

Development of a biofeedback device for recovery of hand functions

With the prevalence of traumas and diseases of the central nervous system, and the complexity and persistence of the associated functional disorders followed by long-term and often permanent disability, rehabilitation of cases with neurological disorder is among the major medical and social problems.

One most serious consequence from affection of the nervous system is impaired hand functions, which is a very significant limitation on the vital activity of patients. Recovery of movement functions in the hands of patients after traumas and diseases of the nervous system is still a very important issue that needs a new solution both theoretically and technologically.

What can be instrumental in improving the movement functions of hand is application of biological feedback, or biofeedback, methods. Currently, biofeedback is understood as a combination of procedures whereby a person gets informed, via external feedback loop, on the status of any physiological processes, which is towards training to “consciously” control these functions. Biocontrol with feedback allows a patient to gain control (self-control) over parameters of voluntary movements, and to cause and fix their shifts in the required direction. Particularly, a patient getting feedback information on the movement characteristics of the self would have a better chance for voluntary control of these. To use biofeedback is most important for recovery of motor functions in patients with impaired sensibility. Additional use of eyes to track the movement parameters in such patients can offset the lack of information coming in through superficial and deep sensibility paths. Using biofeedback, control of movements can be also improved significantly in patients with apraxia, whose ability in voluntary and purposive actions is impaired by affection at the cortical level.

Review of the numerous publications related to biofeedback applications in practice, shows diversity of approaches used and variations of this method. What modification of the technique to choose in each particular case depends first of all on the function to be consciously controlled. Currently, several designs of biofeedback device have been developed. Basically, they are used in rehabilitation of pulmonological patients (control over respiration rate and depth), and in traumatology (“Miotonic”, “Miotrainer”, “Miotonic-02”, “Miocor”, and “Miostimulator”) to recover motion in the injured limb after immobilization is removed, as they allow “seeing” how well performed is the task, e.g. the increased articular angle, and the range of limb movements. However, patients with limb traumas or orthopedic problems can receive a sufficient amount of information from their own muscles and joints via usual physiological tracts, which are deep and superficial sensibility paths. That is why the biofeedback methods would only a little facilitate the recovery process of impaired functions in such patients. However, patients with neurological pathology are who quite often show disorders in perception of somatosensory signals from the skin surface and musculoskeletal tissues, so that visual control remains the only effective way for them to check whether the task was fulfilled properly with the movements made. Therefore, it is just for such patients that biofeedback can provide easier recovery of voluntary hand movements.

Patient's interest in exercises can be increased if the biofeedback is provided in a playing format. In this development, it is done in the way that the movements of a patient are "reflected back" by a puppet moving. Thus, as the movements of a limb on rehabilitation become more precise, varied and better coordinated the puppet will make more movements. The patient watching the puppet movements will get into positive feelings to be more closely involved in training process, which is particularly important in rehabilitation of the patients, both children and adults, with emotional disturbances. Consequently, using a puppet allows biofeedback application in combination with elements of art-therapy, thereby making the exercise more attractive to patients.



The current market for medical equipment offers a wide variety of both mechanical ("Beka Hospitec" company) and electromechanical devices ("Jace Systems") for mechanotherapy of superior limbs. Major limitation of such devices is passive mechanical rehabilitation and no biofeedback available. Moreover, it is impossible with the equipment like this to handle electronic storage of the information on rehabilitation course, statistical treatment of the acquired data and, as a consequence, prediction of the outcome of rehabilitation course.

The proposed project is anticipated to include development, bench tests and clinical trials of a device to check time and strength characteristics of the motor activity of hand, providing examinee a biofeedback to control these parameters. Controllable parameters will be biomechanical characteristics, such as tremor frequency and amplitude, or muscle strength of hand. With environmental monitoring capability designed into this device, it would be possible to account for weather effects on patient during rehabilitation course.



The novelty of the proposed technique includes the following:

- Methodological approach is no adaptation of environment to deficiency of patient's motion functions as its priority is maximum possible elimination of the defect.
- Employs feedback concept and exteriorization method. Here, the puppet serves as an

external controllable object to render the individual's movements outside and, therefore, make them more controllable by conscience and thus use the feedback concept more efficiently.

- The training program involves different levels of movement control.

Playing principle is used for the technique that helps develop psychological compensatory mechanisms.

The device with controllable parameters will be made using two – threshold (“all or nothing”) and proportional (gradual) - feedback types.

After the operating device is bench-tested, the plan is to develop differentiated methods for recovery of finger movements in varied pathogenetic cases of impaired hand functions and test their efficiency with the neurorehabilitation groups at Nizhny Novgorod State Medical Academy (Chair of Neurology and Medical Genetics), Nizhny Novgorod Institute of the Educational Development (Chair of Correctional Pedagogy), Municipal Children Preschool Institution “Forest Tale” (Sarov). Efficiency of the methods will be tested through comparative analysis of the functionalities of hand before and after the rehabilitation course.

Project goals:

- Develop a biofeedback device for rehabilitation and better motor activity of hand, to allow more effective rehabilitation procedures in real time for patients with affection of the central nervous system.
- Create a unique puppet playing method based on the device to be developed.
- Develop differentiated methods for recovery of finger movements in various pathogenetic cases of impaired hand functions.

Expected results:

- Development and construction of a competitive and high-tech biofeedback device to develop the motor activity of hand.
- Reduced rehabilitation time for patients with superior limb movement and coordination disorders.
- Improved quality of rehabilitation, particularly in pediatric practice, by using a playing method. The synergy of psychotherapeutic and functional methods can make application of the operating kinematic model extended to treat children with emotional problems.
- Saving of expenses for drugs and less likelihood of the side effects due to drug treatment.

The expected social effect is determined by a more emotionally colored rehabilitation within a shorter period of time, the ability to personally form the biofeedback signal by a puppet, and improvement in the quality of rehabilitation and therefore the life quality of patients.

We welcome foreign collaborators and partners to this project, whose involvement could be very good for:

- discussion and better definition of the project tasks;
- discussion of the progress and testing of the device and associated methods.

We invite medical personnel for extensive preclinical testing of the prototype and clinical trials of the device.

We invite the teachers at special-care preschool institutions and schools to cooperate for proof testing of the device during correction exercises.