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ACCOUNTING FOR THE PSYCHO-FUNCTIONAL CHARACTERISTICS OF A PERSON IN LEARNING PROSTHETIC MANAGEMENT

Prosthetics is a complex of medical and social measures aimed at compensating anatomical and functional defects of a person with the help of prosthetic and orthopedic means and devices. At the same time, the main task of prosthetics is the maximum possible restoration of the functions of the lost organ and the return of the person to active labor activity. The technical device of a prosthetic-orthopedic product, regardless of its complexity, is considered by prosthetists only in cooperation with the human musculoskeletal system and its psycho-physiological features. The key task of the prosthesis is to create a methodology and a complex for teaching a person how to use a bionic prosthesis. The stage of learning to use the prosthesis is performed last, its duration depends on the technological complexity of the prosthesis, the accuracy of observance of all the principles of modern prosthetics at the previous stages, as well as the characteristics of human psychophysiology.

The article deals with the interaction of a person with a prosthesis. The problem of learning to use the prosthesis is analyzed, taking into account the characteristics of the psycho-physiological characteristics of the trainees. The time characteristics of human interaction with the technical device of the prosthesis in time, from the beginning of the interaction to the end of the commission of the elementary action, the duration of the action, the frequency of execution, and the organization of the elementary movement during this time are considered. Consideration of these factors will allow flexible adaptation of the learning process to the specific characteristics and needs of a particular person to manage a personal prosthesis, as well as to choose an individual teaching method for him.

Keywords: human adaptation to the prosthesis, speed, information processing, perception time, feedback.

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УРАХУВАННЯ ПСИХОФУНКЦІОНАЛЬНИХ ХАРАКТЕРИСТИК ЛЮДИНИ ПРИ НАВЧАННІ КЕРУВАННЮ ПРОТЕЗОМ

Протезування – комплекс медико-соціальних заходів, спрямованих на компенсацію анатомічних і функціональних дефектів людини за допомогою протезно-ортопедичних засобів і пристосувань. При цьому головне завдання протезування – максимально можливе відновлення функцій втраченого органа й повернення людини до активної трудової діяльності. Технічний пристрій протезно-ортопедичного виробу незалежно від його складності розглядається протезистами тільки у взаємодії з опорно-руховим апаратом людини і її психофізіологічними особливостями. Ключовим завданням протезобудування є створення методики й комплексу для навчання людини користуванню біонічним протезом. Етап навчання користуванню протезом виконується останнім, його тривалість залежить від технологічної складності протеза, точності дотримання всіх принципів сучасного протезування на попередніх етапах, а також від особливостей психофізіології людини.

У роботі розглядається взаємодія людини із протезом. Аналізується проблема навчання користуванню протезом з урахуванням особливостей психофізіологічних характеристик того, якого навчають. Розглянуті часові характеристики взаємодії людини з технічним пристроєм протеза в часі, від початку взаємодії до закінчення здійснення елементарної дії, тривалість здійснення дії, частота виконання, організація елементарного руху протягом цього часу. Урахування цих факторів дозволить гнучко адаптувати процес навчання під специфічні особливості й потреби конкретної людини для керування особистим протезом, а також підібрати йому індивідуальну методику навчання.

Ключові слова: адаптація людини до протеза, швидкодія, переробка інформації, час сприйняття, зворотний зв'язок.

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УЧЕТ ПСИХОФУНКЦИОНАЛЬНЫХ ХАРАКТЕРИСТИК ЧЕЛОВЕКА ПРИ ОБУЧЕНИИ УПРАВЛЕНИЮ ПРОТЕЗОМ

Протезирование – комплекс медико-социальных мероприятий, направленных на возмещение анатомических и функциональных дефектов человека с помощью протезно-ортопедических средств и приспособлений. При этом главная задача протезирования – максимально возможное восстановление функций утраченного органа и возвращение человека к активной трудовой деятельности. Техническое устройство протезно-ортопедического изделия независимо от его сложности рассматривается протезистами только во взаимодействии с опорно-двигательным аппаратом человека и его психофизиологическими особенностями. Ключевой задачей протезостроения является создание методики и комплекса для обучения человека пользованию бионическим протезом. Этап обучения пользованию протезом выполняется последним, его длительность зависит от технологической сложности протеза, точности соблюдения всех принципов современного протезирования на предыдущих этапах, а также от особенностей психофизиологии человека.

В работе рассматривается взаимодействие человека с протезом. Анализируется проблема обучения пользованию протезом с учетом особенностей психофизиологических характеристик обучаемого. Рассмотрены временные характеристики взаимодействия человека с техническим устройством протеза во времени, от начала взаимодействия до окончания совершения элементарного действия, продолжительность совершения действия, частота выполнения, и организация элементарного движения в течение этого времени. Учет этих факторов позволит гибко адаптировать процесс обучения под специфические особенности и потребности конкретного человека для управления личным протезом, а также подобрать ему индивидуальную методику обучения

Ключевые слова: адаптация человека к протезу, быстродействие, переработка информации, время восприятия, обратная свіязь.

Problem definition

Prosthetics is a complex of medical and social measures aimed at compensating anatomical and functional defects of a person with the help of prosthetic and orthopedic means and devices. At the same time, the main task of prosthetics is the maximum possible restoration of the functions of the lost organ and the return of the person to active labor activity. The latter circumstance is of great psychological importance and affects the terms of mastering and mastery of the management of the prosthesis. [1]

An integral part of prosthetics that studies the human system - the technical design and development of prosthetic and orthopedic appliances is prosthetic engineering. Prosthetics and prosthetics structure form a medical-technical complex, designed to solve the issues of preparing a patient for prosthetics, choosing a prosthesis design, making it and learning how to use it. In determining the most effective methods of prosthetics, not only the age and sex of a person is taken into account, but also a large number of individual anthropometric, physiological, clinical and biomechanical characteristics, on the basis of which the degree of compensatory adaptability of his body is established. The analysis of this information is a difficult task, and the use of the conclusions of this analysis largely determines the results of prosthetics.

Related publications

The technical device of a prosthetic-orthopedic product, regardless of its complexity, is considered by prosthetists only in cooperation with the human musculoskeletal system and its psycho-physiological features.

There are two options for controlling the prosthesis - without feedback and with feedback. [2] The block diagram of the prosthesis without feedback is presented in [3] and is as follows (Fig. 1).

In a prosthesis without feedback (see Fig. 1), when a person tries to mentally move an amputated limb, the signal from efferent nerve fibers (ENF) using a biopotential pickup device (DRBP) is fed to the biopotential amplifier (ABP), and then after the A/D converter) into the microprocessor (MP). In the microprocessor, the signal is decoded and the command is issued to the actuators (MI) of the prosthesis (P). For this digital code from the output of the MP is converted using a digital-to-analog converter (DAC) into an analog signal and amplified by a power amplifier (PA). Thus, the transformation of control nerve impulses into mechanical movements of the limb prosthesis is carried out.

The disadvantage of such a prosthesis is the lack of feedback from the objects of interaction of the prosthesis with the objects of interaction, which is present in biological systems, which leads to insufficient accuracy of movement.

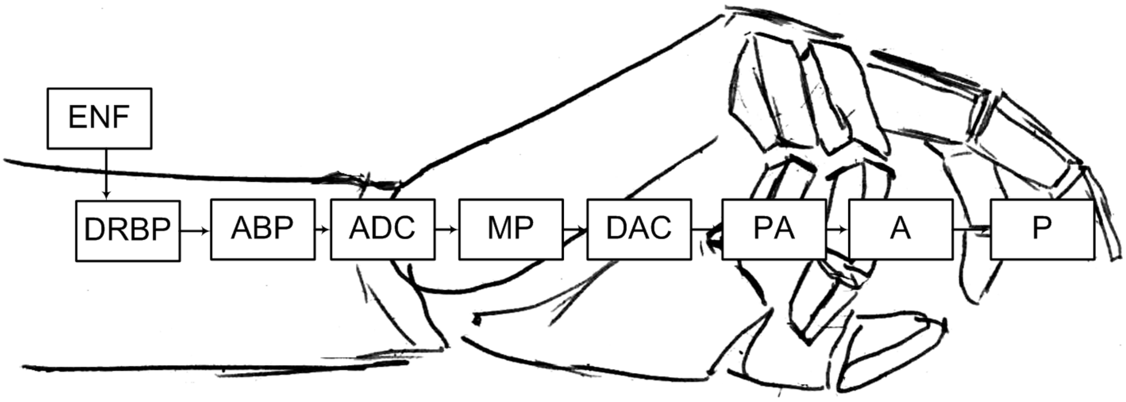

Fig. 1. Block diagram of the prosthesis without feedback

This disadvantage is compensated by the introduction of feedback, which makes it possible to coordinate the movement of a limb due to information about the position in space, speed of movement, applied efforts, etc. [4] With this variant of prosthesis control, feedback is achieved only through visual perception of the prosthesis. Due to the use of active modules in the design of the prosthesis, special sensors in the coating of the prosthesis that mimic the joints and are driven by hydraulic hydraulics, and small electric engines, sensations can be transmitted in response to pressure, touch or temperature changes. Due to the reverse transformation of the electronic signal into the biopotential, which is captured by the sensory nerve endings of the limb stump, the sensation of a person's own limb is achieved. The structural diagram of this type of prosthesis is shown in Fig. 2.

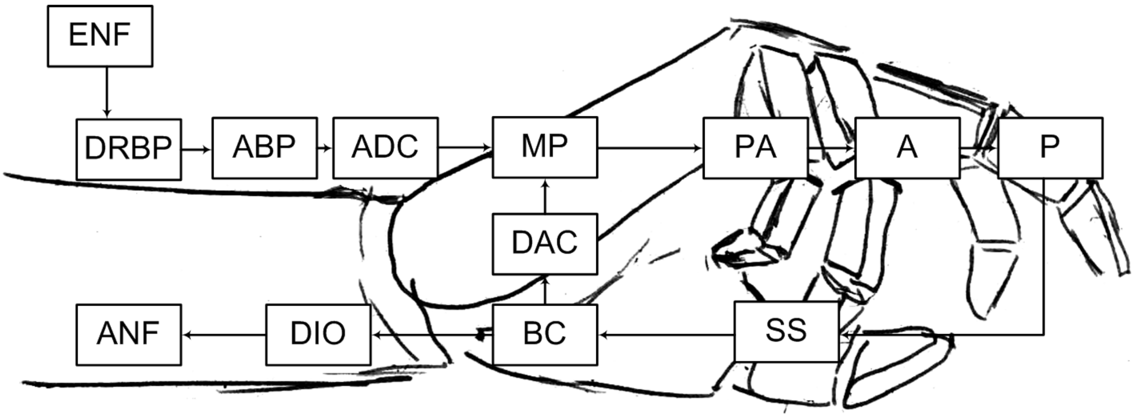

Fig. 2. Block diagram of the prosthesis with feedback

In this scheme, there is a system of sensors (SS), which controls the movement of the prosthesis in space, as well as the efforts developed by the actuators. This information enters the MP and is compared with the specified parameters of the movement. Thus, the adjustment of the movement of the prosthesis. In addition, it is possible "sensation" of the prosthesis with the help of sensors capable of perceiving tactile information that can be transmitted to the remaining afferent nerve fibers (AHF) through the device to interface with the object (DIO). In this case, the person will feel the object to which the prosthesis touches the limb.

Modern models of prostheses involve the installation of temperature and pressure sensors on each finger that can control the seizure of an object with greater reliability, and thus both protect the hand itself and prevent possible damage due to careless movement. With the help of such a kind of artificial leather, you can hold light and fragile objects, such as a plastic cup, which could not be done in prostheses without feedback - the prosthesis simply breaks it. Too little squeezing fingers for the same plastic cup is no less a problem - the cup slips out of your hands.

The key task of the prosthesis is to create a methodology and a complex for teaching a person how to use a bionic prosthesis. The stage of learning to use the prosthesis is performed last, its duration depends on the technological complexity of the prosthesis, the accuracy of observance of all the principles of modern prosthetics at the previous stages, as well as the characteristics of human psychophysiology.

The continuity of the stages and the correct implementation of all the principles of modern prosthetics gives a good effect, accelerates the process of rehabilitation of a person after amputation and the return of lost functions.

The quantitative characteristics of human body movements are methodologically convenient to divide into two main types: biokinematic and biodynamic. Biokinematic characteristics Section of biomechanical analysis of biokinematics studies the movement of living bodies and biological systems. Biokinematic characteristics of human movements are characteristics of the movement of human body parts without taking into account their inertia and acting forces. They include descriptions of changes in body position in space relative to other bodies over time. The main goal is the analysis of various types of motion and the detection of laws showing the relationship between the quantities that characterize these movements (spatial, temporal and spatial-temporal). The physical characteristics of material objects in their interaction (mass, force) - material nature, as well as physical processes are not considered.

Goal of investigation

In order to optimize the process of teaching a person a bionic prosthesis, it is necessary to consider the temporal characteristics of the person's interaction with the technical device of the prosthesis in time, from the beginning of the interaction to the end of the elementary action, the duration of the action, frequency of execution, and the organization of the elementary movement during this time. Together with the space-time characteristics, they determine the nature of human movements.

Presentation of the research material

When a person adapts to the prosthesis, one has to deal with different training times, which is associated with different perceptions of this process by the trainees. At the time of training, i.e. the transition from meaningful action of the prosthesis to the automatic implementation, the psycho-physiological characteristics of a person affect the speed of learning.

To select the optimal training program, it is necessary to take into account the psycho-physiological characteristics of a person, such as the degree of fatigue and information load, as well as additional factors:

a) In the state of psychological tension arising in the process of adaptation of a person to new conditions of activity, there is a mobilization of body reserves.

b) The inertia of psycho-physiological changes in the body when the effects on the person.

Adaptive changes in the functional state of various systems of the human body undergoing a prosthesis under the influence of training loads occur heterochronously. At different stages of this process, the reaction of various systems is specific and not always amenable to prompt diagnosis. The signs of the optimal level of adaptability include the achievement of the maximum of the realized functions (maximum reaction rate and motor actions, the greatest accuracy, a high degree of concentration and distribution of attention, etc.), as well as the duration of the preservation of working functions at the maximum level. [5]

The speed of interaction (perception and comprehension of the incoming information) of a person with a prosthesis as a technical tool is determined by the time of information passing through the closed loop of the human system - the technical structure of the prosthesis and is estimated by the duration of the control cycle. In case of receipt of several signals, a person proceeds to the processing of each of them during the time t_{s_del} after some delay t_{preset}. In this case, the processing time (speed) t_{proc} is characterized by two components:

$$t_{proc} = t_{\text{s\_del}} + t_{preset}$$

and the duration of the control cycle is:

$$T_n = t + \sum_{i=1}^{n} t_{preset\_i}$$

where t is the time to solve a problem by a human, i.e. the time from the moment the signal appears until the end of the control actions; t_{preset_i} is the information delay time in the i - th link of the technical system, and n is the number of links in the human system - the technical system of the prosthesis.

Given a given Tn and known characteristics of the prosthesis and the object of interaction with the prosthesis from a person, such speed is required:

$$t_{proc} \geq T_n + \sum_{i=1}^{n} t_i.$$

On the other hand, t_{proc} can be defined as the sum of the time of each of the stages of information processing - decision making and the implementation of control actions - t_2 and t_3.

The time of a person's activity according to a predetermined algorithm can be represented as a set of times necessary for a person to receive information from feedback sensors and perform response actions:

$$T_n = T_{n.percep} + T_{n.dic} + T_{n.upd} + T_{n.mot}$$

where $T_{n.percep}$ is the time of signal perception (latent period is the time interval separating the human response from the moment the stimulus is applied); $T_{n.dic}$ - decision time; $T_{n.upd}$ - time thinking actions for the muscles of the stump; $T_{n.mot}$ - the time of the motor action on the control body.

Thus, the learner controls the prosthesis and adjusts its operation in accordance with the program, which has temporary characteristics. The implementation of this program depends on the technical characteristics of the system, which determine external, technical, time constraints. In addition, the learner has its own, internal, psycho-physiological properties, which also cause certain time constraints.

At the same time, internal constraints, time of perception and comprehension of information t_P^i, representing the sum of the time of perception of the signal, time of decision making and comprehension of actions to control the muscles $t_P^i = t_{n.\text{percep}}^i + t_{n.dic}^i + t_{n.upd}^i$ may vary depending on the functional state of the person during training. Time perception and judgment in the accomplishment of one and the same result may differ not only among different students, but one and the same person.

We describe the process of processing information received by a person at the time of learning to act with a prosthesis. Nerve impulses produced by a person give a signal to process data and form commands to control the prosthesis. The data coming from the feedback sensors can be characterized by some measure of the complexity of perception by the muscles of a person - *C*, which depends on the degree of difficulty of perception. The complexity of information is directly related to the time of its perception and comprehension by a person and can be found by the formula [6].

$$t_в^i = \frac{1}{V(1-q)} C(h_{i-1}),$$

where t_P^i, is the time of perception and comprehension of i - th information by $t_P^i = t_{n.\text{percep}}^i + t_{n.dic}^i + t_{n.upd}^i$; *V* is the capacity of a person; q - function of the intensity of perception, characterizes the degree of fatigue and information load of a person; $\mathrm{C}(\mathrm{h}_{\mathrm{i}-1})$ - the complexity of the user's perception of the piece of information at the i-th stage of training.

At the same time, taking into account the “objective” and “subjective” factors of the student, the complexity of perception can be determined.

$$\mathrm{C}(h) = \sum_{\mathrm{i}=1}^{\mathrm{K}_c} c(h_i) K_{of} \mathrm{K}_{sf}$$

where $\mathrm{c}(\mathrm{h}_{\mathrm{i}-1})$ is the complexity of the human perception of a piece of information at the i-th stage of communication with the prosthesis, $\mathrm{i} = \overline{1, \mathrm{K}}$; K_c - the number of stages of communication; K_{of} - the coefficient of "objective" factors affecting a person (preparedness, environment, features of prosthesis management, etc.); K_{sf} is the coefficient of the user's subjective factors, reflecting his individual psycho-physiological features.

In addition, the criterion of speed is the time t_{react} to solve the control task, that is, the time from the moment a person responds to information flow until the end of the control actions. This time is directly proportional to the amount of information processed:

$$t_{react} = \mathrm{T}_a + \mathrm{I}H$$

where T_a is the latent human response time, which depends on the modality of the signal and is approximately equal to 0.2 s; *I* - the reciprocal of the speed of processing information by a man, equal to 0.15 + 0.35 s/bit; *H* - the amount of information in bits.

In Fig. 3 shows the physiological and required human response for the perception of the process of prosthetic control during training, where V_{inf} is the speed of information receipt, *V* is the person’s throughput.

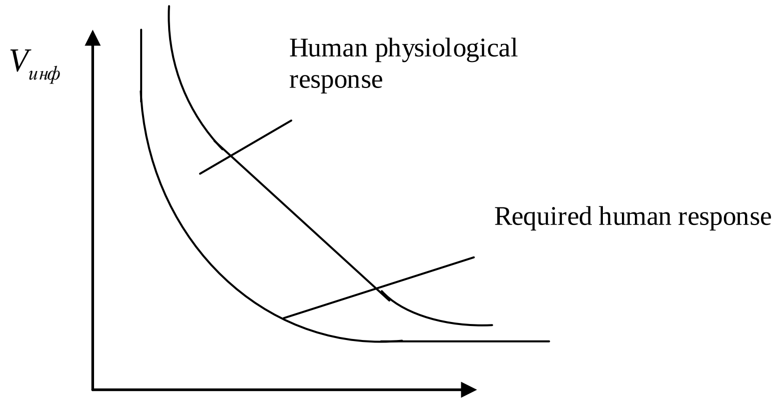

Fig. 3. The physiological and required human response for the perception of the process of prosthetic control during training

Then the mismatch of the ergatic system, in quality, which can be considered a human system is a technical system of the prosthesis that allows you to automatically track the exit of the ergatic system beyond the boundary conditions and correct the person's work when learning to use the prosthesis:

$$P = V\sum_{i=1}^{К_э}\frac{e^{-Zh_i}}{S(h_1)} * t_{ci} \leq 1$$

where h_i - deviations from the standard, which are produced in humans as a result of perception of the previous portion of the information flow; t_{ci} is the time of transmission of a message to the person from the technical system of the prosthesis; Z - the coefficient of tension characterizing the individual characteristics of the perception of information by the student.

Results and conclusions

Thus, the temporal characteristics when teaching a person to use a prosthesis are used as:
- indicator of time constraints;
- an indicator of the speed of the flow of nerve processes;
- characteristics of the learning process;
- characterization of the consistency of the human components with the technical system of the prosthesis. Accounting for these characteristics will allow flexibly adapting the system of management of a personal prosthesis to the specific characteristics and needs of a particular person, as well as to choose an individual technique and complex for training. All this will speed up the process of rehabilitation after amputation and the return of lost functions.

As further ways of developing the system, one can indicate the development of a model with feedback with adaptation to the individual psychophysiological characteristics of a person, with the aim of increasing the controllability of the mechanical model to ensure a greater similarity to human limb.

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