CHAPTER 11
TULANE UNIVERSITY

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A Myoelectric Prosthetic Training System

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INTRODUCTION

A child missing all or part of an arm must learn proper muscle control in order to use a myoelectric prosthesis. These prostheses take the electrical signals from muscles, usually in the stump, to control the operation of a hand, wrist, or elbow. To find suitable muscles, and to gain proper control over these muscles, is a daunting task for both therapist and child.

Children's Hospital wanted an adaptable system to aid this task during the period between the prescription and delivery of a myoelectric prosthesis. In addition to the basic requirements that a device be safe, useful, reliable, and cost effective, the device must be appropriate for the physical and mental development stage of the client and it must make training a positive experience rather than an ordeal. In particular:

- The device should encourage bilateral coordination and bimanual activity.
- The device should have a control strategy that is similar to the prescribed prosthesis.
- The device should be operable with minimal skill on the part of the client, yet it should have features that will encourage ever better skill development without becoming tedious or monotonous.

The system includes an electromyographic (EMG) preamplifier that is common to all devices, visual and auditory indicators useful for problem diagnosis and initial training, and a set of incentive devices that usually consist of a controller and a toy. The class as a whole specified the common elements, but formed into 11 teams each of which designed and built an incentive device for the group's client. These devices are:

- A drum set with electric cymbal
- A motorized dancing doll and stage
- A slot car set with myoelectric speed control
- A reversing screwdriver and "Erector Set"
- An infrared remote control toy car
- A controller for a self-feeder
- A riding car with control of motion, lights, and horn
- A riding car with steering control
- A controller for a video game system
- A controller and trainer for a hand held electronic game
- A toy clown with 8 selectable functions

These projects were demonstrated at a public showing.

SUMMARY OF IMPACT

Children's Hospital will retain the system, and is using it in-house while lending individual devices to clients for home use. Therapists report promising initial results.

TECHNICAL DESCRIPTION

The Problem

A myoelectric arm and hand prosthesis uses electrical signals from stump muscles to control one or more functions on the hand or elbow. The simplest prostheses use a signal from one muscle to control the space between the thumb and forefinger. The space opens when the muscle tension (and thus the muscle signal) exceeds a specified threshold. Relaxing the muscle permits the space to close automatically and grip an object. The speed of operation is fixed and the user controls only whether or not the space is opening. This design uses a one-channel signal with one threshold. Another prosthesis uses one muscle to control both opening and closing. Two thresholds, one low and one high, are used: one governs opening and the other governs closing. A more complex controller may use two muscles (usually an antagonistic pair, if available) with one or more thresholds for each muscle. The muscles can be used simultaneously and sequentially to force the control logic to change the active function, for example to switch from controlling the elbow to controlling the hand. A training system must be able to emulate the controller used by the prescribed prosthesis.

Design strategy

The system was designed to provide maximum flexibility consistent with safety, reliability, and minimum cost. The electrodes and the incentive devices were unique for each project, but common to all was the preamplifier. The muscle signals (EMGs) are small on the order of a few microvolts. These are picked up by surface electrodes. Interference signals of several volts are common and must be rejected. Because of the critical nature of the preamplifier and the uncertain development time, we decided to use concurrent engineering to simultaneously develop the incentive devices along with the amplifier. This does, however, require a *priori* specification of the amplifier input and output connectors, interface characteristics, and performance, but it frees the design teams to focus on the specific needs of their clients.

Depending on the client, some devices used two muscles, while others used only one. Since the cost of two channels in the preamplifier was only marginally greater than providing just one, and the cost of designing **and** constructing two different types of preamplifiers was even more expensive, a two channel unit was specified. Further, we decided to put the controllers into the incentive devices themselves because the control requirements varied and were specific to each device.

Some incentive devices were to use line power (115 VAC), some would use line powered battery chargers, some would use primary batteries only, and some were undetermined at the time of preamplifier specification. In order to guarantee electrical safety of the user, and to avoid designing electrical isolation into some units and not others, all preamplifiers were optically isolated.

The resultant modular system had interchangeable parts and devices. Any electrode set could work with any preamplifier, and any preamplifier could drive any incentive device. The advantages included less cost overall, guaranteed electrical safety, improved diagnostic and repair capabilities, and an ability to reconfigure as the clients or their needs changed. The modularity also allowed the development of two portable devices useful for field measurements, troubleshooting, and training. These are an audio indicator and a meter diagnostic device.

The preamplifier (called the MMA) and the two indicating devices are described below. A description of each training device follows these.

The Myo-Myo-Amplifier (MMA)

The MMA is an inexpensive, two-channel, optically isolated preamplifier. It is compact, lightweight, and battery powered. The MMA acquires myoelectric potentials from surface electrodes and provides a flexible interface for myoelectrically controlled devices.

The input amplifier is a low-power instrumentation grade differential amplifier (Burr-Brown INA102) which is internally trimmed to a guaranteed and stable CMRR of >90 dB. We protected the inputs from overvoltage and static discharge.

A gain stage with first order high and low pass filtration (20-2000 Hz) follows the input amplifier. DIP switches select the gain (0.2 x Normal, Normal, and 5 x Normal).

The output stage uses a voltage to current converter to drive the LEDs of an opto-isolator. The opto-isolator (PS2502-2) has a bidirectional input that eliminates the need to provide a bias signal and provides for the equivalent of full-wave rectification of the EMG signal (necessary for subsequent processing) all in one step. The output interface is the collector and emitter of the opto-isolator phototransistor.

A single 9V rectangular battery provides power. It lasts a month or more when the unit is in operation for 2 hours a day. Insertion of the input (electrode) connector connects the power to the circuit through a loop-back connection within the connector.

The circuit is built on a custom printed circuit board (Figure 11.1). The dozen units required made this economical over point to point wiring. A small case (Archer 270-293) houses the unit. The input is a modular 8-lead jack with a special keyway, and the output is a 4-lead modular jack (Figure 11.2).

Cables are easily made and it is difficult to plug them into the wrong place – a safety feature.

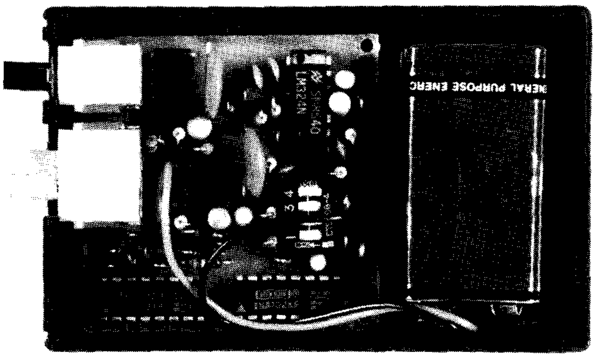

Fig. 11.1. The MMA with Case Top Removed.

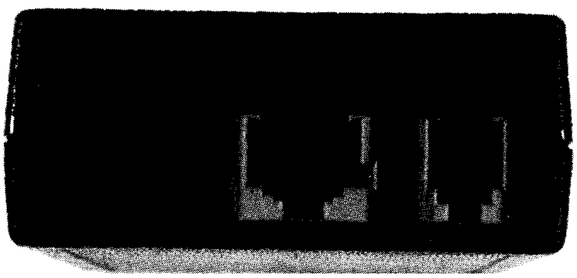

Fig. 11.2. Input and Output Jacks on the MMA

Notes: In most EMG prostheses the preamplifier is incorporated within the body of the unit. Having it in an extra case can be cumbersome. In this application, however, the rewards of modularity, interchangeability, lower cost, and safety make an external unit a better choice. The cost of parts, material, expendable supplies, and machine work came to $60 per unit.

The MMAAA Audio Indicator

The MMA Audio Amplifier (MMAAA) is a battery powered audio amplifier and speaker unit. The basic unit is commercially available (Archer 277-1008). It is fitted with a 4-conductor modular jack that connects to the output of the MMA. Figure 11.3 shows the cable and added switch used for channel selection. The power/volume control is on the other side.

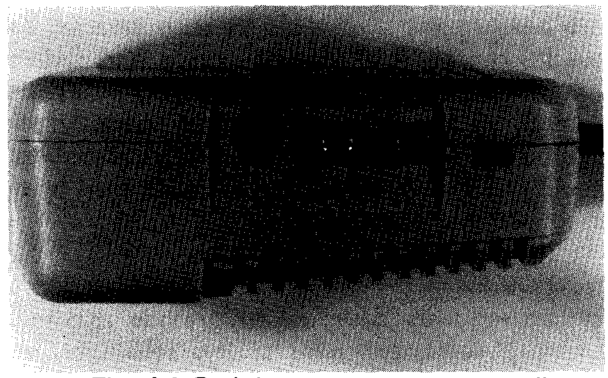

Fig. 11.3. The MMAAA EMG Audio Indicator.

The MMAAA converts the EMG output of the MMA preamplifier to an audible signal. This allows the therapist to search for electrode sites without having to look at a meter. Separation of healthy signals from spurious ones becomes easy. The MMAAA helps to distinguish between troubles such as faulty electrode contact, broken electrode leads, electrical interference, and dead batteries.

Another use of the MMAAA is in patient training. It can help to relate the use of a particular muscle by the sound associated with muscle contraction. This helps the patient "find" a particular muscle and to relate his mental effort to muscle response using the loudness of the sound.

The cost of the unit is $30.

The MMAMM Meter Diagnostic Device

The MMA-Meter-Meter (MMAMM) is a diagnostic and training device for electromyographic application. It takes the output from the two channels of the MMA and displays each on a separate meter. In addition, a set of lights (green, yellow, and red) located above each meter come on in sequence as the signal level increases. The thresholds for each light are indicated by corresponding colors on the meter faces.

The MMAMM is used for training clients to coordinate the use of two muscles. It gives an indication that is proportional to the effort of each muscle as well as introducing the idea of a threshold of operation. This enables the therapist to focus on either relative effort or on fixed goals.

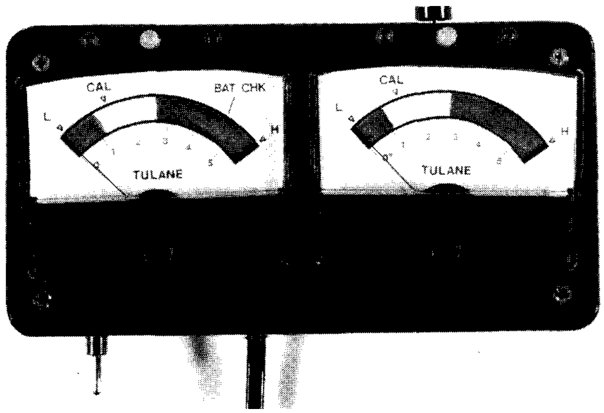

Fig. 11.4. The MMAMM EMG Meter Diagnostic Device.

The MMAMM also tests the operation of the preamplifier and helps to determine the necessary gain settings for each client. An internal calibrated signal source connects to the inputs of the MMA using a special cable. This enables the therapist to determine if the MMA is operating properly, and to find the current gain settings. These are indicated by the L, CAL, and H shown on the meter face.

The cost of the MMAMM is $30.

The Hands-Off Drum Set

Designers: Charles Pickering, Jeffrey Hooper, Jonathan Sherman, Paul Joseph Riley IV

Our client, Daniel, is a two year old unilateral below-the-elbow amputee. It was required that he receive a one channel, one function toy which could train him to use the muscles in the remaining portion of his arm. One channel was specified due to his young age and inexperience with devices of this type. A drum set was chosen because of its simplicity and attraction for young children. It would also enable Daniel to coordinate the use of his good and disabled arm by allowing him to hit the drums with a conventional drumstick with his good arm while playing the electronic cymbal using his disabled arm.

The device consists of four parts: the electrodes, the MMA, a triggering circuit, and the drum set itself. These are connected using modular phone plugs and jacks. The electrodes are stainless steel and are held by an elastic arm band. The output of the MMA is smoothed and passed to a Schmidtt trigger. The trigger output operates a solenoid (taken from a doorbell) which strikes the cymbal. A toggle switch on the drum allows a choice between the cymbal playing, or a light turning on. This allows the parent or client coordinator to disable the cymbal when silence is wanted, but allows the child to continue to use the device. The set is powered by a stepdown transformer. All circuits are isolated, with no chance for contact with the child.

The drum set cost $150.00 to build. Additional sets could be produced for about $100.00 in materials, and would require approximately 30 work-hours to construct. Daniel liked the device immediately and could use it with little instruction.

Fig. 11.5. The Hands -Off Drum Set.

Rina, The Myoelectric Ballerina

Designers: Laura Schrader, Rachel Torba, Nga Do, Chris Eaton, and Marcel Pratt

Our client is a two and a half year old who is missing a forearm and hand. She is reluctant to master her myoelectric arm. She favors her good arm, and uses the prosthesis only as a brace or anvil. In order to help develop her skill we chose a dancing doll that meets her prehensile patterns, interests, and developmental stage. The good hand holds the doll upright and moves it about while the other activates the motor driven dancing function. In order to encourage continued use of the doll and a measure of imagination in her play, we also built a stage with a motorized curtain for the doll to dance on.

The doll is a commercial toy that models a ballerina on pointe. It contains a motor that works the legs forward or backward in small steps. The head turns and one arm moves when the motor runs. A switch worked by the other doll arm has three positions: off, forward, and backward. Two C-cells in the thorax power the doll motor.

Our controller interfaces with the doll through her power supply. We put a shorting jack in the doll's back in series with the batteries. The doll operates normally when the plug is removed. The controller takes the signal from the MMA and closes a relay when a threshold is exceeded. This simple on-off control simulates our client's own prosthesis.

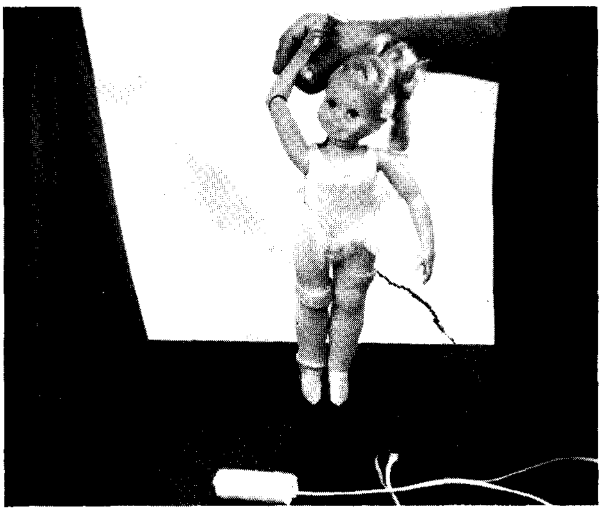

Fig. 1 1.6. Rina, the Myoelectric Ballerina and the Starlight Stage showing the MMA and the Electrode cuff.

The stage consists of a wood platform and an upright frame that holds the curtains. The curtains are moved by a motor beneath the platform. It is controlled by a MC DPDT center off switch. Limit switches stop the motor when the curtain reaches its limits of travel.

When presented with the doll, our client enjoyed her but was frightened by the electrodes. The electrodes are now hidden in a soft cuff that matches the color of the doll's tutu.

Total work hours were in excess of 500; total cost of parts and materials $249. These would be reduced considerably for a second unit.

The Muscle Car

Designers: Mike Aertker, Chris Jones, Khoa Vo, John Yenari

Randy, a five year old, lost his right forearm to bum injury. He needed a one-muscle, two-level myoelectric training device that would capture his attention and be adaptable to his changing needs as he becomes more advanced in his therapy. It is important for him to learn to coordinate the use of his left arm with his prosthesis. He told us that he was interested in cars. We designed the "Muscle Car" to satisfy these needs.

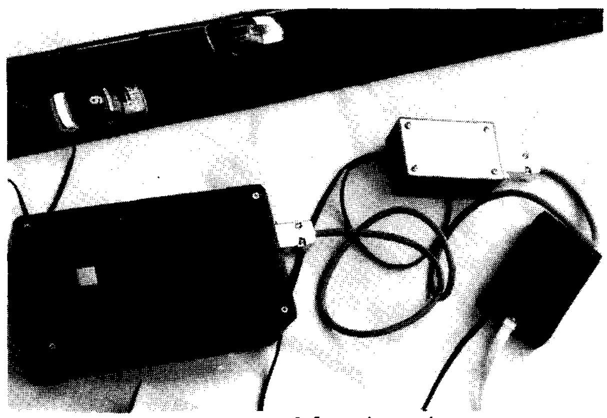

Fig. 11.7. The Myoelectric Muscle Car showing System Box with Turbo Button and Indicator Lights, the MMA, and an Interface Box.

The device is a commercial slot car set with two slots. A new controller replaces one of the original hand controllers. This allows Randy to run his car alone or to race with the car of another child. Speed control is necessary because taking a curve too fast causes the car to roll off the track.

Using the signal from one muscle, a logic circuit selects low or high speed or stop using two threshold levels. Pressing a "turbo button" with the left hand causes a speed increase at either low or high speed, for a total of 4 speeds. Three lights on the system box show the output state of the controller. These features achieve the goals of muscle training and bilateral coordination.

The design team also suggested three race track configurations ranging from simple to complex. After beginning on the simple track, Randy's therapist may then choose to increase difficulty as Randy improves his muscle control.

The controller takes the output of the MMA, smoothes it with a low pass filter, and compares it against two thresholds. There is no need in this application to bypass the low range if only the high range is desired. The controller logic takes the output from the comparators and the turbo button to operate relays that bypass one of 4 resistors in series with the car's original power supply.

Randy could run the Muscle Car at the first trial session, but he could get only "stop" and "high gear." We increased the difference in threshold levels until Randy develops finer muscle control.

Work hours for system development were 1100, and total funds used were $483. To make a second unit would require about $250 and 70 work hours.

My Own Myoelectric Screwdriver (MOMS)

Designers: Darius M. Moshfeghi, Brian J. McGuinnes, Mark V. Morici, William W. Trice

Alexander is seven years old and had an above-the-elbow amputation of his right arm nine months ago leaving an 8" stump. He enjoys building things and thus requires the use of both of his arms for handling, maneuverability, and assembly. We decided to develop an electric screwdriver for Alexander that he would be able to use in conjunction with an erector set.

Using a sheet of heat-deformable plastic, we made a socket for Alexander's upper arm. A conventional side-mount fishing pole holder that has a lock serves as a prosthetic elbow. This was modified so that Alexander could easily reposition the screwdriver into another position with his good arm. The screwdriver body was then mounted into the fishing pole slot. The electrodes attach to the interior of the socket. The batteries were moved to a remote case to lighten the unit. The preamplifier, batteries, and controller mount on a belt.

Low muscle exertion turns the screwdriver on, and higher muscle exertion toggles the direction of rotation. The currently active direction is indicated by a red or green LED on the motor unit.

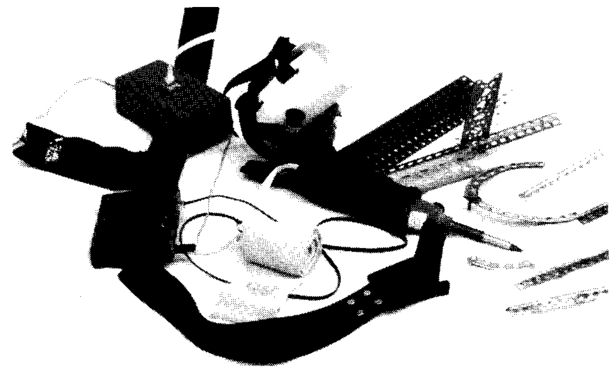

Fig. 1 18. My Own Myoelectric Screwdriver set.

The design isolates Alexander from any outside power source. He cannot recharge the batteries without first disconnecting the wiring that attaches to the electric screwdriver. It is also not possible for Alexander to rotate the screwdriver back into his head/chest region due to a mechanical blocking device that we have added to the assembly.

The total cost of parts and supplies for MOMS was $352. A second one could be assembled for about *$250.*

Myoelectric Infrared Batmobile

Designers: Joi Lenczowski, Christy McCay, Laura Popich, Aaron Stinnett

We designed this incentive training device for a five year old below-the-elbow amputee. This device will train him to recognize and control what remains of the wrist flexor and extensor muscles. He should then be able to operate a two-site prosthesis when he receives it.

An infrared transmitter forms a wireless link for the control of a toy car, the Batmobile. The transmitter fastens to the good wrist, and the electrodes to the stump of the other arm at the site of the future prosthesis. Colored lights on the transmitter denote which muscle is being contracted. To teach muscle isolation the car will respond only when one muscle, but not both, are contracted. The narrow beam transmitter requires the child to aim at the receiver thereby compelling dual arm coordination.

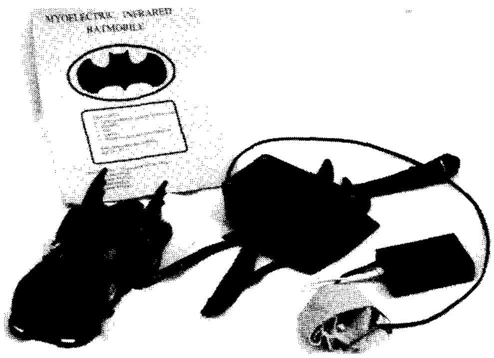

Fig. 11.9. IR Batmobile with MMA, controller/transmitter, and electrode cuff. The IR receiver is visible at the right lower corner of the windshield. A Batman shirt [not shown] pocket holds the MMA and keeps the wires from tangling.

The receiver consists of a GP1U52X infrared receiver/demodulator, that interfaces to a modified commercial radio control toy car. The relays of the switching circuitry activate the car's motor forward for one input frequency and turns in reverse for the other signal.

Our client's first experience with the device occured at the end of a long day of therapy. Despite his tiredness, he was able to work the car reliably in one direction, and occasionally in the other.

The cost of the complete incentive device, including electrodes, pre-amplifier, transmitter, and the receiver/vehicle, is approximately $195. Its' development required 1100 work hours. Future models should have a much smaller and lighter transmitter unit.

Myoelectric Feeder Controller

Designers: Robert Cargile, Lance Champagne, Richard Enmon, Richard Harrelson

We designed a feeder controller for a male, five-year old, quadruple amputee. He can now use myoelectric signals to control the movements of an existing feeder (see Engineering Senior Design Projects To Aid The Disabled, NSF, 1989, pp 178-179) by "flexing" the muscles in one of his stumps. The controller has three **main** components: a pre-amplifier for the muscle signals (MMA), a main logic box, and a joystick for the therapist.

Fig. 11 .1 0. Self Feeder with Myoelectric Control.

The logic allows the user to select one or two muscle control. If one muscle control is selected, **then** the axis of action (front-back or left-right) must be selected also. The direction of movement along an axis depends on the intensity of muscle contraction.

Two-muscle control permits independent control of each axis, The spoon lifting function is controlled by a lever switch on the right of the feeder unit. This is to be operated by the client's arm prosthesis or replaced with another remote switch. All components are connected by cables so the boxes can be located conveniently.

The joystick allows the therapist to manually override the myoelectric control. This feature lets the therapist demonstrate the motions needed, work the axis **not** being controlled, or to help the client when he gets tired. The joystick is not necessary for the operation of the controller and can be unplugged if desired.

The controller and feeder can thus serve two functions: 1) As a stand alone self feeder; and 2) as a myoelectric trainer. As a trainer, the therapist can choose different modes to work one muscle at different output intensities or to coordinate **one** muscle with another.

The final cost of the myoelectric controlling system was approximately $265 and it required over 650 work hours to develop. To replicate the controller would require about 50 work hours and would cost about $180.

Super-Vette

Designers: Gena Ruder, Heather Murphy-Lavoie, Ashley Boulware, Lynn Anne Derdall

Our client is a five year-old female with a congenital defect leaving half of her forearm intact. She is currently learning to use her second myoelectric arm. She is capable of getting along without it and is not very interested in using it. To improve her skills and to facilitate further and more integrated use of the arm, it is necessary to provide a device that will capture and retain her interest, and challenge her current skill level on the myoelectric arm. The client is a self-proclaimed "tomboy". A car will grab her interest and hold it long enough to practice motoring, thus practicing fine control of those muscles needed to power the myoelectric arm.

We chose a Power Wheels Corvette (approximately 60" long x 24" wide) in which our client could ride. The controller is designed to allow our client to power the vehicle forwards and backwards at a fixed speed of 3 mph. Steering is done with the good arm. This requires development of bilateral coordination. She can honk the horn while traveling in either direction with an extra squeeze of the appropriate muscle. Working both muscles simultaneously will toggle the headlights on and off. A portable garage was built to scale. Parking in it will provide a challenge to coordinate. The garage will fold-up for storage or transport.

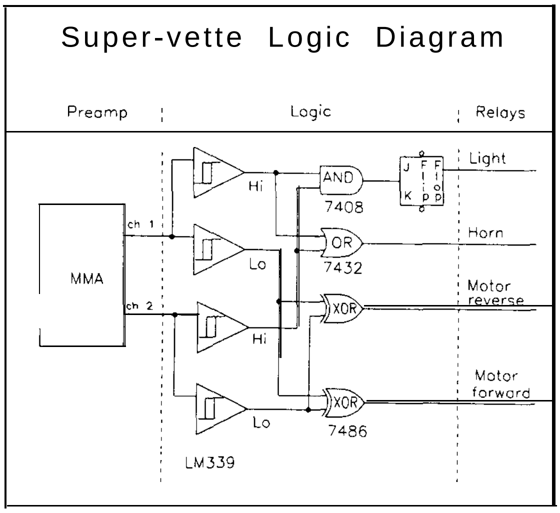

Fig. 11.11. Super-Vette Logic Diagram.

The controller circuit receives a two-channel input from permanent electrodes. After low-pass filtering and threshold comparators, standard logic is used to provide the control. A special requirement is that high current relays must be used for the motor circuit.

In conclusion, the client needed an incentive device that was both tailored to her interests and effective at improving her weaknesses. A black Corvette with a pink and white garage is just the ticket. Work hours for design and construction were 904. Parts and materials approximated $400.

The Ultimate Jeep-A Myoelectrically Steered Riding Jeep

Designers: Julie Dittman, Heather Gareis, Samantha Salkeld, Ann Starr, Michelle Todd

The myoelectrically steered jeep was designed for LaShondra, a 5 year old child congenitally missing her right forearm. The client's main need, as identified by her mother and therapist, was to increase her desire to use her prosthesis in every day activity. Other problems addressed were her need to develop and strengthen the muscle which runs the prosthesis, and the refinement of her control over that muscle.

Our choice of the jeep was influenced by several factors. We felt the jeep was dynamic enough to hold our client's attention for long periods of time and would be viable both indoors and outdoors. Also, the jeep will provide a continual challenge. As her skill level increases, a special course for steering could further challenge her. Performance will be easy to monitor. The jeep's steering design, using only one channel of weak and strong contractions to perform different functions, mimics the control of our client's myoelectric prosthesis. Thus the skills she develops will be easily transferable to her prosthesis. The design dealt with two major parts: the electrical control and the mechanical components. The controller uses a set of three electrodes that are placed on the muscle that will control the client's prosthesis. They are connected to a MMA (class designed part) which isolates and amplifies the myoelectric voltage. The signal is then sent through a low pass filter for smoothing. After this, it passes through a window comparator. The comparator uses preset levels to distinguish between weak and strong contractions. The comparator sends out corresponding signals that control a relay system. Each relay controls one direction of turning. An interlock is provided so that the motor won't try to turn both ways at once. Visual feedback of controller operation is provided by two lights placed on the dashboard. The lights can also simulate turn signals.

Fig. 11.12. The EMG Ultimate Jeep.

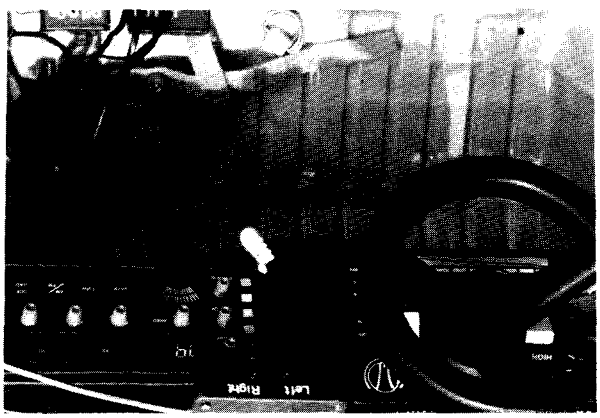

Fig. 1 1.13. Jeep Cockpit Showing MMA and Power Switch [Lower Right) and Signal Lights (Top).

The mechanical design leaves the jeep intact. A tiller bolts onto the steering column out of sight beneath the hood. A reversible DC motor powers a cable and sheave system that turns the tiller. Limit switches protect the system from damage at the mechanical stops. It takes approximately 7 seconds to turn from full right to full left.

We decided not to provide automatic self centering or proportional control since this would not simulate her myoelectric prosthesis realistically. This prototype was produced for $626, but a second could be made for $367.

Video-Flex: A Myoelectric Training Device

Designers: Neil Axelrod, Mark Cruz, Thomas Trinh, Doug Wickman

The objective of this project is to design a myoelectric training device for Alexander, a 7 year old. His right arm was amputated above the elbow. This incentive device will retrain Alexander's biceps and triceps for an artificial arm. We chose the Nintendo video-game system as the incentive device for three reasons: A video game system will excite a child (including a few adults) into playing for hours. Second, the game system is set up such that the therapist or doctor can easily monitor progress by how well the patient plays the game. Third, a game system has an endless amount of new games and thus the client can be reassured of never growing bored of this device.

Fig. 1 1.14. Videoflex Game Controller.

Our device takes control over two buttons of the standard controller. This leaves a joystick-like control for the good hand to work, thus fostering right-left coordination. A second controller is unmodified so that he and a companion can play games designed for two players.

A one muscle, two level controller was needed. An adjustable stump cuff held a dry electrode system. The muscle signal was picked up by the MMA pre-amplifier. Our controller switched logic when the signal passed through two thresholds. Because the games are fast, we decided to allow button A, the low level button, to be activated first (and always) before button B. Button A was released, however, as Button B was activated. This required selection of games that would not be severely disturbed by an A press if B only was desired.

The electrical attachment was straight forward. The buttons were removed and replaced by giant red and green LEDs. When these came on they indicated a button push, this makes the control action visible. The actual interface consisted of reed relays mounted on the button contacts on the PC board of the game controller. This method increases safety by electrical isolation in addition to the optical isolators of the MMA. Our client tried "Dig-Dug II" where his good hand controlled the movements of the protagonist and the buttons controlled the Jack-Hammer and the Pump-Gun against gremlin adversaries. He had never played this game before, but got the hang of it quickly and was disappointed when the session ended.

The commercial game system and the additional supplies and parts cost $249 and took 344 hours to develop. A duplicate system would cost $225 and take about 20 hours to build.

The PAT-Play and Train A Myoelectric Training Incentive Device

Designers: Mark Bufkin, Jeff Emery, Andre Lajoie, Shawn Lewis

Jamie, our client, age 10, suffers from congenital absence of her right forearm, left shank, and two fingers on her left hand. She is adept at using her myoelectric prosthesis; a flexor-extensor muscle pair that open and close the hand using 2-channel proportional control. Two problems need to be overcome: she needs to learn how to regulate the closing pressure better, and she needs to learn how to keep the hand under control when she moves her arm. Since traditional training is tedious and tiring, patients (especially children) lose interest quickly. We were to make a training device to obviate these problems.

Capitalizing on the zeal children have for video games, our design uses EMGs from two muscles to control the operation of the "A" and "B" on a Nintendo Gameboy. These buttons have a variety of functions for different games, but usually they are reserved for the firing and jumping of a video character. The remaining hand is to be used for controling the movements and position of the video character. This configuration of the portable electronic game will provide necessary incentive for training right/left coordination.

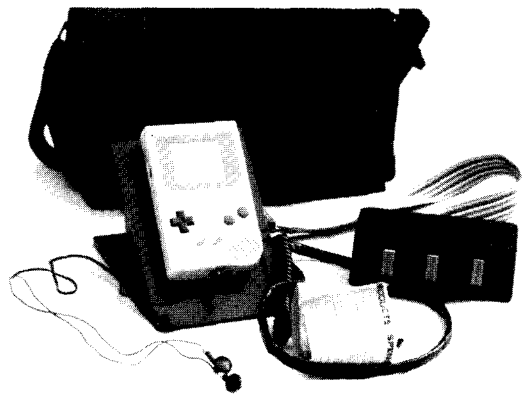

Fig. 11.15. The Play-And-Train Incentive Device.

For developing greater muscular control, the degree of contraction required for each muscle can be set by the therapist. An LED bar graph display (on the right of Figure 11.15) makes the settings and the output of each muscle visible. The center bar graph shows the high and low settings for control action. The therapist controls these settings with two rotary switches on the back of the display case. The output of the muscle controlling the A button is displayed on the left, B on the right. Button action occurs only when the muscle output is within the window marked by the two thresholds. The display device is not necessary for operation of the game, and can be unplugged.

The controller connects to the game using a modular phone connector. The interface uses PC mount reed relays that parallel each button. This leaves the buttons intact and operable, but unneeded for training. Removal of the cable returns the game to its original appearance and function.

The controller is housed in a rugged, collapsible stand. A handsome camera bag houses the system, its cables, spare parts, and additional game cartridges.

Our client took to the game on the first session. The only problems were with electrode placement, her muscles were small and hard to find, and the cuff slipped when she moved her arm repetitively. We are working on a better cuff arrangement.

The total cost of the prototype is $382. If our team was allowed to charge $8/hr, the labor cost of prototype development is $5752.

Hannibal the Happy Clown

Designers: John Crisologo, Rolf Grage, Jeffrey Porter, TimSchrader

Wade, a 3 year old with one arm, has learned to operate a single channel prosthetic arm after only a few months of therapy. He is expecting a dual channel arm that will provide more actions to control. Since the task of learning how to properly operate a myoelectric therapeutic device is long and arduous, we designed Hannibal the Happy Clown to relieve the tedium. Hannibal is specifically designed to teach a preschooler to use a dual-channel, myoelectric prosthesis. By providing a colorful, fun environment, the training should be easier on both the therapist and the client.

Hannibal is an original design. The head is a painted plastic sphere. All of the circuitry and mechanics are housed in the head and base. The wooden base is covered with a costume. The back panel of the base opens for service. Seven functions are provided: 1) Shaking Ears, 2) Light-Up Nose and Horn, 3) Rotating Lights in the Eyes, 4) Jumping Hat, 5) Sparkle Bow-tie, 6) Spinning Lapel Flower, and 7) Crazy Tongue.

The MMA preamplifier picks up two signals from two muscles. These are used to control the clown as follows. When channel 1 surpasses a threshold, a fast counter continuously cycles through N selections. As the signal drops below threshold, the counter stops. The selected function is now indicated by a LED on the lapel label. The selection at this point is essentially random. The value of N is chosen by the therapist using a switch on the clown. This permits simple initial training that can be made more complex at will. By slowing the clock, it becomes a game of skill (using timing) to select a particular function.

Activating channel 2 operates the selected function for as long as the contraction is maintained.

At first sight Hannibal frightened Wade. Hannibal was too big, and Wade didn't know what to expect. Two team members explained as Hannibal was put through his paces. Then the therapist took control of one channel, and finally Wade was willing to try. Wade was a little sad at the ending of the session.

This experience told us that Hannibal is too complex for a small child to work alone. With an understanding therapist and a phased introduction, however, it appears that the prototype meets its design goals. The cost of prototype development is $365. It took 497 work hours to complete, 101 more than planned.

Fig. 11.16. Hannibal.

Shoe Insert to Reduce the Risk of Amputations in Diabetics

Designer: Shawn A. Lewis
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INTRODUCTION

Diabetic neuropathy, a progressive disease that often results from diabetes mellitus, causes a loss of sensation in the lower extremities. This can lead to excessively high load pressures during walking. Studies of the pressure distribution on the bottom surface of the diabetic foot suggests that bone changes can result from these excessively high load pressures. Both the lesions and the altered bone structure tend to increase the pressure at the locus of the high load pressure, thus further affecting the foot in this area. Once this cycle is started it is relatively hard to stop its progress, and all too often it leads to the loss of the foot. In order to break this cycle, a shoe insert signals the wearer when too much pressure is exerted on the bottom of the foot.

SUMMARY OF IMPACT

Perhaps the best way to help a disabled is to prevent the onset of their disability. Current knowledge about diabetic neuropathy suggests that excessively high metatarsal pressures lead to the eventual amputation of the effected limb. Consequently, if the patient could be made aware of these pressures, perhaps amputation could be avoided. This device will do just that. The device makes a rough measurement of the plantar pressure, compares this pressure to a set value, and emits an audible warning to the patient when too much pressure is being exerted. This device was not tested on a patient, but, rather, serves as a prototype device that could be put into service on short notice. Given the current level of research on the problem, it should not be too long.

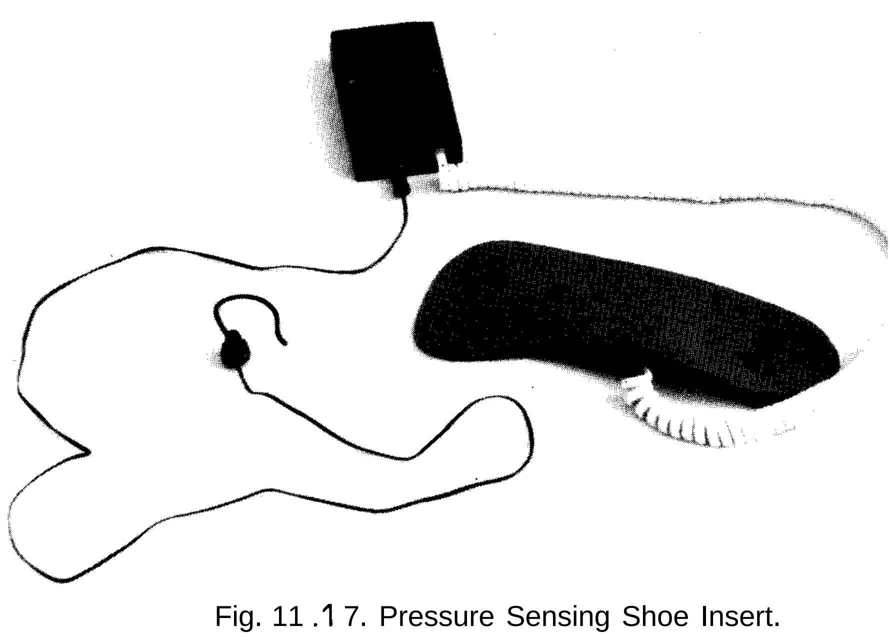

Fig. 11.17. Pressure Sensing Shoe Insert.

TECHNICAL DESCRIPTION

Pressure sensor: A pressure sensing shoe insert was built using a commercially available arch support as the foundation. A force sensing resistor (FSR-a trademark of Interlink) is affixed to the inferior surface of the arch support. The FSR is secured with a small section of foam cushion (supplied with the FSR) that protects it from abrasion and helps to evenly distribute the pressure. The FSR is connected through a modular phone jack to the processor by a telephone cord. The FSR can be affixed to any region of the arch support, thus enabling the device to be tailored to a specific patient. Once a locus of high pressure has been found, this region can be mapped onto the arch support. The FSR can then be attached to this region of the arch support. This flexibility enables the device to be used for a wide range of patients. The sensor has a dynamic range from 0 to 25 kg for direct loading and 0 to 45 kg for lateral loading (1 cm from the edge of the FSR loading).

An additional sensor, such as a Tapeswitch[R], can be placed around the sole of the shoe to detect lateral impacts. This was not implemented because it requires modifying every shoe used in an unsightly way, whereas the arch support can be moved from shoe to shoe.

Processor: The signal is processed within a small, black transmitter box. A 1.5 kHz audio signal is sent to the patient through an earphone for 3/4 of a second each time the pressure threshold has been exceeded. The FSR has been incorporated into the measuring circuit as the upper branch of a voltage divider. The voltage across the lower branch of the voltage divider is compared to the threshold voltage. If the input pressure is greater than the threshold pressure and has a duration less than 0.75 seconds, a 0.75 second, 1.5 kHz signal is emitted. If, however, the input is greater than the threshold pressure for a period longer than 0.75 seconds, then the audio signal is emitted for the duration of the excessive pressure. This signal is carried to the patient via an earphone.

The threshold level can be set by adjusting a 15 turn, 10 KΩ potentiometer. The volume of the emitted signal can be set with another potentiometer.

The processor hangs on the belt and looks very much like a portable transistor radio (a device in common use). Its use should not attract undue attention or psychological trauma that may result from being "different."

Cost: The total cost of this device was $118. This price included: the orthotic arch ($18), the FSR kit ($80), and the circuit components and box ($20).

The Rising Chair

Designers: Laura Schrader, Chris Fritton
Client Coordinator: Charles Keller
Supervising Professors: David A. Rice, Ph.D., P.E. and Ronald C. Anderson, Ph.D.
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INTRODUCTION

The Rising Chair was designed to meet the needs of people who have trouble sitting down smoothly or standing up again. The user, with or without a walker, backs up to the standing chair. Pushing a switch down on one arm causes the chair to settle to the seated position. Pushing the switch up causes the chair to rise again to the standing position.

A device such as this can help maintain independence and delay institutionalization or the need for continuous care. This can improve the quality of life and minimize support costs for an individual who needs help in this area.

SUMMARY OF IMPACT

The Rising Chair assists our client to rise and sit down with ease, something she could not do before. The chair has been in service for several months with no complaints except that the seat was too hard.

TECHNICAL DESCRIPTION

We designed the Rising Chair when the client coordinator saw possibilities from a previous project (The Tulane Hirider Chair, Engineering Senior Design Projects To Aid The Disabled, NSF, 1990, pp 230-231). The basic concept was retained, but a redesign started from the ground up.

The construction uses stressed skin plywood panels to form the integral body and frame of the chair. The kick-panel, seat, and back of the chair are fastened together with continuous (piano) hinges. The base of the chair is another panel, and the triangular sides also carry working loads. This approach minimizes the need for large frame members and heavy joints. Tortional flexing of the seat caused the chair to have too much sway when partially or fully extended. Turning the entire seat into a box beam (visible in the figure as the un-upholstered part under the seat) resolved the problem with minimal added weight.

A 4-bar mechanism stabilizes and orients the back and arm assembly as the chair rises. It leans forward about 5 degrees and lowers the arm ends at the top of its travel in order to make entry and exit easier. The four bars are: the kick-panel; the seat; the rear legs; and a pair of struts (the light member in the figure that lies below and parallel to the seat) on either side. The seat hinges from two of the pivots; lag bolts and nylon bushings form the other two. The highly stressed struts are made of clear spruce and remain uncovered and unpainted so signs of failure can be noticed easily.

A 12 volt motor and screw actuator assembly power the chair. These are the short and long dark cylinders lying behind the strut in the figure. The power supply uses a 12 volt step-down transformer, bridge rectifier, and RC filter to produce DC for the motor. The control switch, visible under the arm in the figure, is a momentary contact DPDT switch that reverses the polarity of the motor voltage. Releasing the switch always stops the motor. In order to avoid wear and tear, limit switches stop the motor at the ends of travel.

The light superstructure of the chair combined with the low location of the heavy actuator keeps the center of gravity low. This plus the broad base keeps the risk of toppling low. Guards at the ends of the seat hinges keep fingers out of trouble.

Foam padding 1.5” thick covers the seat and top of the kick-panel. Contoured padding 2” to 4” thick forms the backrest, and the arms have 0.5” of foam padding. Washable upholstery covers the padding and gives the product a neat and finished, but somewhat institutional, look. Future models might benefit from more shielding of the mechanics and overstuffing to give a homey look.

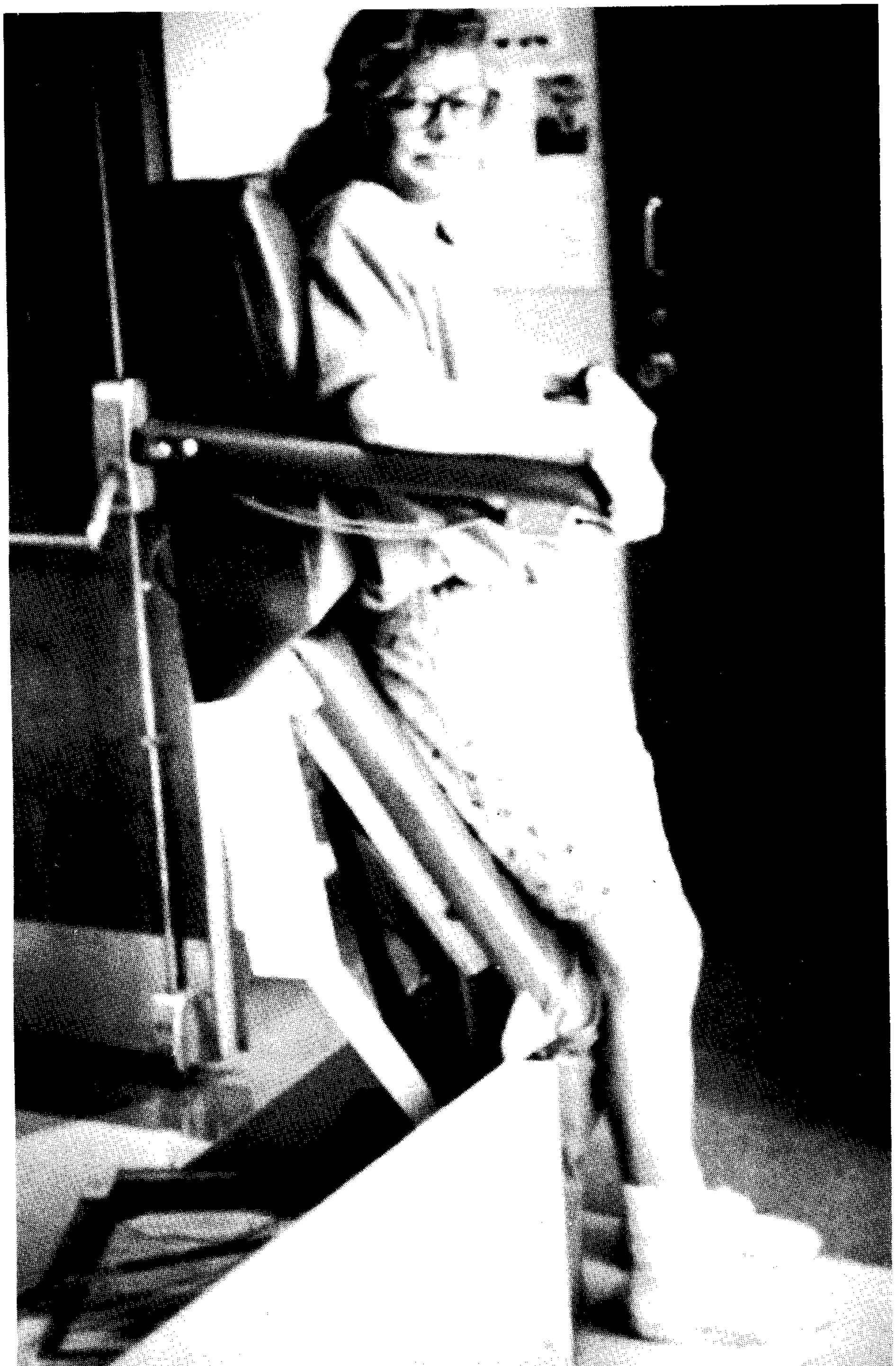

Fig. 11.18. The Rising Chair.