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IMMUNOPHYSIOLOGICAL ASPECTS OF MAN'S ADAPTATION TO HIGH ELEVATIONS

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[Article by M. M. Mirrakhimov, B. T. Tulebekov, M. I. Kitayev, K. A. Amanturova, and K. A. Saburov, Kirgiz SSR Academy of Sciences Institute of High Altitude Physiology and Experimental Pathology]

[Text] Because the national economy is constantly developing in mountainous regions and in connection with the population migration associated with this, research on immunophysiological changes occurring in the human body during adaptation to high altitude climate is acquiring great significance. Recent research has shown that acclimation to high elevations increases the body's tolerance of a number of extreme factors (1) and can be a means for preventing and treating many illnesses associated with hypoxia. But the questions of natural and adaptive immunity in these conditions are poorly illuminated in the literature.

Immunity is interpreted today not only as a defense reaction against infection but also as a complex of immunological mechanisms aimed at maintaining the constancy of the body's inner environment, and thus its integrity (2). The immune response is associated with cooperative interaction of T- and B-lymphocytes with macrophages and other cells in the body. This is why research on the general laws governing alteration of immunological reactivity in the unfavorable conditions of an oxygen deficit requires an examination of the body's capability for producing defensive reactions in response to penetration, into the body from without, of bodies and substances carrying genetically foreign information.

Immune reactions depend on the availability of oxygen in lymph organs (3). Kaplanskiy, Durnova, and Poshchin (4) observed involution of lymph organs in animals 2,500-3,000 meters above sea level. It was demonstrated in (5) that hypoxia in a high altitude chamber causes inhibition of the maturation of immune cells in the chick embryo, and suppression of an immune response in hatched chicks.

The relatively high sensitivity of animals to infectious diseases in significantly rarefied air is associated with a poor oxygen supply to the system of immunocompetent cells. In the opinion of many authors moderate hypoxia causes activation of the immunity mechanisms, and when rarefaction of air is slight the resistance of experimental animals to infection remains unchanged or even grows, but in the presence of high hypoxia the resistance to bacterial and protozoan infection exhibited by animals adapted to simulated high altitude decreases (6-15).

There are many observations emphasizing the influence of hypoxia on the state of the body's immunobiological reactivity.

We know that short-term, mild altitude chamber hypoxia stimulated the phagocytic reactions and bactericidal activity of animal blood serum, while deep, prolonged oxygen starvation caused a drop in blood phagocytic activity and macrophage activity, a decline in complement titer, retardation of the rejection of dermal homotransplants, and inhibition of wound healing and knitting of bone fractures (4,16-18). Krupinina, Korotayev, et al. (19) observed intensification of the phagocytic activity of neutrophils, activation of lysozyme, and growth in the titers of antibodies to influenza virus coupled with a decline in the properdin level in mountain climbers ascending to an elevation of 2,100-2,300 meters, followed by short-term climbs to an altitude of 3,200 meters on the 4th, 12th, and 18th day of adaptation.

The blood of experimental animals subjected to altitude chamber hypoxia was also found to contain autoantibodies binding with homologous antigens from heart, liver, and thyroid tissue (18). The question as to the influence hypoxia has on the body's immune response when animals are immunized with heteroantigens (sheep erythrocytes and so on) remains debatable. According to the data of most authors, short-term presence of animals in an altitude chamber at a low simulated elevation had no influence on production of antibodies and antibody-producing cells or it stimulated such production, while prolonged, deep hypoxia inhibited their synthesis (6,20). Other researchers, on the other hand, noted that long presence of animals in the mountains at high elevation is precisely what intensifies production of specific antibodies (21,22,). However, these data are difficult to interpret, since the research was conducted on different objects and in differing conditions, and different methods were employed. We should also note that the acute effect of altitude chamber hypoxia differs significantly from chronic exposure to low oxygen partial pressure in the mountains. The influence of hypoxia on the body in the mountains combines with the integrated influence of many other factors, which taken together characterize the external environment of the organism. We cannot fail to consider in this regard that man is surrounded by bacterial and other antigens alien to him. But little research has yet been conducted on the state of man's natural and adaptive immunity in mountain conditions. All of this predetermined the need for studying the laws governing the course of immune processes during adaptation and disadaptation of the body to high elevations.

Methods

Eighty persons were under our observation. Immunobiological reactivity was determined in 47 practically healthy individuals permanently residing at moderate elevations (760-980 meters above sea level) and in 33 persons residing permanently at high elevations (2,800 meters above sea level) in Central Tien Shan. A separate group consisted of practically healthy persons (47) whose immunological characteristics were analyzed upon moving from moderate elevations (760-980 meters) to the high elevations of Tien Shan and Pamir (3,200-3,800 meters) on the 5th-6th, 2th-30th, and 40th days of adaptation, and then on the 5th day of disadaptation.

The immunobiological study entailed determination of T- and B-lymphocytes together with the blood's bactericidal systems and some humoral factors of specific immunity.

The activity of the T-lymphocyte system was determined by the lymphocyte blast-transformation reaction (LBR) using phytohemagglutinin (PGA), following the method suggested in (23). The functional state of the B-lymphocyte system was judged from the concentration of immunoglobulins in the blood, which were determined by the radial immunodiffusion method (24).

Complement was determined by titration until 100 percent hemolysis (25) and by the lysozyme titration method until lysis of the test microbe *M. lysodeicticus* (26), and completed phagocytosis was determined with *Staphylococcus aureus* (strain 209) by the Petri dish method suggested by Matusis and Pylayev (27). The last test, which reflects the final phase of phagocytosis, also indirectly characterized the activity of the microphagal (A) system.

The specific reactivity of the body was assessed from the titers of *Staphylococcus* anatoxin, antistreptolysin-O (ASL-O), antistreptokinase (ASK), and V_i antibodies.

Research Results and Discussion

Comparison of the immunological reactivity of persons residing at different altitudes revealed that the level of complement, M immunoglobulins, *Staphylococcus* anatoxin, and antistreptolysin-O was lower among indigenous residents of high elevations than in residents of moderate elevations, apparently owing to lower contamination of the environment by *Staphylococcus* and *Streptococcus* infection (Table 1). Other immunity indices of the natives of the elevations being compared did not differ for practical purposes ($p>0.05$).

Table 1. Level of Some Immunological Characteristics of Permanent Residents of Different Elevations

Показатели (1)	Низкогорье (2)	(3) Высокогорье	p
IgA, мг % (4)	361,0±21,12	332,0±24,77	>0,05
IgM, мг %	121,0±4,76	80,0±4,99	<0,05
IgG, мг %	1610,0±55,50	1693,0±105,00	>0,05
Комплементарный титр (5)	0,054±0,0023	0,042±0,0008	<0,05
Индекс завершенности фагоцитоза (6)	5,53±0,95	4,17±0,87	>0,05
Стафилококковый антитоксин (А. Е.) (7)	0,63±0,03	0,43±0,05	<0,05
Антистерптолизин-О (ед.) (8)	224,0±28,3	181,0±14,0	<0,05
Vi-антитела, титр (9)	1:13 [1:8—1:19]	1:14 [1:9—1:21]	>0,05

Key:

1. Characteristics
2. Moderate elevations
3. High elevations
4. mg-percent
5. Complement titer
6. Phagocytosis completeness index
7. *Staphylococcus* anatoxin (active units)
8. Antistreptolysin-O (units)
9. V_i antibodies, titer

Table 2. Nonspecific and Specific Immunity Factors During Adaptation and Disadaptation of People to High Elevations

(1) Показатели	(2) Исходные данные (760—980 м)	(3) Адаптация (3200—3800 м)			(4) Дезадаптация (760—980 м)
		(5) 5—6-й дни	25—30-й дни	40-й день	5-й день
Титр комплемента (6)	0,054± ±0,0023	0,040± ±0,0032*	0,055± ±0,0035	0,058± ±0,0036	0,06± ±0,0043
Титр лизоцима (7)	1:102 (1:18—1:112)	1:52* (1:40—1:63)	1:85 (1:72—1:100)	1:81 (1:66—1:95)	1:64* (1:52—1:79)
Индекс завершенности фагоцитоза (8)	5,53±0,95	4,6±0,85	—	6,4±0,58	—
Стафилококковый антитоксин (А. Е.) (9)	0,63±0,03	0,35±0,028*	0,58±0,011	0,67±0,022	0,64±0,064
Антистрептокиназа (ед.) (10)	305,8±47,3	271,7±39,7	335,2±42,8	342,8±63,6	290,0±64,0
Антистрептолизин-О (ед.) (11)	224,0±28,3	124,0±38,5*	263,0±34,9	177,2±31,8	163,0±19,6

*The result differs significantly from the initial data ($p<0.05$)

Key:

1. Characteristics
2. Initial data (760-980 meters)
3. Adaptation (3,200-3,800 meters)
4. Disadaptation (760-980 meters)
5. Day
6. Complement titer
7. Lysozyme titer
8. Phagocytosis completeness index
9. *Staphylococcus* anatoxin (active units)
10. Antistreptokinase (units)
11. Antistreptolysin-O (units)

Relocation of healthy people to high altitude was accompanied by a distinct change in the blood's bactericidal systems (Table 2). In the first days of adaptation, the complement and lysozyme titers of blood serum declined significantly as a reaction to a stressful situation, but by the 20th-25th day at altitude the level of these tests returned to the initial value.

Disadaptation led to suppression, relative to the initial data, of integral characteristics of the blood's lytic potential such as complement activity and lysozyme activity.

Considering that complement and lysozyme stimulate the phagocytic reaction in normal conditions (28,29), in our research on the blood's bactericidal systems we also determined completed phagocytosis, which reflects the final protective phase of the phagocytic process. However, the phagocytosis completeness index did not change significantly in response to short-term adaptation to high elevations.

Subjecting the systems of T (thymus-dependent) and B (of bone marrow origin) cells to differentiated analysis during adaptation to high elevations, we selected a combination of tests in which one of them (blast-transformation with PGA) evaluated the overall state of effector cells while the other (immunoglobulin spectrum) indicated the condition of antibody producers (Table 3).

On the 5th-6th day of adaptation lymphocytes cultured in the presence of the mitogen PGA revealed a decrease in their capability for transforming into blast cells. Later the functional activity of T-lymphocytes increased, attaining the background value by the 25th-30th day of observation. Disadaptation did not have a significant influence on blast-transformation of these cells.

Synthesis of A, M, and G immunoglobulins declined in the same way by the 5th-6th day of adaptation, but in subsequent days their level increased significantly, with the exception of immunoglobulins in class G which, as we know, reflect a late immunological reaction to an antigenic influence (29).

The decline in values in the tests of the overall condition of T- and B-cell systems in the first days of the adaptive period can be interpreted as evidence of suppression of the functional activity of the immunogenic apparatus, and of its low capability for assimilating antigenic stimuli. The impression is created that growth in the body's nonspecific resistance to various extreme effects occurring in the initial phase of adaptation combines together with a dramatic decline in its immunological reactivity. In light of data indicating that the adrenal cortex undergoes activation during the first days of adaptation to high elevations (30,31), we could assume that corticosteroids have an immunodepressive action on immunogenetic processes. In subsequent analysis we would have to differentiate the specific action of a montane climate from stressful effects.

Suppression of specific immunity to *Staphylococcus* and *Streptococcus* infection was also revealed at the beginning of the adaptive period, and consequently the danger of bacterial infection increased. The levels of *Staphylococcus* anatoxin and antistreptolysin-O decreased noticeably by the 5th-6th day of adaptation, but in subsequent days the specific antibody titer attained its background value (at moderate altitude). Disadaptation did not have a significant influence on the extent of immunity to *Staphylococcus* and *Streptococcus* infection (Table 2).

Table 3. T- and B-Immunity Systems During Adaptation and Disadaptation of People to High Elevations

(1) Показатели	(2) Исходные данные (760—980 м)	(3) Адаптация (3200—3800 м) 5—6-й дни (5)	25—30-й дни (5)	40-й день	(4) Дезадаптация (760—980 м) 5-й день
IgA, мг%	301,0±21,12	245,0±17,95*	312,0±16,70	326±23,86	315,0±17,82
IgM, мг%	121,0±4,76	76,0±4,36*	113,0±6,14	140,0±14,34	114,4±7,21
IgG, мг%	1610,0±55,3	1152,0±60,0*	1502,0 48,13	1294±44,35*	1344±33,71*
(6) РБЛ с ФГА, %	76,4±1,36	40,2±0,63*	78,0±1,46	—	78,0±2,59

*The result differs significantly from the initial data ($p<0.05$)

Key:

1. Characteristics
2. Initial data
3. Adaptation (3,200-3,800 meters)
4. Disadaptation (760-980 meters)
5. Days
6. LBR using PGA

Of interest is the fact that during the time of depressed immunological reactivity the human body is nevertheless capable of reacting adequately to concrete antigenic stimuli. In particular active immunization of 23 volunteers with "tabte" [sic] vaccine on the 6th day in the mountains of Pamir at an elevation of 3,200 meters above sea level resulted in almost a fourfold increase in the mean geometric titer of V. antibodies (1:52 as opposed to 1:14) and return of the levels of class A, M, and G immunoglobulins to the background values typical of moderate elevations by the 26th day of adaptation. The obtained data permit us to conclude that in the critical period of adaptation, the body can respond to an antigenic stimulus by greater synthesis of specific antibodies. Our research permits the suggestion that there are phasal shifts in immunological reactivity in correspondence with the time of presence of people at high elevations. We find that a number of nonspecific and specific immunological characteristics are suppressed in unadapted people during the first week at high elevations, and that the values of most of the tests return to those typical of the initial barometric pressure by the end of a month of adaptation. Such shifts are adaptive in nature, and they are one form of the body's response to the stressful situation of high elevations. Despite moderate inhibition of

immunobiological reactivity in the initial period of adaptation to high altitude, the human body maintains its capability for responding adequately to additional antigenic stimuli.

Conclusions

1. Man's adaptation to high elevations manifests itself as phasal shifts in the body's immunobiological reactivity. A number of nonspecific and specific immunity factors decline in the first week of the adaptive period, and they undergo stabilization at the initial level recorded at moderate elevation by the end of a month of adaptation.

2. In the initial period of adaptation the T- and B-immunity systems are suppressed as a reaction to the stressful situation of high altitude.

3. Disadaptation causes a decline in the level of immunoglobulins and suppression of certain characteristics of the lytic potential of blood serum such as lysozyme activity and complement activity.

4. A low level of M immunoglobulins and a decline in immunity to *Staphylococcus* and *Streptococcus* infection are observed among indigenous residents of high elevations.

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SOME FEATURES OF MAN'S ADAPTATION TO HIGH LATITUDES

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[Article by V. P. Kaznacheyev, V. Yu. Kulikov, L. Ye. Panin, and V. V. Lyakhovich, Institute of Clinical and Experimental Medicine, Siberian Branch, USSR Academy of Medical Sciences]

[Text] The most important approach to gaining an understanding of vital phenomena is their integrated assessment, which includes both analytical isolation of ever-deeper levels of structural organization, and determination of the principles of integrity, order, and determination of spatial and functional mutual relationships (1). Adaptation is doubtlessly such a physiological and biological phenomenon, the successful study of which would be possible only from the position of a systems approach and the methods of systems analysis.

Biomedical research in northern regions occupies an important place in solution of adaptation problems (2-5). This can be explained first by the fact that extensive development of these regions has now acquired important national economic significance and posed new pressing tasks to hygiene and medicine (6-10), and second by the fact that adaptive mechanisms responsible for formation of adaptive reactions to extreme environmental factors evolve over many generations in the course of development of the northern regions.

Deeper study of these adaptive mechanisms is acquiring important significance not only from the theoretical but also from the practical aspect, particularly in regard to solving the problems of chronic stress, arisal of new pathology, and so on. Thus the uniqueness and specificity of human morbidity in polar regions are providing the groundwork for a new, deeper understanding of the etiology and pathogenesis of the most widespread diseases, and they are permitting us to predict possible future pathology.

In this case we must also consider the fact that those human populations which acquire special adaptive mechanisms in response to the action of ecological factors inherent to the Far North may turn out to be more resistant or more vulnerable to the numerous effects of the factors of scientific-technical progress. This is why biomedical research on the indigenous and

immigrant populations of the northern regions requires a special, integrated approach, and why it cannot always be planned according to those ideas which are successfully applied in other regions.

The integrated program "Human Adaptation" developed by the Siberian Branch of the USSR Academy of Medical Sciences foresees study of the adaptive mechanisms of both the indigenous and the immigrant populations in the Far North at different levels of organization, beginning with submolecular and ending with populational.

Metabolic Aspects of Adaptation at High Latitudes

It has been demonstrated (11) that people coming to the Far North for work exhibit a stable rise in the content of free fatty acids (FFA) in blood serum, this rise being especially pronounced during the period of polar night. The lipid level rises significantly as well. As the time of residence in the North grows longer the size of the total fraction of low density (LDLP) and very low density lipoproteins (VLDLP), which serve as the principal mobile form of endogenous fat in the body, gradually increases (Table 1).

Table 1. Change in Some Biochemical Characteristics of Man's Blood During His Adaptation to Conditions of the Far North* ($M \pm m$; n=20)

Показатели крови (1)	Срок проживания (2)					Жители Новосибирска (5)
	1-2 мес. (3)	6 мес. (3)	1 год (4)	1,5 года (4)	2 года (4)	
(6) Сахар крови, мг %	82±5,1	65±5,9	73±7,2	72±4,0	91±6,3	92±6,0
(7) Общие липиды, мг %	701±30	609±53	559±19,8	666±29	652±32,0	476±21,0
Свободные жирные кислоты, γ-экв/л (8)	519±24	544±14	503±14	440±33,7	458±33,7	245±21,2
11-оксикортикостероиды, мкг % (9)	25,1±0,6	22,0±1,2	24,7±0,9	24,8±0,8	24,8±0,7	19,8±0,47

*The research was conducted during the time of the polar night.

Key:

1. Blood characteristics
2. Time of residence
3. Months
4. Years
5. Novosibirsk residents
6. Blood sugar, mg-percent
7. Total lipids, mg-percent
8. Free fatty acids, gamma-equivalents per liter
9. 11-oxycorticosteroids, µg-percent

The concentration of cholesterol and phospholipids in blood serum also rises, attaining its highest values in the immigrant population residing in the North for 5-10 years and longer. The immigrant population of Noril'sk exhibits a lower blood sugar level at the time of the polar night than does a corresponding group of Novosibirsk residents. This group of Noril'sk residents also exhibited a rise in the blood steroid hormone level.

These data indicate first that the Arctic conditions are subextreme for the immigrant population, and second that man's adaptation in these conditions is typified by a dramatic rise in the role of lipid metabolism in energy support to adaptive processes. It is interesting that the indigenous population of the Far North (Dolgan, Nganasan) also exhibit a rise in the blood serum FFA concentration, while the other characteristics of lipid metabolism are lower than for Novosibirsk residents and the 11-oxycorticosteroid level is practically indistinguishable from the corresponding characteristics of Novosibirsk residents.

A comparison of these results with those of examining the immigrant population would show that the natives experience intensified lipid metabolism due to lipids of exogenous origin--that is, food lipids (evidence of this is found in the low LDLP and VLDLP level). A switch in energy metabolism from the "carbohydrate" type to the "fat" type has also been demonstrated experimentally in response to the action of subextreme and extreme factors on the body (12).

It could be hypothesized that the observed preferential oxidation of fatty acids is a consequence of two causes--the need for compensating for higher energy expenditures with lipids, the latter being a more energy-rich material, and the need for compensating for certain molecular shifts occurring in the structure of cell membranes in response to the constant influence of perturbational factors in the environment.

All of these data indicate that the indigenous population of the North is apparently characterized by a significant shift, stabilized by evolution, in energy metabolism in the direction of preferential utilization of lipids. But what is normal to northern natives may cause development of pathology in the immigrant population of the North as the latter adapts to the higher latitudes. Thus, for example, enlargement of the tissue concentration of lipids creates real possibilities for their oxidation by a free-radical rather than an enzymatic mechanism.

Lipid Free-Radical Oxidation (FRO) Reactions and Their Role in Metabolism in the Cell and the Body as a Whole

The universality of lipid FRO reactions has made their study an important problem of biology and pathology. The greater the energetic and functional stress imposed on the cell within the body, the greater is the probability that lipid FRO reactions would proceed and the lipid regulation system would

break down. In certain stages these reactions could operate as factors limiting the adaptive possibilities of the cell and promoting development, within body tissues, of a complex of nonspecific changes which have been called by some authors the "lipid peroxidation syndrome" (13). The following are typical of this syndrome: Injury of cell membranes coupled with disturbance of their permeability, development of arterial-capillary fibrosis, formation of lipid-protein cross-linkages, and so on.

Biological membranes are protected from excessive FRO reactions within them by bioantioxidants--that is, substances capable of inhibiting radical chain self-oxidation of organic substances by blocking the active centers of such oxidation--peroxides and free radicals (14). The biological role of antioxidants boils down to shifting competitive relationships between the enzymatic and free radical pathways of fatty acid oxidation in the direction of the enzymatic pathway (15). Change in the mechanisms by which lipid FRO reactions are regulated may lead to a transition to the other level of self-regulation, and it may be reversible; these changes may also be irreversible, making it impossible to perform regulatory functions (16). Disturbance of the mechanisms responsible for autoregulation of lipid FRO reactions in the body promotes development of pathological processes.

More and more data are being accumulated showing that information on the state of lipid structures does not have just limited significance; instead, it serves as a major characteristic of the stability of normal chemical transformations in the cell (17). The lipid stroma of membranes, on which electron transport proceeds and where enzymes are deployed for action, is one of the "bottlenecks" of the autoregulatory mechanism, which was persuasively demonstrated in the works of Magomedov et al. (18) who studied the role of antioxidants in alteration of the osmoregulatory mechanisms of fish finding themselves in new environmental conditions. These processes may also have important significance to man.

Examination of healthy persons in Noril'sk and Novosibirsk showed (19) that lipids in the stroma of erythrocytes of Noril'sk residents contain much more lipid hydroperoxides and much fewer antioxidants of nonenzymatic nature than is the case for Novosibirsk residents--that is, the control group. It was also revealed that the resistance erythrocytes display to the action of hydroperoxides is lower in Noril'sk residents than in the control group. Change in enzymatic antioxidants was insignificant in both of these groups (Table 2).

We can apparently suggest on the basis of these data that the conditions of the Arctic, particularly of Noril'sk, promote activation of lipid FRO reactions. We also discovered a decrease in antioxidative activity (AOA) of nonenzymatic lipids on examining healthy persons in Dikson Settlement. Lipid AOA is much higher for the indigenous population of the Far North (Yakuts) than for the immigrant population of these regions and even for inhabitants of the middle latitudes (Table 3). It is entirely probable that in the

Table 2. Peroxidic Lipid Oxidation Reactions and Systems Controlling Their Intensity, in Novosibirsk and Noril'sk Donors (M±m)

Группы доноров (1)	(2) Исследование показателей					
	(3) гидроперекиси жирных кислот $E_{макс}$ 233 нм	(4) антиокислительная активность мл/г	(5) стабильность мембран, угол	(6) супероксид дисмутаза (50%-ное торможение автоокисления адреналина)	(7) глутатионредуктаза, ед	(8) глюкозо-6-фосфат-дегидрогеназа, ед.
Новосибирск (9)	0,134±0,01	235±15,1	22±0,63	0,1±0,02	1,6±0,05	0,7±0,03
Норильск (лица, не сталкивающиеся с производственными вредностями) (10)	0,274±0,02	51±5,0	13±0,17	0,00±0,02	1,7±0,05	0,73±0,01
Норильск (рабочие комбината) (11)	0,314±0,05	—37±4,0	20,4±0,63	0,14±0,03	2,2±0,07	1,16±0,05

Key:

1. Donor group
2. Research indices
3. Fatty acid hydroperoxides, E_{max}, 233 nm
4. Antioxidative activity, ml/gm
5. Membrane stability, angles
6. Dysmutase superoxide (50% inhibition of epinephrine self-oxidation)
7. Glutathione reductase, units
8. Glucose-6-phosphate dehydrogenase, units
9. Novosibirsk
10. Noril'sk (persons not coming in contact with harmful industrial factors)
11. Noril'sk (combine workers)

Table 3. Antioxidative Activity (AOA) of the Blood of Immigrant and Indigenous Populations at High Latitudes (M±m)

(1) Группы доноров	Число обследованных (2)	АОА, ч/смл/г (3)	p
Новосибирск (4)	15	65±5	0,001
Пос. Диксон (5)	23	0	0,001
Коренные жители (якуты) (6)	31	133±12	0,001

Key:

1. Donor group
2. Number of subjects
3. AOA, (ch/sml/gm)
4. Novosibirsk
5. Dikson Settlement
6. Indigenous residents (Yakuts)

course of evolution, northern natives experienced development and consolidation of both enzymatic and nonenzymatic antioxidant systems blocking activation of lipid free radical oxidation reactions. It is also possible that the recorded differences in the lipid AOA of the indigenous and immigrant population are associated with dietary features: The diet of northern natives is dominated by proteins and lipids, and it is distinguished by a high concentration of fat-soluble vitamins. It has been demonstrated (20) that the concentration of vitamins A and E in the blood serum of the indigenous population of the Far North is significantly higher than among residents of the middle zone (Table 4). At the same time the concentration of tocopherol in the blood serum of the indigenous northern population is typified by seasonal fluctuations (Table 5).

Thus both our data and published data afford the grounds for suggesting that man adapts to the conditions of the Far North on the background of E-hypovitaminosis and that it creates real possibilities for activation of lipid FRO reactions and a resulting change in the physicochemical properties of the biological membranes of cells and their aggregates, forming a "microregion" in the given tissue.

Table 4. Concentration of Vitamins A and E and Carotene in Blood Serum of the Indigenous and Immigrant Populations of the North (M±m) (20)

Группы доноров (1)	Число обследованных (2)	Витамин А, мкг % (3)	Каротин, мкг% (4)	Витамин Е мг% (5)
Коренные жители (6)	27	71,47±3,31	33,55±3,17	0,75±0,04
Пришлое население (7)	80	37,42±1,85	78,48±2,64	0,39±0,02
p		<0,001	<0,001	<0,01

Key:

1. Donor group
2. Number of subjects
3. Vitamin A, µg-percent
4. Carotene, µg-percent
5. Vitamin E, mg-percent
6. Indigenous residents
7. Immigrant population

The noted shifts in the lipid FRO reactions of persons in the Far North may be the product of, we believe, a complex of different factors that mutually supplement rather than exclude one another. They include, first of all, an increase in mental and emotional tension in response to climatic, geographic, social, and production factors (21); second, a tocopherol difficiency in the food eaten by the immigrant population (20); third, the available studies on the mechanism of action of electromagnetic fields on

Table 5. Concentration of Vitamin E in Blood Serum of the Healthy Arctic Population in Winter-Spring and Fall-Winter (M±m, mg-percent)*

Время исследования (1)	Число обследованных (2)	Вся группа (3)	(4) Возрастные группы	
			18–40 лет (5)	40–60 лет (5)
Зимне-весенний период (6)	115	0,45±0,02	0,40±0,02	0,38±0,03
Осенне-зимний период (7)	146	0,56±0,02	0,59±0,02	0,48±0,02

*Normal concentrations: Vitamin A--30-70 µg-percent, carotene--80-230 µg-percent, tocopherol--0.80 mg-percent

Key:

1. Time of research
2. Number of subjects
3. Total group
4. Age groups
5. Years
6. Winter-spring
7. Fall-winter

Table 6. Effect of the Earth's Magnetic Field (*K*-index) on Some Biochemical and Physiological Characteristics (Correlation Analysis Performed as in (2))

Physiological Parameter	Correlation	Physiological Parameter	Correlation
17-ketosteroids	Very strong	Blood oxygen tension	Strong
Epinephrine excretion	Moderate	Erythrocyte sedimentation reaction	"
Cholinesterase activity	"	Minimum blood pressure	Weak
Urine vitamin B_1 concentration	Strong	Systolic volume	"
Weighted average skin temperature	"	Minimum dynamic pressure	"
Blood flow rate	"	Peripheral resistance	"
Cardiac ejection	"	Thrombocytes	"
Maximum blood pressure	"	Blood coagulability	"
Pulse pressure	"	Erythrocytes	Very insignificant
Pulse	"	Leukocytes	"
Hemoglobin concentration	"		

Table 7. Characteristics of the Blood Oxygen Balance for Healthy Persons in the Arctic (M±m)

Группы обследованных (1)	Насыщение крови кислородом (2)			Напряжение кислорода в крови, мм рт. ст. (6)		
	артерия (3)	вена (4)	артерио-венозная разница (5)	артерия (3)	вена (4)	артерио-венозная разница (5)
Контроль — Новосибирск (40) (7)	93,1±0,6	50,3±1,7	42,8±1,5	74,0±2,2	34,3±1,0	40,3±2,0
Лица, проживающие в Заполярье до 1 года (19) (8)	93,1±0,5	45,2±5,3	48,2±5,2	75,8±1,7	30,5±2,7	45,3±2,5
Лица, проживающие в Заполярье до 2 лет (33) (9)	93,8±0,3	33,2±2,9	60,6±1,4	76,8±1,3	24,0±1,5	51,0±1,7
Достоверность (10)		$p_{1-3}<0,05$ $p_{1-3}<0,001$ $p_{2-3}<0,05$	$p_{1-2}<0,05$ $p_{1-3}<0,01$ $p_{2-3}<0,05$	$p_{1-2,3}<0,05$ $p_{2-3}<0,05$	$p_{1-2}<0,05$ $p_{1-3}<0,001$ $p_{2-3}<0,05$	$p_{1-2}<0,05$ $p_{1-3}<0,001$ $p_{2-3}<0,05$

Note: The number of subjects in each group is indicated in parentheses.

Key:

1. Group of subjects
2. Blood oxygen saturation
3. Artery
4. Vein
5. Arteriovenous difference
6. Blood oxygen tension, mm/Hg
7. Control--Novosibirsk (40)
8. Persons residing in the Arctic for up to 1 year (19)
9. Persons residing in the Arctic for up to 2 years (33)
10. Significance

biological systems and substrates (22-24) afford the grounds for suggesting that such factors having to do with magnetic fields can also alter the intensity of lipid FRO reactions by their action on molecular and submolecular structures in the cell. Thus examination of 2,400 healthy people in the north of the European SSR in different seasons of the year demonstrated (1) that the most important adaptive functions of the body have moderate and high correlation with the characteristics of magnetic intensity (Table 6).

Thus the complex of ecological factors in the Far North, acting on the human body through various pathways, exert their action at the level of a number of the body's functional systems, to include the level of biological membranes, altering their physicochemical properties and, in particular, the intensity of lipid FRO reactions. Meanwhile, as was noted above, these reactions go a long way in determining the functions of "microregions" in particular tissues, particularly their oxygen metabolism.

It was on the basis of this idea that in addition to evaluating lipid FRO reactions during one of our integrated expeditions, we studied a number of parameters giving us an idea of the nature of oxygen metabolism as a whole--pO_2 and pCO_2 in arteries and veins, and so on. In all, we examined 52 practically healthy men from 18 to 22 years old (25). The obtained data were compared with a similar group of persons (40) residing in Novosibirsk. It was demonstrated that arterial blood oxygen saturation and oxygen tension of healthy young men living in the Far North hardly differ from the corresponding characteristics for the Novosibirsk residents serving as the control group. The changes in these characteristics were most pronounced in relation to venous blood, in which case they were significantly lower for persons living in the North than for the control group (Table 7).

The increase in the arteriovenous difference in oxygen tension was accompanied by development of metabolic acidosis and a rise in the permeability of capillaries in relation to both liquids and protein.

Conclusion

The data presented here allow the hypothesis that in addition to adaptive changes typical of a stressful state occurring in man at high latitudes, a number of specific changes, the primary link of which is associated with structural elements of the cell, occupy an important place. The way receptive and reflex mechanisms act in the structural components of cells remains insufficiently clear for the moment. However, these mechanisms doubtlessly alter the nature and effectiveness of adaptive reactions significantly. Were we to try to synthesize the "stress" phenomena described above at the submolecular and molecular levels, we would have to assume that on the whole they place the cells of organs and tissues in a unique state of stress. As far as the rich spectrum of nonspecific adaptive reactions is concerned, these reactions have been discussed sufficiently well in the modern literature (10,26,27).

In light of Bauer's ideas (28) we can hypothesize that when the body's cells are subjected to chronic stress, the "state of stable imbalance" changes, with entropy exhibiting an increase. This can lead to serious functional and, later, structural disturbances, and threaten the integrity of the biosystem. This is why mechanisms directed at moderating and stabilizing processes leading to an increase in entropy are mobilized in the cells, tissues, and the body as a whole. In our opinion we can include among the latter alteration of energy flows responsible for regulation of antioxidative activity, as well as genetic mechanisms supporting synthesis of enzymatic antioxidants. All of these adaptive mechanisms combine together with numerous other adaptive reactions aimed at supporting and maintaining energetic, plastic, and information flows in the body as a whole.

Thus from our point of view there are grounds for suggesting that people in high latitudes develop a state of unique chronic stress, which can be called the "polar stress syndrome." This syndrome is typified by the features listed above, ones which reflect adaptive mechanisms aimed mainly at stabilizing cell structures experiencing altered conditions for their vital activities.

Change in peroxidic processes is obviously the result of effects having a dual nature: 1) Shifts, mediated by metabolism, in response to the unique complex of ecological factors typical of high latitudes; 2) the direct influence of geomagnetic and cosmic perturbations on biological structures. Development of this "syndrome" does not mean presence of a pathological state; instead, it characterizes the specific features of adaptation, its orientation. The amount of the "biosocial price" (29) paid by man's health in the immediate and remote future remains unknown. Disadaptation may lead to various sorts of pathological states, which may be typified by certain specific traits despite variations in pathogenesis and location. This commonness will obviously be manifested in a tendency toward a sluggish chronic disease course, inadequacy of repair processes, and a tendency toward sclerogenic reactions.

This interpretation of adaptive mechanisms at high latitudes promotes a number of new general questions concerning biological and physiological adaptive mechanisms as a whole. It would be important to conduct deeper research on the adaptive features exhibited by indigenous residents of the Far North, since the most suitable and economical adaptive reactions to the unique cosmic, geomagnetic, and other ecological conditions of the North should be genetically stabilized within them by evolution. New possibilities open up in terms of finding methods for individual selection of people and for predicting and preventing pathological processes in the North. In our opinion the information gained in this way may also be of value to further research on various states of chronic stress.

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BIOCHEMICAL CHANGES OCCURRING IN HEALTHY PEOPLE VISITING THE ARCTIC FOR A SHORT TIME

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[Article by Yu. P. Gichev, Ya. V. Polyakov, V. I. Khasnulin, T. S. Neustroyeva, Yu. O. Kim, and V. P. Kaznacheyev, Institute of Clinical and Experimental Medicine, Siberian Branch, USSR Academy of Medical Sciences]

[Text] The main objective of "human ecological physiology" (1) is to study the mechanisms supporting development of adaptive reactions and promoting improvement of the body's adaptive function; such research follows the important goal of creating the most effective systems by which to assess human health and prevent disease (2).

Two methodological approaches can be used in research on human adaptation, particularly in the North--individual and general (3). The former entails repeated--dynamic--examination of the same individuals over particular time intervals. Obviously this approach is more acceptable for research on short-term adaptation.

The second, the general method, which is also called the "population cross section" method by Anglo-American researchers, entails simultaneous examination of a relatively large group, followed by its subdivision into groups depending on age and length of stay in the North. This approach is more acceptable to research on long-term adaptation and its results. Most investigators of man's adaptation to the Far North have essentially employed the second approach.

According to Danishevskiy the initial phase of acclimatization apparently consists of a short-term adaptive reaction by the body, sometimes referred to in the literature as acclimation. Experiencing the initial phase of adaptation, the body encounters a mass of new impulses from the environment, which significantly alters the functional state of the regulatory divisions of the nervous and endocrine systems and promotes alteration of the body's reactivity (4,5).

Such mobilization of functions is a typical trait of the "breakdown stage" of the body's adaptation (6) to new environmental conditions. As a rule the adaptive biochemical reactions occurring in this stage "proceed immediately after the stimulus begins to act, but they can ensure perfect adaptation only if the stimulus acts for a relatively short time" (6).

This phase of adaptation and the reactions of the body typical of it could obviously be studied more accurately and confidently by using a person making an abrupt move to the North as the subject. The following facts are used in favor of this hypothesis: The subjective worsening of condition following arrival in the inner regions of Antarctica was more pronounced after an airplane flight (7) than after travel in a sled train (8).

It is important to emphasize that persons coming from relatively northern regions and from the moderate zones of the USSR adapt easier and more quickly to the North (4)--that is, the level of the individual's adaptive reactions occurring upon movement from certain geographic conditions into others depends on the contrast in weather conditions and in environmental factors between the place of origin and the region of relocation and acclimatization (9).

Considering all of this, we conducted integrated research on practically healthy people (four men and four women) from 18 to 35 years old, residing permanently in Novosibirsk and sent on business to Noril'sk in November, at the time of the polar night.*

Methods

The research consisted of five examinations--prior to departure for Noril'sk by air, on the 3d, 14th, and 30th day in Noril'sk, and 2 weeks after returning to Novosibirsk. Both the nature of the activity and the work-rest rhythm to which the subjects were accustomed did not change during the round trip between Novosibirsk and Noril'sk.

We studied lipid peroxidic oxidation (10) and the antioxidative activity of erythrocyte lipids (11). We assessed the state of lipid metabolism on the basis of the characteristics of general, free, and esterified cholesterol, phospholipids, and β-lipoproteins determined by commonly accepted procedures (12-14). The functional activity of the adrenal cortex was assessed from the level of 11-oxycorticosteroids in blood plasma (15) and 17-ketosteroids in urine. In addition we determined the concentration of bilirubin and its fractions in blood serum, transaminase and ribonuclease activity (16), and the blood hemoglobin concentration.

*The research was conducted in 1974, which was a year of low solar activity.

Research Results and Discussion

Research on lipid peroxidic oxidation reactions occurring during adaptation to high latitudes is important for the following reasons: 1) We know that lipids are the principal substrates of free radical oxidation, and that they are an important structural element of cell membranes; 2) under certain conditions the natural radioactivity of the environment and cosmic (17) and electromagnetic emissions (18) may activate free radical processes in cell structures.

Analysis of the characteristics of peroxidic oxidation of lipids (POL) and their antioxidative activity (AOA) in the experiment's participants revealed that just 3 days following arrival in the North the POL level of the erythrocytes of all subjects increased by an average of four times in comparison with the initial figures recorded in Novosibirsk. After a month's presence in Noril'sk these characteristics gradually returned to their initial values. In this case inhibition of erythrocyte POL and reduction of its intensity were accompanied by an increase in lipid AOA. Thus after the lipid AOA characteristics declined for 2 weeks (this could be associated with temporary expenditure of the reserve of endogenous antioxidants in the initial period of adaptation), they began to grow dramatically, exceeding the initial characteristics by an average of 70 percent and remaining high throughout the subsequent stay in the North. It should be noted that the dynamics of the POL and AOA characteristics were extremely similar for all subjects during the time of the research (Figure 1).

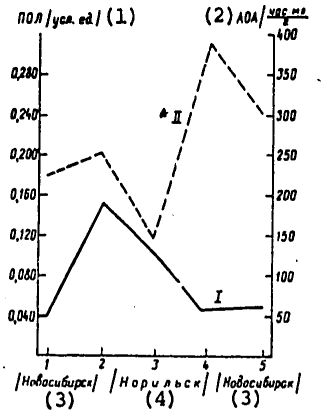

Figure 1. Dynamics of the Characteristics of Peroxidic Oxidation of Lipids (POL) and Their Antioxidative Activity (AOA) During Short-Term Adaptation to Arctic Conditions: *I*--POL, *II*--AOA

Key:

1. POL (arbitrary units)
2. AOA (hr·ml/gm)
3. Novosibirsk
4. Noril'sk

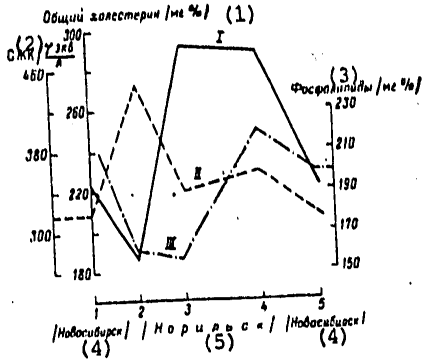

Figure 2. Dynamics of the Characteristics of Cholesterol (mg-percent), Phospholipids (mg-percent), and Free Fatty Acids (FFA--gamma-equivalents per liter) During Short-Term Adaptation to Arctic Conditions: *I*--Total cholesterol, *II*--FFA, *III*--Phospholipids

Key:

1. Total cholesterol (mg-percent)
2. FFA, gamma-equivalents per liter
3. Phospholipids (mg-percent)
4. Novosibirsk
5. Noril'sk

Considering that accumulating toxic products of POL cause damage to cell membranes and indirectly inactivate a number of important cellular enzymes, RNA-ase in particular (19), we studied the ribonuclease activity of blood serum from the same subjects during their presence in the Arctic. We established that significant suppression--by almost 15 percent--of ribonuclease activity occurred in just 3 days after arriving in Noril'sk--that is, precisely at the time when sharp growth in POL characteristics was noted. We also noted a decline in activity of blood serum alanine aminotransferase (see Table).

Analyzing the lipid metabolism of all subjects, we noted a significant rise in the concentration of free fatty acids and of total cholesterol in the blood. In this case the concentration of free fatty acids exceeded the initial figures by an average of 40 percent in the first few days. After 2 weeks the cholesterol concentration increased by an average of 60 percent (basically due to the esterified fraction), and it remained high in the subsequent examinations (Figure 2).

Concurrently with an increase in the cholesterol level, we noted significant changes in the concentration of bilirubin and phospholipids in the blood; these compounds possibly take part in protective antioxidative reactions

Dynamics of Some Biochemical Characteristics
During Adaptation to Arctic Conditions

(1) Показатель	Этапы обследования (2)				
	(3) В Новосибирске	(4) В Норильске			(3) В Новосибирске
	I	II	III	IV	V
ПОЛ, усл. ед. (5)	0,042±0,000	0,158±0,021	0,118±0,007	0,048±0,004	0,053±0,008
АОА, $\frac{\text{чис}}{\text{г·мл}}$ (6)	234±22,2	250±31,9	161±17,2	394±30,7	316±93
Билирубин общий, мг% (7)	0,74±0,14	1,11±0,15	1,35±0,06	0,8±0,2	1,72±0,25
(8) Билирубин связанный	0,69±0,16	0,78±0,14	0,91±0,02	0,60±0,22	1,72±0,23
Билирубин (9) несвязанный, мг %	0,15±0,06	0,35±0,07	0,39±0,02	0,18±0,06	0
АЛТ, усл. ед. (10)	44,1±7,2	23,9±2,11	2,50±1,08	13,8±2,07	39,9±13,5
АСТ, усл. ед. (11)	29,0±5,9	18,4±1,3	24,5±2,8	20,1±3,48	26,9±2,5
РНКаза, мкг/мл (12)	0,441±0,006	0,401±0,006	0,444±0,024	0,446±0,007	0,439±0,014
Холестерин общий, мг % (13)	189±12,3	186,3±24,1	292,7±13,4	288,4±18,1	223,3±7,2
Холестерин свободный, мг % (14)	54,7±7,2	56,1±9,0	17,1±4,7	58,0±6,5	69,1±11,7
Эстерификация холестерина, % (15)	71,0±2,3	73,1±3,1	92,4±1,8	78,7±2,2	68,3±7,34
(16) β-липопротеиды, мг %	568,2±21,8	475,5±20,2	447,7±18,6	511,36±33,15	675,3±90,0
СЖК, у·экв/л (17)	318,1±17,3	446,3±12,6	340,0±17,73	360,0±4,8	316,3±34,1
11-ОКС, мкг % (18)	5,34±0,81	6,96±0,5	7,64±0,78	13,4±1,82	10,23±1,16
Гемоглобин, г % (19)	14,62±0,52	—	—	13,06±0,4	—

Key:

1. Characteristic
2. Phases of research
3. In Novosibirsk
4. In Noril'sk
5. POL, arbitrary units
6. AOA, hr/gm·ml
7. Total bilirubin, mg-percent
8. Bound bilirubin
9. Unbound bilirubin, mg-percent
10. (ALT), arbitrary units
11. (AST), arbitrary units
12. RNA-ase, μg/ml
13. Total cholesterol, mg-percent
14. Free cholesterol, mg-percent
15. Esterified cholesterol, percent
16. β-lipoproteins, mg-percent
17. FFA, gamma-equivalents per liter
18. 11-oxycorticosteroids, μg-percent
19. Hemoglobin, gm-percent

(19). Thus the bilirubin level was high in the first few days after arrival in the North, and it continued to grow during the second week. It is important to point out that the level of blood phospholipids was significantly low during the second week in Noril'sk. We should note that after the subjects returned to Novosibirsk, the AOA and cholesterol characteristics remained above the initial figures. It should also be noted that the dynamics behind the concentration of cholesterol and phospholipids in blood serum, determined through five examinations, turned out to be extremely similar in all subjects.

Investigation of the glucocorticoid function of the adrenal cortex established that the level of 11-oxycorticosteroids (11-OCS) in blood plasma from three persons increased as early as 1 week after relocation; later, by the 4th week in the Arctic, it exceeded the initial concentration by an average of more than two. In this case the 11-OCS level of some subjects increased three and even four times. The 11-OCS level of three out of eight subjects remained high even after they returned to Novosibirsk. As far as changes in the concentration of 17-ketosteroids (17-KS) in daily urine is concerned, we can note a tendency toward growth during the first week after arrival in Noril'sk. Two subjects experienced a significant rise in the 17-KS level.

Interpreting these data in the traditional way, we can probably associate the increase in the concentration of adrenal hormones in response to the body's exposure to the complex of northern natural stimuli with a certain stressful influence of the latter.

Five determinations of blood hemoglobin concentration indicated a significant decrease in the latter in all subjects 3 weeks after arriving in Noril'sk. This fact agrees with the data of authors who have established a decline in the hemoglobin concentration of polar researchers in the Arctic and Antarctic during the time of the polar night (20,21). In this connection it is especially interesting that analysis of Eskimo blood revealed a higher concentration of hemoglobin in winter than in summer (22).

It should be noted that investigation of these biochemical characteristics following the return of the subjects to Novosibirsk by air did not establish noticeable changes such as those accompanying the flight to the North. This fact allows us to assert that the similar changes occurring in the characteristics of lipid metabolism, peroxidative oxidation and antioxidative activity of erythrocyte lipids, the 11-OCS level, and so on, revealed in all subjects, are associated not with "airplane stress" but rather with the influence of specific factors present at high latitudes.

As was demonstrated in previous studies (23), these changes arise in the body to a greater extent "...due to the direct influence of geomagnetic and cosmic perturbations on biological structures, the intensity of which grows significantly at high latitudes." This is perhaps precisely the root of the state the human body exhibits in the Arctic, called the "polar stress syndrome" (23). It is possible that development of this syndrome is a reflection of the specificity of the body's adaptation to high latitude conditions, and that it may set the stage for chronic pathology. We should obviously recall in this connection that a mass survey of Noril'sk residents revealed a greater frequency and earlier arisal of cardiac ischemia (24). It could be thought that as the time of presence in the Far North increases the significance of the correspondence between the new environmental conditions and the changes they elicit in the human body on one hand and the body's phenotypic and genotypic properties on the other rises (2). In fact,

different individuals, and all the more so the indigenous and immigrant residents of northern regions, suffer different consequences in relation to prolonged maintenance of a high level of cholesterol and other lipid components in blood, as well as of the characteristics of lipid peroxidic oxidation. This is confirmed to a certain extent by absence of pronounced changes in the characteristics of lipid metabolism, peroxidic oxidation, and antioxidative activity of lipids among northern natives in comparison with immigrant residents (25,26).

Conclusion

The data presented here indicate that the ecological conditions of the Far North (cold, geomagnetic perturbations, polar night, and so on) promote rapid activation of the body's adaptive reactions, which apparently involve change in free radical processes and lipid metabolism.

Research on the processes of the human body's adaptation to Arctic conditions and their orientation provides information permitting us to develop measures of early diagnosis and prevention of diseases, prediction of probable pathological states, and creation of individualized tactics for maintaining good health.

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PSYCHOPHYSICS

PROBLEMS OF PSYCHOPHYSICS

Moscow PROBLEMY PSIKHOFIZIKI in Russian 1974 signed to press 11 Nov 73 pp 1-10, 65-106, 218-252, 253

[Annotation, table of contents, foreword and two chapters from book edited by B. F. Lomov, Izdatel'stvo "Nauka", 8,400 copies, 254 pages]

[Text] This anthology presents articles devoted to the problems of psychophysical measurement and evaluation of the sensitivity of human sensory systems. It contains a survey and a theoretical analysis of the contemporary status of the threshold problem, an examination of some of the most important methods for measuring sensitivity and the results of experiments in this field.

Table of Contents

Foreword

Psychophysics occupies one of the leading positions in the system of psychological sciences which study the phenomena of the subjective reflection of objective reality and their role in regulating human conduct and activity. This is caused by the fact that psychophysical research is directed at studying the causal relationships between subjective magnitudes and the stimuli which cause them (or rather, which are reflected in them)--stimuli which act on an individual via objective magnitudes. Moreover, the most elementary and initial form of mental reflection--sensation--is the center of attention for psychophysics.*

The emergence of the problems which defined the subject matter of this science is linked to achievements in a number of the fields of physics. Research primarily in the fields of optics and acoustics, the discovery of phenomena which are inaccessible to direct observation and the development of precise methods of physical measurement have demonstrated the limits of human sensory perception and the limited nature of human sensory organs. The discrepancy between the results of physical measurements and the data of direct observation caused a turn toward the study of different forms of sensory reflection of physical phenomena.

Psychophysics was one of the earliest fields of psychology to be formed.

Gustav Fechner, the founder of psychophysics, published his treatise "The Elements of Psychophysics" in 1960; he defined the problem of the relationship between physical and psychological phenomena and tried to solve it using the methods of natural science. As a scientist with a great deal of interest in philosophy and mathematics, he hoped to uncover certain definite quantitative relationships between the physical stimuli acting on the sensory organs and the perceived sensations caused by them. As a philosopher, Fechner proceeded from the premise that physical and psychological phenomena (mind and body) were only different aspects of the same reality. They will appear as different substances depending on the position (point of view) of the observer: introspective and internal (then reality appears as a psychological phenomenon, the mind) or objective and external (then reality appears as a physical phenomenon, the body), i.e., Fechner considered the physical and psychological as derivatives of the subject's position. In order to study the relationships

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*It is necessary to point out that the field of psychophysical research also includes other more complex mental phenomena. However, its problem areas, methodology and research methods were primarily formed during the study of sensation.

between these two aspects, he developed a system of experimental methods and proposed a mathematical description of the relationships revealed during the experiment.

His experimental procedure consisted of a situation where a certain physically measured stimulus acted on the subject's sensory organs and the evoked subjective response was recorded; the latter's dependence on the former was proven.

Fechner believed that these experiments could serve as a direct confirmation of his philosophical concept. However, in reality, they solved another problem: the interrelationship of the subject's two positions was not experimentally proven but the dependence of the psychological on the physical was. In essence, Fechner the naturalist was opposed to Fechner the philosopher.

The studies conducted by Fechner soon lost the philosophical significance which he had given them. However, the approach to a concrete, scientific analysis of psychological phenomena, the experimental methods he developed and the data he obtained served as an inspiring example for those who were striving to make psychology a concrete science. Fechner was one of the main predecessors of experimental psychology. Due to his studies, the basic feasibility of using an experiment to study psychological phenomena and of using quantitative methods for describing them was demonstrated. Thus, the first step was taken toward transforming psychology--which was only looked upon as a field of speculative constructs for a long time--into an experimental science.

It is precisely psychophysics to which we are obligated for the fact that many concepts which were previously considered the exclusive domain of philosophy have been transformed into concrete, scientific psychological concepts. First and foremost, the concept "sensation" belongs in this category.

In studies of sensation, psychophysics is primarily interested in its relationship to a physical stimulus; at the same time, sensation is considered a derivative of the stimulus. Contrary to Fechner's doubtful philosophical positions, there is hardly any room to doubt that this approach meets the spirit of a materialistic direction in natural science. It is a single step from viewing sensation as a derivative of a stimulus to conceiving it as a reflection of this stimulus. It is perhaps possible to state without stretching the point that psychophysics prepared the concept of sensation as an elementary form of psychological reflection: the subjective reflection of separate properties of the objects and phenomena of objective reality acting on the sensory organs.

The fact that psychophysics defined the field of sensation strictly enough for the first time and discovered several basic characteristics of sensory functions was a serious scientific achievement.

It also demonstrated that complex relationships exist between the stimulus and sensation, i.e., (if its data are viewed in light of the theory of reflection) the stimulus is not reflected on a one-to-one, mirror image basis in the sensation, rather a certain transformation of the external reaction takes place during the process of forming the sensation. According to Fechner's Law, the intensity of the sensation is proportional to the logarithm of the intensity of the stimulus. It can be interpreted in such a manner that, as it is reflected in sensation, it is as if a series of physical magnitudes are "compressed," become more compact.

This interpretation does not contradict Stivens' Step Law which is usually set in opposition to Fechner's Law. Furthermore, it makes it possible to define the nature of the transformation of the series of reflected physical magnitudes in a more differentiated manner. According to the data of Stivens and others, a "compression" of the reflected series of physical magnitudes occurs in some modalities (and in relationship to some properties of the stimulus); in others, an "expansion" occurs; and in still others, the relationship of sensation to the stimulus is close to linear. Evidently, the particular role played by the sensations--which reflect particular properties of the stimuli--in regulating behavior and also their biological importance are determined by the nature and magnitude of the transformation which ensures an increase in the efficiency of the information extracted by the sensory organs.

Thus, classical psychophysics laid the foundation for a scientific analysis of the initial and elementary form of psychological reflection--sensation.

However, the concept of sensation which it developed was extremely abstract. It viewed the series of sensations (and the stimuli which caused them) as a unidimensional magnitude; "subjective space" was "compressed" to the limit, or rather it was reduced to a straight line. Sensation was torn from the complex system of psychological phenomena in which it actually exists and it was only viewed through one of its properties. Furthermore, the sensation was prepared in the absence of its bearer--the subject. Perhaps, this abstraction was warranted for the first step in analysis. But, it caused a number of difficulties and contradictions as soon as the task arose to apply the abstract systems to actual reality.

As is well known, Gestalt psychology speculated on this shortcoming of classical psychophysics. A number of special features of the sensory image--features which were hard to explain with the principles of psychophysics at that level of the science's development--were closely studied in the observations and experiments of the Gestalt psychologists. However, instead of trying to explain these features, the Gestalt psychologists proceeded to negate the primary principles and approaches developed by psychophysics. Sensation was declared an invention of psychophysics and perception was adopted as the initial form of psychological phenomena. The stimulus began to be viewed as a derivative of the subjective phenomena (a position directly opposed to the one taken by Fechner's psychophysics); in the end, this led the Gestalt psychologists to a deadend. As F. Kliks demonstrated later, the facts used by the Gestalt psychologists to criticize psychophysics actually do not contradict its primary principles; furthermore, these facts are explained within the framework of the approach to studying sensory-perceptual phenomena developed by psychophysics.*

Classical psychophysics limited itself to a study of the subject's reactions to particular stimuli and it left the processes of complete, multi-dimensional cognition outside its purview. The measurement of sensations and sensitivity was carried out in the same manner as measurements were made with meters: a certain signal is fed to the "input," the "output" is recorded and, based on the determination of the "output's" relationship to the "input," a conclusion is made on the arousal (or lack of arousal) of a sensation and on the level of sensitivity. The system which was subsequently called the "black box" was essentially used here. It did not reveal the system of processes which mediated the "input" and "output" relationship. The experimental equipment at Fechner's disposal did not make it possible to do this rigorously enough. Moreover, even in the simplest psychophysical experiment, the situation presented to the subject appears like a problem to him and he tries to find a solution to it.

Therefore, it is unavoidable that the process which takes place between the action of the stimulus and the voluntary reaction to it turns out to be rather complex. It is an extremely difficult matter to extract the components of this process which would make it possible to draw an unambiguous conclusion about the characteristics of the sensory function. In any event, a more or less adequate model of the entire process must be available for this purpose. Many of the difficulties encountered by classical psychophysics were precisely caused by the fact that, in comparision to a sensory experiment, the reactions of the subjects in a psychophysical experiment are mediated to a greater degree by the reflection of the stimulus and by the conditions and requirements of the experiment. The rejection of a number of facts which did not

*F. Kliks. "Elementy psikhofiziki vospriyatiya prostranstva" (The Psychophysical Components of Spatial Perception), Moscow, 1966.

fit into the system that classical psychophysics was based on, the refinement of details and the modification of several methods did not save the situation. New approaches were required for the problems being studied. The development of these approaches laid the foundation for modern psychophysics. One of the new approaches is connected with applying the statistical theory of decision making to the experimental situation of psychophysics.

In contrast to classical psychophysics which attempted to study the effect of an isolated stimulus which could serve as the sole source for stimulating the sensory system, this approach assumes that the stimulus (signal) will appear on a background of noise (moreover, the existence of the sensory system's own noise is taken for granted). The first stage in reflecting the stimulus is separating it from the background noise, its detection. In this situation, decision making becomes the most important feature which mediates the relationship between the stimulus and the response.

As experiments have demonstrated, the subject's response is not only (and not even so much) determined by the level of sensitivity of his sensory system but also by the criterion which he uses in his evaluation. Moreover, the criterion can change and this leads to a change in the reactions. In this way, extrasensory factors are included in psychophysical analysis. This feature is a new and important step toward studying the processes which mediate the relationship between the stimulus and the response. The picture of the subject's behavior within a psychophysical experiment is becoming more complete in comparison with the one drawn by classical psychophysics.

Another trend has been observed in modern psychophysics due to the employment of so-called direct scaling methods (plotting a scale of sensations) in contrast to the indirect scaling methods employed in classical psychophysics.

The just noticeable differences between stimuli served as the basis for plotting the scales (series) of subjective magnitudes (sensations) when the indirect scaling methods were used in classical psychophysics. The scale was an additive one and--as already pointed out--it was, as a rule, unidimensional.

The direct scaling methods make it possible to use the subjective evaluations (obtained from the subjects) of the magnitudes of the stimuli and also the intervals and relationships between them; this creates a fundamental opportunity to plot multidimensional scales. With these scales, it was demonstrated that the stimulus-sensation relationship is a great deal more complex than it was presented by classical psychophysics.

During the development of psychophysics, its problem areas have expanded, its research methods have been improved, experimental data has been accumulated and its conceptual equipment has been enriched. As already pointed out, it has had (and continues to have) a great deal of influence on the other psychological sciences (and the sciences related to them): the general theory of psychology, experimental, engineering, differential and mathematical psychology as well as the psychophysiology of the sensory organs. It has also had a definite influence on social psychology which has used several principles of the methods developed in psychophysics for constructing subjective scales. Of course, psychophysics also feels a feedback effect from the enumerated sciences.

For us, it is especially important to reemphasize the significance which psychophysics has for the development of a general theory of psychology. As already pointed out, the latter is indebted to psychophysics for the development of a number of aspects of the problem of sensation.

True, psychophysics--both classical and contemporary foreign psychophysics--dwells on the problem of the nature of sensation, its essence. It either appears as a certain aspect of reality which is defined by the subject's position and the quantitatively related physical phenomena or as an element of the phenomenological world which is set in opposition to the physical world and separated from it (certain trends in contemporary foreign psychophysics), but it is not viewed as an image of the stimulus. At the same time, the data accumulated in psychophysics, a number of the principles developed and the causal relationships discovered lead to the conception of sensation as an elementary form of the subjective psychological reflection of the phenomena of the objective world. This is precisely where its primary importance lies for a general theory of psychology.

Psychophysics has still not risen to the conception of sensation as the image of a stimulus. To a significant degree, this is explained by the fact that it views sensation as something already formed; the continuum of sensation which is compared with the continuum of stimuli is taken, so to speak, as a given.

The process of sensation formation remains outside the purview of psychophysics; this very fact evidently explains many of the contradictions among psychophysical concepts.

To a significant extent, the neurophysiological mechanisms of the sensory systems have also remained beyond the bounds of psychophysical research; without an analysis of these mechanisms, it is hardly possible to understand how external (physical) magnitudes are transformed into a subjective reflection of them.

It seems to us that the study of sensation as a process which develops over time and its neurophysiological bases comprise the most urgent task of psychophysics today--a task which defines the prospects for its further development.

The results of psychophysical research are also important for solving a number of practical problems. If a causal relationship exists between specific subjective magnitudes and the objective magnitudes which cause them and if this relationship is known to us, it will be possible for us to control the former by purposefully changing the latter. These problems arise in the development of systems for transmitting information to the individual in man-machine systems, in measuring skills, in experimental aesthetics and in certain other fields. Incidentally, let's point out that it is precisely the need for solving these problems which has caused a new rise in psychophysical research (interest in it was lost for a long period of time); this rise has led to the formation of so-called contemporary psychophysics.

The current problems in psychophysics can be divided into two large classes. One of them includes the entire group of problems related to the study of thresholds; the other includes the study of sensory scales used to measure sensations above the thresholds.

This collection of articles, which was prepared by the Laboratory of Psychophysics of the USSR Academy of Sciences Institute of Psychology in conjunction with researchers from other scientific research institutes, is devoted to the first group of problems.

It opens with K. V. Bardin's article which provides a theoretical analysis of the threshold problem in classical and contemporary psychophysics. The article introduces the reader to the group of issues being studied in conjunction with this problem; it provides a description and a critical analysis of the basic psychophysical theories of the operation of the sensory system, describes the contemporary state of research conducted in this field and outlines several future possibilities.

E. M. Rutman's article discusses the possibility of using evoked potentials in psychophysical research. The author provides a brief description of the method of evoked potentials and sets forth some data obtained from experiments where evoked potentials were used to study the sensory systems of man and animals. The prospect for using evoked potential as one of the possible involuntary reactions which characterize the observer's state during a threshold experiment is discussed. This article is important due to the fact that it crosses the bridge from pure psychophysics to psychophysiology.

K. V. Bardin's next article is devoted to one of the three classical methods of psychophysics--the average error method which is employed on an extremely widespread basis. Along with a detailed description of this method, the author provides a critical analysis of its psychological principles and his interpretation of some of the data obtained with it (this part of the article is in the nature of a discussion). The results of the author's original experiments which reveal the different strategies of the observer's actions during a threshold experiment are of special interest for the future development of the threshold problem. A new direction is thereby outlined in psychophysics, a direction which links the threshold problem to the problem of activity which has been widely developed in Soviet psychology.

The articles listed make up the anthology's first topic--a discussion of theoretical problems. The presentation of strictly experimental results is another topic.

Yu. A. Indlin's article thoroughly describes a completed study of human discrimination of audio signals. The special methodological procedures for setting up the experiment and the methods of analyzing the data developed by the author make it possible to refine the nature of psychometric curves and to test the original propositions of one of the classical threshold concepts--the ϕ (γ) hypothesis--and also to refine the limits of its application.

N. I. Chuprikova's article is a presentation of the results of a psychophysiological study of thresholds. The author demonstrates the effect of extrasensory factors on the threshold characteristics of the visual system and tries to uncover its physiological mechanisms.

A. A. Astashenko's article critically examines the assumptions which the basic theories of the operation of the sensory systems are based on. The author also cites the results of his own experimental research which revealed some of the special features of the subjects' responses to stimuli located within the threshold zone.*

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*In classical psychophysics, the threshold was viewed as a point in a continuum of stimuli, a point which corresponded to the "just noticeable sensation." Due to the research of K. V. Bardin, N. A. Garbuzov, M. B. Mikhalevskaya, Ye. N. Sokolov and others, the concept of a threshold zone--as an area of the continuum of stimuli which cause a minimal sensation--was introduced. The study of the threshold zone is of tremendous importance for an understanding of sensation as a process.

Yu. M. Zabrodin's article sets forth the results of an experimental study of the processes for detecting, discriminating and identifying multidimensional acoustic signals (like speech); the study was conducted by a group of researchers under the author's direction. The experimental data obtained make it possible to view the detection, discrimination and identification of these signals as a complex process which depends upon the physical characteristics and structure of the signals, the special features of the observer's activity and the probability distribution of the flow of incoming information. The results presented in the article will raise the problem of the relationship between detection and identification, a problem which is extremely important for understanding the process of forming a psychological reflection of complex signals.

The authors and editors will appreciate any responses or critical comments.

B. F. Lomov

Methods

The Possibility of Using Average Evoked Potentials in Psychophysics

E. M. Rutman

Human scalp-recorded evoked potentials are being used more and more frequently in the most diverse fields of psychology and psychophysiology. The use of this method to solve a number of the problems in psychophysics will undoubtedly be beneficial and it will probably expand. This assumes a clear understanding of what can and cannot be obtained in an experiment with recorded evoked responses. In the final analysis an exaggeration of the possibilities of any method can lead to its being discredited.

The purpose of this article is to provide a brief description of the method of recording evoked responses and of the modern concepts of their nature while pointing out the theoretical and methodological complexities of the method and to provide a brief summary of the work using evoked responses whose results may be related to the problems of psychophysics. We will attempt to provide the reader with a concept of evoked potentials which is sufficient to analyze the work using this method and to resolve the issue of the advisability and feasibility of using it in his own research. Where necessary, the bibliography will make it possible to become acquainted with the issues discussed in more detail.

1. Evoked Potentials

1.1 Definition of evoked potentials. Sensory Evoked Potentials, Motor Potential, the E-Wave

In neurophysiology, the term "evoked potential" signifies any group of variations in potential in any section of the nervous system which arises under the influence of external stimulation and which is in a relatively rigorous temporal relationship to it.

This article will examine the evoked responses recorded from the human scalp. They are recorded with the normal electrodes and amplifiers used to obtain an electroencephalogram (EEG)--recordings of the brain's bioelectrical activity made from the scalp (Kratin et al, 1963). As is well known, independently of any external stimuli, variations in potential--a manifestation of the brain's so-called spontaneous or background bioelectrical activity--are constantly observed on the human scalp. Thus, the evoked potentials develop on the background of the spontaneous fluctuations. Therefore, both the fluctuations in potential evoked by the external stimulus and the spontaneous (or background) manifestations of bioelectrical activity are simultaneously reflected in the EEG.

Since the amplitude of the responses to external stimuli are as a rule less than the amplitude of the fluctuations in the background bioelectrical activity, single reactions to a stimulus are usually indistinguishable on the background of the latter. It became possible to record evoked potentials by using diverse methods for isolating the signal from the noise. As a first approximation, the evoked activity is viewed as "being suspended" in the spontaneous activity (Perry, 1969) although a rather complex relationship actually exists between the EEG and the evoked potential. The isolation of the evoked potential from the overall pattern of bioelectrical activity is based on the premise that a repetition of the stimulus evokes a repetition of a similar response when the background activity is random. Then, the summation of a sufficient number of EEG segments for the stimulus should lead to the isolation of the reaction to the stimulus no matter how small it is compared to the background (random) level of activity (Figure 1).

There are various specific methods for isolating evoked potentials (superposing a number of responses on graphic film, algebraic summation on recording tape and using computers--adding and averaging evoked potentials, cross correlation analysis, etc.); the works of Perry (1969) and Donchin (1969) are recommended for becoming acquainted with them and the current devices for recording evoked potentials.

In light of the forgoing, human scalp-recorded evoked potentials can be defined as "the sum of the individual responses--it is not necessary for each of them to be discernible alone--evoked by repeated by repeated stimuli" (Perry, 1969). This condition is an extremely significant methodological feature which limits the use of evoked potentials. It follows from it that the presentation of a single stimulus is not sufficient to record evoked potentials. The number of repeated stimuli required to obtain a sufficiently clear-cut evoked potential depends upon the ratio between the amplitude of the fluctuations in potential

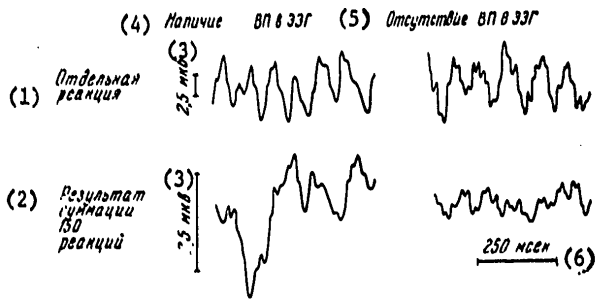

Figure 1. Isolating a Visual Evoked Potential

Key:
1. Individual response.
2. Result of adding 150 responses.
3. Microvolts.
4. Evoked potential present in EEG.
5. No evoked potential in EEG.
6. Milliseconds.

The curve in the upper left corner is an EEG with an evoked potential for a single stimulus; the curve on the right is a background EEG (a stimulus is not present); the curve in the lower left corner is a summed visual evoked potential for 150 presentations of the stimulus; on the right is the control curve (a summation of 150 EEG sections without any stimuli. The beginning of the curves correspond in time to the presentation of the stimulus. The recording is bipolar; electrodes are along the sagittal line, 5 cm above the occipital lobe; the upward variation is positive for the top electrode (Perry, 1969)

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evoked by a single stimulus and the amplitude of the fluctuations in background activity (in other words, the signal-to-noise ratio).

Since, as a rule, the evoked potential consists of several fluctuations with different amplitudes, the minimal number of stimuli required to isolate an evoked potential depends upon which component the researcher is interested in: the greater the amplitude of the component being studied, the lower the number of stimuli required to record the evoked potential. To reduce the number of repeated stimuli required, it is advisable to select subjects

with low-amplitude background activity in certain cases since the latter can be rather sharply distinguished in different people (Vaughan, 1969). It especially makes sense to do this when a study of the early, low-amplitude components of the evoked potential is desired.

In determining the number of stimuli required to obtain a sufficiently clear-cut evoked potential, the researcher is between Scylla and Charybdis since an increase in the number of stimuli required to reduce the noise level in the recorded evoked potential is unavoidably linked to an undesirable increase in the duration of the experiment. The characteristics of the evoked potential change depending on the subject's state and, all other things being equal, the probability of a change in state is greater the longer the experiment lasts. Therefore, beginning at a certain time, getting rid of the variation in evoked potentials due to too small a number of summed responses (i.e., a large noise level) is linked to an increased variation in the evoked potentials due to the fluctuations in the subject's state. In his research manual on visual evoked potentials, Perry (1969) writes that a summation of 50-100 responses is sufficient to obtain stable, averaged evoked potentials in the majority of cases. The work of Ellingson et al (1973)--who studied the variation in visual evoked potentials for adults and children--points out that the variation and form of the evoked potentials when 32 responses were added was not very different from the same characteristics of the evoked potentials when 50, 60 and 100 responses were added. A significantly greater number of responses is recommended for recording the early components of evoked potentials for audio stimuli near the threshold (Goldstein et al, 1972).

In resolving the issue of the minimal number of stimuli required, the researcher usually relies on a visual analysis of the recorded evoked potentials while trying to obtain the evoked potentials which exceed the background activity and amplitude and which are sufficiently stable for repetitive recording. The number of added responses used in practice during experiments with recorded evoked potentials naturally depends upon the goals of the study and it fluctuates from 20-25 (very rarely less) up to several hundred and even several thousand. From 25 to 100 responses are most frequently added.

Theoretically, given a sufficiently large number of summations, the background acitivity should approach zero. In practice, this number of summations is difficult to achieve and, as a rule, there is a certain level of background activity in the recorded evoked potentials. This is undoubtedly one of the causes of interindividual and intraindividual differences in

evoked potentials. To a certain degree, it is possible to judge the level of background activity in the evoked potentials if, as shown in Figure 1, the EEG segments during the intervals between signals are summed and averaged concurrently with the summation and averages of the EEG segments following the presentation of the signal (i.e., concurrently with the recording of the evoked potentials). Perry (1969) believes that it is necessary to continually conduct this kind of control when recording evoked potentials.

> The fact that each individual evoked potential is an everage characteristic for a certain number of responses distributed over time requires the researcher's careful attention to the effect of factors which may change with time. This is primarily the effect of extinction or habituation on the evoked potentials--these terms signify a natural reduction in the amplitude of the evoked potentials as the stimulus is repeated; after a certain time, this reduction reaches its maximum level so that the evoked potentials change very little during subsequent repetitions of the stimulus (Thompson, 1966; Fruhstorfer et al, 1970). In addition, fatigue, exhaustion and fluctuations in the level of wakefulness also affect the amplitude of evoked potentials (Fruhstorfer, Bergstrom, 1969).
>
> For example, when studying the effect of stimulus intensity on evoked potentials, if "packets" of stimuli with the same intensity are presented in succession while moving sequentially from a low to a high intensity (or the reverse), the difference between the evoked potentials obtained at different intensities will be partially caused by the effect of the factors cited above. The way out of this difficulty is via a random presentation of stimuli; during such a presentation, the factors cited will have an equal effect on all the recorded evoked potentials in a random manner. It is also important to be aware of the fact that an evoked potential being recorded at any point on the scalp is not only the result of a temporal summation of potentials but also of a spatial one. The recording electrode reflects the fluctuations in potential for a given point on the scalp in relation to another specific point.

> These fluctuations are the final result of the interaction between the potentials caused by the activity of different groups of nearby neural elements and the fluctuations which arise due to the electrotonic conduction from remote sections. Moreover, if, for example, fluctuations in potential with different directions and equal amplitudes arise in different structures near the electrode, no changes in potential will be detected by the electrode.

The literature describes evoked potentials in response to sensory stimuli of any modality: auditory, visual, tactile, percutaneous electrical, taste, olfactory. All of them can be designated by the term sensory evoked potentials since they are evoked by stimulating the brain's afferent sensory systems. In addition, the fluctuations related to the activity of the motor area of the cortex (motor potential) and with certain states like intent, expectation and disposition (E-wave) are evoked potentials. They are recorded based on the same principle of isolating the signal from the noise as for sensory evoked potentials. In the case of motor evoked potentials, the only difference is that the EEG segments are not summed after the stimulus but before the motor response which is determined by the moment the button (or electricomyogram) is pressed serves as a "point of reference" in precisely the same manner as the time the stimulus is presented serves as a "point of reference" for sensory evoked potentials (so-called reverse averaging). Thus, a definite sequence in the fluctuations before movement began has been recorded in a number of works (Vaughan et al, 1968; Kornhuber et al, 1969); part of these fluctuations are reflected best by the motor area of the cortex which corresponds to the extension of the group of muscles carrying out the movement.

The E-wave was revealed during a recording (with a DC amplifier) of slow fluctuations which arose during the interval between the preparatory and starting stimuli in a motor response situation with a constant interval. A negative variation in the potential was recorded; this variation arose naturally in response to the preparatory signal and it increased at different rates depending upon the interval between the preparatory and starting signals (Walter, 1964). Moreover, the external signal was used as a time "marker" linking the development of the process which formed the basis of the E-wave (or which was reflected in it) to a specific point in time; this was required for summation. The terms "emitted potentials" or "emitted events" are also used to designate this kind of fluctuation in potential in the central nervous system since they essentially arise not in response to

the external stimulus but due to the stimulus which will be presented (Weinberg et al, 1972) or due to the future response. The data accumulated on the E-wave testifies to its relationship with states like intent, disposition, expectation and attention (Tecce, 1972).

This article will only examine the sensory evoked potentials which are undoubtedly related to the reception and processing of sensory information and which are of significant interest for psychophysical research.

1.2. Description of Evoked Potentials.
The Evoked Potential's Dependence on the Modality of the Stimulus and the Recording Point.
Methods for Analyzing Evoked Potentials.

Figure 2 shows evoked potentials in response to stimuli of different modalities; the evoked potentials were recorded from the same subject at different points on the scalp. The evoked potentials represent a complex sequence of fluctuations in potential which begin 20-50 milliseconds after the stimulus, last for 300-500 milliseconds and obviously depend upon the modality of the stimulus and the recording point. It is believed that different components of the evoked potentials may reflect the stimulation of different structures of the cortex; this stimulation arises in response to the arrival of impulses from different structures (see 2.3 for more detail). In Figure 8, it can be seen that the characteristics of the evoked potentials change as the intensity of the stimulus changes and depending on the recording method--monopolar or bipolar. In addition to the special features of stimulation (modality, intensity, frequency, etc.) and the recording points and method, the subject's state at the time of recording (level of wakefulness or stimulation, selective attention for the stimulus, etc.) also has an effect on the characteristics of the evoked potentials.

Due to the lack of standardized conditions for recording evoked potentials, it is possible to encounter--in different articles--both very similar and extremely diverse evoked potentials recorded in the same areas by stimulating the same modality. As yet, there are no generally accepted "standards" for evoked potentials, not even for the most widespread set of recording conditions. Since there is no "standard" for an evoked potential which could serve as an assurance that the fluctuations recorded on the scalp represent potentials which originated in the brain and are not the result of extracerebral fluctuations in potential (see 1.5), each researcher who records evoked potentials should try to thoroughly conduct all the control studies which preclude recording fluctuations of extracerebral origin.

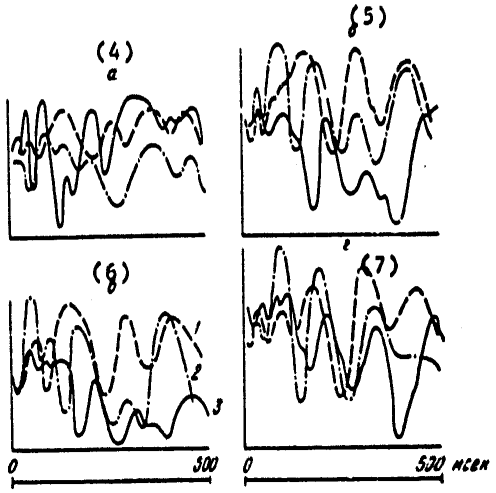

Figure 2. Average Evoked Potentials for Somatosensory (1), Auditory (2) and Visual (3) Stimuli.

Key:
4. Occipital lobe
5. Temple
6. Fissure of Rolando
7. Vertex

Monopolar recording; inert electrode on the contralateral earlobe. Positive for the active electrode is downward; period of analysis is 500 milliseconds. All the evoked potentials were recorded from a single subject (Gastaut, 1967).

The articles devoted to intermodal comparison of evoked potentials (Gastaut, 1967; Goff, 1969; Vaughan, 1969) and the articles with detailed studies of the characteristics of evoked potentials for a specific modality (visual evoked potentials--Perry, 1969; somatosensory--Goff et al, 1962; auditory--Davis, 1966, Butler, 1972) can be recommended for a detailed knowledge of the characteristics of evoked potentials which depend upon the modality of the stimulus and the recording point.

In this article, it is only pertinent to emphasize some of the most general results of an intermodal comparison of the characteristics of evoked potentials which are of significance to the psychophysicist who intends to use evoked potentials in his

research. It is necessary to know that the early components of evoked potentials (during the first 60-100 milliseconds) are primarily emitted only near the cortical area which corresponds to the modality of the stimulus. (Auditory evoked potentials are an exception; their early potentials are emitted in the parietal region as well as, and according to some data better than, in the temporal region.) The late components of evoked potentials (100 milliseconds and later) are recorded clearly enough throughout the entire surface of the scalp and they are distinguished from the early components by their greater amplitude and smaller variation both in an intraindividual and interindividual respect.

In light of the foregoing, percutaneous electrical stimulation is the most appropriate for studying the early components of evoked potentials (Lindsley, 1969); visual stimuli can also be used; auditory stimuli are the least suitable for this purpose since, in general, the possibility of recording stable early reactions to an auditory stimulus is a controversial issue (Lindsley, 1969; Butler, 1972). When studying the early components of evoked potentials, the electrodes should be placed near the cortical area which corresponds to the modality of the stimuli being used (Lindsley, 1969).

For this purpose, the points recommended for placing the electrodes on the scalp are slightly different in various works. There are no unanimous recommendations for this problem; the standard system for placing electrodes on the scalp for an EEG--the so-called 10/20 system (Kratin et al, 1963)--can be recommended for use; this system takes individual differences in head size into account. In this system, points C_3 and C_4 correspond to that area of the Fissure of Rolando which, when directly stimulated, evokes a sensation in the contralateral arm which is innervated by the median nerve. Naturally, this point also is the most suitable one for recording potentials evoked by stimulating the median nerve or by tactile stimulation in the area of innervation for the same nerve. A point located along the center line midway between points O_z and P_z, i.e. between the occipital and parietal regions, is recommended for recording early responses to visual stimuli. For auditory evoked potentials, either the mid-temporal region, point T_3 or T_4, or a point on the center line of the scalp or near it on a level with point T_3 is recommended. In contrast to early components, the late components can be recorded at any point of the 10/20 system; they are emitted best either in the same place where the early components are or, regardless of the modality, in the central parietal region.

Usually, individual recorded evoked potentials are cited for illustrative purposes in works using recorded evoked potentials

and a description is provided of the basic, overall characteristics of the evoked potentials obtained during an analysis of all (or a certain part of) the evoked potentials recorded in that study. There are still no generally accepted rules for describing evoked potentials--different authors describe them differently. (If it is remembered that many years were needed to introduce the modern, generally accepted terminology and description for EEG's, then the current situation for evoked potentials will not seem depressing.)

As with every sequence of fluctuations, evoked potentials can be described by indicating: their latent periods (LP) from the time the stimulus is presented until the observed fluctuations peak; the amplitude of individual fluctuations (from the peak of the previous fluctuation to the peak of the current fluctuation or from the zero point in potential to the current peak; for more details, see the descriptive methods in the works of Perry, 1969 and Donchin, 1969); and their polarity. However, many authors prefer to describe evoked potentials in other ways. Individual fluctuations in evoked potentials are singled out as individual components of evoked potentials; the number of the latter depends upon the criteria for the amplitude used by the author to isolate individual components. The isolated components are designated by letters or figures. An example of this kind of description is shown in Figure 3. The lack of standardized methods for recording and describing evoked potentials complicates the analysis of the results of studies conducted in different laboratories and, with a superficial comparison, this leads to mistakes in evaluating and interpreting them.

The rather widely used description of visual evoked potentials proposed by Ciganek (1961) is a typical example of this (Figure 3). Ciganek's description is one of the earliest. He isolated a number of components, designated them with numbers and hypothetically correlated them in a specific manner (true, this correlation was changed later) to specific structures or systems. After this, the designation of components of evoked potentials according to Ciganek's description was frequently encountered in the literature. Moreover, Ciganek's description--which was made for visual evoked potentials which were recorded bipolarly (one electrode in the occipital region and the other in the parietal region)--was used for evoked potentials obtained through monopolar recording (see below for recording method). The differences in form and polarity for the components--differences which are dependent upon monopolar and bipolar recording--are shown in Figure 8. The reader can draw his own conclusions on the problems and possible mistakes in identifying the components when the designations for components of bipolar recorded evoked potentials are transferred to monopolar recorded evoked potentials.

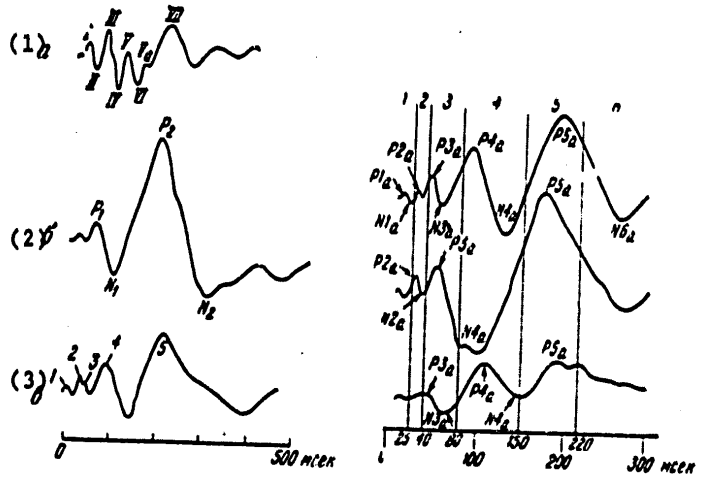

Figure 3. Examples of Different Designations for Components of Evoked Potentials (Goff, 1969)

Figure 4. A System for Designating Components of Evoked Potentials Considering Three Modalities (Goff, 1969)

Key:

1. Visual evoked potential (Ciganek, 1961).
2. Auditory evoked potential (Davis et al, 1966).
3. Somatosensory evoked potential (Goff et al, 1962).

Essentially similar fluctuations can be designated differently and undoubtedly different fluctuations can be designated with the same number or letter in the different descriptive systems. As a result, in surveys of the literature, it is possible to find reports on ostensibly similar results by different authors although a unidirectional change in the amplitude of the evoked potentials for the different components is actually pointed out in these works. This fact should be taken into consideration when analyzing the literature. The system for describing evoked potentials proposed by Goff (1969) attempted to overcome these difficulties (see Figure 4).

The entire evoked potential is divided into six time segments: 0-25, 25-40, 40-80, 80-150, 150-220, 220 milliseconds and above; the segments are assigned numbers from 1 to 6, respectively.

The division into segments is based on the assumption that at least part of the components in each time segment reflect the activity of functionally similar systems when a stimulus of any modality is active. Thus, it is assumed that fluctuations during the first 25 milliseconds after the stimulus reflect the firing of afferent impulses in the projection tracts; at the same time, early muscle reflexes to the stimulus may appear; the first positive fluctuation related to the activation of cortical neurons, etc. appears during the 25-40 microsecond period. After the evoked potential is divided in this manner, each component is designated by the appropriate ordinal number for the time segment in which the component appears. The capital letter before the number of the component indicates the polarity (N for the negative component and P for the positive component) and the small letter after the number indicates the component's ordinal location within its time interval (see Figure 8).

Moreover, the appearance or disappearance of any component will only affect the last letter in the designation (the component's location in "its" time interval); the number designating the time interval the component appeared in will not change like it does in a classification system which is simply based on the components' ordinal numbers. This system is better than the others but it also complicates things more than it facilitates them, as was pointed out in a discussion on this problem (Goff, 1969; see the discussion after the report). After all, if the intensity of the stimulation (the system proposed for the evoked potentials of adults with an average intensity stimulation) or other conditions known to have an effect on the latent periods are changed, the isolation of the time segments upon which the description is based will be unsuitable: essentially the same processes will appear somewhat later (or earlier) and this again leads to confusion if this descriptive system is applied to them.

It is obvious that there still are no methods for identifying components which are precise enough to make it possible to define and designate--with a sufficient level of confidence--the components in accordance with their morphogenesis and (or) their functional significance independently of the conditions for recording the evoked potential; any description of an evoked potential which contains any definition of the components except for their latent periods, polarity and amplitude is only a complicated evaluation and interpretation of the results (Myslobodskiy, 1966; Rutman, 1969; Goff, 1969). When describing evoked potentials, it is also always necessary to point out the location of the electrodes, the method of stimulation and the phsycial characteristics of the stimulus.

It is necessary to try to "draw out" all the characteristics of evoked potentials mentioned (the components' latent periods, polarity and amplitudes and the recording conditions) when analyzing the literature and comparing data when any descriptive system has been used where the components are designated with letters and (or) figures. When describing evoked potentials, it is advisable to designate the individual components with a letter indicating the polarity and a figure indicating the latent period up to the peak; this method will be used hereafter in this article. For example, a positive fluctuation with a latent period of 200 milliseconds will be designated: P 200; a negative fluctuation with a latent period of 250 milliseconds will be designated: N 250. It is better to indicate the extreme values or the average with the average quadratic deviation (for example, P 190-215, N 240-253 or P 200$\pm$ 9.7) and not the average values for the latent periods (for example, when averaging a group where the spread is large and it makes sense to cite it).

The selection of a method for analyzing the recorded evoked potentials is an important step in research. The problem is one of presenting the evoked potentials in the form of a reasonable collection of quantitative characteristics which can be compared. A visual evaluation of the evoked potentials--isolating the main components and determining their latent periods (from the presentation of the stimulus to the maximum fluctuation) and (or) their amplitudes--is the simplest and most widespread method. Amplitudes are measured from the peak of the preceding fluctuation to the peak of the fluctuation being studied, from the zero potential line or from a certain arbitrary center line. Each method has its advantages and shortcomings. It is best to use both methods as is done in certain studies. Various methods are also used for evaluating the evoked potential as a whole--for example, the autocorrelation or the cross correlation function--when comparing evoked potentials, a histogram of amplitude values for evoked potentials, etc. (Perry, 1969; Donchin, 1969).

There are a number of methods for analyzing evoked potentials but, as a whole, this problem is still a subject of research. It is not possible to discuss it within the limits of this article. It should only be emphasized that it is necessary to become acquainted in detail with the existing methods for analyzing evoked potentials before conducting any research using them; the special section in Perry's book (1969), Donchin's survey (1969) and Rachkin's survey (1971) can be recommended for this purpose.

1.3. Modern Ideas on the Morphogenesis and Functional Significance of the Individual Components of Evoked Potentials

A definition of evoked potentials and an overall description of them were given above. A problem of primary importance remains open: what are the cerebral structures or systems whose activity is reflected in the characteristics of the evoked potentials or whose activity causes them?

As was already stated, the form of the evoked potential depends on the modality of the stimulus and the recording area (Figures 2, 5 and 8). The early components of evoked potentials (with a LP up to 60-100 milliseconds) are primarily recorded only over the projection area of the cortex which corresponds to the modality of the stimulus; the late components are recorded in a diffused manner over the entire scalp. This corresponds with the features of the so-called primary and secondary or specific and nonspecific responses which were previously isolated while studying evoked responses in animals (Rose, Lindsley, 1965). The early electrical reactions which appear in the projection areas of the cortex in response to the arrival of impulses along the specific, afferent thalamocortical fibers are called primary or specific responses. The secondary or nonspecific responses include all the subsequent electrical reactions which are caused by the activity of other cerebral systems. It was demonstrated in experiments on animals that the secondary responses were caused to a significant degree by the reticular and thalamic nonspecific systems (Morison, Dempsey, 1943; Rose, Lindsley, 1968; Skinner, Lindsley, 1967).

After it was discovered in a number of studies that the early and late components of evoked potentials in man change under the influence of anesthesia and during sleep and are restored like the primary and secondary components in animals, a number of researchers began to view the early components of human evoked potentials as primary (specific) and the late components as secondary (nonspecific); thus, the individual components of evoked potentials began to be used as an indicator of the activity (or state) of different systems, namely, specific and nonspecific systems (Ciganek, 1961, 1963; Goff et al, 1962, 1966). It should be pointed out that there are actually no clear-cut criteria for making the above described divison of components of evoked potentials into primary and secondary (specific and nonspecific)--not one of the characteristics was both necessary and sufficient (Rutman, 1969; Myslobodskiy, 1966).

In addition to dividing the components of evoked potentials according to their assumed relationship with specific and nonspecific systems, a division of the components into

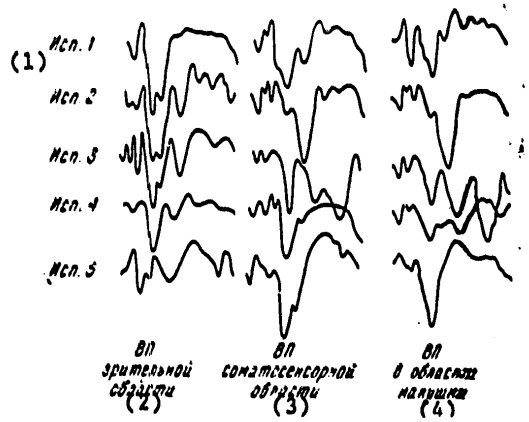

Figure 5. Average Visual Evoked Potentials in the Visual, Somatosensory and Crown Regions for Five Subjects. (Period of analysis, 500 milliseconds. Positive on bottom--Gastaut, 1967).

Key:
1. Subject.
2. Visual region.
3. Somatosensory region.
4. Crown region.

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modal-specific and modal-nonspecific components also appeared. The first included all the primary (specific) components of evoked potentials and the latter included all the secondary (nonspecific) components, especially the N 100-150 and P 200 fluctuations which are emitted best in the region of the crown for any stimulus modality and are therefore frequently designated the literature as the crown potential or the vertex potential.

This kind of division of components of evoked potentials implicitly provides a basis for assuming that the different components are related to the activity of different systems or structures which support the modal-specific and modal-nonspecific processing of sensory information. The systems of the latter type could include, for example, the so-called polysensory neurons whose existence was demonstrated by the work of Buser and Imbert (1961). It is possible that this relationship holds for some of the modal-nonspecific components but it has not been rigorously demonstrated anywhere. The division of components by their modal specificity was actually accomplished according to purely descriptive features: the term "modal-specific" designated the

components whose characteristics (polarity, latent period, form, recording area) clearly changed depending on the modality of the stimulus and the term "modal-nonspecific" referred to the components which had similar characteristics when stimuli of any modality were operative.

If an attempt is made to see the substantive aspects of the term, all th listed features are not sufficient for categorizing components as modal-nonspecific. The problem is that the activity of different, modal-specific neural systems can be reflected similarly (i.e., as similar evoked potentials) by the same electrode when making scalp recordings. This possibility is specifically demonstrated by Ciganek's experiments. In one of his studies (1965), evoked potentials with very similar characteristics were described for sound and light in the occipital region; this led to the conclusion on the complete non-specificity of evoked potentials for sound and light recorded in the occipital region.

However, a subsequent experiment (1966) disproved this assumption. This experiment studied the effect of the interval between a sequentially presented click and flash of light on the characteristics of the evoked potential in response to the flash. Presenting the click 50-250 milliseconds before the flash did not have any effect on the characteristics for the greater part of the evoked potential for the flash. At the same time, it was well known (Ciganek, 1964) that periods of refraction, inhibition and facilitation are observed during similar intervals between two flashes. It follows from this that the potentials evoked in response to light and sound--which are similar in form--are actually generated by different structures whose activity is manifested in a similar manner when recorded by the macroelectrode (just one, the latest fluctuation with a latent period of approximately 200 milliseconds, changed under the influence of the preceding click; as a result of this, it was assumed that this fluctuation was generated by the same structures in the case of the click and flash of light.) This study vividly demonstrates that a similar form for potentials evoked by different stimuli is not a sufficient indication that the structures generating the evoked potential are identical and that there is modal nonspecificity for evoked potentials.

The concept cited above--on the relationship between different components of evoked potentials and the primary projection areas and nonspecific activating systems and on the division of components according to modal specificity--were generally accepted for a certain period of time but they have changed significantly, especially regarding the late components (after 100 milliseconds). in the past 4-5 years under the influence of new cases.

It will be worthwhile to discuss these changes in more detail in order to put researchers from related fields on their guard against using the current interpretations of evoked potentials too easily and hastily.

Bearing in mind that the origin and "significance" of the components of evoked potentials are still an object of study themselves, the concepts on the genesis of evoked potentials should be very cautiously and critically used in analyzing the mechanisms of cerebral activity.

In 1969, Vaughan conducted a special study of the amplitude of a positive fluctuation with an approximately 200 millisecond latent period (P 200--or, as mentioned above, the so-called vertex potential) at various points on the scalp depending on the modality of the stimulus. It turned out that, although the P 200 was emitted very well in the region of the crown for all the modalities used (light, sound, electrical percutaneous stimulation or stimulation of the nerve), the area of maximum amplitude and the nature of the change in amplitude on the scalp differ due to the modality of the stimulus. An analysis of the results led the authors to conclude that the P 200 fluctuation is generated in the cortical projection area which corresponds to the stimulus modality, while it was recorded over the entire surface of the skull due to physical conduction.

On the other hand, detailed research on the origin of the individual components of somatosensory evoked potentials led to a similar revision of the concepts on the nature of late components of late potentials. A concurrent recording of somatosensory evoked potentials from the surface of the skull and from the surface of the cortex formerly showed that the early components are recorded in a narrow area on the side contralateral to the stimulation, in the appropriate cortical projection area. The late components have a longer regenerative cycle than the early components; they are recorded in both hemispheres and, in contrast to the early components, they are sensitive to barbituates and sleep. According to the previously described classification, the short, latent components of the evoked potentials were considered the primary and specific components and the late components were considered to be reflecting the arrival of impulses from the trunk of the recticular formation to the cortex or they were considered to be nonspecific thalamic nuclei along the extralemniscate paths, i.e., secondary or nonspecific (Goff et al, 1962, 1966).

This concept became generally accepted in the literature on evoked potentials. However, during the course of research, cases which contradicted this hypothesis were accumulated. Thus, while

recording somatosensory evoked potentials from people with structural lesions in one of the hemispheres, Liberson (1966) discovered that, if a depression or absence of an evoked potential was observed in the damaged hemisphere, then the evoked potentials were correspondingly reduced or they disappeared in the healthy side. Liberson pointed out the discrepancy between this case and the concept of nonspecific firings being reflected in the late components of evoked potentials.

In 1970, the study by Williamson et al was published; it was specifically devoted to testing the hypothesis on the relationship between the late components of evoked potentials and the nonspecific stem systems.

The logic of the study is as follows. It is well known (based on experiments with animals) that the specific and nonspecific systems are relatively independent: when one of them has failed or is cut off and the other is stimulated, evoked potentials in response to stimulation of the remaining system can be observed in the cortex. It follows from this that, if the late components really reflect the arrival of impulses to the cortex along the nonspecific firing paths, then they (the late components) should be retained in patients with damage to the specific paths which are higher than the regions where the collaterals branch out from the specific paths to the nonspecific formations.

A reduction in or absence of the early components and a retention of the late components should be expected in these patients. However, a study of a group of patients with a lesion in the parietal region of one of the hemispheres and a corresponding sensory disturbance has shown that, in cases of a reduction in or absence of the early components of evoked potentials, when a stimulation is directed to the damaged side, the late components were also reduced or absent in both hemispheres. When stimulation was directed to the healthy side, relatively "normal" late components of the evoked potentials were recorded in both hemispheres.

The authors came to the conclusion that the entire evoked potential on the side contralateral to the stimulation was caused by the activity of the primary somatosensory cortex which is only activated by the specific lemniscate path and the late reactions of the ipsilateral hemisphere reflect its subsequent activation by interhemispheric links, possibly by the corpus callosum. Thus, the late components are related to the interhemispheric transmission of information.

The modal specificity of the vertex potential is also convincingly demonstrated in a study by Davis et al (1971). They studied the changes in the vertex potential to stimuli of four modalities

(auditory, visual, electrical percutaneous and tactile) by presenting a conditioned stimulus 50 milliseconds before the test stimulus of the same or a different modality. Before the experiment, all the stimuli were balanced for subjective intensity. The amplitude of the evoked potential always declined under the influence of the conditioned stimulus but this reduction was approximately two times greater for the intramodal interaction than for the intermodal interaction. The degree of reduction in the evoked potential for the intramodal interaction was equal for the different modalities. This fact supports the concept of the specificity of the origin (separate generators) of the vertex potential for the different modalities. At the same time, a similar level of reduction in the evoked potential for the interaction between all modalities was discovered during an analysis of the intermodal interaction. It is easiest to explain this fact with the existence of a single system common to all the modalities. The authors are completely correct in pointing out that the concept of the reflection of diffuse associative or activating reactions in the vertex potential and the concept of the vertex potential being generated in the projection areas corresponding to the modalities are not mutually exclusive.

Thus, on the basis of the cited experiments and a number of other works, the fluctuations in potential which arise during the 100-250 millisecond period after the stimulus are presently viewed as modal-specific fluctuations related to the activity of the neural systems of the corresponding cortical projection areas. At the same time, this does not mean that the characteristics of these fluctuations are not affected by nonspecific systems.

During recent years, researchers have been devoting more and more attention to the late components of evoked potentials with latent periods of 250 milliseconds and more, specifically, the so-called late positive fluctuation (LPF) or P 300. It is not an obligatory component of the evoked potential; it appears and changes regardless of the modality and physical parameters of the stimulus and it is related to the psychological characteristics of the stimuli, such as, significance, degree of predictability, the requirement for making a decision due to the stimulus, etc.

Desmedt's work (1965) is one of the first containing a description of P 300. Evoked potentials for accomplishing the task of detecting a signal were recorded. A concurrent increase in the amplitude of P 300 and in the sensitivity of the observer were noted. P 300 was also noted (Donchin, 1967) in a situation where the subject had to react to visual stimuli of a certain configuration. It only appeared after the stimuli which required a reaction and it was not observed after other visual stimuli.

The appearance of or increase in the LPF was described (Sutton, 1965, 1967) in relation to the time that uncertainty was removed--i.e., either after the stimulus whose appearance removed the uncertainty or corresponding to the time when the stimulus was expected and its absence also removed the uncertainty. A relationship has been demonstrated between the LPF and probability (see Section 2 of this article).

Hillyard (1969) conducted a study of LPF in a signal detection situation. The P 300 was only observed in those cases where the subjects detected the signal. In those cases where there was a signal but the subjects did not perceive it and in the cases where there was no signal, the P 300 did not appear. Cases of a false alarm were too small to record the P 300. Based on his own data and a number of other experiments where the P 300 was recorded, the author concluded that the P 300 reflects the process of detecting a signal which belongs to a certain category of signals the observer is prepared to perceive due to their significance in solving the tasks he is faced with. If the "filters" of attention are selectively directed at a certain configuration of stimuli and if the given stimulus is determined to belong to this configuration and to require the appropriate reaction, it evokes the appearance of the P 300. It is as if this component indicates that the expected signal has been perceived during decision making. Thus, this work does not examine the P 300 as an indicator that uncertainty has been removed and a decision made in general but only in relation to certain stimulii ("significant" stimuli, stimuli serving as the object of attention, etc.).

Ritter and Vaughan (1969) interpret the functional significance of the P 300 differently. At first, they discovered that unexpected changes in the stimulus which did not require the attention of the subject--who was reading a book at that time--or an unexpected presentation of the stimulus caused the P 300 fluctuation to appear.

Since the conditions of stimulation which cause the P 300 were close to the conditions which cause the orienting response, the authors at first concluded that the P 300 was a correlate of the orienting response. However, the continuation of these studies led the same authors to cases which were not explainable by interpreting the P 300 as a correlate of the orienting response. They studied evoked potentials in a situation for discriminating visual or audio signals. An average of one out of the ten flashes (presented on a random basis) differed from the rest by a somewhat lower degree of brightness.

The sounds were presented in a similar manner in another series. The subjects had to note the appearance of the weak flash (or

sound). If they were easily distinguished from the rest, the P 300 only appeared after the signal stimulus. Moreover, in those cases where there was a signal but the subject did not notice it, the P 300 did not appear. It would have been natural to conclude from this that the P 300 appeared as a correlate of signal detection. However, it turned out that, if the difference between the signal and nonsignal stimuli was very small and the task of discriminating them was consequently harder, the P 300 fluctuation appeared after each stimulus, or rather, after the time when the stimulus should have been presented, regardless of whether it was perceived or actually presented. The authors concluded that the P 300 accompanies (or supports) the activity of a certain neurophysiological mechanism connected with signal perception and discrimination.

The P 300 cannot be a correlate of the mechanism of comparison since it only arises after the signal stimulus during an easy discrimination, while a comparision is conducted for each stimulus. The P 300 also cannot be viewed as a correlate of a cognitive decision made about the signal since it appears after all the stimuli, including stimuli which were not perceived in a difficult discrimination. As a result, the authors concluded that the P 300 reflects the activity of a central perceptual mechanism which establishes the significance of the stimulus and conducts a cognitive evaluation of it. This mechanism is not always switched on but only ostensibly in "difficult" or "important" cases: during an easy discrimination, it is only switched on after the signal stimulus to verify the magnitude of the stimulus; during a difficult discrimination, it is switched on as each signal is perceived.

In a special study of the amplitude of the P 300 at various points on the scalp, Vaughan and Ritter (1970) concluded that the P 300 is generated in the parietotemporal region. The authors suggested that the late (after 250 milliseconds) components be designated as an associative cortical potential (ACP) in contrast to all the preceding components which are viewed as sensory evoked potentials.

Based on the work of Klinke et al (1968, where the ACP was recorded in the absence of the expected stimulus), it is assumed that the ACP consists of a small initial positive fluctuation, a subsequent negative fluctuation and then the most pronounced positive fluctuation follows; this latter fluctuation has been described in a large number of works as the P 300 or the LPF. The first two components of the ACP are usually concealed by the late components of the sensory evoked potential, specifically the P 200 fluctuation. The authors stress the significant variation in the latent period for the most pronounced positive component of the ACP which fluctuates depending on the experimental

conditions, specifically, depending upon the difficulty of distinguishing the values from 250 to (at least) 550 milliseconds. The authors believe that the sensory evoked potential (i.e., the evoked potential up to 200 milliseconds according to their definition) determines the minimal time required to record and initially analyze the sensory input but it does not supply the central nervous system with enough information to implement the response appropriate to the information. The latter is supplied by the ACP, its initial part.

Articles which describe later components in addition to the P 300 have begun to appear recently. These components are recorded for accomplishing the task of discrimination. Wilson et al (1973) pointed out the changes in P 300--and the slow positive fluctuation with a latent period of 400 milliseconds and more--due to the accomplishment of a task in discriminating visual stimuli. The amplitude of these fluctuations were correlated to accomplishment of the task. Similar components and changes in them which were correlated with successful discrimination have also been noted in auditory evoked potentials (Jannes, 1972).

From the above, it is evident that a large part of the work directed at studying the nature of evoked potentials is attempting to define the morphogenesis of individual components and only in the case of the P 300 component is an attempt being made to determine the functional significance (find the functional correlate) of the component regardless of its morphogenesis. This kind of approach to an analysis of individual components of evoked potentials is extremely advisable and may be especially fruitful in studying evoked potentials within the framework of psychophysical problems. In this respect, it is worthwhile mentioning the functional systems approach to the analysis of individual components of evoked potentials used by V. B. Shvyrkov (1973 a,b). Although his studies were conducted on animals which were awake and while a review of the data on evoked potentials in animals is undoubtedly required for an understanding of the nature of human evoked potentials, it goes beyond the scope of this article.

Based on material from his own experimental data, the author compared the time sequence for components of evoked potentials and the time structure of the processes occuring in a functional system (Anokhin, 1973) within the framework of a simple motor response to a conditioned stimulus. As a result, he arrived at the proposition that the primary responses -- in all the structures where they appear-- correspond to the time for drawing from the memory the information which will be used in the afferent synthesis (the initial recognition of the stimulus is completed before the primary positive maxima); the negative component corresponds to

the arrival to the cortex of the stimuli which comprise the afferent synthesis (at this time, there is a more detailed evaluation of the stimulus parameters than during its initial recognition); and the late positive fluctuation which coincides with the beginning of the conditioned EMG response reflects the completion of the processes of the afferent synthesis and decision making.

The components of the evoked potential do not of course reflect the nature of the cited processes but they do attest to their being switched on (or completed). It is worth emphasizing the fact noted by the author (Shvyrkov, 1973 b) that "before and after the development of a conditioned reflex in a rabbit which is awake, the same stimulus can evoke responses with a completely different configuration, and different stimuli--light and current--can evoke similar responses but in different regions." This indicates that the regions to which the impulses--which appear in response to the stimulus--are directed can change and that the stimulus ostensibly "triggers" a certain set system of interrelationships between the structures which existed before the stimulus and which determine the special features of the evoked response to the stimulus in this situation.

It would be worthwhile to make broader use of this functional systems approach to an analysis of evoked potentials in the research on human evoked potentials. A. M. Ivanitskiy (1972) attempted to conduct a similar evaluation of the individual components of evoked potentials but the specific system he proposed drew too many objections.

Thus, according to the concepts which presently exist, it makes sense to isolate: the early components of the evoked potential (60-100 milliseconds) which reflect to a particular degree the arrival of impulses along the specific firing paths to the cortical projection areas and the early reactions of neurons in the projection area; the "late" components which appear during the 100-250 millisecond period (according to the data from a majority of the studies, these include the most pronounced P 200 component) which are specific in the sense that the entire cortical projection area of the corresponding modality is required for their development although their characteristics are significantly affected by nonspecific cerebral systems and which also possibly reflect interhemispheric interaction; and finally, the latest components with latent periods of 250-300 milliseconds and more which evidently are modal-nonspecific. Of them, the P 300 fluctuation described above, which appears in the associative cortex, is studied the most today.

The components of evoked potentials with latent periods of 250-300 milliseconds and above are noted as a rule if the stimuli require some sort of response and if they are switched on in the subject's activity (usually they are described in experiments where signal discrimination is required); they are undoubtedly of significant interest for psychology and, specifically, for psychophysics. However, it should be remembered that, in spite of the significant progress in our knowledge of evoked potentials, the concepts on the morpho-functional genesis of their individual components are far from being complete and clear. In light of this, it is beyond doubt that the categorical, confident designation--which is sometimes made in the literature--of components with latent periods of 150-200 milliseconds and over as resulting from the activation of the reticular formation or some other nonspecific system are at least premature and frequently are misleading. The researcher in psychophysics who decides to use the method of recording evoked potentials to solve his problems must be completely aware of this when analyzing the literature, planning his experiment and interpreting the results.

When we are recording any electrophysiological phenomenon which is correlated with a behavioral response, we do not know whether this phenomenon itself is a necessary link for carrying out this behavioral response or whether it only "accompanies" it in the majority of cases. Uttal (1967) proposed that recorded physiological indices be divided into signs and codes. The recorded indices which contain information used in subsequent sections of the nervous system and which have an effect on behavior are considered to be codes and the indices which are found to be correlated with behavior, but do not necessarily have an effect on it and are not necessarily used in subsequent links of the nervous system, are considered to be signs.

In analyzing evoked potentials from this point of view, Uttal concludes that they are more a sign than a code. This issue cannot be considered resolved at present. The prospects for using evoked potentials both as a sign and as a code are linked to the level of knowledge on the sources of individual components and the primary factors which regulate and modulate them. In simple terms, if the evoked potential is a sign then it is necessary to understand what it is a sign of and on what operations of which functional or morphological systems it (its components) can provide information to the researcher. The success of using evoked potentials to study the mechanisms of cerebral operations depends on the level of knowledge in this area.

1.4. Some Special Features of Evoked Potentials Which are Significant for Their Use as a Physiological Indicator

1.4.1. Variation in Evoked Potentials

Figures 5 and 6 show examples of evoked potentials for a single subject and for several subjects. A significant variation in evoked potentials can be seen in the figures. In recording evoked potentials (especially when summing a small number of responses) for a single individual under constant conditions, it is easy to see that completely similar curves are observed more sharply than different ones are. However, the intra-individual variation (Figure 6) primarily concerns the amplitude of the individual components; the latent periods are rather stable and the primary, "overall picture" of the evoked potential is retained for a given subject. The intraindividual variation in evoked potential can be caused by a number of factors: habituation (extinction), a change in the level of wakefulness and a change in the degree of attention to the stimulus while the evoked potential is being recorded. The effect of these factors is demonstrated in a number of works (see Chuprikova's Surveys, 1967; Rutman, 1969; Perry, 1969). Since all the factors cited change to a certain degree over time, it is necessary to reduce the length of the experiment as much as possible to decrease their effect on the evoked potential. A variation in evoked potential can also be caused by their "contamination" by potentials of extracerebral origin (see below).

The interindividual variation (Figures 5 and 6) is a great deal more pronounced than the intraindividual variation. The interindividual variation serves as serious interference when evoked potentials are used as an instrument in studies requiring the analysis of group data. It is clear that all the causes of intraindividual variation also pervade interindividual variation (different rates of habituation and different states for the same conditions depending on the individual features of the subjects). In addition, individual features of the relationship between the cerebral surface and the scalp has an effect on the characteristics of evoked potentials; based on external criteria, the same spot on the scalp of different people can have a different relationship to the same cerebral region.

There are works which show a significant effect on the characteristics of evoked potentials of relatively small differences in electrode placement. Thus, Perry (1969) studied visual changes in evoked potentials due to amblyopia (damage to visual acuity without any visible structural damage to the visual system). When evoked potentials were recorded in just one spot on the occipital region, changes in evoked potentials which correlated

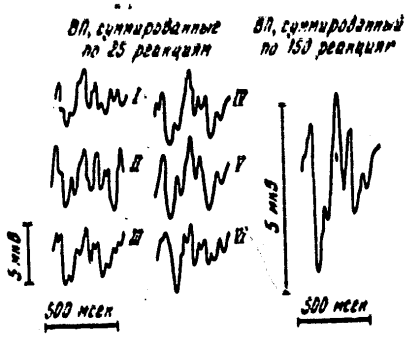

Figure 6. Variation in Visual Evoked Potentials for One Subject. (Recording conditions are the same as for Figure 1--Perry, 1969).

Key:
1. Evoked potentials summed for 25 responses.
2. Evoked potentials summed for 150 responses.
3. Microvolts
4. Milliseconds

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with the clinical manifestations of the visual damage were detected for 20-50 percent of the subjects. When evoked potentials were recorded at four points in the occipital region instead of one, changes in evoked potentials were detected for all the cases of amblyopia. Thus, the fact that visual evoked potentials which are usually very similar within the occipital region can change in various ways during amblyopia provides a basis for attempting to look for changes in evoked potentials in a similar way within the framework of psychological research.

The interindividual differences in evoked potentials may be related to some sort of presently unknown, individual characteristics of the nervous system. For example, a significant correlation between latent periods for evoked potentials and the level of intelligence have been demonstrated in a number of works (Shucard, Horn, 1972). Interindividual differences in evoked potentials may lead to a situation where differences in evoked potentials related to a certain factor being studied, which are reliable for each individual subject, turn out to be unreliable when the results are correlated for the group as a whole (Perry, 1969). It is frequently very difficult to accurately determine similar components of evoked potentials for different subjects. At the same time, it is precisely an evaluation of the changes for a

group of subjects which is frequently required. Evidently, it is necessary to isolate subgroups within the subject group with very similar evoked potentials for a separate evaluation of the results by subgroups. For example, the work of Arnal et al (1972) is of interest in this respect; it isolates the most characteristic types of visual evoked potentials for children and adults; and Ruchkin's work (1971) is also of interest; it proposes a method of analysis for nonhomogeneous sets of evoked potentials. Since a certain part of the interindividual variation is evidently caused by differences in background activity, perhaps it would be advisable to select subjects with similar levels of background activity. The sources of variation in evoked potentials and ways of "overcoming" it continue to be an object of study (Callaway et al, 1973; Childers et al, 1972; Hoopen, Reuver, 1972).

1.4.2. Validity of Evoked Potentials.
Extracerebral Components of Evoked Potentials.
Selecting a Recording Method (Bipolar and Monopolar Recording)

A number of works (see the bibliography in Perry's book, 1969) have been devoted to proving the intracerebral origin of evoked potentials; the primary proof has been obtained when evoked potentials were simultaneously recorded from the cerebral surface and the scalp (Figure 7). The problems of correlating the activity recorded on the scalp and the activity directly recorded from the cerebral surface are complex and require special treatment. It is sufficient to emphasize the following here. The intracerebral origin of the main part of the evoked potential can be considered proven. However, the existence of myogenetic reactions which were in a relatively strict time relationship with the stimulus were discovered in the first experiments studying the origin of scalp-recorded evoked potentials (Bickford, 1967).

It was also discovered that a certain part of the evoked potential may be a reflection of the corneal-retinal potential, a reflection of changes in potential due to eye movement or blinking (Vaughan, 1959; Corby, Koppel, 1972) or a change in scalp potential (Picton, Hillyard, 1972). The "contamination" of evoked potentials by a mixture of extracerebral potentials represents serious interference; this requires close attention to the recording conditions which have an effect on the emission of extracerebral fluctuations in potentials and it requires a number of special procedures to get rid of them or to reduce their "level" in the evoked potential.

First of all, it is necessary to be sure that the subject is comfortable and the muscles are relaxed. The greater the distance between electrodes, the greater the possibility of a "mixture" of muscle potential; therefore, a bipolar recording is better in this respect. However, due to the difficulty in

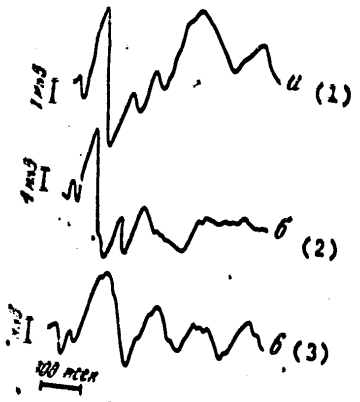

Figure 7. Visual Evoked Potentials Simultaneously Recorded from the Scalp and from the Cerebral Surface (Corletto et al, 1967)

Key:

1. From the scalp before the operation.
2. From the cerebral surface.
3. From the scalp after surgical removal of the occipital lobe. Bipolar recording electrodes-- 3 cm to the side and 3 cm above the occipital lobe in the occipital region and 7 cm to the side of the center line in the parietal region. The cortical electrodes were placed at several points on the exterior and interior surfaces of the occipital lobe and in the rear sections of the parietal lobe. The pupils were immobilized by homatropine; the eyes were closed. Frequency of stimulation: 1 flash each 1.5 seconds. Average calculated for 100 responses. Downward fluctuation is negative in the occipital region.

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interpreting bipolar recorded evoked potentials and their lower amplitude (Figure 8), monopolar recording is usually preferred (Goff, 1969; Cracco, 1972). During a monopolar recording, it is recommended that the indifferent electrode be placed on the earlobe contralateral to the active electrode (Lindsley, 1959; Goff, 1959) or (for visual evoked potentials) beyond the head (Lehtonen, Koivikko, 1971). The ear lobe provides the least number of extracerebral "mixtures" of evoked potentials.

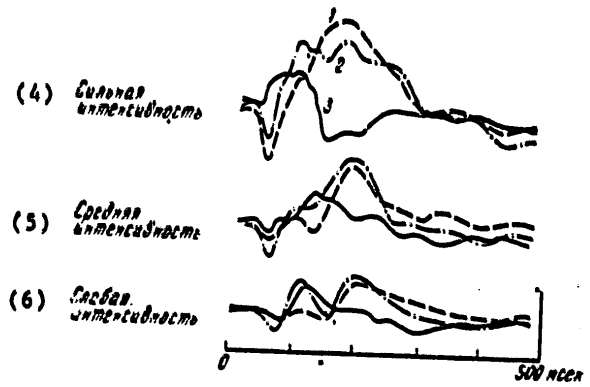

Figure 8. Comparison of Bipolar and Monopolar Recordings of Evoked Potentials for a Flash of Light at Three Levels of Intensity. (For the monopolar recording: indifferent electrode on the left ear; positive for the active electrode is upward. For the bipolar: negative in the occipital region is downward.)

Key:

1. Parietal region.
2. Occipital region, monopolar recording.
3. The same regions, bipolar recording (Goff, 1969).
4. Strong intensity.
5. Average intensity.
6. Weak intensity.

A simultaneous recording of an electrooculogram is used to eliminate eye movement "mixtures" in the evoked potential, and the fluctuation in potential which comprises a certain percentage of the value of the fluctuations recorded by the electrooculogram are subtracted from the evoked potential (Corby, Koppel, 1972). However, the definition of the subtracted value has still not been completely worked out; it is different for different points on the head and specifically depends on what caused the fluctuation in potential in the electrooculogram--a blink or a vertical eye movement. Unfortunately, due to their complexity, these operations are only being conducted in a very small number of studies. Since the myogenetic "mixtures" in the evoked potential are distinguished by a greater level of variation than the evoked potentials (Goff, 1969), a lack of stability in the subject's evoked potential should provide a warning of muscular or other artifacts.

2. Survey of Some Experiments Using Evoked Potentials

2.1. The Relationship Between Evoked Potentials and the Intensity of Stimulation

The study of the relationship between the intensity of the stimulus sensation and its objective characteristics makes up a significant part of psychophysics. This relationship is undoubtedly not linear since its precise nature has still not been established: not all researchers share Stivens' confidence in the step relationship (which is based on a large amount of experimental material) and the supporters of the classical concept of a logarithmic relationship also rely on numerous experimental cases.

Be that as it may, the question arises of the mechanism upon which the established nonlinear relationship between the characteristics of the stimulus and the magnitude of the sensation caused by them is based. One of the ways of searching for this mechanism is to study the characteristics of the recorded indices of the sensory systems' activity at all levels, beginning with the most peripheral--the receptor. A large number of this kind of study--studying the dependence of the characteristics of the activity evoked at different levels of the sensory system on the intensity of the stimulation--have been conducted on animals. However, a subjective evaluation of the sensation cannot be obtained from animals. Scalp-recorded evoked potentials--for evoked potentials recorded directly from the brain (during certain illnesses)--present a novel opportunity to concurrently study the psychophysical and physiological indices in man.

From the very time that the method of recording evoked potentials was first introduced into laboratory practice, a number of works (Perry, 1969) have been devoted to studying the relationship between the characteristics of evoked potentials and the intensity of the stimulation (strictly speaking, it was the very presence of this relationship which served as an encouraging fact in the very first experiments, when it was necessary to confirm both the cerebral origin of the new index and its causal relationship with the stimulus).

The experiments which correlated the dependence of the sensation (a subjective evaluation of intensity or scaling) and the amplitude of the evoked potential on stimulus intensity are of greatest interest. The results of the experiments are rather inconsistent and they frequently concern different components.

For example, Franzen and Offenloch (1968) studied the correlation between the amplitude of evoked potentials for tactile stimulations of different intensity and the psychophysical finding on the

magnitude of the stimulation; they described the relationship between the amplitude of the evoked potential and the intensity as a step function and they pointed out the "complete isomorphism between the psychophysical and neurophysiological results." They defined the amplitude from the peak of the early "double-peaked" positive fluctuation (with latent periods for the two positive peaks of 30-40 and 43-53 milliseconds respectively) to the peak of the subsequent negative fluctuation. The evoked potential was recorded in a bipolar manner; one of the electrodes was located near the corresponding cortical projection area. (Kaydel) and (Spreng) obtained different results; they studied the relationship between the amplitude of the evoked potential--during the 130-170 millisecond period after the stimulus--and the intensity of the auditory, percutaneous electrical and tactile stimuli. In all cases, they also found a step relationship but the exponent (the index of the level in the formula obtained) was less than for the corresponding psychophysical curves. The ratio between the exponents which expressed the relationship between the evoked potential and the intensity for different types of stimuli was the same as the similar ratio between the psychophysical exponents.

In a similar study using percutaneous electrical stimulation, Beck and Rosner (1968) also described a relationship detected between the amplitude of the evoked potential and the intensity of the step function and they pointed out that the exponent for the evoked potential was lower than the one for the description of the psychophysical data. The principle they discovered concerns the amplitude of the late fluctuation (with a latent period of 200 milliseconds) in the cortical projection area and the early fluctuation in the frontal region. After correlating the psychophysical and electrophysiological responses to the changes in stimulus intensity, the authors concluded that there was a nonlinear relationship between them. In their work, Sato and Kitigima (1965) noted an increase in the amplitude of evoked potentials for visual stimuli which was proportional to the logarithm of the intensity. While studying the dependence of the amplitude and latent periods of evoked potentials on the intensity of the stimulation, Kreutzfeld and Kunt (1967) emphasized the identical nature of the causal relationships they found in people and cats and they concluded that the increase in amplitude with the increase in intensity can be described both as a logarithmic and as a step function and that both relationships are close.

In their study, Ball and Lang (1972) describe a linear relationship between the amplitude of the P 100 and P 175-200 components and the intensity of tones within the 50-100 decibel range (the subject had to evaluate the tones and press the appropriate key).

Side by side with the data on the step or logarithmic or linear relationship between the characteristics of the evoked potential and intensity, there are a number of works which deny that the stimulus intensity is reflected in the evoked potential. In his article "Neural Events and Psychophysical Law" (1971), Buchsbaum asserts that evoked potentials are a long way from reflecting the force of a law and they are closer to reflecting the effect of a complex system of interpretation and modulation of the stimulus being perceived. It has been demonstrated in a number of this author's and other authors' works that the amplitude of the evoked potentials for different subjects can increase, remain the same or decrease with an increase in the intensity of the stimulation (Silverman, 1972; Buchsbaum, Pfefferbaum, 1971).

These studies show that individual differences exist in a certain range of changes in intensity. If the dependence of the amplitude of the evoked potential (the amplitude is measured from the peak of P 80-90 to the peak of 120-140) on intensity is expressed as an inclined angle for the linear function of the relationship between amplitude and intensity, then it turns out that this magnitude is a stable, individual characteristic which is traced for different modalities. The importance of a different inclined angle leads to the fact that, with an increase in the intensity of the stimulation, the amplitude of the evoked potential continually increases in a certain manner for some people while, for other people, when the intensity of the stimulation is increased within the same range of intensity, the increase in the amplitude becomes less pronounced at a certain point in time than it is for the first group or it stops and, in a number of cases, a decline is observed. These results led to assuming the existence of a central intensity control mechanism or a sensory "filter" whose purpose is to protect the nervous system against the effect of overstimulation Depending on the sensitivity of the nervous system, this mechanism "switches on" in different people in response to a different intensity of stimulation; this is what causes the differences observed.

A reduction in the amplitude of evoked potentials at a certain point in time when the intensity of the stimulation is increased has also been demonstrated in studies on animals, specifically in the work of Maykovskiy and Sobiyezhek (1972) on animals which were awake. An increase in the intensity of percutaneous electrical or auditory stimulation at first caused an increase in the amplitude of both the early and subsequent components of evoked potentials and an increase in the recording area for late components. Beginning at a certain point in time, a further increase in stimulation (which frequently coincided with the appearance of agitation or restlessness in the animals) caused a reduction in the amplitude of the cited components of evoked

potentials. An analysis of the simultaneous changes in background activity showed that the changes observed in the evoked potentials were not dependent upon them.

Without going into a detailed discussion of the work in this area, it is worth pointing out that Stivens (1969) emphasizes that "the magnitudes of some relationships which are, according to our assumptions, monotonic can, in reality (this is discovered with more thorough research), have a maximum; after 'reaching' this maximum, it is as if they 'retrace their own steps.'"

The reasons for the discrepancies in the results of different researchers can be: the differences in the recording regions, the method of stimulation, the component of the evoked potential being defined, an effect which is not accounted for from extrasensory factors and the well known fact of the similarity between logarithmic and step functions within certain limits; this similarity makes it possible to describe the same set of data as both a logarithmic and a step function.

A number of works have demonstrated the possibility of different changes in the individual components of evoked potentials due to intensity. Thus, Shipley et al (1966) studied visual evoked potentials in relation to intensity which they increased from 0.5 to 3.5 of the logarithm of intensity over the threshold with a 0.5 logarithmic step. At first, as the intensity increased, the amplitude of all the components increased for all the subjects but, beginning at a certain level (different for different subjects), the amplitude stopped increasing or even decreased with a further increase in intensity. Moreover, different components stopped increasing or began decreasing at different levels of intensity. This means that the amplitude of the evoked potential-to-intensity curve can be different depending on the component being studied.

It was pointed out in a study by Rosner and Goff (1967) that the early components of somatosensory evoked potentials do not change with an increase in the intensity of stimulation during percutaneous electrical stimulation. A relationship with intensity was only discovered in the changes to the P 200 component's amplitude Based on this fact, the authors concluded that the cortical endings of the specific discharge fibers which support the topical firing of peripheral receptors to the cortex do not support the function of subjectively defining intensity.

Teruo and Tetsuro describe a different relationship between perceived intensity and the various components of evoked potentials in their work (1966). They recorded evoked potentials directly from the somatosensory cortex while stimulating the median nerve in the arm with a current. In a certain position, they noticed

a decrease in the early components and an increase in the late components of the potential evoked by stimulating the median nerve in the arm with a current; moreover, the subjects sensed a higher level of intensity over a broad area where the stimulus was applied. As the position was changed, they observed an increase in the early components and a decrease in the late components of the evoked potential; the stimulation was perceived as being weaker and local in nature.

In his study of the dependence of potentials evoked by percutaneous electrical stimulation on intensity, Ikut (1972) defined the amplitude from peak to peak and the average latent periods for the entire group of five components isolated in the evoked potential; the P 44 and P 170 components were the most pronounced. When the intensity was increased, the latent period was only significantly reduced for the P 44; the amplitude of the various components changed in different ways. The experiment was conducted on 42 schizophrenic patients.

L. A. Novikova (1973) studied the changes, related to intensity, in the potentials evoked in the occipital region by a flash of light. Eight gradations of intensity were created with filters. An increase in intensity led to a regular increase in the amplitude of the P 100, N 150, P 200 and N 230 components and to a reduction in the latent periods for these components.

A number of works have studied the dependence of latent periods of evoked potentials on the intensity of stimulation (Tepas, Armington, 1962; Rietveld, Tordior, 1965; Diamond, 1964; Vaughan, Hall, 1965; Vaughan et al, 1966). As the intensity declined, all the works noted an increase in the latent periods; moreover, the dependence was, as a rule, reflected as a step function. However, it is worthwhile pointing out that, in spite of the similar nature of the dependencies discovered, the results of these studies cannot be called unambiguous since the discussion is about components with different latent periods. Thus, the first work cited above studied a component of an evoked potential with a latent period of 126 milliseconds and the subsequent ones studied components of evoked potentials with latent periods of 48, 71, 108 and 100 milliseconds, respectively. In the aforementioned work by Shipley et al (1966), changes in the latent periods were analyzed for all the components of visual evoked potentials in relation to intensity.

A tendency toward an average reduction in the latent periods of 25-35 milliseconds has been noted when the logarithm of intensity is increased by one.

Overall, the overwhelming result is the case where the latent periods decrease and the amplitude of the individual components of the evoked potential increase as intensity increases; along with this, there is the case which has been noted on numerous occasions where the increase stops or the amplitude even decreases when intensity increases beginning with a certain, sufficiently high level of stimulation. Due to the complexity in correlating the components of evoked potentials for different recording conditions, it is presently difficult to tell, based on the data in the literature, which of the components are the most informative in studying the relationship between evoked potentials and intensity. It is only clear that changes in evoked potentials were observed both for the early and late components as intensity changed; moreover, the changes were noticed more frequently in late components than in early components (see the bibliography in Perry's book).

Evidently, it is necessary to clearly isolate (based on data in the literature and in future experimental studies) the dependence of the amplitude and the latent periods of evoked potentials on intensity for different components.

When analyzing the literature, the location of the electrodes should also be borne in mind due to the possibility of a different relationship between the evoked potentials and intensity in different sections. Thus, Goff (1969) recorded potentials with three intensities evoked in the parietal and occipital regions by a flash of light (Figure 8). As the intensity increased, an increase was observed in the P 190 in both regions but, for the weak and average intensity, the P 190 was emitted the same in the occipital and parietal regions and, for the strong intensity, the P 190 was greater in the parietal region (incidentally, this case is interesting due to the aforementioned theory of a "sensory filter" which, beginning at a certain point in time, "protects" the nervous system from overstimulation).

The study by (Umkis) et al (1964) can be cited to demonstrate the possible effect of extrasensory factors on the amplitude and form of evoked potentials when studying the relationship between evoked potentials and intensity. The authors noted a change in the form of the evoked potential when the intensity was reduced to the near threshold level (a single slow fluctuation appeared instead of the two neighboring, positive fluctuations). This change was interpreted as reflecting the transition from the photopic to the scotopic visual mechanism. However, since the changes concerned rather late components of evoked potentials, another explanation is also possible. Reducing the intensity to the near threshold level leads to a lack of confidence in the subject on the presence or absence of the stimulus; this is connected with the appearance (in cases where the stimulus is included in some sort of task) of a positive fluctuation with a

latent period of approximately 300 milliseconds (Sutton, 1969). This fluctuation, which is only indirectly related to the change in intensity, could be taken for a reflection of the changes in intensity.

The problem of whether the evoked potentials contain a code for intensity or only signs of it remains open.

In itself, the nearness in the characteristics of the relationship between evoked potentials and intensity and between sensation and intensity naturally still does not prove a cause-effect relationship. Experiments which suggested a distortion in perception under hypnosis or anesthesia were not connected with any change in evoked potential (Beck et al, 1966; Holliday, Mason, 1964) or the experiment of Coquery et al (1972) in which changes in somatosensory evoked potentials due to voluntary or involuntary movements could be simultaneously observed both with corresponding changes in perception and with no change in the perception of stimulus intensity speak against such a relationship (or about its ambiguity).

The similarity (or even the identity) between the psychophysical curve and the evoked potential amplitude-intensity curve still do not prove that the amplitude of the evoked potential is a code for intensity. If it is taken into account that the reaction time in choosing can reach 250 milliseconds (and this may occur in those cases where the discrimination of stimuli is based on an evaluation of intensities), then the changes due to intensity in the amplitude of a component of the evoked potential with a latent period greater than 200 milliseconds can be viewed as concurrent to perception or as a result of it but not as preceding it or as being a potential cause of the evaluation of stimulus intensity. Moreover, many studies describe the relationship precisely between late components of evoked potentials and intensity.

Davis and Onishi (1968) (cited in Sutton, 1969) described the increase in the vertex potential as intensity increased; due to the various other characteristics of the vertex potential (specifically, the relatively long regenerative period), it is not by accident that they concluded that the evoked potential is not a code for intensity.

2.2. Defining the Sensitivity Threshold

It is completely natural that the appearance of the method for recording evoked potentials aroused a lot of hope for the productive use of a new indicator in defining the sensitivity of sensory systems and, specifically, in discovering the physiological bases for subliminal perception.

Schwartz and Shagass (1961) made a special study of this problem. Based on their studies of the somatosensory evoked potentials in cats (a correspondence was discovered in the thresholds for the stimulated nerve and the cortical response) and their correlations of human scalp-recorded evoked potentials in response to tactile stimulation and the subjective report on the sensation of near threshold stimuli, the authors concluded that the thresholds for the appearance of sensation and for the appearance of evoked potentials are the same and, thus, no physiological basis was discovered for "subliminal perception."

Similar results were obtained by Debecker and Desmedt (1965) (cited in Libet, 1967) when recording evoked potentials for tactile and electrical stimulation in the area of the anterior central convolution and by Domino et al (1964) when recording somatosensory evoked potentials from the scalp and epidurally.

However, the value of these experiments is reduced by the following facts. It is necessary to have a prior awareness of the limitations placed on the method of recording evoked potentials, namely--the requirement for summing a certain number of responses to obtain a single index at a time when the subjective report "yes"--"no" can be received in response to each presentation of the stimulus. In addition, when making scalp-recordings, the bioelectrical responses are significantly reduced in comparison to their size when recorded from the cerebral surface. Therefore, the threshold estimated by the evoked response recorded from the scalp can be signficantly larger than the true threshold estimated for the bioelectrical response; this threshold could be discovered by a direct recording from the brain or without the "noise" interfering with the estimate.

This means that the match obtained during the experiment between the thresholds for the subjective report or any behavioral indicator and for the evoked potential still does not prove a true match since it is possible that the "true" threshold for the evoked potential is actually lower than the one obtained during the experiment. In this respect, the case where lower thresholds are discovered for the evoked potential than for the behavioral indicators is more important; it would seem that they could serve as a completely reliable basis for further discussion and searches. There are such experiments.

To this day, the study by Libet et al (1967) is still one of the most important studies in this area. The study was conducted during operations for motor hyperkinesis or algesic syndromes. The recording electrodes were placed on the soft cerebral membrane on the surface of the somatosensory cortex. Evoked

potentials were concurrently recorded by electrodes located on the scalp. Percutaneous electrical stimulation or electrical stimulation of the specific nucleus of the thalamus served as the stimuli.

The study is distinguished by the extremely precise localization of the recording electrodes since the spots for stimulating the skin or the thalamus were selected in such a manner that the sensation which appeared was localized in the same spot as the sensation which appeared during direct stimulation of the cortex in the area of the recording electrodes. The subjects were requested to define the stimulation on a three point scale: "feel it," "feel nothing," "not sure." The "not sure" responses were rare (less than five percent) and there were no false positive responses. Evoked potentials were recorded (summed and averaged for 500 responses) independently for threshold stimuli (the intensity at which a sensation was not evoked by all the stimuli), for above threshold stimuli (an intensity two times higher than the threshold intensity--all the stimuli cause a sensation) and for subliminal stimuli (the intensity at which a sensation does not appear). Two areas were independently isolated in the subliminal zone: stimulation 15-25 percent (zone A) and 25-40 percent lower than the threshold stimulation (zone B).

Two interesting facts were discovered. The electrode located on the cortical surface recorded very similar evoked potentials for threshold and above threshold stimulation (in the latter case, the amplitude was higher), while the electrode located on the scalp only recorded evoked potentials for above threshold stimulation. When the area of stimulation was increased (the median nerve was stimulated instead of a small section of skin), evoked potentials were also recorded from the surface electrode for threshold stimulation. The second, more interesting fact consists of the discovery of the zones of subliminal evoked potentials. During subliminal stimulation in zone A, when not a single stimulus caused a sensation in a single case, the early positive and subsequent negative fluctuations were clearly recorded; these fluctuations were similar to the initial group of fluctuations for threshold stimulation but with an extremely lower amplitude.

The basic difference in the evoked potentials for the subliminal (imperceptible) stimuli and the evoked potentials for threshold or above threshold stimuli consisted of the absence of the later fluctuations during subliminal stimulation; these are the fluctuations which appear after the initial positive-negative group of fluctuations. With a further reduction in stimulation (zone B), the evoked potentials ceased being recorded altogether.

Thus, in this study, a subliminal zone was discovered where there is a clear bioelectrical response in the projection zone without any sensation. During stimulation of the specific nucleus of the thalamus and during direct stimulation of the cortex, it was also possible to observe distinct early components (the positive fluctuation was as large or even larger in amplitude than for above threshold stimulation of the skin) with a complete lack of any report of any sensation for the stimulation. However, the late fluctuations were not observed in any of the cases where there was no sensation.

The authors concluded that, although the initial positive fluctuation increases when it passes from the threshold zone to the above threshold zone, the increase in this fluctuation alone is not sufficient for a sensation to appear. The late components correlate better with the appearance of a sensation; they are as significant as the early components in perceiving the stimulus, if not more so.

The results of this work contain a physiological confirmation of the existence of a subsensory zone of perception. The authors assume that stimuli similar to those of zone A may play some role in behavioral responses to the so-called nonperceived stimuli.

However, this work is not free of methodological errors which cast doubt on the legitimacy of the conclusions. It is necessary to dwell on the methodological shortcomings of this work. As in the overwhelming majority of similar studies, it compares discreet indices obtained for qualitative binary responses ("yes," "no" plus "don't know" in the best of cases) and quantitative, gradual responses--the evoked potentials. It is natural that, in this case, the threshold for the evoked potentials may seem lower than the threshold for the perceived sensation due to the margin of doubt if a sufficiently large part of the responses in the doubtful area fall within the category of "no" responses. Five percent of "don't know" responses and the absence of false positive responses increases the probability of this explanation.

It is difficult to expect that the threshold indices will coincide when the threshold is being determined by such different methods. Sutton (1969) correctly views this situation as logically equivalent to expecting the same information on evoked potentials when they are being described by the two-step, qualitative scale "all or nothing" or by a graduated determination of the amplitude.

Sutton sees a way out of this discrepancy by introducing a sufficiently large, graduated scale of levels of confidence for a response when determining the threshold and subsequent average

evoked potential individually for each "rung" on this scale. A similar method was applied in a number of studies using evoked potentials and certain differences were discovered in evoked potentials due to the level of confidence in the perception of near threshold stimuli (Donchin, 1966; McAdam, Rubin, 1968). Sutton also suggests another way: in the case of a binary response to a stimulus ("yes"--"no"), it is necessary to evaluate each individual evoked potential (this should be done by the experimenter or a computer) according to the "all or none" principle corresponding to the criterion adopted for the amplitude; after this, a comparison of the thresholds for these indices will be correct. However, the match in the thresholds will depend upon whether the same criterion is being used by the subject and the experimenter and a search for the "same criterion" may turn out to be a very laborious task.

In examining the complexity of the criterion problem, Sutton (1969) cites the results obtained in his laboratory. The psychophysical threshold and the threshold for pupillary response to the same visual stimuli were compared. The psychophysical threshold was determined from the "yes-no" responses and it was compared with the average value for the pupillary response to the corresponding stimuli. The subjects were divided into three groups: those with matching indices for the threshold intensity values, those with higher values for the psychophysical threshold than for the pupillary response and those with the opposite relationship. These results were evaluated as resulting from the subjects' different criteria. It was assumed that conservative subjects said "yes" using a high criterion, i.e., only with a high degree of confidence, and their threshold for the pupillary response was lower. With a lower criterion, the thresholds matched or the threshold for the pupillary response was higher. Although this explanation is an hypothesis, there is no doubt that it is not only necessary to detect a lower threshold for cortical evoked potentials, it is also necessary to demonstrate their stability for changes in criteria in order to resolve the problem of subliminal perception with evoked potentials.

In connection with the foregoing, it is also possible to cite the results of the study conducted by Rosner and Goff (1967) on somatosensory evoked potentials for near threshold stimuli. Using the method of minimal changes, the absolute psychophysical threshold and the threshold for the appearance of scalp-recorded evoked potentials were determined for eight healthy subjects during percutaneous electrical stimulation in the area of innervation for the median nerve.

The absolute, psychophysically defined thresholds were close both for the majority of the components of evoked potentials and for the responses of the peripheral nerve. At the same time, some components of the evoked potentials were detected for each of the subjects at a level slightly lower than the psychophysical threshold. The authors evaluated the latter case as a manifestation of the fact that the subject frequently sets the detection criterion somewhat higher than the level at which the nervous system responds to sensory input.

While simultaneously studying the thresholds for auditory evoked potentials and the absolute psychophysical thresholds of perception, a deviation was detected for these thresholds; the deviation was dependent upon the frequency of the tone presented. The threshold for the appearance of the evoked potential was 10 db higher than the psychophysical threshold for 250 and 500 hz tones and 20-22 db higher for 4,000 and 6,000 hz tones (Henderson, 1972).

2.3. Evoked Potentials and the Probability Characteristics of Stimulation

The first study of changes in evoked potentials in relation to the probability of a stimulus being presented in a given sequence of stimuli was conducted in 1965 by Sutton and his coworkers. They recorded evoked potentials for sound and light. The stimuli were presented in pairs: a warning stimulus and a test stimulus. The interval within a pair was 3-5 seconds. Two series were conducted: in one, either light or sound always followed the warning signal; in the other, either light or sound had a certain probability of following the warning signal. Special schedules were used which ensured the random presentation of the test signals for the given probability. The evoked potentials for sound were compared for the first ("definite") and second ("indefinite") series. The greatest difference was discovered in the late positive fluctuation with a latent period of approximately 300 milliseconds: the amplitude was higher in the "indefinite" series. A comparison of evoked potentials for stimuli with different probabilities (0.3 and 0.7) showed that the amplitude of the late positive fluctuation was higher for the less probable stimulus.

In a third series of experiments, the subjects had to guess what would be presented next: sound or light. Sound and light were presented on a random basis with a probability of 0.5; the evoked potentials for correct guesses and the evoked potentials for mistakes were summed separately. The amplitude of the late positive fluctuation was higher for mistakes in predictions. The difference in the amplitude of "guessed" and "unguessed" evoked potentials changed due to the effect of the probability of the

stimuli, the frame in play, the sequence of correct and incorrect guesses and the physical parameters of the stimuli presented. All of the factors listed had a slight effect on the early components. An analysis of the evoked potentials recorded for sound and light led the authors to conclude that the positive fluctuation with a latent period of approximately 300 milliseconds which changed in the above studies is not specific to a modality. It turned out that if the evoked potentials for sound and light are "made more complicated" with large negative fluctuations (a latent period of 110 milliseconds for sound and 150 milliseconds for light), it was found that the latent positive fluctuation appeared 190 milliseconds after the negative fluctuation and it was the same for light and sound.

In their subsequent work, Sutton et al (1967) showed that the changes described in evoked potentials due to probability cannot be explained by changes in attention and that the evoked potentials reflect in some manner the information characteristics of the stimuli presented. The work is called: "Information Delivery and Sensory Evoked Potential." Evoked potentials were recorded in response to individual or paired (with an interval of 180 milliseconds) clicks in a situation where the subject knew ahead of time which (individual or paired) sound would follow during the guessing (a subject game).

It turned out that a pronounced positive fluctuation appeared in the game situation after the second sound; this fluctuation was not present when the subject knew about the signal to be expected. The positive fluctuation also appeared in those cases where there was no second sound. Its latent period corresponded to the time when the second sound should have been presented if a paired signal had been presented. If the interval between the paired sounds was increased, the positive fluctuation appeared with a correspondingly large latent period. The authors concluded that the latent period of the positive fluctuation is related to the time that uncertainty is removed.

This was also confirmed in another series of experiments. The subjects were presented the same random sequence of individual and paired signals which could be low or loud. The evoked potentials were summed for the same physical signals in two different situations: the subjects had to guess whether a low or loud sound would follow (it was not important whether it was individual or paired), or conversely they had to guess whether an individual or a paired sound would be presented irrespective of the volume. The intervals between sounds in a pair were constant. In the first case, a pronounced positive fluctuation only appeared after the first sound (the first sound was sufficient for information on the volume since the volume within a pair did not change);

in the second case, the fluctuation primarily became pronounced after the second sound or, in the case of individual sounds (somewhat lower in amplitude), after the time when it should have been presented.

Thus, it was demonstrated that the latent period of the positive fluctuation is not a function of the sound itself but of the time when the sound should be presented, that is, the time that uncertainty is removed. Consequently, the absence of the event can also serve as a stimulus. In this case, the amplitude of the positive fluctuation described is evidently lower due to the time dispersion when summing and averaging the evoked potentials (the inaccuracy of "internal time"). The authors concluded that the positive fluctuation described is a reflection of the process of obtaining information regardless of whether it is related to the presence or absence of the stimulus. The appearance of evoked potentials at the time when the stimulus should have been presented but is not presented was also demonstrated in the study by Klinke et al (1969). A rhythmic stimulation was presented; the stimuli were skipped now and then; the EEG segments were summed and averaged immediately after the time when the stimulus should have been presented but wasn't. The P 300 fluctuation was the most pronounced component in the recorded evoked potentials.

In the study by Weinberg et al (1970), the appearance (at a time when the stimulus was expected but was not presented) of an evoked potential very similar in form to the evoked potential caused by the stimulus expected was shown (as recorded directly from the brain).

So that the difficulties in using evoked potentials (variation, extracerebral "mixtures," the obscurity in the genesis and functional role of individual components, etc.) will not cause a pessimistic attitude toward the possibility of utilizing this method in psychophysics, it is worth emphasizing that evoked potentials probably do not vary any more than the subjects' oral responses which are used as the basic index of the activity of sensory systems in psychophysics. Success depends upon the ingenuity and success in searching for methods to process the data and "extract" the necessary information from the recordings of fluctuations in potential, just as it did during the development of classical psychophysical methods.

It should be taken into account ahead of time that the changes in the amplitude of evoked potentials on the scalp due to any variables do not necessarily correspond precisely to the changes which can be recorded directly in a particular section of the nervous system for processing sensory information. This is one of the possible sources of the ambiguity and complexity in the

relationships discovered, specifically, the discrepancy in the relationship between the intensity of the amplitude of evoked potential on the one hand, and the subjective sensation (evaluation) of intensity, on the other.

The possibility of the further use of evoked potentials in psychophysics depends upon the progress in knowledge on their morphofunctional nature. A sufficiently in-depth knowledge of the existing concepts, an understanding of their incomplete nature and contradictory or ambiguous cases and a further, creative solution to issues, such as methods for evaluating and analyzing evoked potentials, are required for productive use of evoked potentials.

In light of today's knowledge on the nature of evoked potentials and the experimental data on the correlation between several characteristics of evoked potentials and mental processes, their use appears possible and promising in several areas.

First, evoked potentials can be used as a response index for certain sections of the central nervous system (this is necessary both for studying the problems of subliminal perception and for the threshold problem--evoked potentials are an additional indicator of the nervous system's response and they are an index of sensitivity).

Second, using evoked potentials as an index of the participation (degree of inclusion) of extrasensory factors in the operation of sensory systems is at least as valuable today, if not more so. This index is primarily needed to exclude variables relating to extrasensory factors or to hold them constant while studying the characteristics of the sensory system itself (as it is viewed in modern psychophysics). In addition, evoked potentials may be a valuable instrument in studying the physiological mechanisms of the effect of extrasensory factors. The presence of data on the relationship between the characteristics of bioelectrical activity preceding a near threshold signal and success in detecting the signal (McAdam, Rubin, 1971), the correlation between evoked potentials and success in signal discrimination, the change in the correlation as the activity indices are increased (Jannes, 1971; Wilson, 1973) and similar works are raising hopes for success in this field.

The discovery of the evoked potentials which appear without any external stimulus at the time when the stimulus is expected with a sufficiently high level of probability promises new opportunities in understanding and studying extrasensory factors.

An analysis of the current work which shows changes in evoked potentials due to the probability characteristics of the stimulus sequence and due to the discrimination and detection tasks and further research in this area are of interest for a comparison with the concepts "guessing," "false alarm," "decision making criteria," etc.--concepts which have arisen within the framework of a number of existing signal detection theories--and for an analysis of possible physiological mechanisms for the phenomena being studied.

The following can be noted in relation to signal detection theories. All current signal detection theories isolate the sensory system itself--with its relatively stable characteristics (sensitivity, resolution, range of perceived stimuli, etc.)--and the "observer"--a certain extrasensory system which uses the results of analysis conducted by the sensory system in accordance with the task and past experience (decision making criteria, centrifugal effects on the sensory organs, etc.). To what extent is this "observer" related to conscious perception?

In 1966, Jasper raised the same issue in neurophysiology in a different form: "Is there an anatomically independent neural system with a definite central location, with broad functional relationships to all the cerebral sections, which is switched on by the conscious perception to select patterns of neural activity from the instantaneously, constantly changing patterns, in contrast to a system which is constantly turned on to the information processes which are not perceived and which carries out the automatic movements?"

In the opinion of Goff--the author of a number of basic works on the nature of evoked potentials--"the characteristics of the late components of evoked potentials lead to the idea that they may reflect the activity of such a neural system."

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Human Detection and Identification of Complex Acoustic Signals

Yu. M. Zabrodin

1. Research Goals and Methods

1.1. Research Goals

In modern experimental psychophysical research, there is a large class of experiments which study the thresholds for receiving and processing simple signals. Moreover, the experimental situation is usually set up in such a manner that a single physical characteristic of the signal changes (for example, intensity, frequency range, form, duration, spatial location, etc.). All other signal characteristics or parameters remain unchanged.

At the same time, the problem of research on the features of reception and primary processing of complex, multidimensional signals (their detection, discrimination and evaluation) is studied a great deal less. It is clear that this problem is sufficiently important since it is the next (after research on unidimensional signals) logical step in solving the problems of selecting a descriptive method for actual, incoming signals, on the characteristics of their subjective reflection and on the organization of the mental processes which support reception and processing of information arriving as input for the sensory systems and which support decision making and implementation.

The structure and special features of sensory and perceptual processes--which represent different aspects for perceiving actual signals--are easily shown in modes of activity which are primarily related to signal reception and to accomplishing simple tasks of observation.

The following four modes are presently accepted: detection, discrimination, classification and identification. The modes listed primarily differ from each other by the task which the individual accomplishes during the process of receiving information. This leads to a difference in the structure and

dynamics of the corresponding sensory and perceptual processes and to a difference in the interaction between these processes and other mental structures (B. F. Lomov, 1966; V. K. Gayda, T. M. Gushcheva, Yu. M. Zabrodin, T. P. Zinchenko, 1971).

Current applied experimental research on receiving and processing multidimensional signals is devoted to studying the sensitivity and resolution of human sensory and perceptual systems when receiving a stream of signals with a complex structure and which are internally consistent and coherent and which carry a semantic load (for example, complex systems of visual codes and signs, oral speech signals, radiotelephone codes, etc.). Moreover, the analysis of the resolution of human sensory systems is not only sharply complicated by the increase in the complexity of the signals themselves but also by including semantic aspects of the cognitive processes--aspects which are not easily subjected to measurement and quantitative analysis--in sensory and perceptual activity.

Our goal is an experimental study of the detection and identification of complex, multidimensional signals by reducing their semantic load as much as possible. This study should uncover specific approaches for developing psychophysical methods of measuring the thresholds of multidimensional stimuli and it should also evaluate the possible effects of individual parameters in the structure of multidimensional signals on human threshold characteristics. During the first phase of the work, our goal was to evaluate certain of the general and most important principles for detecting multidimensional signals based on the example of human detection and identification of complex acoustic signals. This article presents the results of this phase of our study.

The experiments were conducted under the author's direction at the School of Psychology of Leningrad State University in 1970-72. V. I. Zabotina, V. B. Zelenskiy, S. Ya. Molchanova, L. M. Solovova and students I. Timofeyeva, Ye. Bogdanskaya, Ye. Piyevskaya and B. Gribkov participated in the work.

1.2. Research Methods

We selected random (Poisson) streams of nonsense syllables with different phonetic structures as material for the stimuli. The following were selected as variable parameters of the stream: stream density and intensity; signal/noise ratio; the intensity, duration and similarity of the individual signals making up the stream; the probability of a significant signal appearing and the probability of its visual reinforcement.

The research methods were a modified version of the constant stimuli method. Significant signals were presented against a background of homogeneous and heterogeneous noise. Detection was accomplished based on stored standards.

Although we shall employ the term "detection" to designate a mode of the subject's operation in the subsequent description and discussion of results, it is necessary to point out that the experimental method we have adopted differs in some ways from the current psychophysical experimental studies of the detection process as the first stage in receiving information. Our research actually studies the process of receiving a stream of complex signals; signal detection and identification occurs within this process. If the experimental conditions for the subjects in our experiment are compared with the previously cited classification of modes, it is possible to state that, in a certain sense, our method of organizing the experiment represents an intermediate version between the methods for studying the processes of classification and identification. Our explanation for this is as follows.

As is well known, during classification, a signal is isolated by comparing it with a single standard which is either objectively present or recorded in the observer's memory and the response is usually formed according to the "yes-no" system.

In our method, the subject had to isolate a signal if it coincided with one of six different signals stored in his memory. He was not required to respond to the appearance of insignificant signals (i.e., those which did not match the standards). Thus, just as in signal identification, the subject's response was basically formed according to the "yes-no" system but it had the special feature that the subject refrained from responding when an insignificant signal appeared and when noise alone appeared. Our subjects' actions thereby approximated the work of an actual observer.

During signal identification, the observer usually has to classify each newly appearing signal according to a certain system and relate it to the appropriate class or number in the signal index. In special cases, identification requires a complete description of each signal in terms of the language code of the actual object (R. Luce, R. Bush, E. Galanter, 1963).

In our experiments, the subject also had to deal with a number of signals; although six different standards corresponding to the signals were stored in the subject's memory, he was required to relate them to a single class--significant signals--and the subject responded to all significant signals with a single response--pressing the "signal" button.

The evaluation of the results of the observer's operations was conducted according to the currently generally accepted indices of detection efficiency: the reaction time for correctly detecting it, the probability of correct detection and the probability of a false alarm.

Twenty subjects participated in the experiments.

2. The Effect of Signal Stream Characteristics on Detection Efficiency

2.1. The effect of Signal Stream Density on Detection Characteristics

It has been known for a long time in psychophysics, experimental psychology and engineering psychology that reaction time, or signal processing time, increases with an increase in the number of different signals being processed. The relationship between reaction time and the number of alternatives or between signal processing time and the amount of information contained in them is described in many sources (see, for example, B. F. Lomov, 1966; K. Morgan, D. Cook, A. Chapanis, M. Land, 1971). The basic result consists of the fact that reaction time depends upon the number of different, equally probable signals being processed in the following manner: $t_p = c \lg (n+1) + T_m$, (2.1.1)

where T_m is the time for making the response (0.15-0.2 sec.); c is an emperical constant (0.3-0.6 sec.); n is the number of (different) signals being processed.

Considering the fact that human throughput capacity changes within very broad limits for different tasks in processing information--from 2 to 70 bits/sec--and also the fact that it is difficult for an individual to evaluate the level of information for complex signals, it is possible--using expression (2.1.1)--to approximately calculate the maximum density of the stream of acoustic signals which we are interested in and which is within human processing capabilities.

Let a stream of acoustic signals proceed to the observer. Then, the time during which the observer can process the signal which has arrived will be: $t_{обр} = \frac{1-\tau_s}{n}$, (2.1.2)
where τ_s is the minimal signal duration required (according to studies by students of psychoacoustics, it is 0.15-0.3 sec. for our signals), n is the number of signals per sec.

It is obvious that for the limiting case, when working with an ideal observer with a small number of recorded errors, the time calculated according to (2.1.2) must match the time calculated according to formula (2.1.1), i.e. $c\lg(n+1)+T_m=\frac{1-\tau_s}{n}$. (2.1.3)

After transposing and removing the logarithm sign, we obtain the following general expression from expression (2.1.3):

$$n+1=10^{-\frac{T_m}{c}}\cdot 10^{\frac{1-\tau_s}{nc}}. \quad (2.1.4)$$

We can solve equation (2.1.4) for an individual case which approximates the situation for detecting complex acoustic signals which we are interested in. Assume $T_m = 0.2$ sec., $c = 0.5$ sec., $\tau_s = 0.3$ sec. Then equation (2.1.4) takes the following form:

$$n+1=10^{-\frac{0.2}{0.5}}\cdot 10^{\frac{0.7}{n\cdot 0.5}}=10^{\frac{1.4}{n}-0.4}.$$

After computing, we get n = 1.68 signals/sec. or about 100 signals/min.

However, it is clear that continuous processing of a stream with a density of 100 different signals per min. is an extremely difficult (if not impossible) task for an individual. This then is the essence of the maximum value obtained. The value is, so to speak, an upper estimate of the observer's maximum capability.

We are interested in an average, real observer's maximum capability to process a signal stream; therefore, we undertook an experimental verification of this capability by using the density of 100 signals/min. as the theoretical maximum. A 15-minute acoustic test was selected for this verification; it was a random, Poisson-distributed signal stream in which signals were encountered which were a distance of no more than 0.6 sec. from each other (this time corresponds to the signal repetition period in a stream with a density of 100 signals/min.).

Hereafter, we will designate the interval between signals (in seconds) by τ ss.

In the different series of the experiment, five different tests were used with the following average values for signal stream density (per minute):

10 (τss $\leq$ 0.6 practically none),
20 (τss $\leq$ 0.6 at 0.71%),
30 (τss $\leq$ 0.6 at 1.8%),
40 (τss $\leq$ 0.6 at 5%),
50 (τss $\leq$ 0.6 at 12%).

The results of the experiment are presented in Figures 1-3 and Table 1. As can be seen, the number of signals processed begins to decline sharply as the density of the signal stream increases above 20-25 signals/min. In addition, note that, if the interval between signals was τ_{ss}= 0.6 sec., then the processing probability for the next signal was 0.1 according to the experimental data.

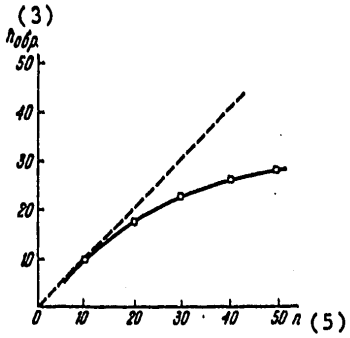

Figure 1. Relationship Between Number of Signals Processed and Number Presented (per minute).

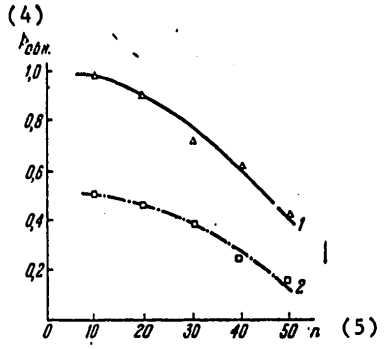

Figure 2. Relationship Between Signal Detection Probability (P_D) and Signal Stream Density (n).

Key:

1. Trained observer.
2. Untrained observer.
3. Number of signals processed.
4. Probability of detection.
5. Number of signals presented.

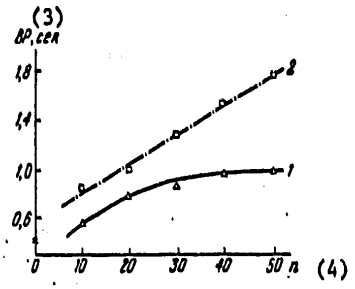

Figure 3. Relationship Between Reaction Time and Signal Stream Density.

Key:
1. Trained observer.
2. Untrained observer.
3. Reaction time.
4. Number of signals presented.

(1) Темп предъявления (плотность потока), сигналов/мин	(2) Количество обработанных, сигналов/мин	Вероятность обнаружения значимых сигналов в $P_{обн.}$ (3)		Время реакции ВР, сек. (6)	
		(4) тренированные испытуемые	(5) нетренированные испытуемые	(4) тренированные испытуемые	(5) нетренированные испытуемые
10	10	0,98	0,5	0,55	0,85
20	18,8	0,91	0,45	0,78	0,98
30	22,6	0,71	0,38	0,85	1,28
40	26	0,60	0,25	0,95	1,53
50	28	0,40	0,15	0,93	1,72

Table 1. Relationship Between Detection Efficiency Indices and Signal Stream Density, (Probability of False Alarm for All Experiments is 0.005.)

Key:
1. Rate of presentation (stream density), in signals/minute.
2. Number of signals processed, in signals/minute.
3. Detection probability for significant signals.
4. Trained subjects.
5. Untrained subjects.
6. Reaction time, seconds.

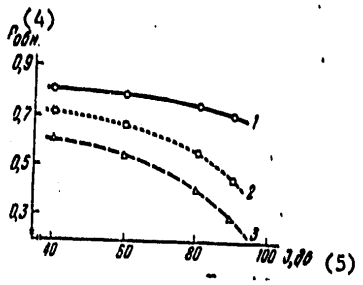

Figure 4. Relationship Between Signal Detection Probability and Average Stream Intensity for Signals with Different Intensities.

Key:
1. + 2 db.
2. - 4 db.
3. - 8 db.
4. Probability of detection
5. Decibels

The basic detection efficiency indices--the probability of correct detection (P_D in Table 1 and Figure 2) and detection reaction time (RT in Table 1 and Figure 3)--for trained and untrained subjects have an overall tendency to change but they are quantitatively significantly different. Thus, with an increase in sigr l stream density, the probability of correct detection for trained and untrained subjects declines--from 0.98 to 0.40 and from 0.5 to 0.15, respectively. The reaction time for both groups of subjects increases uniformly. This result accords well with the well known fact of the increase in reaction time when the observer's discriminatory capability declines and when the conditions of observation become worse (R. Shosholl', 1966).

At the same time, the detection probability for untrained observers is significantly lower (by an average of 0.35) while the reaction time is significantly greater. Moreover, the reaction time for untrained subjects increases almost linearly with the increase in signal stream density.

A different pattern is observed for trained observers. With a significant decline in the probability of detection and an increase in signal stream density, trained observers do not show

a constant linear increase in RT. When the density of the stream reaches 20-25 signals/min., there is an abrupt change in the linear increase for the RT curve.

Within a range of change for the stream density of 30-50 signals/min., the reaction time for trained observers remains almost constant. This phenomenon is somewhat unexpected and it is necessary to study it further experimentally.

The results of the experiment show that, as the signal stream increases higher than 20-25 signals/min., there is a decline in the observer's work efficiency, both in the number of signals processed and in the indices for the probability of correct detection and reaction time. The decline in the detection probability is similar in nature for trained and untrained subjects but the detection probability is significantly higher for trained observers. The difference in reaction time between trained and untrained subjects conforms to another principle. Moreover, the crest in the RT curve for trained subjects is observed for approximately the same stream density of 20-25 signals/min., at which the first noticeable change occurs in the number of signals processed versus the number of signals arriving. An approximate, experimental estimate of the threshold signal stream density for $P_D = 0.5$ is 40-50 signals/min.

2.2. The Effect of Signal Stream Intensity on Detection Efficiency

According to the widely known Weber's Law, there is a definite relationship between the level of the value for discrimination and initial stimulus intensity. If both values are expressed in a single physical dimension, this relationship is recorded in the following manner (S. Stivens, 1960): $\delta = \frac{\Delta I}{I} = \text{const}, \quad (2.2.1)$

where δ is Weber's fraction (by definition); ΔI is the value for the increase in the variable stimulus which is caused by the just noticeable changes in sensation; I is the intensity of the initial or standard stimulus.

Imagine that we have conducted an experiment to determine the differential threshold of the sensory system's sensitivity. Based on the data from this experiment, we calculated that the value of the differential threshold for stimulus I_1 is equal to ΔI_1 . Assume that we selected a value for the standard stimulus I_1 in such a manner that this stimulus would cause a sensation whose intensity would be located somewhere in the lower part of the middle zone of the sensation range. Then, we begin to change the value of the standard stimulus so that

I_2 $I_2 >$ I_1, etc. and we viewed values obtained as standards in determining the new differential thresholds. Moreover, we discovered that the stimuli which differ from the standard by the value ΔI_1, were becoming less and less different since the value of the relative difference $\gamma = \Delta I_1 / I$ was being reduced. This fact follows directly from Weber's Law since the value of γ will be less than the value of Weber's fraction which describes the threshold value in relation to the difference:

$$\gamma = \frac{\Delta I_1}{I} < \delta = \frac{\Delta I_1}{I_1}, \text{ если } I > I_1 \quad \text{(if)} \qquad (2.2.2)$$

The result noted in expression (2.2.2) remains true for a large area of sensation in the middle and upper ranges of intensity since it is well known that the value of Weber's fraction is constant (and least) precisely in the middle range of sensation intensity. Thus, in the situation described, we should observe a uniform decline in the probability of detection when stimulus intensity increases.

The experimental verification of this proposition was conducted as follows: a random stream of signals was made up; its intensity could change in fixed gradations of 2 db within a range of $\pm$ 10 db from the stream's average intensity. Within this range, the gradations of intensity had an equal probability of occuring. The sequence of arrival for signals with different intensities was random. The energy distribution for the entire signal stream conforms to (Reley's) Law. The average level of the signal stream served as a point of reference fo. the initial intensity (the analog of value I in expression 2.2.2).

Three signal gradations were selected for the analysis: 2 db higher; 4 and 8 db lower than the initial level of intensity. In addition, average detection results for all signals within $\pm$ 10 db of the initial level were estimated. Five different versions of values for the stream's average level of intensity were studied: four fixed (stationary) levels of 40, 60, 80, 90 db and one dynamic (movable)--with the level being adjusted by the subject himself so that it was convenient for the observer. Moreover, the relative position of signals on the intensity axis was not changed.

The results of the experiment are presented in Table 2 and Figures 4 and 5. The results show that detection efficiency declines significantly when the average (stationary) level of signal stream intensity (for all signals) is increased. Moreover, the average reaction time increases and this also confirms the well known result (R. Shosholl', 1966) on the inverse relationship between the probability of correct responses and reaction time during a change in the relative difference between signals. Unfortunately, the data obtained were

not sufficient to calculate precise parameters for the relationship between detection probabilities and relative signal differences for changes in the initial level of intensity.

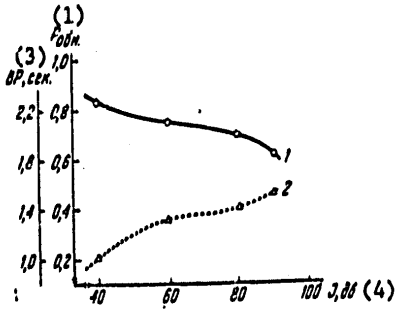

Figure 5. Relationship Between Detection Probability Reaction Time and Average Stream Intensity.

Key:
1. Detection probability (P_D).
2. Average reaction time (RT)
3. RT, in seconds.
4. Intensity (I), in decibels.

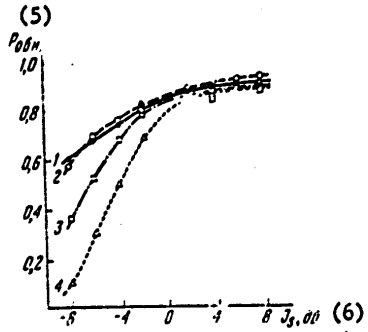

Figure 6. Relationship Between Detection Probability and Signal Intensity for Different Signal Noise Ratios (Psychometric Curve)

Key:
1. ∞
2. 3:1.
3. 2:1.
4. 1:1
5. Detection probability (P_D).
6. Signal intensity (I_S), in decibels.

Table 2. Relationship Between Detection Efficiency Indices and Average Signal Stream Intensity (Probability of False Alarms is 0.005 for All Experiments).

(1) Средняя интенсивность потока сигналов, об	(3) Интенсивность сигнала (об) относительно средней интенсивности потока			(4) Среднее значение по всем сигналам	
	−8	−4	+2	(5) вероятность обнаружения $P_{обн.}$	(6) время реакции ВР, сек.
(2) Саморегулировка	0,60	0,88	0,95	0,95	1,25
40	0,62	0,73	0,82	0,85	1,08
60	0,56	0,67	0,78	0,77	1,35
80	0,42	0,57	0,75	0,72	1,42
90	0,30	0,45	0,72	0,68	1,56

Key:
1. Average signal stream intensity, in db.
2. Self-regulated.
3. Signal intensity (db) in relation to average stream intensity.
4. Average value for all signals.
5. Detection probability (P_D).
6. Reaction time (RT), in sec.

Nevertheless, the result is not quite normal. We assumed that the detection probability within this range should not change significantly since the relative difference between signals measured on a decibel scale does not change when the average level of signal stream intensity is changed. The analog of Weber's fraction which was calculated for this case also does not change. Nevertheless, the detection probability declines as if formula (2.2.2) is correct, i.e., as if there was a change in the relative difference between signals. It follows from this that either Weber's Law does not operate in this range of changes for complex signals (from 40 to 90 db) or the relative difference between signals does not remain subjectively constant.

It is also necessary to dwell on the results obtained for the variable level of signal stream input intensity. As seen from Table 2, the probability of correct detection was the highest when the subject regulated the level himself. It would be logical to assume that the subjects worked at average stream intensities less than 40 db in this case. However, this is not so. During the course of the experiment, we had the opportunity--with a special device--to record the current level of intensity for the input stream and its dynamics when regulated by the

subject himself. It turned out that this level never dropped below 40 db and never raised above 80 db. Moreover, all 20 subjects who participated in the experiments changed the level of intensity for the stream within very broad limits in this range during the experiment. The individual strategies were extremely diverse both for the initial arrangement and for the dynamically regulated level.

2.3. The Effect of the Signal/Noise Ratio on Detection Characteristics

According to the logic of the preceding paragraph and based on purely physical concepts, it is clear that the relative difference in $\mathcal{D}$ can be dependent upon the characteristics of noise or interference and, primarily, upon the signal/noise ratio in the signal stream. The effect of noise on detecting and discriminating simple signals has been described in the works by J. Swets, V. Tanner and T. Birdsall (1964), D. Green and J. Swets (1966), V. Tanner (1967), K. V. Bardin and Yu. M. Zabrodin (1969, 1972) and others. At this point, we are primarily interested in the effect of the intensity of noise on the detection efficiency indices for complex acoustic signals. In the majority of cases--as was revealed in the research on visual forms--complex signals are more efficiently discriminated and identified (see, for example, V. Gayda et al, 1971).

In our experiment, the signal/noise ratio was considered as the relationship between the average signal stream intensity and the average white Gaussian noise intensity within the 50-10,000 hz range. Four gradations were selected for the signal/noise ratio-- ∞ (no noise); 3:1; 2:1; 1:1.

The results of the experiments are presented in Table 3 and Figure 6. The results show that a decrease in the signal/noise ratio reduces detection efficiency: the probability of correct detection falls from 0.84 to 0.62 when the signal/noise ratio is changed by 10 db, i.e., from 3:1 to 1:1. It can be seen from Figure 6 that the psychometric curves (the relationship between the probability of a correct response and signal intensity) drops sharply as the noise intensity is increased, especially in the area for the weakest signals. It can also be seen that a significant reduction in the probability of correct responses only occurs when signals are detected whose intensity is lower than the average stream intensity. The detection of signals whose intensity is higher than the average stream intensity (in Figure 6, the signals with a positive value for intensity in decibels) practically remains at the previous level. Moreover, as can be noted, the detection threshold increases and signals 4-6 db lower than the average stream intensity level become threshold signals.

Table 3. Relationship Between Detection Efficiency Indices and Signal/Noise Ratio

Соотношение сигнал/шум	Интенсивность сигнала (дб) относительно среднего уровня интенсивности потока								Средняя величина для всех сигналов		
	−8	−6	−4	−2	+2	+4	+6	+8	$P_{обн.}$	$P_{лт}$	ВР, сек.
∞	0,58	0,70	0,75	0,82	0,85	0,81	0,92	0,93	0,78	0,005	1,02
3:1	0,51	0,67	0,72	0,84	0,86	0,88	0,90	0,92	0,81	0,002	1,25
2:1	0,38	0,54	0,68	0,80	0,85	0,87	0,89	0,91	0,78	0,017	1,40
1:1	0,111	0,32	0,52	0,67	0,81	0,88	0,89	0,90	0,62	0,02	1,78

Key:
1. Signal/noise ratio.
2. Signal intensity (db) in relation to the average level of stream intensity.
3. Average value for all signals.
4. Detection probability (P_D).
5. Probability of false alarms (P_{FA}).
6. Reaction time (RT), in seconds.

As can be seen from Table 3, when the observer is working with weak noise (a signal/noise ratio of 3:1), the detection efficiency indices are on the average higher than when he is working with noise (confidence level is $p \leq 0.05$). A similar improvement in detection efficiency has also been observed in other studies in engineering psychology and experimental psychology.

The experimental fact of a possible shift in the observer's criterion for small signal/noise ratios which we observed can be considered a very important result. (A definition of the observer's criterion as the dividing line for the intersection of the characteristics of detected and undetected signals is provided in the works by J. Swets, V. Tanner, T. Birdsall, 1964; and K. V. Bardin's article in this collection.) The criterion shift can be illustrated by the increase in the probability of false alarms with a simultaneous reduction in the probability of correct detection when the signal/noise ratio changes by 10 db--from 3:1 to 1:1 (see Figure 9, curve 1).

This dynamic relationship between the probability of correct detection and the probability of false alarms also experimentally demonstrates that there is a certain reduction in the

observer's sensory ability within the range being studied.

A comparison of the results presented in Tables 2 and 3 shows that a 10 db change in the signal/noise ratio has a significantly greater effect on the change in the probability of correct detection than the same 10 db change in the average signal stream intensity has within the most unfavorable range (from 80 to 90 db). This change in the probability of correct detection = 0.22 for the signal/noise ratio change and 0.05 for the change in the average intensity of the stream; the differences are significant at a level $p \leq 0.01$. The second difference in the results presented in Tables 2 and 3 consists of the fact that a change in signal stream intensity which reduces the indices for the probability of correct detection and reaction time does not change the value for the probability of false alarms. A change in the noise level leads to a decrease in all three indices for detection efficiency. This fact requires a theoretical explanation.

3. The Effect of Internal Acoustic Signal Characteristics on the Efficiency of Their Detection

In the previous sections, we stated that the random stream used as the basic material for the stimulus in our experiments was composed of signals which differed in their physical characteristics.

We used a set of 2,000 nonsense syllables for the signals which made up the stream; they primarily differed from each other in phonetic structure. In addition, the signals had different intensities within a $\pm$ 10 db range of the average level of stream intensity. Within this range, ten gradations of intensity with intervals of 2 db were selected. The intensity of each syllable could take any of these ten values. Furthermore, the duration of each signal could take any of ten fixed values within a range of 1 to 10 arbitrary units. This range was within the limits of 0.3 to 3 sec. on a real-time scale for a stream with an average density of 30 signals/min. Finally, four values were used in our experiments for the probability of a significant signal's appearance (P_s = 0.01; 0.05; 0.10; 0.20) and four values were used for the probability of reinforcing the significant signal with a simultaneous flash of light (P_r = 0.0; 0.50; 0.80; 1.0). Twenty subjects--experienced observers--participated in the experiment.

The results of the experimental research in this section make it possible to evaluate the general principles for the effect of the isolated signal characteristics on efficiency indices for their detection.

3.1. Detecting Signals with Different Intensities

The experiments being described used acoustic signals whose intensity changed within a 20 db range (± 10 db from the average level of the signal stream intensity). We selected 10 gradations of 2 db intensity each. This selection made it possible to evaluate certain features for detecting signals whose relative position remained unchanged on the intensity scale both when the overall level for the stream was changed and when white Gaussian noise was added.

The results of the experimental study are shown in Tables 4 and 5 and Figure 7. These results show that, when there is a change in signal intensity, the curve for the probability of correct detection is like a normal S-shaped psychometric curve. With a reduction in the signal/noise ration, i.e., as the conditions of observation become worse, the psychometric curve shifts to the right along the axis of intensity and its slope increases during this shift. If the signal/noise ratio = 1:1--which corresponds to curve 2 in Figure 7--for the conditons of observation, then the value of the detection threshold measured at the level where $P_D = 0.5$ is -4.2 db. This means that the threshold signals have an intensity 4.2 db lower than the average level of signal stream intensity. In the absence of noise, all the signals in the selected range of intensity changes are above threshold signals. This means that an increase in the detection threshold is observed when noise is present.

Table 4. Relationship Between the Probability of Correct Detection and Significant Signal Intensity (P_{FA} - 0.005 when there is no noise; P_{FA} - 0.01 for a signal/noise ratio of 1:1.)

(1) Условия эксперимента	(2) Интенсивность сигнала (*дб*) относительно среднего уровня интенсивности потока								
	−8	−6	−4	−2	0	+2	+4	+6	+8
Без шума (3)	0,58	0,70	0,75	0,78	0,82	0,85	0,89	0,92	0,95
Сигнал/шум (4) 1:1	0,11	0,32	0,52	0,65	0,80	0,83	0,87	0,89	0,93

Key:
1. Experimental conditions.
2. Signal intensity (db) in relation to the average level of stream intensity.
3. Without noise.
4. 1:1 signal/noise.

Table 5. Relationship Between Reaction Time and Significant Signal Intensity.

(1) Условия эксперимента	(2) Интенсивность сигнала (db) относительно среднего уровня интенсивности порога								
	−8	−6	−4	−2	0	+2	+4	+6	+8
Без шума (3)	1,76	1,68	1,56	1,53	1,35	1,30	1,21	1,16	1,12
Сигнал/шум (4) 1:1	1,72	1,76	1,78	1,83	1,68	1,53	1,513	1,51	1,51

Key:

1. Experimental conditions.
2. Signal intensity (db) in relation to the average level of stream intensity.
3. Without noise.
4. 1:1 signal/noise.

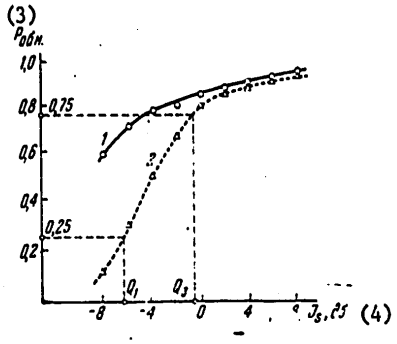

Figure 7. Relationship Between Detection Probability and Signal Intensity. (Psychometric Curve)

Key:

1. Without noise.
2. With noise.
3. Detection probability (P_D).
4. Signal intensity, in db.

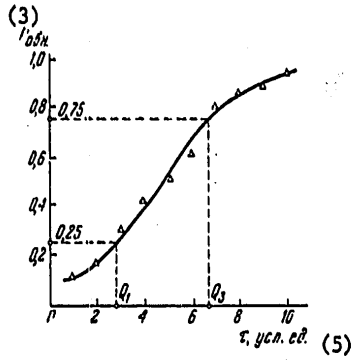

Figure 8. Relationship Between Signal Detection Probability and Duration (each division on the abscissa is 0.3 sec.).

Key:
1. Without noise.
2. With noise.
3. Detection probability (P_D).
4. Intensity in arbitrary units.

The standard deviation for correct detection responses, which is proposed by certain researchers as a measure of sensitivity (Gilford, 1954), can be calculated in the following manner:

$$\sigma \cong 1{,}5 \cdot \frac{Q_3 - Q_1}{2} = \frac{-0{,}5 + 6{,}5}{2} \cdot 1{,}5 = 4{,}5\,\partial\delta \qquad (3.1.1)$$

In expression (3.1.1), Q_3 and Q_1 correspond to the third and first quartiles of the psychometric curve (see Figure 7).

The good match between the threshold value (4.2 db) and the value for the standard deviation of the psychometric curve (4.5 db) can be pointed out. We can see that the psychometric curve shifts to the left along the abscissa toward the lower values for the intensity of detected signals as the signal/noise ratio increases. At the same time, its slope decreases and, consequently, the standard deviation of the psychometric curve increases.

The curve for reaction time when signals with different intensities are detected has a somewhat unusual appearance. A deviation from the well known inverse relationship between detection

and discrimination reaction time and the value of the difference between signals in the threshold zone is observed. The greatest deviation and even, contrary to the expected decrease, a certain increase in reaction time for correct detection was noted in our experiment in the area for signals whose intensity was 0; -2 db. Remember that the level of average intensity for the stream was selected as the initial reference level. Thus, the deviations noted experimentally by the observed curve for reaction time correspond to signals very close to this level.

This result is not easily explained. It is possible that, when working with signals close to the average level of intensity for the stream, the observer begins to experience some doubt in the correctness of his actions. These doubts may not be reflected in the value for the probability of correct detection but they may objectively manifest themselves as an increase in reaction time. Such an experimental case was recorded, for example, by K. V. Bardin (1968). It is also possible that the observer somehow reorganizes his detection strategy when approaching the level of average intensity for the signal stream and this reorganization is objectively reflected by an increase in reaction time. In any case, the RT curves obtained are very similar to the multilevel curves for adaptive reorganization in the sensory system (Krakov, 1946).

3.2. The Effect of Signal Duration on Signal Detection Efficiency Indices

In Section 2.1, we stated that the duration of an acoustic signal is one of the most important factors in discriminating it. We were interested in the problem of within what limits can the duration of a complex acoustic signal (τ_s) have an effect on the human capability to detect it within a random stream of different signals with a sufficiently large density for the stream and with noise. In the experiment described below, the subjects had to detect acoustic signals with different durations (within 10 gradations in a stream with an average density of 30 signals/min. and an intensity of 60 db on a background of white Gaussian noise with a signal/noise ratio of 1:1. The intensity of the signals subject to detection was selected to equal the average intensity of the stream (0 db). Minimal signal duration was 0.3 sec. and maximum signal duration was 3 sec. The results of the experiment are shown in Table 6 (see also Figure 8).

It is possible to approximate a curve similar to the normal psychometric curve with the data obtained. However, a further clarification of the type of relationship obtained is required. Our results make it possible to draw a conclusion on the existence of the signal duration's definite effect on signal detection

Table 6. Relationship Between Signal Detection Probability and Signal Duration.

Длительность сигнала в усл. ед.	1	2	3	4	5	6	7	8	9	10
$P_{обн.}$	0,12	0,18	0,30	0,43	0,51	0,60	0,80	0,85	0,89	0,05

Key:
1. Signal duration in arbitrary units.
2. Detection Probability (P_D).

---

probability. Under conditions similar to ours, the threshold signal duration (determined for a detection probability P = 0.5) equals 4.5 arbitrary units which is about 1.5 sec. on a real time scale. A correction to the result obtained in Section 2.1 for the maximum density of the stream of different signals which an observer can process immediately follows from this.

Let's rewrite expression (2.1.4) and determine the value of the signal stream threshold density for our specific case using the parameters for this expression which were refined by our experiment.

$$n+1=10^{-\frac{T_m}{c}}\cdot 10^{\frac{1-\tau_0}{c\cdot n}}$$

Assuming that all the components of reaction time increase proportionally under the difficult conditions of detecting signals in a signal stream with noise, let's calculate the refined value for T'_m in the following manner:

$$T'_m=T_m\cdot\frac{t_{ш}}{t_0}, \qquad (3.2.1)$$

where T_m is an imperical constant whose value was selected as 0.2 sec. when calculating (2.1.4); $t_ш$ is the experimentally obtained average reaction time for detecting a signal with noise (a signal/noise ratio of 1:1); t_o is the average reaction time for detecting a signal when there is no noise.

Let's take the data on average reaction time from Table 3. Then:

$$T'_m=0{,}2\cdot\frac{1{,}78}{1{,}02}=0{,}35.$$

It is clear that if we want to calculate the value of n directly from expression (2.1.4), then we will encounter certain difficulties. Since τ_0, which is experimentally established, exceeds 1 sec., expression (2.1.4) loses its significance. Therefore,

for the convenience of our calculations, let's not determine n--which is by definition the number of signals per second--but the value n'--the average number of signals in 2 sec. Then, the modified formula for calculating the threshold density of the signal stream takes the following form:

$$n'+1=10^{-\frac{T_m'}{c}}\cdot 10^{\frac{2-\tau_s}{n'\cdot c}} \qquad (3.2.2)$$

Using (3.2.2), we can calculate the value of the threshold density of the stream for the average observer working under conditions similar to ours. After making T'_m = 0.35; c = 0.5 and = 1.5 sec., we get:

$$n'+1=10^{-0,7}\cdot 10^{\frac{0,5}{n'\cdot 0,5}}$$

or:

$$n'+1=10^{\frac{1}{n'}-0,7}$$

From the last expression it follows that n' = 1 or n = 30 signals/min.

If our assumption about the proportional change for all components of reaction time during correct detection is incorrect, then T'_m should not change significantly, i.e., $T_m' \approx T_m$.

After making T'_m = 0.2; c = 0.5; τ_s = 1.5 sec., expression (3.2.2) will look like this:

(3) $$n'+1=10^{-0,1}\cdot 10^{\frac{0,5}{n'\cdot 0,5}}$$

or:

(4) $$n'+1=10^{\frac{1}{n'}-0,4}.$$

After making the calculations, we will find that n' = 1.33; from this, it follows that n = 40 signals/min.

The results obtained for n make it possible to conclude that the threshold density of a signal stream for an average observer will be within 30-40 signals/min under conditions close to ours. The values of the threshold density for the signal stream which were calculated on the basis of the experimentally refined data are in good agreement with the results of the other experiment described in Section 2.1. This agreement between the calculated and experimental data confirms the reliability of the formula for calculating the threshold density of a stream for an average observer with previously determined empirical constants, the main one being τ_s.

3.3. The Effect of the Structural Similarity of Acoustic Signals on Signal Detection

The previous experiments have shown that the effect of basic signal characteristics on detection efficiency indices basically complies with the general principles established in the research

on simple signal detection. The significance of signal similarities in the detection process became the next issue for experimental study. We were interested in the effect of similarities between signals on certain detection efficiency indices, specifically, the probability of correct detection and the probability of false alarms. The following group of experiments was undertaken to study the special features of this effect. A stream of different signals with an average density of 30 signals/min. and a 60 db average level of intensity for the stream served as the material for the stimulus. The subjects had to detect the significant signals among the others in the stream on a background of white Gaussian noise (a signal/noise ratio of 1:1) and without noise. The significant signals (syllables like sgs) were selected to form three groups of equal value according to their physical characteristics (number of signals, average signal intensity, duration, etc.). The basic difference between the groups consisted of the degree of similarity in the phonetic structure of the signals within a group. The first group was made up of signals which had the greatest phonetic similarity. The first phonemes for these signals actually matched ("r" and "ya"). The third group was made up of signals with the maximum possible difference in their phonetic structure. The second, intermediate group united signals which had a sufficiently noticeable similarity in structure: signals with the same first phoneme ("r") were collected here. It is clear that the intragroup similarity was less pronounced in the second group than in the first. The difference in detection efficiency indices for each group of signals was studied independently for the same group of trained subjects. The results of the experiment are presented in Table 7 and Figure 9.

Table 7. Detection Efficiency Indices Related to the Degree of Structural Similarity for Signals.

(1) Степени сходства сигналов (группа)	(2) Работа без шума		Соотношение сигнал/шум 1:1 (5)	
	(3) $P_{обн}$	(4) $P_{лт}$	(3) $P_{обн}$	(4) $P_{лт}$
I	1	0,005	0,83	0,009
II	0,72	0,014	0,76	0,020
III	0,66	0,034	0,39	0,050

Key:

1. Degree of signal similarity (group).
2. Working without noise.
3. Detection probability (P_D).
4. Probability of false alarms (P_{FA}).
5. 1:1 Signal/noise ratio.

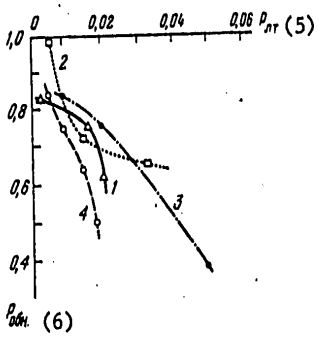

Figure 9. Receptor Operating Characteristics for Different Modes of Detection.

Key:

1. When the signal/noise ratio is changed.
2. For signals with different phonetic similarity without noise.
3. For signals with different phonetic similarity and a 1:1 signal/noise ratio.
4. When the probability of the signal appearing is changed.
5. Probability of false alarms.
6. Detection probability.

Since the isolated groups of signals do not have a clearly pronounced measure (estimate) of the degree of similarity, they are not depicted on a metric scale. The numbers corresponding to the groups only reflect the fact of their ordered nature according to the degree of intragroup similarity for signals. Thus, the difference between the groups is described by an ordinal scale and, therefore, it does not make any sense to make individual relationships between the detection efficiency indice and the value for phonetic similarity (or the number of the group). This can be explained in the following manner. It is normally accepted to estimate the characteristics of the observer's sensitivity according to a certain psychometric curve. The form and location of this curve makes it possible to find the basic indices of sensitivity--the threshold value and the standard deviation for correct detection responses. However, it is well known that an ordinal scale remains invariant for any uniform transformations. This means that, if we had attempted to construct a psychometric curve based on data measured according to an ordinal scale, we would have obtained any uniformly increasing function

as a result, for example, S-shaped, linear, logarithmic, step, etc.

From our point of view, it is of greater interest and greater significance to depict the results obtained in the form of receptor operating characteristics (ROC) since the experimental data acquire a certain graphic nature in this case and they can be compared to the experimental results described in Section 2.3.

It follows from Figure 9 that a gradual decline in the observers' ability to detect signals occurs as the degree of phonetic similarity for the signals changes from the maximum to the minimum (during the transition from signal group I to III). This is manifested in a decline in the probability of correct detection and a simultaneous increase in the probability of false alarms. According to theoretical concepts, this dynamic relationship between the probability of correct detection and the probability of false alarms may be related to the decline in the observer's sensory capability and the shift in the observer's criterion along the decision making axis.

The ROC curves in Figure 9 have a different curvature without noise (curve 2) and with noise (curve 3). Moreover, as the degree of similarity between these signals, which must be detected on the background of rather strong noise (curve 2), changes, the ROC curve is very reminiscent of the ROC curve for the change in signal/noise ratio as an overall characteristic of the signal stream (curve 1). Let's recall that curve 1 in Figure 9 illustrates the experimental results described in Section 2.3 (the curve is constructed based on the data from Table 3); in this experiment, the change in noise is the basic operative factor. It can be seen from Figure 9 that curve 1 also changes abruptly under the effect of noise.

In considering these results, it can be assumed that the form of the ROC changes in a certain manner under the effect of intensive, external noise and this form describes a reduction in detection capability. In any case, the upward curvature of the ROC most correctly explains the effect of noise. However, this conclusion requires additonal experimental verification.

The following can be pointed out regarding the form of curve 3 in Figure 9. It is well known that almost any signal, the totality of signals or a mixture of signal and noise can be geometrically represented as a certain point or as a limited volume in the appropriate multidimensional space (see, for example, J. Pierce, 1967). Moreover, it is natural to believe that a group of signals occupies a certain area in space which is made up of the combination of these volumes. Then, a geometric

interpretation of the observer's task in our case consists of defining the borders of this area and also the best method for defining the borders of the signals as certain volumes within the signal area.

With additional interference, the tasks become extremely complicated--it is necessary to thoroughly isolate the signal area from the nonsignal (interference) area and, only after this, is it possible to begin estimating the borders for the signal classes. With noise, all the enumerated borders are "washed out" and the areas do not yield to an unambiguous (correct) division, especially when, based on its characteristics, the interference is close to the borders of the signal classes. The task becomes even more complicated if the interrelationships between the signal classes within the signal area are not clearly defined. For practical purposes, in our case, the observer's task is somewhat simpler--it is enough to define the border or to separate the entire signal area from the area of interference. Moreover, the simpler and more compact the signal area is, the easier it is to detect signals. It can be assumed that groups of more similar signals are reflected in a more compact area or, in any case, in an area of smaller volume in the observer's subjective sensory space. This area can be relatively easily isolated from the area of interference. Groups of signals which have sharp differences in their properties may be reflected in areas which are poorly related to each other or they may even be reflected as isolated volumes. In the latter case, it is natural that the search for and detection of the borders of the areas or volumes may be extremely complicated and, consequently, the detection of the signals themselves may decline.

The discussion cited here is something of an attempt to explain these poorly studied phenomena. There is still not a lot of experimental data in this area and it is necessary to conduct a large number of experiments and accumulate factual data before proceeding to a theoretical synthesis. However, it seems to us that the research method presented here, which links the experimental results of signal detection for different degrees of similarity with the construction and analysis of the receptor operating characteristics, may significantly expand our concepts about the characteristics of the structure of subjective sensory space. The possibility of using more or less precise methods in analyzing the detection situation for nonmetric characteristics of input signals is very encouraging to us.

3.4. Evaluating the Effect of the Probability of the Signal Appearing on the Probability of Signal Detection

Changing the probability of a significant signal's appearance to study the special features for detecting this signal has been employed for a rather long time. Therefore, following tradition, we decided to verify whether the probability of the signal's appearance has any effect on the probability of its detection when working with complex acoustical signal streams. An experiment was conducted for this purpose; it included several series within which the probability of the significant signal's appearance was changed in accordance with the following gradations: 0.01; 0.05; 0.10; 0.20. The average signal stream density was equal to 30/min. The stream intensity was 60 db; the signal/noise ration was 1:1. The results of the experiments are presented in Table 8 and in Figures 9 (curve 4) and 10.

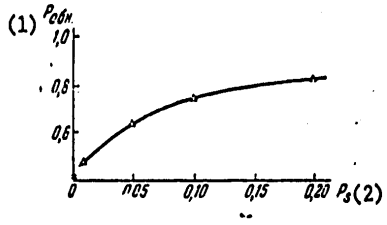

Figure 10. Relationship Between the Probability of Correct Detection and the Probability of the Signal's Appearance

Key:
1. Detection Probability.
2. Probability of appearance.

Table 8. Relationship Between Detection Efficiency Indices and Probability of Signal Appearance.

(1) $P_з$	0,01	0,05	0,1	0,2
(2) $P_{обн}$	0,49	0,64	0,75	0,83
(3) $P_{лт}$	0,017	0,015	0,008	0,005

Key:
1. Probability of appearance
2. Detection probability.
3. Probability of false alarms.

The experimental data showed that a nonlinear increase in the probability of correct detection (P_D) occurs as the probability of the significant signal's appearance (P_s) increases. The nature of the relationship noted between P_D and P_s can indicate a shift in the observer's criterion toward a lower value for the threshold when the probability of the significant signal's appearance increases. However, this shift does not completely agree with the well known results obtained for simple signals (J. Swets, V. Tanner, T. Birdsall, 1964). Curve 4 in Figure 9 depicts the receptor operating characteristic for a change in P_s. This ROC has an unusual appearance.

It is rather similar to the ROC curve constructed for the data from the experimental studies described in Sections 2.3 and 3.3. It could be thought that the ROC curves obtained as a result of our experiments reflect some kind of special features for detecting complex signals. However, such a conclusion may be premature since our ROC's were obtained for an extremely low probability of false alarms. The latter fact also makes it possible to assume that such an unusual appearance for the operating characteristics might be linked to an as yet unknown property of the observer's operations within a zone with a very low probability of errors like false alarms. A similar result could have been obtained for the ROC if the shift in criterion for a small number of false-alarm type errors had not been sufficiently compensated for.

3.5 Probability Reinforcement of the Significant Signal and Its Effect on Detection Efficiency Indices

As is well known, human sensory capabilities are limited. In experimental and applied psychology, it has become accepted to describe these limitations as different kinds of threshold or maximum characteristics of human sensory and perceptual systems. Thus, it is accepted to talk about the maximum throughput capability, absolute sensitivity thresholds, detection, discrimination and identification thresholds, etc. These maximum characteristics are usually examined in relation to the physical characteristics of streams of actual signals; the following are the most important of these physical characteristics: the spatial-temporal characteristics of the stream and the signals making up the stream; the probability structure of the signal stream; the amount of information transmitted; the intensity characteristics of the stream and the signals making up the stream; the level and nature of interference.

In the majority of studies, the maximum characteristics for sensory and perceptual systems are examined when signals directed at a single modality are being received.

Under real conditions, the individual is at the same time perceiving a number of simultaneously operating signals of different modalities. The practical tasks of receiving and processing information present a number of problems for psychologists and psychophysiologists, problems connected with studying the interaction among the analyzer's different systems. In connection with this, the problem of the special features of interaction and the mutual effect of the different systems of analyzers on each other (Krakov, 1948; Sokolov, 1958) and the special features of human sensory and perceptual organization (Anan'yev, 1970) is emerging.

The experimental work of psychophysiologists and psychologists, work which studies the joint activity of different sensory and perceptual systems, can be arbitrarily divided into several groups. Work strictly in the field of the psychophysiology of sensory systems can be placed in the first group. It studies the special operating features of each system and the changes in its characteristics effected by signals arriving at the input of other analyzers. The mechanisms for simultaneous functioning of different systems of analyzers are studied. Thus, it primarily studies changes in the sensitivity for signals of different modalities when signals of other modalities are operative (Krakov, 1948; Danilova, 1960; Steklova, 1959, and others). It is assumed that interaction among the analyzers takes place within the overall system of the directional reflex caused by the effect of these signals (Sokolov, 1958; Steklova, 1959). Moreover, it turns out that, under certain conditions, the functional characteristics of one of the analyzer systems can be increased by including other analyzers in the work.

The next group of studies is linked to a study of the possibility of concurrent human information reception when using signals of different modalities. This group of studies is linked to evaluating the conditons which make it possible to increase human throughput capability by increasing the amount of information being simultaneously (and independently) processed (for example, the works of Webster, Hazlerood, 1967; Dem'yanenko, 1958 and others). It has been shown that the so-called "integrated effect" can appear as insignificant interference to the primary activity in certain cases. However, the possibility of concurrent human information processing is extremely limited: the introduction of an additonal task frequently reduces the level of quality in carrying out the primary task.

The group of studies of greatest interest to us are linked to a study of the possibility of increasing human work efficiency when receiving information duplicated along several sensory channels. It has been proven, for example, that the reaction time for signals simultaneously appearing along two and three modalities (auditory, visual, tactile analyzer) are shorter

than the reaction time for the same signals individually (Shosholl', 1966; Bernstein, 1971). In addition, it has been shown that polymodal information duplication can significantly increase the efficiency of signal detection and identification. Signals arriving along several sensory channels can provide a more complete description of the state of the object being controlled.

Thus, in his research, Grishin (1968) studied the comparative efficiency (detection precision) for receiving audio-visual information: monomodal (purely acoustic) and bimodal (sound presented simultaneously with a dynamic spectrogram of it); the methods of presenting acoustic information were compared. The results of this study, which are partially presented in Table 9, make it possible to conclude that bimodal presentation of information makes it possible to sharply increase the detection and identification efficiency.

Table 9. Signal Detection Characteristics for Different Methods of Presenting Information (in percentages).

Способ предъявления	Тренированные испытуемые	Нетренированные испытуемые
Визуальный	59±7	62±13
Слуховой	30±6	22±12
Комплексный	89±6	97±5

Key:
1. Method of presentation
2. Visual
3. Auditory
4. Combined
5. Trained subjects
6. Untrained subjects

Similar data were obtained by Pomiluyko and Tutushkina (1972); they studied the problem of the efficiency for detecting new signals when visual information was presented by tachistoscope. Data from the study are partially presented in Table 10. In our terms, the first series is work without duplicating the visual information; the second series is speech duplication before the visual information appears; the third series is speech duplication when the data card appears with new signs. The results of the study show that duplicating information

actually does not reduce the time in searching for a first, new sign (t_1) but it significantly decreases the overall time in searching for new signs (t_2) and it reduces detection errors.

Table 10. Effect of Bimodal Information Presentation on Reaction Time and Number and Quality of Errors.

(1) № серии	(2) Время (сек.)		(3) Ошибки, %	
	t_1	t_2	(4) пропуск цели	(5) ложная тревога
I	3,34	9,25	13,2	16,0
II	3,16	7,70	6,8	8,8
III	3,27	7,46	9,2	9,4

Key:
1. Series number.
2. Time (in seconds).
3. Errors in percentages
4. Target misses.
5. False alarms.

At the same time, there are a number of works which cite data on the lack of any advantages for audio-visual information presentation over monomodal, specifically, in those cases where information is processed logically (see, for example, Devoe, 1966).

In summarizing the results for polysensory information presentation (polysensory information models), Filippov (1972) singles out different types of information models, specifically, those where the basic signal is duplicated by a signal of another modality. Moreover, the duplication can be continued either throughout the entire period for receiving and processing information or only during certain phases for receiving it.

In our study, we proposed to show how information duplication has an effect on the efficiency indices for detecting and identifying complex acoustical signals. We examined two versions of information duplication; multiple repetitions of a message along the same sensory channel (monomodal duplication) and information duplication along two sensory channels (bimodal duplication).

For monomodal duplication, we examined the problem of the effect of the number of signal repetitions on the efficiency in detecting it; for bimodal duplication, we studied the effect of the probability of reinforcing a significant signal in the auditory modality with a flash of light which appeared simultaneously at the outset of the significant signal.

The material used for a stimulus in these experiments and the basic design of the experiment were the same as in the previously described studies. A stream of Poisson-distributed nonsense syllables with an average value of 30 signals per minute arrived at the subject's earphones. During a single experimental series, the subject listened to a stream consisting of 1,000 different nonsense syllables with six significant signals among them. Each significant syllable appeared five times during the series. Detection and identification were accomplished based on standards stored in the memory. The subject had to detect the significant syllable on a background of white Gaussian noise and react by pressing the "signal" button. The following were the variable parameters in this experiment: number of signal repetitions; signal intensity; probability of reinforcing the significant syllable with a flash of light; the signal/noise ratio.

Data were obtained for a group of four trained subjects selected from 20 individuals who had participated in previous experiments. During the first series of experiments, the subjects accomplished their work under two different signal/noise ratios (S/N = 1:1 and S/N = 3:1) without any reinforcement for significant signals. In subsequent series, the signal/noise ratio was maintained at 3:1. The significant signals were reinforced by a simultaneous flash of light with a probability of 0.5; 0.8; 1.0. During the experiment, the same flash of light was used to reinforce 16 insignificant syllables randomly distributed in the signal stream primarily in order to focus the subject's attention on the phonetic program. Detection efficiency indices were evaluated when the experimental data were analyzed: the probability of correct detection, reaction time and the probability of false alarms. The results of the experiment are presented in Tables 11-15 and Figures 11-17.

An analysis of the experimental results shows that the introduction of reinforcing light signals significantly improves all the detection efficiency indices--the probability of correct detection increases sharply, the reaction time decreases and the probability of false alarms also decreases (see Table 12). Moreover, not a single false alarm occured for the insignificant syllable reinforced by the flash of light during all the series of the experiment.

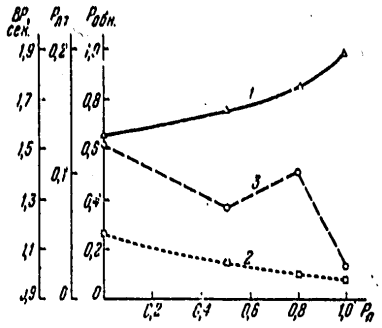

Figure 11. Relationship Between Detection Efficiency Indices and Reinforcement Probability.

Key:
1. Detection probability (P_D).
2. Probability of false alarms (P_{FA}).
3. Reaction time (RT)

An analysis of the detection efficiency indices for signals with different intensities in relation to the reinforcement probability shows the following. As can be seen from Table 13 and Figures 12 and 13, an increase in the probability of reinforcement has an especially strong effect on detection efficiency for signals with low intensity. Thus, the detection probability for signals 8 db lower than the average intensity of the stream increases from 0.11 without reinforcement to 1.0 with a probability of reinforcement of 0.5. When reinforcement is used, practically all the signals go over into the range of always being detected. An analysis of the reaction time characteristic during detection makes it possible to assert that the introduction of duplicative visual information also facilitates signal detection.

The data from Table 13 and Figure 13 also show that a reorganization of the detection mechanisms, especially in the area where signals are close to the average intensity for the stream, may occur when supplemental information is introduced.

The results of the monomodal duplication of information are presented in Table 14 and Figures 14 and 15. It can be seen that the monomodal duplication of information also increases the detection efficiency indices: as the number of signal repetitions increases, the detection probability increases and reaction time decreases. As can be seen from Figure 14, the joint

effect of monomodal and bimodal duplication leads to a significant increase in all the detection indices.

Table 11. Relationship Between Detection Efficiency Indices and Noise Intensity.

(1)	(2)	(3)	(4)	(5)
Интенсивность шума, дб	$P_{обн.}$	ВР, сек	$P_{лт}$	Общее количество ошибок *
90	0,54	1,56	0,062	80
60	0,67	1,35	0,048	61

* Считается среднее количество ошибок на 1000 поступивших сигналов.

*Calculated as the average number of errors per 1,000 signals which have arrived.

Key:
1. Noise intensity, in db.
2. Detection probability.
3. Reaction time, in sec.
4. Probability of false alarms.
5. Average number of errors.

The relationships between the detection indices and the rank of the integral signal characteristic (k) were constructed to refine the joint effect of monomodal and bimodal duplication on detection efficiency. The rank of the integral signal characteristic was calculated as follows. At first the product $k = I_s \cdot v$ was calculated, where I_s is the signal intensity; v is the number of signal repetitions. Then, the significant syllables were ranked in accordance with the numerical value obtained from the product. The rank numbers increase with an increase in intensity and in the number of repetitions. The experimental results obtained are presented in Table 15 and Figures 16 and 17. As can be seen, the integral characteristic is a good indicator of signal detectability.

In evaluating the results of these experiments, it can be stated that the introduction of supplemental information makes it possible to sharply increase all the detection efficiency indices. As could be expected, complete duplication (with a reinforcement probability of 1.0) provides the best results.

A reduction in the reinforcement probability to 0.8 insignificantly reduces the detection probability but, at the same time, the reaction time increases during detection. With a reinforcement probability of 0.5, the detection probability is higher than it is when working without duplication and the reaction time is even lower than it is at a reinforcement probability of 0.8. Monomodal duplication provides similar results but its effect on the detection efficiency indices is somewhat lower.

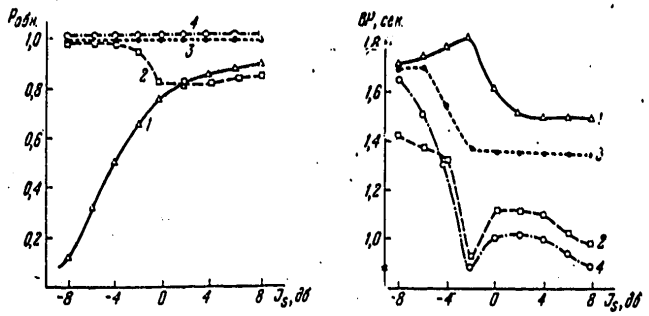

Figure 12. Relationship Between Detection Probability and Signal Intensity for Different Reinforcement Probabilities. (In Figures 12-17: 1 - P_r = 0; 2 = P_r = 0.5; 3 = P_r = 0.8; 4 - P_r = 1.0.)

Figure 13. Relationship Between Reaction Time and Signal Intensity for Different Reinforcement Probabilities.

Key:
1. Detection probability
2. Signal intensity, in db.
3. Reaction time, in sec.

It can also be pointed out that information duplication is a more powerful means of increasing detection efficiency indices than is an increase in signal intensity or an increase in the signal/noise ratio (compare the data in Tables 3, 4, 11 and 13).

Table 12. Relationship Between Detection Efficiency Indices and Reinforcement Probability.

(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
$P_{ц}$	$P_{обн.}$	$P_{лт}$	ВР, сек.	$P_{п}$	$P_{обн.}$	$P_{лт}$	ВР, сек.
0	0,667	0,05	1,52	0,8	0,851	0,023	1,41
0,5	0,759	0,03	1,38	1,0	1,0	0,017	1,08

Key:
1. Reinforcement Probability.
2. Detection probability
3. Probability of false alarms.
4. Reaction time, in sec.

4. Discussion of Research Results

This study had the goal of revealing some of the special features for human detection and identification of complex acoustic signals. The research results show that, in general, the detection and identification of complex signals comply with the same principles which are characteristic of simple signal detection and identification.

At the same time, there are certain significant differences.

1. All the detection indices decline with an increase in signal stream density. The formula cited in Section 2.1 for calculating the maximum signal stream density makes it possible to estimate the maximum stream density in those cases where the empirical constants included in it are known and, primarily, the threshold duration for detecting and identifying individual signals within the stream. The data obtained by calculating the threshold density for a stream (in Section 3.2) were 30-40 signals per minute which agrees with the experimental results in Section 2.1. It was shown that, when processing a stream of signals, the reaction time for trained subjects remained almost constant within the limits of 30-40 signals per minute while the reaction time of untrained subjects increased linearly throughout the entire range of changes in stream density.

An inverse relationship was discovered between reaction time and detection probability. This result does not accord very well with Swets et al's well known psychophysical theory of signal detection. Specifically, the operating mechanism of the

sensory system linked to systematic analysis of incoming information and to the zoned nature of the sensory threshold--in any event in situations similar to ours.

Table 13. Relationship Between Detection Efficiency Indices and Signal Intensity for Different Signal Reinforcement Probabilities.

(1) $P_п$	(2) Интенсивность сигнала (дб) относительно среднего уровня							
	−8		−6		−4		−2	
	(3) $P_{обн}$	(4) ВР	(3) $P_{обн}$	(4) ВР	(3) $P_{обн}$	(4) ВР	(3) $P_{обн}$	(4) ВР
$P_п = 0$	0,11	1,72	0,32	1,75	0,51	1,76	0,67	1,81
$P_п = 0,5$	1,0	1,42	1,0	1,37	1,0	1,32	0,95	0,916
$P_п = 0,8$	1,0	1,709	1,0	1,71	1,0	1,55	1,0	1,362
$P_п = 1,0$	1,0	1,65	1,0	1,51	1,0	1,30	1,0	0,892

(1) $P_п$	(2) Интенсивность сигнала (дб) относительно среднего уровня									
	0		2		4		6		8	
	(3) $P_{обн}$	(4) ВР	(3) $P_{обн}$	(4) ВР	(3) $P_{обн}$	(4) ВР	(3) $P_{обн}$	(4) ВР	(3) $P_{обн}$	(4) ВР
$P_п = 0$	0,78	1,62	0,82	1,53	0,85	1,49	0,89	1,51	0,90	1,50
$P_п = 0,5$	0,82	1,129	0,82	1,12	0,85	1,10	0,85	1,07	0,87	0,989
$P_п = 0,8$	1,0	1,354	1,0	1,35	1,0	1,356	1,0	1,351	1,0	1,36
$P_п = 1,0$	1,0	1,03	1,0	1,037	1,0	1,00	1,0	0,95	1,0	0,897

Key:
1. Reinforcement probability
2. Signal intensity (db) in relation to the average level.
3. Detection probability.
4. Reaction time.

---

2. The results of the study on the effect of signal stream intensity on detection efficiency makes it possible to suggest that, in situations where complex signal streams are received, Weber's Law may be either incorrect even in the medium range of intensities or the processes related to complex signal discrimination require a search for new descriptive methods for threshold characteristics in evaluating the similarities and differences between these signals.

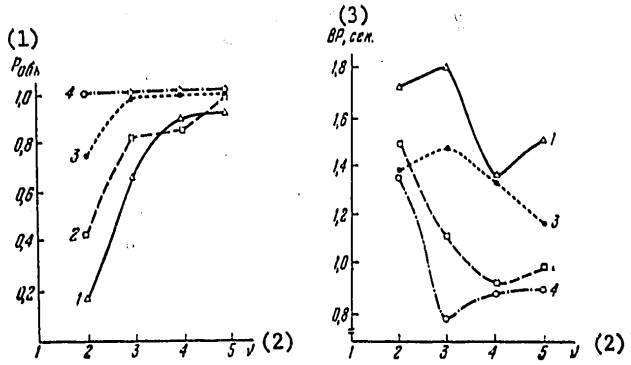

Figure 14. Relationship Between Detection Probability and Number of Signal Repetitions for Different Reinforcement Probabilities.

Figure 15. Relationship Between Reaction Time and Number of Signal Repetitions for Different Reinforcement Probabilities.

Key:
1. Detection probability.
2. Number of signal repetitions.
3. Reaction time, in sec.

Table 14. Relationship Between Detection Efficiency Indices and Number of Signal Repetitions for Different Reinforcement Probabilities.

(1) Вероятность подкрепления $P_п$	(2) Число повторений сигналов ν							
	2		3		4		5	
	(3) $P_{обн.}$	(4) ВР	(3) $P_{обн.}$	(4) ВР	(3) $P_{обн.}$	(4) ВР	(3) $P_{обн.}$	(4) ВР
$P_п = 0$	0,167	1,73	0,667	1,8	0,91	1,36	0,917	1,51
$P_п = 0,5$	0,429	1,485	0,83	1,129	0,85	0,916	1,0	0,986
$P_п = 0,8$	0,75	1,38	1,0	1,47	1,0	1,362	1,0	1,156
$P_п = 1,0$	1,0	1,376	1,0	0,797	1,0	0,892	1,0	0,897

Key:
1. Reinforcement probability.
2. Number of signal repetitions.
3. Detection probability.
4. Reaction time.

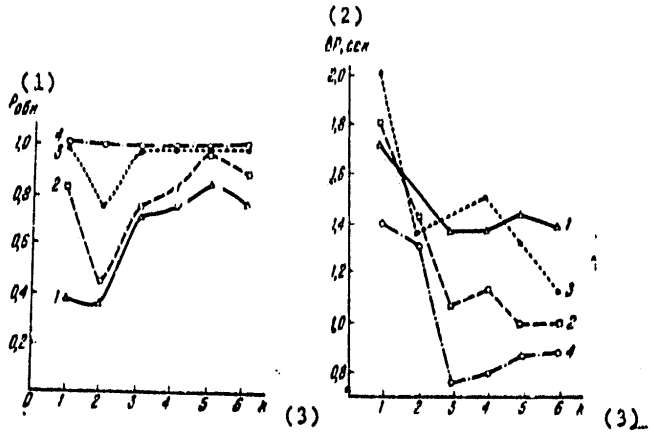

Figure 16. Relationship Between Detection Probability and Rank of the Integral Signal Characteristic for Different Reinforcement Probabilities.

Figure 17. Relationship Between Reaction Time and Rank of the Integral Signal Characteristic for Different Reinforcement Probabilities.

Key:
1. Detection probability.
2. Reaction time.
3. Rank of integral signal characteristic.

---

3. An analysis of the experimental results shows that, for complex signal detection and identification, a change in the signal / noise ratio with an increase in noise intensity reduces the efficiency of signal reception. The experiments cited in Section 2.3 make it possible to suggest that there is a certain shift in the observer's criterion when the detection conditions deteriorate. It is not very clear why an increase in the average signal stream intensity only changes the probability of correct detection (Table 2), while a change in the signal/noise ratio changes both the probability of correct detection and the probability of false alarms (Table 3). It is necessary to point out that, in this case, the detection theory proposed by Swets et al does not provide an acceptable explanation.

Table 15. Relationship Between Detection Efficiency Indices and Rank of the Integral Signal Characteristic for Different Reinforcement Probabilities.

(1) $P_п$	(2) Ранг интегральной характеристики сигнала $k = I_s \cdot v$											
	(3) 1	(4)	(3) 2	(4)	(3) 3	(4)	(3) 4	(4)	(3) 5	(4)	(3) 6	(4)
	$P_{обн.}$	ВР	$P_{обн.}$	ВР	$P_{обн.}$	ВР	$P_{обн.}$	ВР	$P_{обн.}$	ВР	$P_{обн.}$	ВР
$P_п = 0$	0,37	1,73	0,305	1,532	0,707	1,36	0,75	1,35	0,86	1,43	0,77	1,32
$P_п = 0,5$	0,823	1,70	0,429	1,425	0,75	1,06	0,833	1,13	1,0	0,96	0,89	0,98
$P_п = 0,8$	1,0	2,0	0,75	1,38	1,0	1,42	1,0	1,47	1,0	1,32	1,0	1,15
$P_п = 1,0$	1,0	1,38	1,0	1,370	1,0	0,75	1,0	0,775	1,0	0,89	1,0	0,89

Key:
1. Reinforcement probability.
2. Rank of integral signal characteristic, $k = I_s \cdot v$
3. Detection probability.
4. Reaction time.

---

4. When studying the effect of the internal intensity of the signals making up the stream, it was discovered (see Section 3.1) that the signal detection threshold measured in relation to the average stream intensity with a $P_D = 0.5$ has a value of -4.2 db and this coincides very precisely with the value of the standard deviation obtained by a psychometric curve (Figure 7). This is a very important result since, up to this time, there has not been a unified point of view in psychophysics on which of the above cited measures should be considered a measure of sensitivity for the sensory system.

5. In our opinion, the method of analyzing non-metric characteristics of complex signals--such as, signal similarity which suggests using ROC's to present and analyze experimental results--which we selected makes it possible to obtain some new data on the characteristics of complex signal detection and identification. This method of analysis made it possible to experimentally show the sequential deterioration in the detection efficiency indices during the transition from signals with greater similarity to those with lesser similarities. In the comparative analysis of ROC's (Figure 9), it turned out that the effect of signal similarity (curve 3) and the effect of noise (interference) (curves 1 and 2) change the observers' detection capabilities in different ways since

the curves have different curvatures. This result raises the issue of the possibility of describing the characteristics for signal similarity in terms of compactness and the closeness of the signal images in subjective sensory space. Such a description could help uncover the mechanisms and structure for organizing subjective sensory space.

6. The study of the effect of the probability of the signal's appearance on the efficiency of detecting it also raises a number of questions for modern theories of signal detection in psychophysics. First of all, it is not clear whether the result obtained is explained by the characteristics of signal detection and identification or whether the strange and unusual form of the ROC (curve 4 in Figure 9) is explained by the characteristics of the observer's work in the zone of very small probabilities of errors like "false alarms."

7. The results of the study on duplicating significant signals makes it possible to include that signal duplication using signals of another modality has a greater effect on detection and identification results than does monomodal duplication. A number of experimental and methodological comments follow from this. First of all, they include using visual signals to designate the intervals of observation when studying audio signals and the converse, i.e., in a certain sense the "purity" of experimental methods such as the "yes-no" method, the several modifications of the method of forced selection, and others, is doubtful. In an indirect way, the result obtained is casting doubt on the issue of the correctness and utility of using feedback in studies of threshold processes and, consequently, the suitability of using certain theories of a purely sensory bent to explain the operation of sensory systems.

Thus, the results obtained in our study may have beneficial theoretical experimental and practical applications. At the same time, this study raises a number of new problems requiring further experimental and methodological development.

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SOME FEATURES OF THE EFFICIENCY OF FEMALE ATHLETES IN DIFFERENT PHASES OF THE MENSTRUAL CYCLE

Moscow FIZIOLOGIYA CHELOVEKA in Russian No 2, 1979 pp 221-227

[Article by V. A. Doskin, T. V. Kozeyeva, T. S. Lisitskaya, and Ye. V. Shokina, All-Union Scientific Research Institute of Physical Culture, and the State Central Institute of Physical Culture]

[Text] Women's sports are developing swiftly in all the world. Women's world records are constantly rising, and with slight exceptions they are only 7-13 percent below the achievements of men in the same forms of sports. (1,2).

The great demand placed on the woman's body during training and in competitions have necessitated initiation of a number of studies performed at the interface of several scientific disciplines. These works have been devoted mainly to the study of specific features of the female body in different athletic situations.

Investigation of the literature would show that all works dealing with the effect of sports on the female body can be arbitrarily subdivided into two major groups. Some investigators believe that the unique features of the female body and cyclic extragenital changes (the aggregate of all changes occurring outside the reproductive system in the female body on the background of sexual cycles) do not have a significant influence on athletic efficiency (3-7). Others (8-12) forward serious arguments in favor of a meticulous analysis and a consideration of the unique features of the female body, mainly of the approximately monthly variations for which the ovarian-menstrual cycle is responsible.

Considering this disagreement in the literature as well as the lack of integrated pedagogical and physiological-psychological studies in this area, we made it our objective to study changes in the athletic efficiency of women during the ovarian-menstrual cycle, and to establish the relationship of these changes to rhythmic changes in the functional state of female athletes.

Methods

In the first phase we performed an epidemiological investigation making use of a specially developed questionnaire taking detailed account of the variations in efficiency with a monthly rhythm, as well as fluctuations in various psychological indices. This questionnaire was given to more than 200 female athletes including gymnasts, sharpshooters, skiers, and rowers.

In the next phase we subjected students of the State Institute of Physical Culture majoring in gymnastics to integrated physiological-psychological studies. With this purpose we recorded subjective reports of health, the sense of vigor, and mood as determined by the "SAN" (13), pulse, arterial pressure, oral temperature, the aftereffect of spiral rotation (14), the critical light flicker fusion frequency, and a number of other indices from 60 sportswomen before and after training, each day for 2 calendar months.

Because the objective of the research was mainly to trace the mutual relationships between rhythmic extragenital changes experienced by sportswomen and their athletic activity, we performed a special study of the psychomotor function of gymnasts with the help of the "lineogram" subtest using the "myokinetic psychodiagnostic" method (15). This method permits us not only to obtain information on psychomotor indices most important to female athletes, but it also opens perspectives for analyzing behavioral tendencies and human processes hidden from superficial observation.

In all phases of the work we kept track of the training loads experienced by the female athletes, the volume of which was controlled by the gymnasts themselves in accordance with the plan of the experiment.

Research Results and Discussion

Our research showed that a significant proportion of the sportswomen experienced certain deviations during the course of the monthly cycle (Table 1).

As we can see from Table 1 the greatest changes were noted in the premenstrual period and during the time of menstruation. These changes were observed with almost identical frequency among all sportswomen, and they recurred each month at a strictly defined time, usually 7-10 days before menstruation.

It should be emphasized here that periodic changes in the monthly cycle vary in duration and exhibit pronounced individual features. This is apparently why in addition to a worsening of the athletic efficiency of most sportswomen in certain phases of the cycle, some exhibit an increase in efficiency in the same period.

Despite the fact that a significant proportion of the sportswomen note a decrease in efficiency, a worsening of mood, and so on during menstruation, an average of 86 percent of the women demonstrate complete psychological readiness to participate in competition.

Table 1. Periodic Changes in the Efficiency and Functional State of Sportswomen

(1) Фаза цикла	(2) Характер изменений	(3) Гимнастика: художественная (4)	Гимнастика: спортивная (5)	(6) Лыжный спорт	(7) Стрельба	(8) Академическая гребля	(9) Всего
	(10) Число спортсменок, %						
(11) Менструальная	(12) Снижение работоспособности	77±12	69±6	71±15	83±8	71±13	74±2
	(13) Ухудшение настроения	54±14	52±6	57±15	58±10	64±13	55±2
	Ухудшение зрения (14)	—	—	0	25±10	—	22±1
	Повышение работоспособности (15)	8±5	23±5	28±15	12±6	21±11	19±3
	Готовность участвовать в соревнованиях (16)	93±8	91±4	—	92±6	93±7	86±1
(17) Постменструальная	Повышение работоспособности (15)	23±12	19±5	0	12±6	44±14	19±3
(18) Овуляция	Повышение работоспособности (15)	8±5	13±4	0	42±10	28±13	19±3
	Ухудшение зрения (14)	—	—	—	4±3	—	4±1
(19) Предменструальная	Нервное напряжение (20)	38±14	16±5	58±15	50±10	50±14	32±2
	Повышение работоспособности (15)	46±14	13±4	0	25±9	44±14	21±2

Key:

1. Phase of cycle
2. Nature of changes
3. Gymnastics
4. Performing
5. Athletic
6. Skiing
7. Sharpshooting
8. Crew rowing
9. Total
10. Number of sportswomen, %
11. Menstrual
12. Decline in efficiency
13. Worsening of mood
14. Worsening of vision
15. Increase in efficiency
16. Readiness to participate in competitions
17. Postmenstrual
18. Ovulation
19. Premenstrual
20. Nervous tension

Pronounced neurotic disturbances occurring during menstruation frequently even transform into somatic disturbances. Indicative in this regard is the fact that almost a third of the female sharpshooters noted a worsening of vision during menstruation. Other female athletes ventured similar complaints.

An analysis of athletic gymnastic activity showed that the number of gymnastic routines performed by female athletes varies in approximately a

monthly cycle (Figure 1). In this case the dynamics behind change in the number of gymnastic routines--taken as an integral characteristic of the athletic efficiency of female gymnasts--in relation to individual days of the approximately monthly cycle exhibit an entire spectrum of low amplitude fluctuations for which noise factors are responsible. Smoothing of the curve with the goal of eliminating the influence of secondary factors showed that the athletic efficiency of gymnasts increased in the middle of the cycle and decreased in the premenstrual and postmenstrual phases.

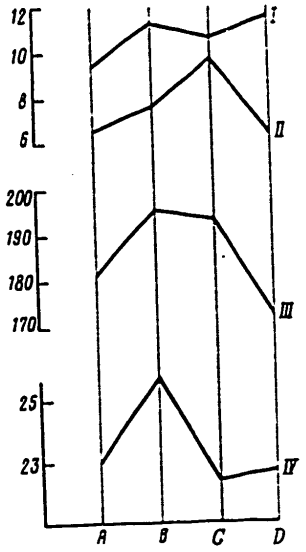

Figure 1. Number of Gymnastic Exercises Performed in Different Phases of the Ovarian-Menstrual Cycle: *A*--Menstrual, *B*--postmenstrual, *C*--ovulation, *D*--premenstrual. Vertical--number of gymnastic exercises: *I*--Jumps, *II*--combinations, *III*--routines, *IV*--higher-order exercises

Discussing the overall efficiency of gymnasts, we should note that the number of combinations, which is a significant characteristic of special working ability and which inherently considers the intensity of the load, exhibits somewhat different dynamics. This index grows in the first two phases of the cycle and attains maximums at the time of ovulation.

In order to permit fuller analysis of the efficiency of female gymnasts we intentionally singled out the number of exercises on the horizontal bar for examination, inasmuch as being one of the elements of an all-event gymnastic

competition, on one hand they are interpreted as exercises requiring a high degree of coordination, usually eliciting a state of mental tension, anxiety, and restlessness, and on the other hand they are complex exercises, always having a prominent place in the training process. This is precisely why the number of exercises on the horizontal bar can be interpreted conditionally as a cumulative index of the volume and intensity of the training load. Our analysis showed that the dynamics behind the quantity of elements performed on the horizontal bar followed changes in the curve reflecting the total number of combinations. An increase in the total number of combinations and a certain increase in the number of elements performed on the horizontal bar occurred in the second half of the monthly cycle. The dynamics of the total number of combinations are a mirror reflection of the shape of the curve reflecting the number of exercises of higher complexity. A similar law is also seen in relation to the number of elements of greater complexity performed on the horizontal bar in comparison with the total number of elements performed on the horizontal bar. Apparently the number of the most risky, complex, and dangerous exercises--higher-order exercises, the content of which reflects to a certain extent the mental tension in the athletic gymnast's activity, grows in that period of the monthly cycle in which the way the gymnasts feel and their mood are at the highest point (Figure 2).

At that moment when, judging from a number of psychophysiological indices, a pronounced ergotropic shift is observed (Figure 2, Table 2), the number of higher-order elements decreases due to growth in the number of combinations (see Figure 1).

In all probability the law we revealed reflects features of rhythmic changes in the functional state of female athletes resulting from the ovarian-menstrual cycle. These are what elicit the rhythmic changes in nature of the athletic efficiency of sportswomen.

It should be noted here that monitoring of the dynamics behind the functional state of sportswomen after training demonstrated that it takes a relatively long time for the functional level to recover. Inasmuch as these phenomena basically reflected the dynamics behing immediate changes in the body, the rhythmic nature of the functions was masked over in a number of cases.

The results of research on psychomotor functions deserves special attention; they showed that psychomotor tone--that is, the tension accompanying movements and the capability for maintaining static forces for a long time--increases from the beginning of the monthly cycle to its end (Figure 3).

In this case the difference between indices for the left and right (dominant) hands increases dramatically. We assessed this tendency as an increase in tiring toward the end of the monthly cycle or, in other words, as a special vital state characterized by progressive failure of functional recovery from the beginning to the end of the cycle. This state was associated with disturbance of control over motor functions resulting from a dramatic increase in emotional excitability.

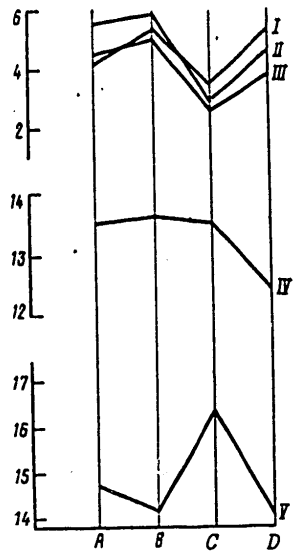

Figure 2. Dynamics of Psychophysiological Indices in Relation to Phases of the Ovarian-Menstrual Cycle: Horizontal--see Figure 1; vertical: I-III--points in the "SAN" test; IV--time (sec); V--frequency (Hz). I--subjective feeling of health, II--vigor, III--mood, IV--aftereffect of spiral rotation, V--critical flicker fusion frequency

We noted another unique feature of psychomotor functions on the background of these changes: The amplitude of test movements increased, as did their chaotic nature, which apparently happened due to weakening of central control over movement amplitude. This indicates that restlessness and anxiety dominated in the state of the female athletes at the beginning of the cycle. This anxiety and restlessness became more intense toward the middle of the cycle, and by the end they sometimes even transformed into a feeling of fear.

This pattern was the product of growing mental overexcitement, as is also evidenced by the dynamics behind the critical light flicker fusion frequency, by the aftereffect of spiral rotation, and by inadequate "control" over anxiety, which drops dramatically toward the end of the monthly cycle.

The dynamics behind the principal psychomotor indices also provide a good explanation for the nature of fluctuations in athletic efficiency. Returning in this connection to an analysis of the latter, we should emphasize that reduction of the total number of higher-order gymnastic elements and, equally so, of exercises of this complexity on the horizontal bar was

Table 2. Dynamics of Some Psychophysiological Indices in Different Phases of the Ovarian-Menstrual Cycle

Показатели (1)	(2) Фазы цикла			
	менструальная (3)	постменструальная (4)	овуляция (5)	предменструальная (6)
Пульсовое артериальное давление, мм рт. ст. (7)	34,8±1,5* / 38,2±1,2	38,8±1,1 / 40,0±1,2	38,8±1,4 / 42,2±3,1	40,2±0,7 / 39,1±0,9
Частота пульса, уд/мин (8)	82,7±1,8 / 94,0±2,0	81,2±1,4 / 96,8±1,6	82,1±2,4 / 90,2±2,7	82,0±1,2 / 95,5±1,3
Латентный период простой зрительно-моторной реакции (мс), разница между правой и левой рукой (9)	61,4±3,8 / 60,2±6,7	60,2±5,4 / 55,4±1,4	68,9±11,0 / 68,9±6,2	61,7±3,5 / 67,0±12,2
Электрокожное сопротивление, усл. ед. (10)	51,9±8,0 / 32,5±7,7	44,7±5,2 / 28,2±3,3	43,9±9,8 / 35,8±5,3	37,1±3,1 / 33,1±2,5
Сила сжатия правой кисти, кг (11)	33,4±0,5 / 33,2±0,6	33,7±0,5 / 33,6±0,6	30,0±1,0 / 32,7±0,6	33,0±0,4 / 38,7±0,4
Сила сжатия левой кисти, кг (12)	31,1±0,5 / 31,1±0,3	31,2±0,4 / 30,8±0,4	26,6±0,9 / 29,9±0,4	30,7±0,3 / 35,9±0,3

*Numerator--indices during training, denominator--after training.

Key:
1. Indices
2. Cycle phase
3. Menstrual
4. Postmenstrual
5. Ovulation
6. Premenstrual
7. Arterial pressure, mm Hg
8. Pulse, beats per minute
9. Latent time of simple oculomotor reaction (msec), difference between right and left hand
10. Electrocutaneous resistance, arbitrary units
11. Gripping force of right hand, kg
12. Gripping force of left hand, kg

associated namely with a progressive sense of anxiety turning into fear at the end of the cycle. This was obvsiously one of the principal factors of interference to the performance of complex, dangerous higher-order gymnastic exercises. But this did not hinder the gymnasts from increasing the intensity of the training load by doing a larger number of combinations in this period. Growth of this index of the special efficiency of gymnasts in the second half of the cycle stems in our opinion from growth in psychomotor tone and general mental arousal. But the increase in overall productivity of the training sessions leads to noticeable tiring toward the end of the monthly cycle.

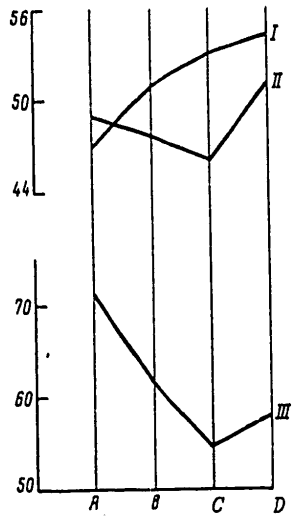

Figure 3. Dynamics of Some Indices of the Psychomotor Test in Relation to Phases of the Ovarian-Menstrual Cycle: Horizontal--see Figure 1; vertical: Standardized test units in T-norms; *I*--psychomotor tone, *II*--emotiveness, *III*--anxiety

Conclusion

We can conclude from the data presented above that it is important to study rhythmic changes in functional state of female gymnasts occurring in approximately a monthly cycle. Depending on individual features of the sportswomen, these variations may vary in intensity, from minimal, masked by various factors, to extremely significant. Apparently those researchers who deny such a dependence of efficiency on approximately a monthly extragenital cycle worked in their analysis of large groups of female athletes with facts obtained from women exhibiting a low amplitude in their monthly rhythm. In this connection we should recall certain features of the sexual maturation of athletes and the fast rate at which the starting age in many forms of sports is decreasing, which doubtlessly has a significant influence on the nature of oscillatory processes in the female body.

The described features of cyclic processes occurring in the female body significantly supplement information on female athletes, and they can be employed in initial selection of the athletes. In this case one of the criteria may be the desired tolerance of loads in individual phases of the ovarian-menstrual cycle. The dynamics behind the condition of sportswomen during the monthly cycle must become the basis for individualizing all training, since high athletic efficiency can be achieved only in the event that the rhythm of the training load is consistent with biological rhythms inherent to the body.

In order to achieve a physiological optimum in the training of gymnasts, we suggest a number of recommendations based on the data presented here:

1. It would be best to plan the learning of the most complex exercises and improvement of the techniques with which they are performed in the first half of the ovarian-menstrual cycle, reducing the quantity of exercises requiring complex techniques in the premenstrual period.

2. The second half of the ovarian-menstrual cycle should be a time of emphasis on intensity of the athletic training load; the quantity of simple exercises should be increased during this time, though the necessary conditions for functional recovery must be ensured.

3. The second half of the ovarian-menstrual should be devoted to training in a "calm" situation, reducing the amount of responsibility the athletes bear for incorrectly or inaccurately completed exercises.

4. Correct organization of warm-up exercises in preparation for complex exercises acquires special significance in the second half of the ovarian-menstrual cycle. Much attention must be devoted in the warm-up exercises to achieving relaxation of the muscles and ensuring movement precision.

5. When sportswomen are to participate in competitions, the phase of the cycle in which the competition will occur must be considered, and the tactics of the performance must be planned in accordance with this.

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