Adaptation of Muscle to High Intensity Exercise

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The objectives of this research project are to further define the process whereby skeletal muscle adapts to high-intensity (weight-lifting) exercise and to elucidate the mechanisms which control this process.

In this project, adult cats are operantly conditioned to flex their right wrist against increasing resistance to receive a food reward. This procedure has the advantage of inducing significant hypertrophy in the muscles of one limb, while the muscles of the opposite limb can be used for comparative studies. This exercise regimen has been shown to increase the number of fibers in the muscles of the exercised limb. The mechanism for this increase has been shown to be fiber splitting.

In this study, the structural and histochemical features of muscle fibers that are undergoing division by splitting are characterized, and the adaptive changes that occur in the exercising muscle that contribute to fiber splitting are investigated. Alterations in the contractile properties of the exercised muscle are explored, and pharmacological blocking drugs (d-tubocurarine and decamethonium) are used to evaluate the component parts of mixed muscles. Electromyography (EMG) is used to assess adaptive changes in the function and recruitment of exercising muscles.

This study will further elucidate the dramatic structural and functional alterations that occur in skeletal muscle that is adapting to high-intensity exercise, and will define the mechanisms that control these adaptive processes.

NATIONAL SCIENCE FOUNDATION
1800 G STREET, WASHINGTON, D.C. 20550
SCIENCE AND TECHNOLOGY TO AID THE HANDICAPPED

James C. Aller, Sc. D., Program Manager

Microprocessor-Based Integration of Artificial Reflexes and Sensory Feedback for Prosthetic Control

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This is a final project report, award number PFR-80-09412, based on work supported by the Small Business Innovation Research Program from 9/1/80 to 2/28/81.

This project seeks to improve the performance and usefulness of a microprocessor-based prosthetic arm so that the requirements for continuous visual supervision of prosthetic movements are lowered.

Artificial reflexes and sensory feedback in a prosthetic device have been recognized as important factors for improving prosthetic performance. Associated with the loss of a limb a variety of reflexes and senses are lost. If these are to be substituted, the question arises which are most relevant for a given lost limb function, and for a particular individual.

By way of a literature review of psychometric measurements and current neurophysiological models, the nature of the problem is identified as an optimization problem. In the particular setting the problem presents itself as a stochastic problem in a high dimensional parameter space. Conventional experiment designs and regression techniques are inadequate to acquire the information necessary for optimization with a reasonable experimental effort for a given individual.

In order to cope with these difficulties, a novel stochastic optimization algorithm is developed based on hybridization of ideas from stochastic function minimization, conjugate gradient methods (orthogonal projections), and other statistical concepts. The concept of "high dimensionality" is developed and is cast into a probabilistic framework.

The algorithms can be utilized to construct on-line, for a particular amputee, the necessary artificial reflex laws and sensory feedback codes. These laws and codes may then be placed in a microprocessor controlling the prosthetic device.

Use of Voice-to-Text Conversion in Deaf-Hearing Dialogues

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Earl Craighill, Ph. D.

This is the first year of a 3-year continuing award, proposal number ECS 80-23527, fiscal year 1981.

This research explores methods of coupling voice-to-text (VTT) conversion technology with speech synthesis devices to allow better communication between the deaf and the hearing.

The research specifies, demonstrates, and evaluates VTT systems that are practicable and useful in dialogues between a hearing person talking over a phone to a deaf person who is typing.

Specific tasks are to: (i) Define the necessary system parameters of a usable VTT system, including the level of recognition performed by machine, the degree of accuracy of machine operation, and the amount of training required by deaf and hearing persons; (ii) Demonstrate an operational system coupled to the phone network; (iii) Determine the extent to which deaf users can provide their own syntactic and semantic analyses; and (iv) Identify key research problems that require solution.

Experiments are conducted to simulate communication between deaf and hearing persons and include simple information-transfer tasks as well as fully interactive representative dialogs.

Voice Response Aids for the Handicapped—An Innovative Technique

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David Y. Wong, Ph. D., Electrical Engineer

This is a final project report, award number PFR-80-09724, based on work supported by the Small Business Innovation Research Program from 9/80 to 2/81.

The usefulness of voice response devices for the handicapped, especially the blind, is a well acknowledged fact. As an example, it would be much easier for the blind to operate a computer if the machine could respond to the operator with voice. This study involves a technique for storing speech in a highly efficient manner based on recent advances in the information theoretic coding of speech signals. The technique allows the vocabulary of a voice response device to be expanded by factors of two or better at little additional cost. The development of these coding techniques will allow speech sounds to be stored digitally in a highly efficient manner in a portable device. Without such coding techniques, voice response devices would simply be too bulky and expensive for general use.

Although the technique of vector quantization is still in its theoretical state of development, it offers significant advantages (32,000 bps) over conventional digital coding (2400 bps) techniques.

The feasibility of a voice response system based upon an efficient linear predictive coding (LPC) primitive approach is studied in this project. The LPC primitive approach is a direct application of the recently developed vector quantization theory of speech coding. Primitive sets of various sizes were generated to encode the speech signal. Rate distortion performance with respect to the training data and the primitive set size was investigated. Quality of the synthetic speech samples was also evaluated by qualified researchers as well as handicapped persons. From these evaluation studies, it is concluded that natural-sounding synthetic speech can be produced from LPC models encoded with only 128 primitives. With such coding efficiency, speech storage cost can be reduced to only one-third to one-fourth of existing voice coding techniques. As the approach is compatible with LPC synthesizers, commercially available microelectronic components can be readily utilized in applying the technique.

Applications of the proposed speech storage technique are to expand the vocabulary of prosthetic talking devices, cut the cost and weight of reading machines for the blind, aid the development of voice response computer terminals and equipment at minimal cost, and greatly enhance the development of computer-based educational programs for the handicapped.

Hearing Aids for Spatial Perception and Localization

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George F. Kuhn, Ph. D.

This research is proposal number ECS 80-22377, fiscal year 1981, based on work supported under the Small Business Research Initiation Program Solicitation (PFR 79-17067).

This research develops numerical and analytical models for the localization cues for normally-hearing subjects and for those using hearing aids. These models are compared to experimental results measured on an anthropomorphic manikin as well as to models based on regular geometries, such as cylinders and spheres. New hearing-aid design concepts are developed which simulate or reproduce the localization cues available to the normally hearing subject. Thus, the aided subject would, using these new hearing aids, have available the same localization cue as the normally hearing subject. It is expected that these new hearing-aid design concepts will not only improve the aided listener's ability to localize cues, but also improve intelligibility when worn in the presence of background noise.

In addition to the design of the hearing-aid input stage, analyses are made of the "transfer function" from the hearing aid to the eardrum. This research project is primarily aimed at a reproduction of the normal acoustic signal at the output stage of the hearing aids. The technique can then be applied to ensure a good, predictable, and tractable transfer function for the hearing aid.

Low-Cost, High-Performance Speech Recognizer for the Handicapped, Phase II

Threshold Technology, Inc.
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Delran, New Jersey 08075

Phillips B. Scott

This is proposal number ECS 80-22376, fiscal year 1980, based on work supported under Phase I of the Small Business Innovation Research Program Solicitation (Award No. PFR 79-17038).

This research involves analyses of techniques leading to the development of low-cost, high-performance speech recognition devices suitable for use by the handicapped. Such devices will permit physically handicapped individuals to communicate with and control their environment. Existing low-cost speech recognition devices are not adequate for this application. The research studies techniques whereby existing high-quality speech recognition devices can be modified or adapted so that they can eventually be produced at a low cost while maintaining high performance. The techniques studied include simplification of speech preprocessing, restructuring of classification hardware architecture, and improving classifier software for persons with speech handicaps.

Electrodes to Aid the Handicapped

Annex Research
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John A. R. Kater, Electrochemist

This is proposal number 80-09361, fiscal year 1980.

Individuals suffering from chronic renal failure are severely handicapped. A reliable and low cost method to measure potassium (K^+) and calcium (Ca^{2+}) blood electrolytes during hemodialysis is needed. Imbalance of these electrolytes can cause cardiac arrythmias, irreversible complications, and death. The thrust of this research is to study the feasibility of solid-substrate technology in the development of disposable K^+ and Ca^{2+} electrodes and simple, portable, dedicated digital meters suitable for bedside monitoring during dialysis.

These steps would result in lowering the cost of hemodialysis treatment while providing better care.

Described are cost-effective miniature ion-selective electrodes (I.S.E.'s) suitable for the intermittent bedside measurements of potassium ion and free ionized calcium in whole blood. Solid-substrate potassium and calcium ISE's have been fabricated and evaluated in-vitro. Results also indicate that the use of miniature solid-substrate ISE's for direct measurements of electrolytes in whole blood with portable, battery-operated ion analyzers has many other useful applications in the treatment of the critically ill. Simple and rapid measurements are also very useful in the management of patients during surgery, intensive care, diabetic shock, and in the emergency room. Applications in pediatrics are anticipated.

Analysis and Design of Implants for a Fractured Femur

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This is proposal number ECS 80-18270, fiscal year 1981.

Clinical management of femoral fractures has been generally based on an empirical approach. There exists a need to develop a rational basis for fracture healing improvements which will eliminate abnormal stress distributions in the healing fracture area that cause either disuse atrophy with osteoporosis and bone resorption, or overload hypertrophy.

Research investigators in the Department of Civil Engineering and the School of Medicine at the University of Southern California are collaborating on a project to develop and experimentally verify a mathematical model of stress distributions in the upper part of the human femur. This model will be employed to study the design and effect of internal fixation devices used to fix the fracture elements and promote healing.

A mathematical model using a nonlinear finite element computer program is being developed to consider the effects of substructuring, contact elements, healing phenomena, as well as new nonlinear material law models. The initial study models both the intact human femur and intertrochanteric fractures stabilized by condylocephalic nails. For validation and refinement of the analytical model, the Universal Scientific Computerized Test System simulator is being employed to load cadaveric femurs with and without implants. Multiple-channel strain gage data from sensors located in the specimen are used to describe the behavior of both the femur and the fixation devices. The stress-strain behavior of the composite system can then be used to refine and develop a practical computer model for analysis of fracture healing.

Visual Feedback Speech Training for the Deaf—Phase II: Speech Analysis Using Acoustic and Glottal Sensors

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Walter C. Gish

This is a summary of a completed project, award number PFR78-21347, for the period from 3/1/79 to 1/31/81.

A previous NSF study of visual feedback speech training aids concluded that an effective aid must be capable of extracting the speaker-invariant features of speech. This project is the second of four proposed phases leading to the development of a useful visual display of speech. The research in this phase focused on fundamental problems in speech analysis. The problems addressed were the separation of periodic and random components of speech sounds and the accurate estimation of formants, particularly for high-pitched voices. Theoretical considerations suggested that the necessary speech analysis capability was possible only if the analysis was restricted to the closed-glottis interval. Extensive experiments with synthetic speech and studies of the speech of four adult males, two females, and two children (one male and one female) were conducted. The results suggest that analysis over the closed glottis interval yields extremely accurate formant estimates, no degradation with high-pitched voices, immunity to source-tract interactions, and improved modeling of nasals, voiced fricatives, and fast formant transitions.

The Effect of Chemical Modification of Bone Cements on Their Young's Moduli

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B. David Halpern, Ph. D., Chemical Engineer

This is proposal number 80-09941, fiscal year 1980.

As prosthetic procedures are used on increasingly younger and more active patients, the functional life of the prosthetic system must be extended. The present cement used in fixation of prostheses in vivo has been the principal cause of orthopedic failures. Gross modulus mismatches in mating bone to prosthesis by cement has led not only to prosthesis failure but to bone resorption, tissue necrosis, and deterioration and/or movement of the implant devices and other complications, particularly as the implants age.

The specific objective of this research is a study of the effect of systematic variations in the composition of a proposed bone cement. To be useful as a cement, the rheological properties of compositions of polymer and monomer have to be suitable, and rates of polymerization at room temperature have to be within a certain time frame. The research approach consists of two stages—a material synthesis stage during which several acrylate and methcrylate polymers are being prepared, and a physical testing stage to determine the Young's moduli of the "cured" composition of these cements.

Improved bone cement would significantly reduce medical care cost, improve surgical techniques, and allow patients to lead more active and productive lives.

It was found that varying the composition of the polymer powder has only a minor effect on altering the physical properties. The nature of the monomer did influence the compressive strengths and moduli. A correlation between the second order transition temperature of the homopolymers of the lower monomeric cement component and Young's moduli was found. An unexpected discovery was the observation that cements made with isobutyl methacrylate had higher compressive strengths and moduli than those based on the isomeric n-butyl methacrylate.

This feasibility study has shown that the compression parameters of orthopedic cements may indeed be controlled by the modification of the composition of the monomer phase. The matching of the moduli of the cements with the static and dynamic requirements of the prosthesis-bone interface is expected to lead to the design of materials which will exhibit improvements in their long-term performance as bone cements.

Usefulness of Auditory Cues for Spatial Perception in Blind Populations

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Donald H. Mershon, Ph. D.

This is proposal number ECS 80-23787, fiscal year 1981.

The goal of this research is to examine some of the ways in which individuals, both sighted and blind, can use naturally occurring cues to perceive the distance of objects which make their own sounds (e.g., other people, machines, animals, etc.) and to determine the quantitative relationships between physical and perceived distance in different acoustical settings.

Physical analyses of sound presented from different distances are compared with judgments of perceived distance. Both blind and blindfolded observers are used. Different types of stimuli and acoustical settings are studied.

The identification of just how common sounds can achieve a clear distance localization should allow similar kinds of physical variation to be produced electronically as a means for communicating more effectively about the distances of objects detected by mobility devices.

The results may assist the development of mobility aids by allowing such devices to present information to the wearer in a more readily assimilated form. Increased knowledge may also make possible more rapid training of newly blinded individuals in the full use of their normal hearing as a basis for mobility.

Enhancement of Speech Intelligibility for the Hearing Impaired

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James M. Kates, Electrical Engineer

This is award number PFR-8009372, from 9/1/80 to 2/28/81.

Project summary—Conventional hearing aids are inadequate for people with sensorineural hearing loss. A truly effective hearing aid would be one that would work in a noisy environment. A substantial improvement in hearing aids may be possible by designing signal processing that takes into account the properties of speech generation, perception, and the characteristics of sensorineural hearing loss.

The goal of this research was to enhance speech intelligibility by removing pitch irregularities and by emphasizing perceptually important speech features. By removing pitch irregularities, the effects of noise are further reduced through adaptive filtering of the speech waveform. The use of signal processing in the hearing aid is leading to a significant improvement in the quality of hearing aids.

Final report—In this feasibility study, Signatron has tested a set of computer programs that can noticeably improve speech intelligibility for the hearing-impaired. The processing first emphasizes the speech features by removing noise and pitch irregularities from vowels and by adaptively enhancing the characteristic frequency content of consonants. This is followed by dynamic-range compression and a high-frequency emphasis that helps overcome aspects of the sensorineural hearing loss. The processing was tested on the perception of stop consonants through a simulated hearing impairment; intelligibility improved, from an average of 32% of the phonemes identified correctly without any processing to 68% correctly identified when the full processing was used.

Potential commercial applications of this research lie in the area of processors to enhance speech intelligibility. The applications of signal-processing hearing aids are of special interest, since conventional hearing aids are often inadequate for people with sensorineural hearing loss. Additional applications include a larger processing unit that could be added to a telephone, radio, or television to allow the hearing-impaired to make full use of modern telecommunications.

NOTE: Dr. James C. Aller has replaced Dr. Donald R. McNeal as Program Manager. A reorganization of March 8, 1981, transferred the Science and Technology to Aid the Handicapped program in a new Division of Electrical, Computer, and Systems Engineering.