Proceedings of the Sixth Annual Conference on Rehabilitation Engineering

San Diego, California
June 12-16, 1983

1983–
The Promise
of Technology

RESNA
Rehabilitation Engineering Society of North America
An Interdisciplinary Society for the Advancement of Rehabilitation through Technology

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Bruce R. Bowman, Sc.D.
Editor

Donald R. McNeal, Ph.D.
Daniel W. Monzingo, J.D.
Conference Co-Chairpersons

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The Rehabilitation Engineering Society of North America (RESNA) is an organization concerned with the exploitation of science and technology in the rehabilitative process. Its membership includes rehabilitation professionals (drawn from all pertinent disciplines), providers, and consumers. A goal of the organization is to promote interaction between these groups so they can better understand and serve the needs of those who can benefit directly from the application of rehabilitation engineering technology.

This volume represents an excellent cross section of the results of rehabilitation research during the past year. Its interdisciplinary character epitomizes the philosophy of RESNA; that is, that rehabilitation engineering is a team approach that requires the skills of many professionals--physicians, engineers, therapists, nurses, to name a few--as well as consumers, without whose input the advancement of rehabilitation technology would be severely curtailed.

This year's theme, The Promise of Technology, was demonstrated not only by the scientific papers that comprise this book but also through instructional courses, advanced topic discussions, luncheon seminars with experts, product demonstrations, student design projects, tours of rehabilitation facilities, and an exhibition.

The editors thank all those who contributed so importantly to this publication.

Bruce R. Bowman, Sc.D.
Chairman
Scientific Papers

Keeping with the goals of RESNA, this year's authors of scientific papers cover a diversity of professions reporting on a diversity of topics. A total of 152 papers were accepted covering 16 subject areas. Authors represent 25 states as well as Canada, England, Yugoslavia, Sweden, and Japan.

Much of the success in soliciting the large number and high quality of papers submitted this year was due to efforts of the 15 Session Chairpersons. Each Session Chairperson, an expert in their field, accepted the responsibility of personally encouraging leading colleagues in their area of research to submit papers to RESNA. The Session Chairpersons were responsible for setting up panels of experts to review papers submitted to their session to insure that papers accepted were of high standards of excellence. Each chairperson put a great deal of time, effort and pride into developing their session and offered many valuable suggestions regarding organization of the scientific papers.

I would like to thank the Session Chairpersons for their much-needed contributions. I also would like to thank the Organizing Committee, particularly Conference Co-chairperson Donald McNeal, and the RESNA office for all their valuable assistance, and commend this year's authors for their excellent work and interest in participating in RESNA.

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SHOULDER EXERCISE INCENTIVE SYSTEM

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ABSTRACT

A shoulder driven control for commercially available video games is described. It is designed to provide an incentive for therapeutic exercise of shoulder girdle muscles during rehabilitation in quadriplegia. Clinical experience with the system is discussed from the perspective of teaching a person to use the remaining voluntary shoulder muscles for balance and trunk positioning as well as arm placement.

INTRODUCTION

During the early phases of physical rehabilitation, a quadriplegic patient must learn to use limited remaining voluntary muscular resources to perform as many skills as possible. Shoulder girdle muscles, which can exert forces in a wide range of directions, are necessary for trunk balance as well as arm positioning in quadriplegia. Trunk movement ability is of special importance because it is the only independent voluntary mechanism for adjusting seating pressures in this group of patients. Nevertheless, the focus of shoulder exercise during rehabilitation is improving the arm positioning function.

At our center, exercise of the shoulder girdle muscles is incorporated into mat activities and whole arm conditioning exercise for the achievement of self care skills. Since no specific exercise is directed at the balance and trunk positioning function of the shoulder girdle muscles, we have developed a shoulder driven video game controller to serve as an incentive for recently injured quadriplegic patients to work on this during rehabilitation.

BACKGROUND

Maintaining interest in therapeutic exercise is an essential role for therapists, whose very presence provides an incentive to work. For infants and children, play is central to most therapeutic exercise routines. Although older patients can make exercise an end in itself, it is easier if it is fun. Exercise incentives provided by electronically mediated tasks with video displays have been used to encourage stroke and head injury patients(1-3), in whom visual-motor integrative function itself may be impaired(4). In this study we introduced a modified game controller which specifically requires use of the shoulder girdle muscles for game play. In this report, we describe clinical experience with the exercise system which consists of a shoulder harness to which the controller attaches and the video game.

MATERIALS AND METHODS

The first step was to design and build a rough prototype to see whether the trunk positioning exercise characterized by protraction, retraction and elevation of the scapula was suitable for driving a video game, and whether these movements in quadriplegics would result in noticeable shifts of body position. Next, an advanced prototype controller was designed and built. The specific design objectives included quick set-up, a stable connection between the top of a user's shoulder and the control itself, and reproducibility with inexpensive parts. We wished to have a reasonably flexible design so that the control could be used to exercise other joint movements later.

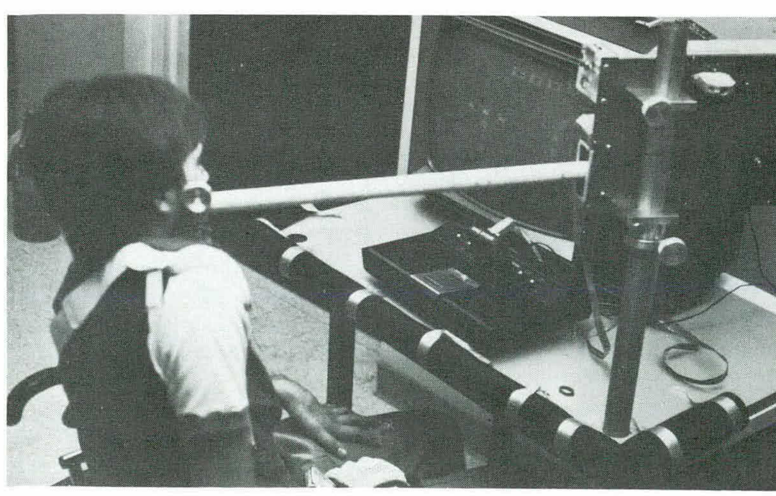

Figure 1. Quadriplegic using the system.

The mechanical design of the controller circuit permits independent registration of movements with 2 degrees of freedom, up and down and forward and backward. The movements drive slide potentiometers whose positions may be read by the electronics. Adjustable comparitor circuits permit changing the distance a user must move before the movement results in the simulation of the Atari(TM) joystick. An adapted reset switch permits independent use by a quadriplegic after initial set-up. The second prototype system is pictured in use in figure 1.

With the completion of the second prototype, a clinical trial was initiated. Six patients used the games while numbers of repetitions of the necessary movements were counted; game scores and time playing were also recorded.

A third mechanical prototype has also been completed which gives a smoother functioning system for further investigation. It is designed for use with a monitoring system in parallel with the video game so that objective data on the movement itself may be recorded automatically.

RESULTS

Observations of the initial experience with the first prototype demonstrated improvement of skills with each bout of exercise. In addition, users endurance with the system increased. Average game scores at each consecutive session for the two patients who used the initial prototype most are illustrated in figure 2. These users, and the others, reported appreciation of the skills we were trying to encourage. The need for easy set-up was recognized, and addressed in further development.

In the second clinical trial, we observed a nearly log-linear relationship between the Space Invaders(TM) game scores and the numbers of repetitions of forward/backward movements. We observed that the up and down movements did not match so well since some players constantly kept the control in the up position which corresponds to the firing button on the Atari(TM) control.

Several able-bodied volunteers played the shoulder control game while sitting in a wheelchair barograph(5). This device records relative seating pressures with a visual display. The barograph seating surface is not cushioned and is used for asensory patients only for teaching purposes. As expected, playing the game resulted in observable shifts of weight.

DISCUSSION

This study illustrates the role of directed exercise incentives during therapeutic exercise. We chose the shoulder movement because of the difficulty our therapists encounter in teaching the important shoulder girdle controlled body movement functions to recently injured quadriplegics; other joints which may be used without major changes in the mechanical system include wrist, fingers and hip. Other adaptations would be necessary to make the system work for exercise of any other joints. The success we had with the shoulder game was sufficient to introduce the system into our regular rehabilitation therapy.

The use of off-the-shelf video games for incentive, as compared with the standard video tasks described by others, provides a degree of familiarity to the patient. However, the mechanical design for this system is not as integrally related to the electronically mediated task as might be in the other systems. The separation of game objective from exercise objective is seen as a factor in increased incentive.

The recreational incentive to a poorly defined exercise is paramount, and served as the stimulus for this project. As expected, the observed response of the rehabilitation patients emphasizes the potential for use of a system such as ours for a other exercises for able-bodied as well as disabled persons.

Our further work includes refinement of the control and attachment of a monitoring system. These will be described in the presentation.

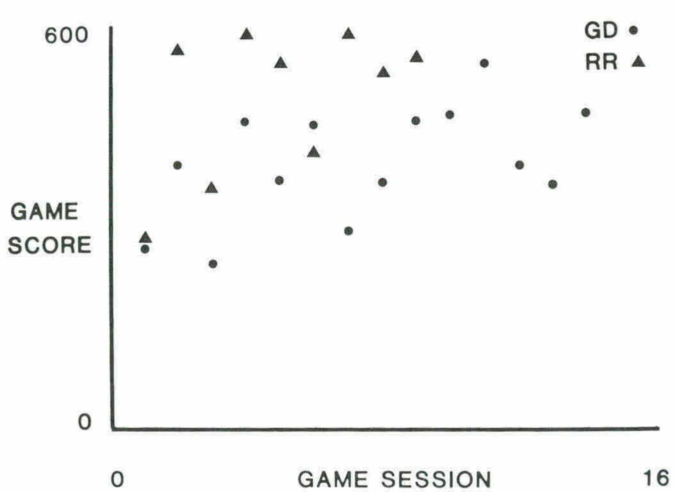

Figure 2. Two users' scores using the first prototype system.

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ABSTRACT

This paper discusses an innovative application of technology to facilitate recreation by severely handicapped individuals. Adaptive controllers for video games and computers for use by these people have been developed which replace joysticks. These controlles can be used by people with spinal cord injury, cerebral palsy, muscular dystrophy, amputations and stroke. The controllers interface with the Atari 400/800 computers, Commodore Vic-20 computer, Atari 2600, Sears Telegame, and Colecovision. Adapters are available for the Texas Instruments, Apple, and Radio Shack TRS 80 computers.

INTRODUCTION

Tommy Gonzales, 13, is a video game freak, the kind you hear about who plays for hours in the arcade on a single quarter. Once he was playing the only PacMan machine in his neighborhood for such a long time that a group of older boys got impatient waiting for their turns and threw him into a trash can! That was before a gunshot severed his spinal cord. Tommy is now a C-3 quadriplegic. He is only able to move his head and needs the aid of a respirator to breathe. For seven months he lay in the hospital unable to participate in his favorite activity. With the help of a specially adapted mouth control he's back to playing video games for hours at a time, without assistance. It's one of the very few things he can do for himself. With the mouth operated joystick, he scores over 20,000 on PacMan.

John Carasik is a 12 year old boy with severe cerebral palsy. He is spastic and has almost no control over the muscles in his body. But the ones he does control, he can use to smash electronic space debris with as much pleasure as any youngster his age. His favorite game varies and his scores are always improving. At last count, he had gotten over 30,000 on Missle Command. John has just recently been able to play video games because he's acquired a controller he can use. He plays with a botton controller that he operates with his feet. It is mounted on the footrest of his wheelchair and consists of five large soft-touch button switches. He resets the game with a similar button mounted on the side of his chair.

John is non-vocal and uses a computer to communicate. Most of his conversation consists of a list of the cartridges he wants for his video game. The controller has opened up a whole new world for him. Before he got it, video games were a frustration for him and his mother. She would operate the joystick under his direction, but never seemed to react fast enough. She tried all sorts of methods of strapping the joystick to John's wheelchair and body at various points, trying to find some way for him to be able to operate it himself. Even so, she'd have to be with him to reset the game every time it was over. But it's a different story today. John can play for an hour or more, totally independently.

Kirk Kilgour, 34, was perhaps the finest hitter/blocker to ever play for the U.S. National Volleyball Team. He won the NCAA Most Valuable Player Award during his college career and is a well-known coaching figure in both Europe and America. He presently coaches volleyball at Pepperdine University in Malibu, California. Kirk is a quadriplegic, but still a very competitive man who searched for close to two years for a way to play video games. Now he plays for hours at a time and can wipe out a screen of space invaders using a mouth controller. He also has a multiple game board which allows him to select from up to eight cartridges with the press of a button.

Tommy, John, and Kirk are examples of a growing number of severely handicapped people who are discovering for the first time that there <u>is</u> something they can do on their own that is fun. They find it a tremendous morale booster as well as an interesting way to develop the muscular skills they need in order to function. Operating the four-button joystick, for example, requires the same motion as operating a pushbutton phone or an adaptive driving panel. Operating a paddle control requires the same motion as turning a stove knob or a doorknob.

BACKGROUND

The challenge was to convert a unit that had been desinged for manual manipulation, a joystick, into a unit that could be used by someone not possessing the normal capabilities. Various ideas were experimented with including puff, suck and puff switches, telephone keypads mounted at mouth height, helmets and various types of switches. Eventually, with the help of several handicapped people and their enthusiasm for the project, a workable design was found and expanded upon. The devices allow severely handicapped people to play the very same video games that millions of other people are playing, thus making them feel less different. Since each handicap and each person is slightly different, a variety of hardware is required to suit various individuals. Many different switching devices were tried and the most versatile was found to be a soft-touch button box controller.

Most young adults with spinal cord injuries had their accidents while involved in some exciting activity. These are not sedentary people and one of their biggest mental problems is boredom. Playing video games, whether on a game console or computer, gives them a chance to be active--to respond both mentally and physically as they dodge asteroids, defend cities, or maneuver a chicken across a 10-lane highway while horns honk and engines roar.

For non-oral children who eventually will use a computer to communicate, a video game can be the first step to interaction with the computer.

One of the first abstract concepts these children have to grasp is that they can control movement on a CRT screen by pushing a button. A video game appears to be an excellent way to reinforce this concept.

MATERIALS AND METHODS

For the C 2-3 level quadraplegic, a tongue operated video game controller is availalbe. It has switches for 4 directions, a "fire" button, and a game reset and game select switch. It is made from a telephone keypad with plastic surfaces glued on the keys which are used. It can be mounted on a plate attached to a body jacket, or on a wheelchair control arm or lapboard.

For a person who has head movement, there is a mouth-operated joystick. This consists of a joystick shaped like a lollypop with a puff/suck switch mounted through its center for "firing" action. Mounted on the side of the housing is a double-throw, double-pole switch for reset and select functions.

For people who have movement of their arms, but not their hands or fingers, a controller is available with arcade-quality leaf switches activated by large buttons which require very little pressure to operate.

The button switches are applicable to a wide variety of handicaps. Amputees can use them with a hand, an arm, wrist or foot as well as with a mouthstick. People with weak muscles find them much easier to use than standard joysticks. The buttons can be placed far apart, allowing people with cerebral palsy and others with spastic or difficult-to-control momements to hit one button switch without concurrently hitting a second one. The buttons can be wired for remote operation. This allows a "fire" button to be activated by a knee or head, etc., while the directional switches are being operated by a hand, arm or foot.

Figure 1. The Finger-Tip Controller, found to be applicable to a wide variety of handicaps.

For people with the desire and ability to operate a joystick, but who don't have enough strength to curl their hands, a cradle has been developed that fits over the top of a conventional joystick. The operator can push and pull it. It can be padded for extra comfort or a velcro strap can hold a hand firmly in place in the cradle. The joystick is glued to a piece of ABS plastic which is then clamped to a table with C-clamps. Remote firing and game select and reset switches can be included.

All these adaptive controllers are made from off-the-shelf items. The stands for the mouth and tongue controllers are made of ABS pipe; the button switches are purchased from a manufacturer of arcade equipment; and the mouth controllers are standard joysticks modified with puff/suck switches. The plastic boxes are purchased from a plastics company.

RESULTS

The number of individuals and institutions using this equipment which has been developed over the past two years testify to its value. People in the following locations are using these modified video game controllers to play competitively: Canada, Alaska, California, Connecticut, Florida, Illinios, Indiana, Kansas, Massachusetts, Michigan, New Jersey, New York, North Dakota, Oregon, Pennsylvania, South Dakota, Tennesee, Washington, Wisconsin.

Organizations using these controllers with their clients include: Carl Harvey School for the Physically Handicapped, Santa Ana, CA; Cerebral Palsy Center for the Bay Area, Oakland, CA; Crippled Children's Society, Pasadena, CA; Fairview State Hospital, Costa Mesa, CA; Memorial Hospital Medical Center, Long Beach, CA; Northridge Medical Center, Chatsworth, CA; Palmcrest Convalescent Hospital, Long Beach, CA; Rancho Los Amigos Hospital, Downey, CA; Santa Clara Valley Medical Center, Santa Clara, CA; Sharp Rehabilitation Center, San Diego, CA; Stanford Children's Hospital, Palo Alto, CA; Sunnyview Hospital & Rehabilitation Center, Schenectady, NY; Torrance Memorial Hospital, Torrance, CA; University of Virginia Rehabilitation Engineering Center, Charlottsville, VA.

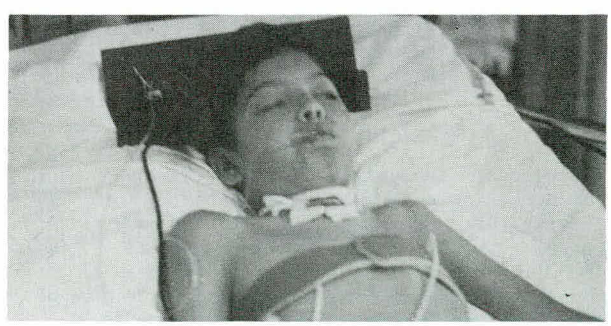

Figure 2. Use of a head-operated video game controller keeps Tommy Garcia, a C-2 quadriplegic occupied while he is confined to bed due to a pressure sore. This controller is limited to two-directional action--either up/down or left/right and uses a puff/suck switch for "firing". One of the games it works well with is Space Invaders.

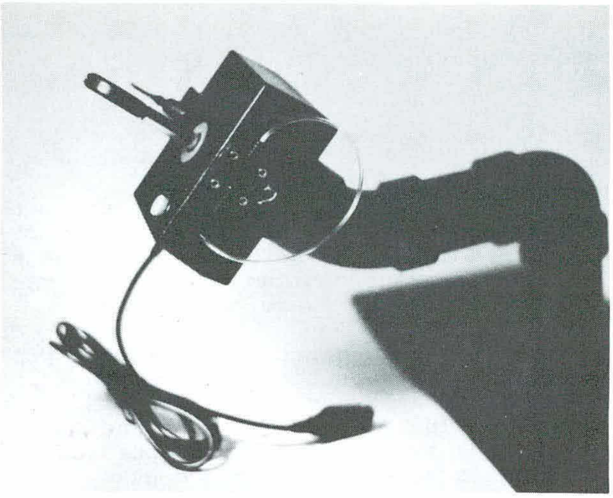

Figure 3. Mouth operated controller with lolly-pop-shaped joystick, puff/suck switch for "fire" and double-pole, double-throw switch for reset and select functions.

CONCLUSION

Sandy Blatt, a 35-year-old quadriplegic from Pittsburth, says of video games, "It's so necessary, especially when you're dealing with a disability all day long. It's great to jump on one of those machines and have a good time. It's independent recreation. It's one more way for me to become a part of society again. It makes it possible to become less of a second-class citizen and more first class. That's the bottom line for me."

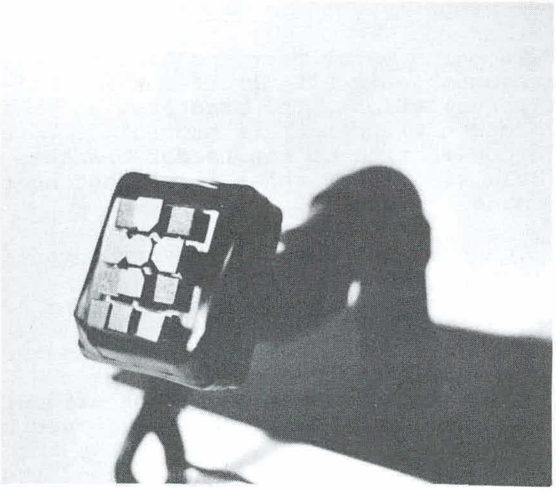

Figure 4. This tongue-operated video game controller made from a telephone push-button keypad includes game reset and select switches and can be used by people with only tongue movement.

Video games are excellent devices for rehabilitation/recreation therapy. They are self-motivating, provide exercise in motor skills, coordination and concentration, and encourage social interaction. These adaptive controllers are available now to benefit the handicapped community.

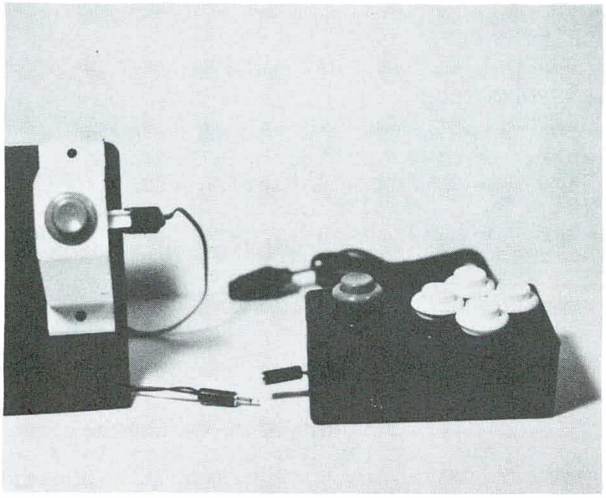

Figure 5. A FingerTip Controller with a remote firing button which can be placed at a spot convenient to the player. Good for people with muscular dystrophy, this controller requires a very slight amount of pressure to activate the switches.

ACKNOWLEDGEMENTS

I'd like to thank all the recreational therapists, rehabilitation engineers and most of all the enthusiastic handicapped people who have encouraged me and worked with me to make this equipment available. I also thank my wife, Diane, for constructing this paper.

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VIDEO GAME FEEDBACK EXERCISING SYSTEM FOR A DISABLED SKID LOADER OPERATOR

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INTRODUCTION

Late in 1980, after three years of work, we finished the modification of a Skid Loader for a farmer in our area (Fig. 1). Our client is paralyzed and can only use his elbows to operate the machine; he uses sixteen switches to start and stop the motor, to set the throttle and brake and to control the movement of the machine, the arm and the bucket.

He has been using the machine, on a regular basis, several hours per day on his farm. Unfortunately, due to the nature of his disability, he can only work in mild weather, which in our part of the country means that he is idle during the late Fall, Winter and early Spring.

Controlling the machine in the demanding environment of the farm requires considerable dexterity, which is only acquired with practice and is quickly lost in the periods of inactivity. Since winterizing the machine is not acceptable, for medical reasons, we turned our attention to possibilities of keeping the user in good physical shape when he is not using the machine.

Figure 1

BACKGROUND

An exercising machine, simulating the operation of the Loader controls was proposed. This was to be accessible from a wheelchair, with minimum adjustments required before the exercise session.

It was recognized, early in the project, that perhaps the most important problem was to ensure that the exercising system would be used regularly and that the individual switches would be operated according to some predetermined plan. We had had a similar problem with ablebodied persons and were, at that time, investigating the use of electronic games as part of the exercising equipment for the ablebodied population (see Acknowledgements). Because of our preliminary successes in that area we decided to use a similar method for the Exercising System.

MATERIALS AND METHODS

The Exercising System (Figure 2) consists of a frame and electronics system.

Frame

A welded aluminum frame is used. It is lightweight for portability; the weight of the wheelchair on the side-platforms ensures stability when the system is in use.

The arms which carry control brackets are adjustable in all directions for initial installation. The brackets, shown in the picture without their protective cover, are a duplication of the Loader brackets and hold sixteen switches corresponding to the Loader controls.

The vertical body of the frame contains a switching panel for the controls.

Electronics System

Several electronic games were tested in the prototype. All of them were of a "switch-control" rather than "potentiometer-control" type and all of them performed well.

One of the two stick controls of the game was replaced by a switching panel. The panel facilitates assigning any of the 16 switches in the elbow brackets to any of the five functions required to play the game (forward, back, left, right and "fire" button).

The second stick control is left intact for the second player.

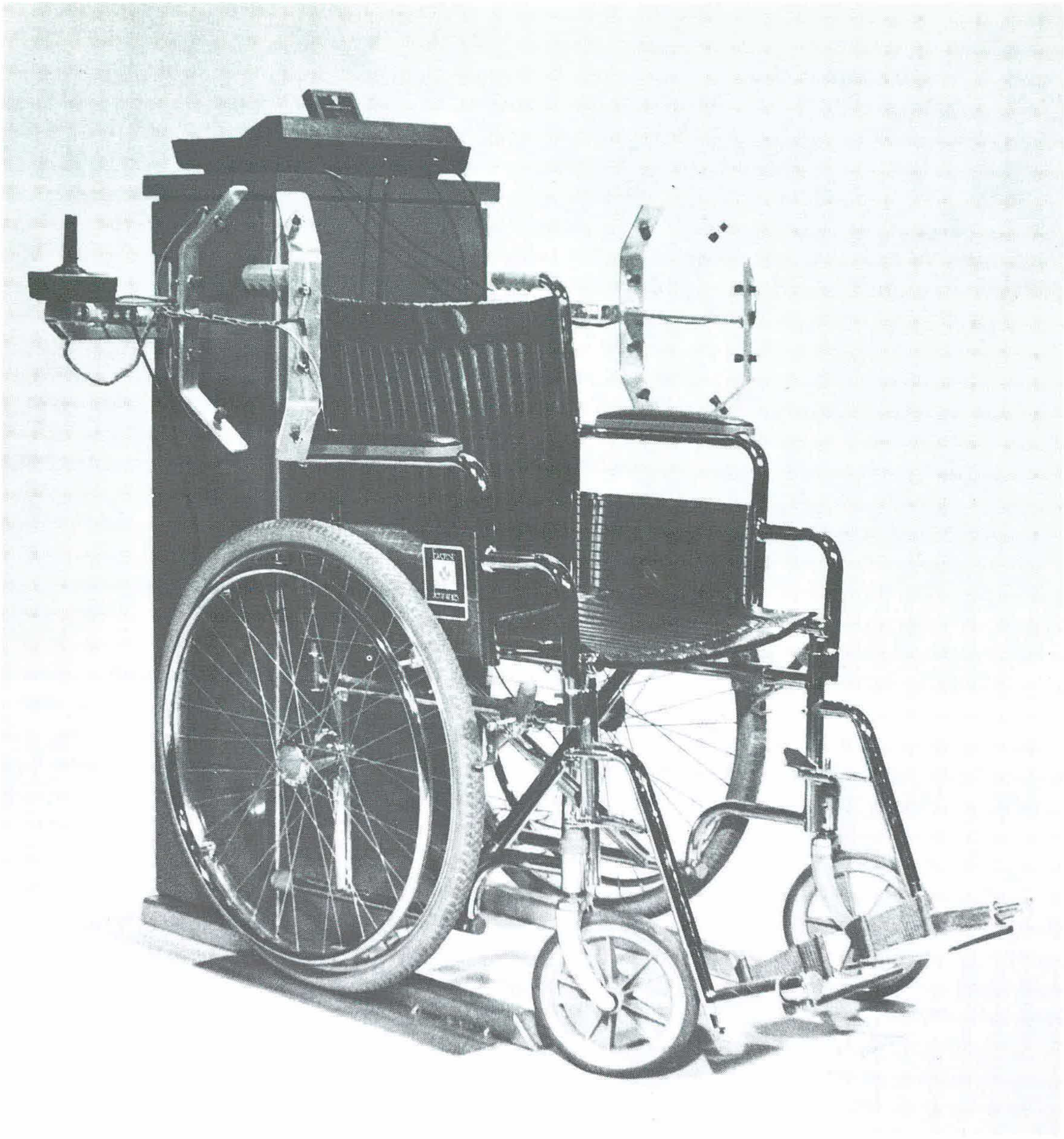

Figure 2

A protocol has been prepared for periodic switch assignment changes; this assures balanced use of switches above the horizontal support (easier task) and below (more demanding task).

Use

The exerciser is positioned in front of a television set; no special device is required, the exerciser can share a family television set. The wheelchair is backed onto the side-platforms and the brakes are set. The user then places his elbows in the control brackets and after the second player/assistant has switched the power on, selected the game and initiated it, the user can play, operating the preselected switches.

The game shown in Figure 2 was used, typically, with the tank/airplane battle cartridge. It requires only forward, left, right and fire buttons. The tank-like shape moves on the screen, turns left or right in thirty degree increments and fires from the "cannon". Additional operation of a left or right control can curve the path of the "projectile".

The game is attractive as a first-approach selection because of its independence on time. This is important for the beginner; other cartridges are available and were quickly acquired by the user (presents from his family). We do not favour the time-limit games for this application if we do not have control over the timing (see Discussion, use of a computer instead of a game).

RESULTS

The exercising system has been well received and has been used daily, since late 1982, when it was delivered. Some beneficial side-effects, such as family participation in these regular exercises have been reported. We have had no negative comments and are considering, given our original objectives, the project a success.

In the absence of an objective evaluation mechanism we will monitor the user's performance when he begins to use his Loader in the Spring.

DISCUSSION

The first electronic game we modified, in 1974, was used for recreational purposes by disabled patients in a local hospital. It was not until the year 1981 that we started to use the games as video and audio feedback for exercising equipment. The system described here is the simplest one in a series of our exercising aids for the disabled and the first one delivered and tested in a practical application.

From its conception, the shape and complexity of the system was predetermined. The location, shape and size of the operating controls are a copy of those used on the Loader and the function of the electronic game is just to encourage the user to exercise regularly and to use the whole array of switches.

We have been producing, together with this unit, two more units, with more universal applications. Their controls are adjustable in a wider range and are spring loaded. Adjustable tension and the use of shock absorbers widens the range of potential users.

On a higher level, our current development of this idea is in two directions. A system is being finalized, with a computer instead of a game; the computer provides the playing function, just as the game did, but with the option of selecting speed, size and other characteristics of the screen shapes. It also performs switch selection and periodical switch assignment modification.

The second system will serve as a simulator and will be used for the Loader operation instruction. The Loader in Figure 1 has a remote-control steering system, mainly for training purposes and we were using a close-circuit television system to train the operator. We are hoping that our new simulator will replace much of the expensive hardware and will shorten the training time.

ACKNOWLEDGEMENTS

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