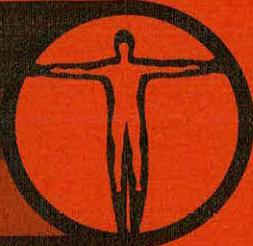


**PROCEEDINGS  
OF THE  
FOURTH ANNUAL  
CONFERENCE  
ON  
SYSTEMS & DEVICES  
FOR  
THE DISABLED**

**Seattle, Washington  
June 1, 2, 3, 1977**



**University of Washington School of Medicine**

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# PROCEEDINGS

## FOURTH ANNUAL CONFERENCE ON SYSTEMS & DEVICES FOR THE DISABLED

Seattle, Washington  
June 1, 2, 3, 1977

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## TABLE OF CONTENTS

	PAGE
SCIENTIFIC EXHIBITS.....	5
SESSION A                      WEDNESDAY, JUNE 1.....	9
SESSION B                      WEDNESDAY, JUNE 1.....	49
SESSION C                      THURSDAY, JUNE 2.....	81
SESSION D                      THURSDAY, JUNE 2.....	115
SESSION E                      FRIDAY, JUNE 3.....	151
SESSION F                      FRIDAY, JUNE 3.....	179
SUPPLEMENTAL PAPER.....	205
AUTHOR INDEX.....	211

## APOLLO ELECTRONIC VISUAL AIDS

The new Apollo System SE, a two-camera, split-screen Electronic Visual Aid CCTV system that permits partially sighted person to read or to do two things at the same time.

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## BIOMEDICAL, ELECTRONIC, PHYSICAL INTERFACING; IS THERE A ROLE FOR SOLID STATE DEVICE CONTROLS ENHANCING EMPLOYMENT AND INDEPENDENT LIVING?

Division of Vocational Rehabilitation staff development consultant specializing in evaluating severely disabled clients and implementing job site modification. Employer and Division of Vocational Rehabilitation client, job site modification consultation. Assist employers in implementing Affirmative Action plans as required by Section 503 of the Rehabilitation Act of 1973. Self-monitoring diagnostic urine bacterial quantification systems for high-risk clients. Working models of job site modifications for palsied and high-level quadriplegics.

Clinical Convenience Products, Inc.  
2066 Helena St.  
Madison, Wisc. 53704  
(608) 251-2882

## TOSC-2 ENVIRONMENTAL CONTROL SYSTEM

One of a selection of six dual input switches can be used by the severely disabled to operate a TOSC-2 system. Control functions include: Call buzzer or nurse call connection; Two-way intercom control; Electric door lock; Build-in speakerphone and full dialer; Radio on/off and tuning; TV remote control; Cassette recorder to record, rewind and play; Light in bright, dimmed or off mode; Three additional power outlets and control switch terminals.

Prosthetic Services  
Dept. of National Health & Welfare  
c/o Sunnybrook Medical Center  
2075 Bayview Avenue  
Toronto, Ontario, M4N 3M5  
(416) 486-3568

## ELECTRONIC COMMUNICATION AND CONTROL SYSTEMS

Non-verbal communication aids and related devices for classroom and personal use, including aids using symbols, pictures, letters, words and messages and capable of signalling, displaying and printing. Environmental control systems to permit operation of electrical devices in the hospital, at home, or on the job, such as answering and dialing the telephone, controlling

b

radio, TV, lamps, electric bed, intercom, nurse call, etc. and operating job related equipment.

Prentke Romich Co.  
RD 2, Box 191  
Shreve, Ohio 44676  
(216) 567-2906

#### DISPOSAL MODULAR WATERBEDS AND WATERSEATS FOR WIDESPREAD COMMUNITY USE

A system of flotation developed at the University of Rochester (Strong Memorial Hospital). Floating only those areas in pain or in danger of decubiti, equipment goes home with patient to prevent further problems. Focus is on preventative services on a community basis thru low cost. Lightweight units utilizable by anyone. In Rochester, N. Y., this effort has been successful. Virtually all nursing services in the city use the equipment. Ultimate purpose of the design is to make decubitus care economically feasible in third world areas.

Rochester Modular Waterbeds  
111 Oneta Road  
Rochester, N. Y. 14617  
(716) 275-3271

#### TACTILE LEARNING DEVICES FOR THE BLIND--SENSORY QUILLS

The exhibit is a drawing and writing device which is available in two styles. One is enclosed in an attache case, and the other is a larger unit designed for table top service. The device allows a user to move a stylus about the surface of paper, causing an immediate raised line wherever the stylus is placed.

Socratic Education, Inc.  
Box 4491  
Victoria, Texas 77901  
(512) 578-9141

#### AUDIO-PONG: AN ELECTRONIC GAME FOR THE BLIND

On exhibit is an experimental prototype of an electronic audio pong game for the blind, similar to video pong games but based on auditory rather than visual signals. The game consists of a typewriter-sized box to which are connected two sets of headphones and two hand-held modules. The game is completely self-contained, and need not be interfaced to a television screen. Each time a player wins a point, his or her score is announced by a synthetic speech "score keeper" which announces "over" when the first player reaches ten points.

Telesensory Systems, Inc.  
1889 Page Mill Road  
Palo Alto, CA 94304  
(415) 493-2626

## HIGHLY FLEXIBLE COMMUNICATION AIDS FOR THE NON-VOCAL SEVERELY PHYSICALLY HANDICAPPED INDIVIDUAL

Summary information will be provided on communication aids which have been developed throughout the world. In addition, three communication aids based upon a highly flexible, teacher-alterable control module will be demonstrated. These include the Autocom, the Versicom, and a new Blissymbol Printing Communication Aid developed under the auspices of the Blissymbolics Communication Foundation and the National Research Council of Canada.

Trace Research Center  
University of Wisconsin  
922 ER8, 1500 Johnson Drive  
Madison, Wisconsin 53706  
(608) 262-6966

## CHIN CONTROL ADAPTIONS TO STANDARD ELECTRIC WHEELCHAIR

A standard electric chair was modified to offer mobility independence for a severely involved cerebral palsied. The modifications consist of a chin control to operate the chair with an adaptation to swing the control in and out of operational position. The handicapped person is then able to free himself of the chin control for other activities such as eating, speaking.

United Cerebral Palsy Center  
4409 Interlake North  
Seattle WA 98103  
(206) 632-2827

## MEASUREMENT AND SEATING A MULTIPLY HANDICAPPED CHILD

The exhibit demonstrates the Shadow-Moire technique for measuring a child (adult) requiring custom supportive seating. In addition there will be a slide presentation describing all aids as provided by the Shriners' Hospital, Winnipeg Unit. The slide presentation will be supplemented with a Progress Report available to those dealing with the daily needs of the handicapped.

University of British Columbia  
Department of Surgery  
Vancouver, British Columbia

Shriners' Hospital for  
Crippled Children  
633 Wellington Crescent  
Winnipeg, Manitoba R3M 0A8  
(204) 452-4311, X 250

## A MECHANICAL RESTING SURFACE FOR THE PREVENTION OF DECUBITAL ULCERS

This exhibit demonstrates the potential effectiveness of a mechanical resting device in preventing the development of ischemic ulcers. Since safe resting pressures--within the range of capillary pressure--cannot be effected by static support cushions regardless of their composition, intermittent relief of pressure is essential. Resting pressure fluctuations measured beneath the ischial tuberosities of normal subjects while sitting on a motorized, mechanical surface will be compared with

pressure measurements obtained on static, currently-utilized cushions and pads. A battery (4 D-size)-operated, mechanical wheelchair seat which provides intermittent relief of pressure to the entire seating surface will be demonstrated.

Michael Kosiak, M.D.  
University of Minnesota  
640 Jackson Street  
St. Paul, Minn. 55101  
(612) 221-2062

#### MICHIGAN TRACKING SYSTEM & VISION TESTING AND TRAINING EQUIPMENT

A system of workbooks used to improve eye tracking abilities and improve comprehension. Equipment put in school free of charge for testing eyes and doing therapeutic correction of vision problems.

Ann Arbor Publishers  
Worthington, Ohio

Vision Conservation Institute  
c/o Ambrose Clemo  
Harrisburg, Idaho  
(208) 689-3523

#### VISUALTEK VIDEO VISUAL AIDS

Video visual aids, including Visualtek models RS6, Miniviewer, and Commuter. The equipment on display will provide a wide range of magnifications and portability, enabling virtually anyone with some residual vision to both read and write. The equipment is designed mainly for use by the partially sighted, and is currently in use at thousands of locations in the United States and Canada.

Visualtek  
1610 - 26th St.  
Santa Monica CA 90404  
(213) 829-3453, 870-8006

#### WASHINGTON REGIONAL LIBRARY FOR THE BLIND & PHYSICALLY HANDICAPPED

A display of the equipment, materials, and services offered by the Washington Regional Library for the Blind and Physically Handicapped to eligible borrowers throughout the state of Washington. The Regional Library provides free library service to blind, visually impaired, physically handicapped (unable to hold book or turn pages) and learning disabled persons. These services include braille materials, recorded materials, reference, audio programmed learning and the equipment needed to utilize the materials.

Washington Regional Library  
for the Blind & Physically  
Handicapped  
811 Harrison  
Seattle WA 98129  
(206) 464-6930

### "GENIE" ENVIRONMENTAL CONTROL

The Genie Environmental Control is a 12-channel environmental control system with pneumatic switches and other custom switches for special needs.

Western Technical Products  
923 23rd Ave. East  
Seattle WA 98112  
(206) 323-2303

### COMMUNICATION BOARDS FOR NON-VERBAL INDIVIDUALS

Scanning type communication board, with multiple operating modes and versatile display technique, allows relatively easy communication for daily living by profoundly involved individuals.

Zygo Industries, Inc.  
P. O. Box 1008  
Portland, OR 97207  
(503) 292-4695

## SESSION A WEDNESDAY, JUNE 1

- |     |  |       |
|-----|--|-------|
| A-1 | SHOPPING FOR DEVICES AND SYSTEMS<br>BY THE DISABLED<br><hr/> M.A. LEBLANC, REHABILITATION<br>ENGINEERING CENTER, STANFORD                                      | P. 11 |
| A-2 | SIMPLE EQUIPMENT FOR THE<br>HANDICAPPED<br><hr/> R. LEVY, U OF MONTREAL, IND. DESIGN<br>K. WAKSVIK, MACAY CENTER, MONTREAL                                     | P. 14 |
| A-3 | A PRACTICAL DESIGN APPROACH TO<br>REHABILITATION PRODUCTS<br><hr/> K. MALLIK & J. MUELLER<br>GEORGE WASHINGTON UNIVERSITY                                      | P. 19 |
| A-4 | INFORMATION RETRIEVAL AND SELECTION<br>OF AIDS FOR THE DISABLED<br><hr/> J. J. VASA, BIO-MEDICAL ENGINEERING<br>UNIT, QUEEN'S UNIVERSITY, ONTARIO              | P. 23 |
| A-5 | REVIEW OF TECHNICAL AIDS<br>FOR HANDICAPPED CHILDREN<br><hr/> P. EVACHEWSKI, HOLTE, PAUL & VON<br>KAMPEN, SHRINERS HOSPITAL, WINNIPEG                          | P. 31 |
| A-6 | THERMAL PLASTICS FOR DESIGN/FABRICATION<br>OF ADL DEVICES FOR CHILDREN<br><hr/> D. HOBSON, HANKS, CHIARIZZIO, HUGGINS<br>& TREFLER, UNIV. OF TENN. REHAB. ENG. | P. 37 |
| A-7 | A MODULAR SEATING SYSTEM FOR<br>PHYSICALLY HANDICAPPED CHILDREN<br><hr/> E. TREFLER, HUGGINS, HOBSON, HANKS &<br>CHIARIZZIO, UNIV. OF TENN. REHAB. ENG.        | P. 41 |
| A-8 | COMPLETE SYSTEM TO MEET SEATING REQUIRE-<br>MENTS FOR MULTIPLY HANDICAPPED<br><hr/> R.L. DAHER, HOLTE & PAUL<br>SHRINERS HOSPITAL, WINNIPEG                    | P. 44 |

## SHOPPING FOR DEVICES AND SYSTEMS BY THE DISABLED

LeBlanc, M.A.  
 Rehabilitation Engineering Center  
 Children's Hospital at Stanford

How do consumers and providers of devices and systems get information about them? This information is usually gathered by word-of-mouth, catalogs, and articles and lacks the hands-on experience of trying them out before purchase. The situation often is complicated by opinions that the devices are expensive and that too much is expected of them. These problems are discussed briefly and solutions proposed.

CATEGORY:	INTENDED USER GROUP: <i>Physically Limited People</i>
Device Development <input checked="" type="checkbox"/>	
Research Study <input type="checkbox"/>	AVAILABILITY OF DEVICE: <i>N.A.</i>
STATE OF DEVELOPMENT: <i>N.A.</i>	
Prototype <input type="checkbox"/>	AVAILABILITY OF CONSTRUCTIONAL DETAILS: <i>N.A.</i>
Clinical Testing <input type="checkbox"/>	
Production <input type="checkbox"/>	
AVAILABLE FOR SALE: <i>N.A.</i>	FOR FURTHER INFORMATION CONTACT: <i>Maurice A. LeBlanc, Chief      Rehabilitation Engineering Center      Children's Hospital at Stanford      520 Willow Rd., Palo Alto, CA94304</i>
Yes <input type="checkbox"/> No <input type="checkbox"/>	
Price:	

Where does a consumer go for information?

At the present time there are very few ways a disabled person in the USA can get information on what devices and systems are available to him/her, if he/she can use them, and what they cost. There have been some worthwhile efforts to provide information:

\* The Committee on Prosthetics Research and Development of the National Academy of Sciences started an informal listing of "Publications and Organizations of Interest to the the Physically Disabled" (*Orthotics and Prosthetics*, December 1973, pp.34-37, Cynthia Hiltz).

\*Raymond C. Cheever, publisher and editor of *Accent on Living*, started an "Accent on Living" computerized retrieval system containing information to help persons with disabilities to live more effectively. (P.O. Box 726, Bloomington, Illinois 61701).

\*The publication *Green Pages*, has emerged as a "Complete National Directory of Products and Services for the Disabled". (641 West Fairbanks Ave. Winter Park, Florida 32789).

These and other efforts help but still leave the gap of enabling a consumer not only to read catalogs and articles, but to actually see, handle,

and evaluate the usefulness of devices and systems before they are prescribed and purchased.

Scandinavian Stores for the Disabled

In some Scandinavian cities there are "stores" staffed by therapists, where consumers can go to see and test the various technical aids available. This is a very worthwhile and efficient way of passing knowledge to those that need it.

Consumers in the USA presently get information through a hodgepodge of sources including medical professionals, publications, fellow consumers, Aunt Josey, and the guy/gal next door. None of these sources is usually complete or comprehensive, and the process of acquiring information can take a long time of a little here and a little there. And even then there is the situation where Consumer Charley buys a brand new Whosit Mark II and finds out one week later about a Whamie I which does a better job and costs less !\*0!

Another Answer to the Problem

In the Rehabilitation Engineering Center at Children's Hospital at Stanford, we have established display and assessment areas of mobility and communication aids and controls.

We have been using these areas for over two years to:

\*Show medical and education professionals what devices and systems exist.

\*Show consumers, including children and parents, what is available and what the options are.

\*Assess the usefulness and appropriateness of the various aids.

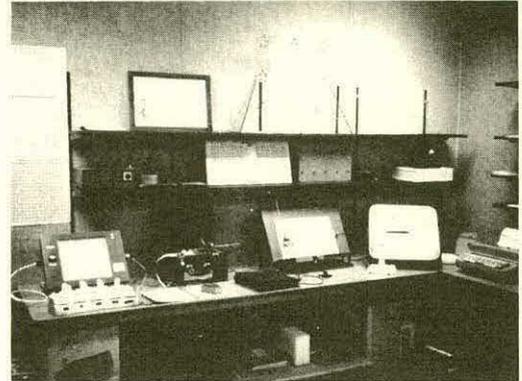
\*Evaluate possible means of control by residual body motion by having the person operate different controls, which are viewed as "interfaces" between the person and the aid.



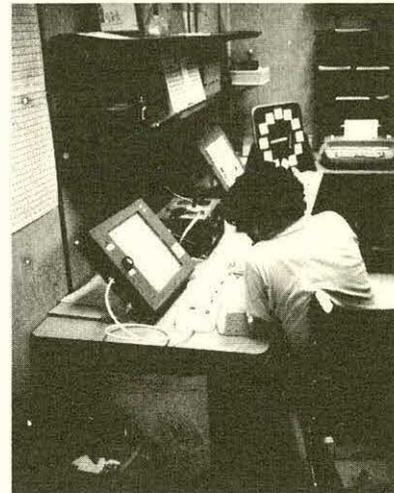
*Mobility Display and Assessment Area*



*Child Trying a Mobility Aid*



*Communication Display and Assessment Area*



*Young Man Trying a Communication Aid*

#### Other Considerations

\*As discussed at a recent Workshop on the Delivery of Rehabilitation Engineering Services in the State of California (January 16-18, 1977, Kellogg - West Center, Pomona), the costs of rehabilitation engineering devices are inherently high because:

- Volume is low
- Product liability and insurance are involved
- The method of procurement is different than the usual marketplace of selling directly to the consumer off the shelf. With medical devices physicians, counselors, insurance administrators, etc. have to be informed and "sold" as well.

- The patient must be properly assessed/evaluated to determine if a device is appropriate. A \$2 switch may have a \$100 price tag because of the service necessary with hardware.
- In many cases the devices must be custom-made and fitted to work satisfactorily. People come in all sizes, shapes and dispositions, and standard devices are not always appropriate.
- New FDA medical device legislation may require additional testing and/or product change.

\*Consumer- and even more so the third party payees - tend to "shop" for devices. Unlike the cost of surgery, which few people discuss or question, people naturally look for bargains. However as we all know, the lowest (or highest) in price is not necessarily the best. There are many considerations which need to be taken into account in purchasing products.

\*Another phenomenon is the high expectation from some people after watching the "Six Million Dollar Man" on TV. I spoke with one boy who was fearless because he thought that if he lost a limb, for instance, that he would receive a better "bionic" one. Such reasoning sounds far-fetched but exists. Also people ask "If we can send men to the moon, why can't you make Johnny a better device?"

#### Realities

\*First, it is obvious that somehow the consumer has to have more and better information on what is available and useful. He/she must know what his/her options are in order to reach decisions. This is a gap which needs to be filled.

\*Secondly, consumers and others must understand the reasons for relatively high prices of devices and systems compared with other, more common products in the marketplace. This is a job for the rehabilitation engineering profession.

\*Thirdly, people must be made aware of what is and what is not possible. With the human arm containing 42 degrees of freedom via 62 muscles which may occupy up to 50% of the motor area of the brain. (Herbert Elftman, PhD, Control of External Power in Upper-Extremity Rehabilitation, Committee on Prosthetics Research and Development, National Academy of Sciences, 1966), it is a difficult job indeed to even approach duplicating the Lord's work.

\*Lastly, we as engineers and researchers must be truly aware of the consumer and the process by which devices and systems reach consumers. All the shiny new products of research are not worth a wooden nickel unless they reach and are found to be useful by the people in need of them.

## SIMPLE EQUIPMENT FOR THE HANDICAPPED

by

R. Levy, Chairman, Department of Industrial Design,  
Faculty of Environmental Design, University of Montréal  
K. Waksvik, Occupational Therapist,  
Mackay Center for Deaf and Crippled Children, Montréal

This paper sets out to describe certain projects now under study concerning the design of simple special equipment for the physically handicapped, and includes a description of some of the main problem areas which can benefit from this kind of intervention. Industrial designers, working in close collaboration with occupational therapists in a clinical setting, are developing simple and inexpensive aids which promote functional independence of handicapped students in the areas of communication, feeding, and seating. In an annex of the paper, a description of the participating organisations is given.

CATEGORY:	INTENDED USER GROUP: Physically handicapped children and adults
Device Development <input checked="" type="checkbox"/>	
Research Study <input type="checkbox"/>	AVAILABILITY OF DEVICE: Not presently available
STATE OF DEVELOPMENT:	
Prototype <input type="checkbox"/>	AVAILABILITY OF CONSTRUCTIONAL DETAILS: Available
Clinical Testing <input checked="" type="checkbox"/>	
Production <input type="checkbox"/>	
AVAILABLE FOR SALE:	FOR FURTHER INFORMATION CONTACT: Ron Levy,
Yes <input type="checkbox"/> No <input checked="" type="checkbox"/>	Section Design Industriel
Price:	Faculté de l'Aménagement
	Université de Montréal, Montréal, Canada

Introduction

All those who work in the field of rehabilitation wrestle with the barriers to total functional independence which result from a physical or sensory handicap. For many of the minimally to moderately involved physically handicapped, functional independence can be attained through physical and occupational therapy techniques applied consistently over varying periods of time, and in conjunction with other therapeutic measures. However, severe physical disability often precludes significant progress through therapy. The severely involved cerebral palsied will often be limited to only very small gains over long periods of time. Therapy will be uneconomical, and frustrating for both client and therapist. Others, such as those suffering from degenerative diseases like muscular dystrophy, will slowly lose normally acquired skills and become more and more dependent in daily living activities. Still others, for example those born with severe arthrogryposis, will have very defined physical limitations due to fixed congenital deformities which will not respond to traditional

physical or occupational therapy. In these instances, it is important for the therapist to look for solutions through the design of special equipment which in many cases demands technical expertise of a specific nature. A profound lack of service in this area in the province of Québec has led to the formation of a design clinic attached to the University of Montréal, and its involvement with the Mackay Center for Deaf and Crippled Children.

Areas of intervention for the design of special equipment

The Mackay Center serves a population of hearing impaired and/or physically handicapped children ranging from pre-school age to 18 years. Among the physically handicapped, are disabilities such as cerebral palsy, spina bifida, muscular dystrophy, and arthrogryposis. The following problem areas have been defined by therapists as those which would benefit from the development of special equipment.

Seating: Appropriate seating is a fundamental need of many physically

handicapped individuals. Many of the moderately to severely involved cerebral palsied are unable to maintain an upright sitting posture due to specific patterns of muscle hypertonicity. The introduction at a very early age of special chairs or wheelchair inserts facilitates the maintenance of a good upright sitting position, makes certain demands on head control, improves visual input, attention, use of arms and hands, and general mental stimulation<sup>1</sup>. For those suffering from muscular dystrophy, adequate spinal support through seating introduced before fixed deformities have set in, will prevent or at least retard the development of spinal deformities. A good sitting posture and lack of spinal deformity will facilitate remaining hand skills, and lend itself to greater psychological well being. In both cases, adequate seating will facilitate home management, and in some instances semi-independence, in areas such as dressing, feeding, toileting, or bathing.

Communication: The severely involved cerebral palsied may lack the fine oral coordination necessary for comprehensible speech. In a growing number of centers, Blissymbols are being introduced at the pre-reading level, and developing effective communication skills via symbols is fast becoming a priority. As the student begins to learn the alphabet, he can use letters to indicate initial consonants, and gradually spell out whole words. While Blissymbols, word boards, or alphabet boards provide an alternative means of communication, lack of sufficient motor control to point to characters on a communication board may still hinder independence in this area. Some individuals will be limited to yes/no responses as the display is scanned manually for them.

Much has been done in the field of communication for the non-verbal physically handicapped in the past years, and we cite, among others, the excellent work undertaken at the Trace Center<sup>2</sup>, Tufts University<sup>3</sup>, the National Research Council of Canada<sup>4</sup>, and the Ontario Crippled Children's Centre (where Blissymbols were first introduced as an alternate communication system and where several prototype displays have been developed<sup>5,6</sup>). However, few devices allowing independent communication for the severely disabled are commercially available. When available, cost is often prohibitive, and unless located in the same geographical area as the distributor, there is little possibility of adequate pairing of user and interface.

Feeding: Independent or semi-independent feeding for the physically handicapped remains an important goal worthy of a great deal of effort. For the cerebral palsied, consistent therapeutic techniques almost from birth can improve

oral function, but upper limb incoordination may always prevent getting food to the mouth. Available mechanical feeders may fulfill the basic needs of some, however we are not aware of a suitable commercially available feeder for the more severely involved cerebral palsied, or for those whose difficulty is primarily one of restricted joint range of motion, as in arthrogryposis.

Mobility: For the young physically disabled child, independent mobility, allowing a more active participation in daily life, as well as exploration of the environment, is an important developmental goal. Many children of school age who cannot propel their wheelchairs could operate commercially available toys, such as foot-powered cars, tractors, trains, etc., of which there are a wide variety for pre-schoolers. Other mobility aids could include mechanically or electro-mechanically powered hand-operated vehicles, or mechanical adaptations allowing independent operation of a regular wheelchair. Appropriate seating would in many cases be a prerequisite for the most efficient use of upper and lower limbs.

Play: There is a need for toys and games which would match the handicapped individual's physical abilities, and "response-feedback toys", such as those developed at the Ontario Crippled Children's Centre for the cerebral palsied<sup>7</sup>, where specific physical and occupational therapy goals can be coupled with play.

Learning: Many handicapped students would benefit from devices which would allow greater classroom independence, special equipment for art classes and music instruction, etc.

At the time of writing, the association between the Mackay Center and the Design Clinic is just 6 months old, and only a very few of the problem areas described above have been studied in a preliminary fashion. Close collaboration between therapists, who assess the needs and potential of physically handicapped students, and Design Clinic personnel, who are responsible for the development of specialized aids, is stressed at all stages. Feedback from user, therapist, teachers and parents is utilized in refining preliminary prototypes.

The methodological approach adopted by the clinic for its projects is divided into three phases. The first deals with the clear identification of the perceived problems in terms of their contexts. The second consists of a comprehensive modeling process in which the 'problematique' is structured. The third phase deals with the iterative design process of resolving the identified problem. In all phases,

systems theory, design methods, and creative problem solving techniques are used.

#### Aids completed or under way

Examples of aids already developed are presented below. It is hoped that in the future, the clinic may become more actively involved in all the problem areas defined.

#### 1. Alternative Blissymbol displays for the non-verbal physically handicapped

Alternative displays have been developed for wheelchair bound cerebral palsied students with limited reach, students who ambulate with the aid of a walker, and students who are independently mobile. The following prototype displays are presently being field tested:

a) The "Mini-Bliss": The 400 symbol display which is presently available measures 20" x 20". This size has been found to be too large for students whose reach is limited due to a combination of short arm length and restricted arm movement secondary to the presence of spasticity. The display was therefore reduced by one-third, while wide side margins were added to accommodate additional symbols as needed. The overall size of the "mini-Bliss" is 17" x 11", twice the standard 8½" x 11". Initial results have shown that this reduced display renders all symbols accessible, reduces the effort required in reaching towards symbols located at the extremities of the display, and improves speed of communication.

b) The "Roll-o-Bliss": A second solution to the problem of limited reach is of a more dynamic nature, and consists of a device which will bring the desired symbols within easy reach of the user. The "mini" symbol display is placed within a freely rotating transparent plexiglass cylinder, and either attached at a convenient position to the wheelchair tray, or placed in a plexiglass stand with a choice of three levels of height. The user simply rotates the cylinder to locate the appropriate symbol. This rotational characteristic, which contains an element of play, is enthusiastically received by young students. The cylinder rotates with minimal applied force and when appropriately positioned, encourages the use of the arm in a position of pronation and extension with the hand open and wrist extended, as opposed to the typical spastic pattern of flexion and internal rotation. For one young girl with very poor head control, whose head always falls forward, the placing of the cylinder at eye-level appears to facilitate her keeping her head up, as she no longer has to look down to locate symbols. Her parents have also found the cylindrical

display advantageous in that the symbols are readily available to her during meal-time, whereas before they were covered by her plate. The cylinder is easily detachable from the wheelchair tray for portable use. It has also been attached to a walker for a young teenager who now invariably has his communication system with him wherever he goes. Other applications of the "Roll-o-Bliss" are presently under study.



THE "ROLL-O-BLISS"

c) The "Fold-o-Bliss": A convenient portable display was designed, using the "mini-Bliss" format, for non-verbal individuals able to walk unaided. It consists of an inexpensive, commercially available, menu-type plastic folder, 8½" x 11", with rigid inserts. The symbol display is simply cut in half and placed in either side of the folder. The outside of the folder can be used to accommodate additional symbols, frequently used words or phrases, etc. The "Fold-o-Bliss" is being used in its open position on wheelchair trays, since the plastic envelope provides durable protection of the display.

#### 2. A head positioned optical pointer for communication

A lightweight optical pointer which is worn on the head has been designed for a severely involved spastic quadriplegic with no speech, who is unable to point to characters on a communication board. The initial prototype weighs less than 50 grams and has an aesthetic sensibility to make it readily acceptable to the young teenager who is using it. The device merely rests on her head and supports a multi-directional light source of a parabolic shape. A sensitive switch allows her to turn the light on or off independently. A call button is included in the switch unit. The head-gear is moulded from "H" section plastic strips, which help to meet the specifications of light weight and strength.

The power source is provided from a re-chargable cadmium battery. The light is detachable from the head-gear, and the possibility of locking a typing stick into its place is being studied. This would enable the student to use the same head-gear for both one-to-one communication and for written work.

The optical pointer has proven to be the most direct and rapid means of communicating for this young girl. More complex sentence structure and an increase in spontaneous communication has been observed. It is felt that this is due to her increased ease and speed of communication.



HEAD POSITIONED OPTICAL POINTER

### 3. Other aids under study

Two other aids are presently being developed: specially designed eating utensils to allow a student with severe arthrogryposis to feed himself independently, and a multi-purpose bolster seat for cerebral palsied students who have difficulty maintaining an upright sitting position due to spasticity. The seat, adjustable in height, will be designed for classroom use, and will also serve as a low bathseat. At the time of writing, these aids have not yet been clinically tested.

**ANNEX I:** The Mackay Center for Deaf and Crippled Children is an amalgamation of two schools: the Mackay Institute for Protestant Deaf Mutes, and the School for Crippled Children. Both of these schools, as the names would indicate, were begun for very specific reasons and were among the first special schools in Canada. The Mackay Center's purpose is to provide an educational program in a rehabilitation type setting, where each pupil has an opportunity to advance academically and physically to achieve his optimum functional level. This involves a concern for his physical progress through intensive therapy as required, a concern for his academic progress through an educational program adapted to his needs, and a concern for his social and emotional adjustment through a structuring of experiences throughout his school career

which will allow him to cope successfully with real life problems. The Center serves 80 hearing impaired and 160 physically handicapped children ranging from pre-school age to 18 years. As the ultimate goal for each child, he must become as self sufficient as it is possible for him to be considering the limits of his disability. Any pupil no longer requiring the special services provided by the Mackay Center is integrated into regular school or some other appropriate program.

**ANNEX II:** In September 1976, the Industrial Design section of the Faculty of Environmental Design at the University of Montréal started a new teaching clinic as an integral part of the Industrial Design programme. This clinic has as its goal the development of design expertise in fields other than the traditional industrial mass production of products. In this respect the clinic is oriented towards what has come to be known as "social design" and as such is actively involved in design projects and research for the physically and financially handicapped. Although it is recognised that in many instances various university departments engage their students in projects which involve the handicapped, the Design Clinic has taken this process a step further. Whilst assisting a student in a project, the clinic takes on the responsibility for the completion and quality of the end result, and provides the possibility of follow-up analysis of equipment in use, which may lead to improvements and perhaps innovative new designs.

In the area of study concerning the physically handicapped, it is important to note that the clinic is not actively involved in providing prosthetic or orthotic services. Rather, it is concerned with the development of special equipment for persons suffering from abnormalities such as cerebral palsy, spina bifida, arthrogryposis, muscular dystrophy, and other disorders.

The industrial designer brings to this field a particular expertise, which includes a knowledge of ergonomics and anthropometrics, of problem solving methodologies, of materials and their characteristics, of mechanics, of communication techniques, of aesthetics and environmental design. It is hoped that the activities of the Design Clinic will promote a desire on the part of the young designer to create a career in this field, and also that the recipients of the services of the clinic will begin to provide the opportunities for the permanent employment of these designers.

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## A PRACTICAL DESIGN APPROACH TO REHABILITATION PRODUCTS

K. Mallik Director, Job Development Laboratory

J. Mueller Research Designer

The Job Development Laboratory of RT-9, George Washington University, Washington, D.C. has, through such projects as Job Development and Enhanced Productivity for Severely Disabled Persons, demonstrated design solutions to common functional problems of vocational rehabilitation. The Laboratory has illustrated that many severely disabled persons having poor employment prospects can be gainfully employed in homebound or on-site jobs by using a "low-technology" approach to the design of aids, adaptations, and environmental modifications. The employment of a designer or engineer for this purpose has meant the difference between inactivity and employment, and between dependence and independence for many severely disabled persons. This experience has led to the recommendation that a basic design and fabrication facility and staff be incorporated into the services of state Departments of Vocational Rehabilitation.

CATEGORY:	INTENDED USER GROUP: Rehabilitation Consumers and Professionals
Device Development <input type="checkbox"/>	
Research Study <input checked="" type="checkbox"/>	
STATE OF DEVELOPMENT:	AVAILABILITY OF DEVICE: NA
Prototype <input type="checkbox"/>	
Clinical Testing <input checked="" type="checkbox"/>	AVAILABILITY OF CONSTRUCTIONAL DETAILS: On Request
Production <input type="checkbox"/>	
AVAILABLE FOR SALE:	FOR FURTHER INFORMATION CONTACT: K. Mallik
Yes <input type="checkbox"/> No <input checked="" type="checkbox"/>	Job Development Laboratory
Price:	George Washington University
	Washington, D.C. 20037

## "THEY CAN PUT MEN ON THE MOON; WHY CAN'T THEY...?"

This common outcry against the apparent unconcern for the problems of the American Consumer, i.e. stuck zippers, flat tires, tasteless decaffeinated coffee, temperamental toasters, etc. is directed squarely at the conscience of the designers and engineers of our environment. With considerably more justification, however, we might also ask, "Why can't they solve the even-more-widespread functional problems of the disabled person who must face these injustices and much more in the pursuit of independence? The answer, of course, is that "they", or rather we, can solve these problems. But it has been the trend, especially in rehabilitation technologies, to set our designers and engineers about the most complex tasks, with the intent that simpler problems will be solved by the "filtering down" of technological advances. NASA Technology Utilization Programs, for example, are beginning to work with rehabilitation professionals in identifying common functional problems of the disabled person in terms to which NASA engineers can address themselves. In short, the "high-technology" problem solvers realize the need for a liaison with the everyday consumer. This is especially true of the disabled consumer, who has only recently been recognized as a consumer with all the appropriate rights and privileges.

When, in the pursuit of independence, it becomes necessary to solve functional limitations for which no commercial product is available, the disabled person has sought the help of the willing therapist, counselor or family members. Despite their understanding of the problems, their knowledge of materials, processes, and design techniques is not always sufficient to find the best solution. The realization of the need for rehabilitation professionals who can apply both high-and low-technology to the needs of the consumer has come slowly. Some larger rehabilitation centers and State Departments of Vocational Rehabilitation (DVR) are laying plans for the integration of such expertise into their programs during the next few years, and with good reason. The Job Development Laboratory has illustrated the value of simple, economical technology in solving problems of the severely disabled employee in office and homebound jobs, as well as in daily living functions. The adaptations, modifications, and custom equipment on the following pages show the emphasis on creativity in finding solutions which are durable, economical of available resources, easily constructed, and discerning of the user's appreciation of these items as the consumer products they are designed to be.



Phone Dial & Button Selector

Since white-on-black copy is easier to distinguish for this visually-impaired person than black-on-white, the largest possible white numerals were applied. To make the extension buttons distinguishable by touch, a plate was fabricated covering the unused buttons which also texture-codes the other extension buzzers.

Magnifier & Reading Stand

To reduce eye and neck strain during the working day, reference documents were placed on a stand convenient to reading distance and eye level. Maximum visual acuity was achieved through an illuminated magnifier.

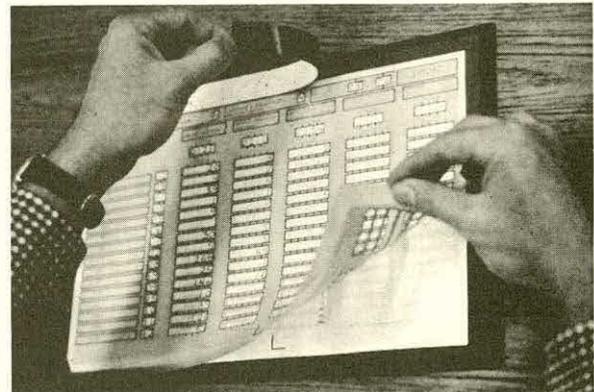


"Apollo" Visual Aid

In order to follow rows of figures more conveniently, a visually-impaired Civil Service employee utilizes this commercially available "Apollo" aid with a clear acrylic sliding rule. The edge of the rule appears on the viewing screen as a line below the selected row, as shown on the screen.

Library Data Sheet Overlay

At the National Library of Medicine, computer search time is recorded on blue-line computer statement forms. As the lines are quite light, recording data in the proper boxes was difficult for the library aid, who is legally blind. By cutting "windows" out of an acetate overlay and outlining in black, recording of data became easier. The computer sheet and acetate overlay are aligned with prominent black corner marks and held to the steel surface with flexible magnetic tape.





#### Microfilm Viewer Switches & Telephone Operation

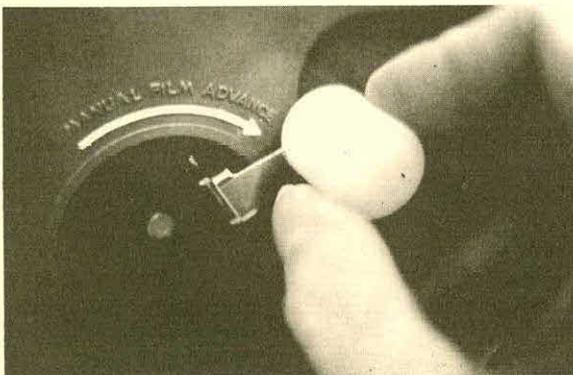
Homebound telephone surveyor for the Office of Human Development, H.E.W., utilizes a microfilm viewer to quickly access source materials instead of original documents.



Having very limited strength and reach due to muscular dystrophy, he uses on-off and forward-reverse microswitches mounted into an adjustable table for easy reach. He manipulates the telephone push buttons with his thumb while supporting his hand on the table edge.

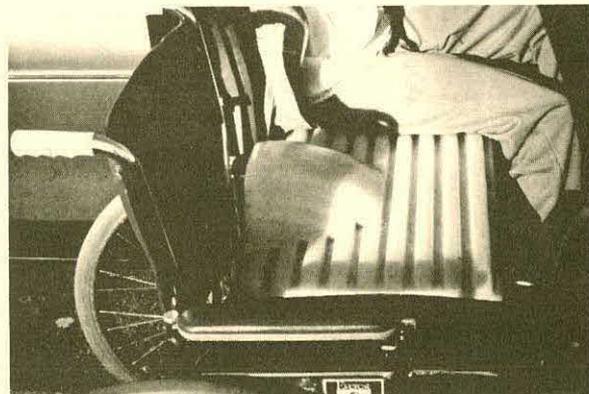
#### Microfilm Camera Film Advance Knob

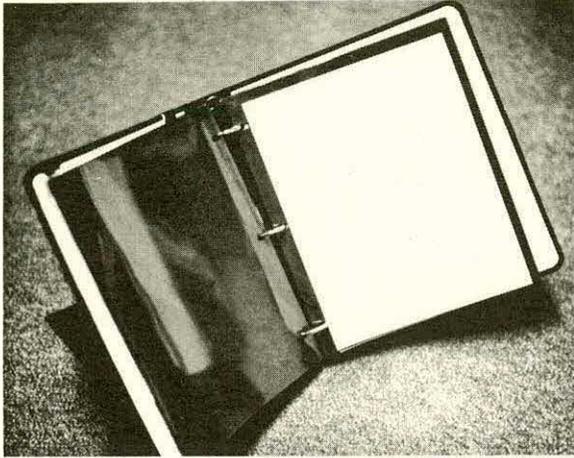
Small spring-loaded crank was modified with a lighter spring and large knob to make grasp and rotation easier despite spasticity due to cerebral palsy.



#### "Fender" Transfer Board

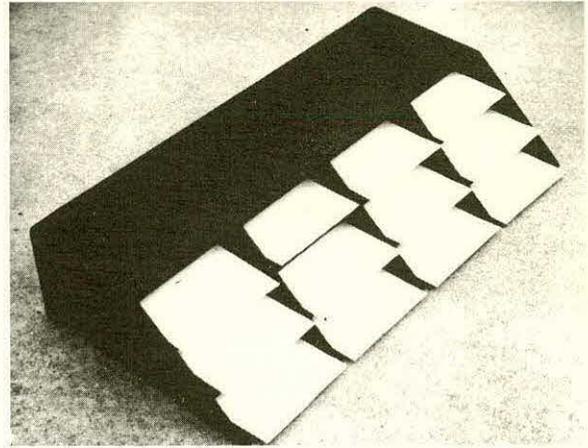
To facilitate safer wheelchair transfers for quadriplegics with little trunk support, a polypropylene surface was vacuum-formed which extends the full depth of the seat and over the wheel for smoother, safer transfers.





Ring Binder Stand

Difficulty in page manipulation was encountered by a homebound survey clerk for the Office of Human Development, H.E.W. due to rheumatoid arthritis. By standing the binder at the ideal angles with a simple wooden stand to minimize dexterity necessary, speed was increased.

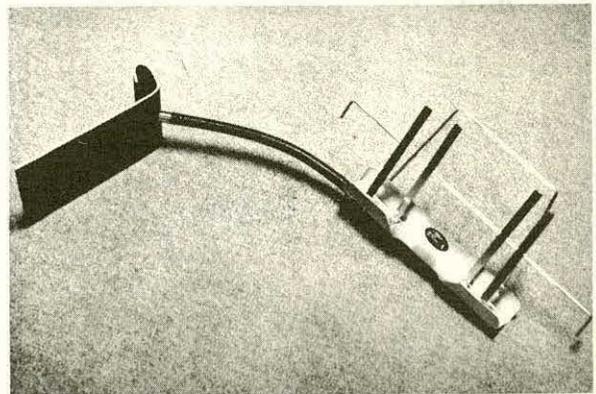


Card File

Space is at a premium at the desk of the Personnel Locator at the General Accounting Office. His reach and grasp are greatly limited due to a high-level spinal cord injury, so personnel locating cards were organized as compactly as possible with this open staggered-stack file.

Bed-Rail Book Stand

Training manuals for voice-operated computer training are studied by this C<sub>1-2</sub> level client (brain damaged due to gunshot injury). Through the use of this flexible book support which clasps to the side rail of the bed, he can study in a supine position. This method was used for evaluation, aptitude, and motivation tests.



#### Acknowledgement

This project is supported, in part by a Rehabilitation Research and Training Center (RT-9) grant (16-P-56803/3-12) from the Rehabilitation Services Administration, Department of Health, Education, and Welfare.

A CATALOG SYSTEM FOR CONSISTENT INFORMATION RETRIEVAL  
AND SELECTION OF AIDS FOR THE DISABLED

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With increasing numbers of aids available on the market, a need for an information system is obvious. Collecting manufacturers' literature is time consuming and the information obtained is inconsistent. Available catalogs eliminate, to a certain degree, the first problem; however, based on the same literature they often suffer from inconsistency and lack of methodical organization.

A catalog system was prepared that is based on personal communications with manufacturers and is organized according to the needs of those selecting and prescribing aids for the disabled.

<p>CATEGORY:</p> <p>Device Development <input checked="" type="checkbox"/></p> <p>Research Study <input type="checkbox"/></p> <p>STATE OF DEVELOPMENT:</p> <p>Prototype <input checked="" type="checkbox"/></p> <p>Clinical Testing <input type="checkbox"/></p> <p>Production <input type="checkbox"/></p> <p>AVAILABLE FOR SALE:</p> <p>Yes <input checked="" type="checkbox"/> No <input type="checkbox"/></p> <p>Price:</p>	<p>INTENDED USER GROUP: Therapists, persons involved in selection of aids for the disabled.</p> <p>AVAILABILITY OF DEVICE: Publication in the Rehabilitation Digest (Canadian Rehabilitation Council for the Disabled) to commence in the Summer of 1977.</p> <p>AVAILABILITY OF CONSTRUCTIONAL DETAILS: 1977.</p> <p>Available from the author or CRCD.</p> <p>FOR FURTHER INFORMATION CONTACT: Biomedical Engineering Unit, Queen's University, Kingston, Ontario Canada K7L 3N6. CRCD, Suite 2110, One Yonge Street, Toronto, Ontario, Canada M5E 1E8.</p>
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### Introduction

Several years ago the main problem in prescribing an aid was the general lack of aids on the market. Today the problem seems to have changed; the aids are available, but they are hard to find, hard to understand and hard to compare, unless the interested person is willing to spend a considerable amount of time going through the pages of manufacturers' literature or available catalogs. If we want to ensure a wide-spread use of aids, we can not depend on a few experts who can find their way through the literature. The information should be readily available and it should be organized in a meaningful way; information retrieval should be fast, accurate and as effortless as possible.

### Problem

The basic source of information on aids is manufacturer's literature. However, not only does it take considerable effort just to obtain it, but even an extensive file of manufacturers' leaflets

does not guarantee success in selecting the ideal aid.

In general, literature on aids suffers from one or more of the following shortcomings:

- a literally handwritten description with a flowery language; it may contain some of the desired information, but is hard to decipher.
- unclear photographs: poor reproduction, poor composition (a front view only, does not show the depth of the aid), some features shown in photographs not described in the text.
- attractive literature, glossy and colorful but with very little information.
- description of the aid not clear and sometimes not complete. The aid may, for example, consist of three main parts but there is just one size and weight shown, without saying to which part it is referring.
- statements like: "Aid available soon" with little meaning, especially without a date of printing.
- the aid may be said to control a telephone. Is it any telephone, modified dial, touch-tone? Will the aid just call

the operator, one number, any number? Incoming calls only? In many cases it just is not known.

- vital information missing - that is, for instance, information on C.S.A., Bell approval of the aid. The aid may have been approved or may not have been. It may also be impossible to obtain approval even if the prospective buyer was willing to try himself.
- information incomplete to the extent that it may be misleading. The output printer is using paper; it may not be mentioned that it is a heat-sensitive paper which is expensive or that it is a paper strip - an unpleasant surprise for the buyer.
- a list of dreamed-up applications may be enclosed. It states that the aid could be made to do things that will actually involve additional expenses, modifications and development.
- the aid may be an outright fraud. It may not be able to do what is claimed it could and it may be made in such a way that it will not be reliable, will fail often and will be a general hazard.

More problems are found when two aids with otherwise reasonable descriptions are to be compared:

- there may be one or more parameters not available in one of the descriptions; therefore the comparison will be impossible.
- the sizes are given in numbers; to compare the aids the user may actually have to draw them on a piece of paper.
- to find a particular bit of information it will be necessary to search through the whole description; even if the information is there, it is not in the same place in both descriptions.
- the photographs or drawings of aids may have been done with different perspectives and scales, which will not aid in forming easily comparable mental pictures of the aids.

It is still more difficult to compare more than two aids. If a person is looking for an aid with a particular feature and he knows that there are aids in his file that do not contain that feature and therefore are useless to him, he must still go through the whole file and read every entry to determine which aids to leave out and which to consider. He will then attempt comparison either by memorizing the features of the aids and comparing them mentally or by making a table on a separate sheet of paper in order to get more reliable results.

The problem of searching for literature on aids was, to a certain degree, alleviated when some of the catalogs of aids were introduced. But the problems of selection of aids, matching of the aid with the person etc., as described in the Introduction, are still a matter of concern.

## Method

From notes accumulated during several years of work with available literature, a list of desirable features for the proposed catalog was assembled. It was felt that a suitable catalog should offer:

**CONSISTENCY OF CONTENTS AND FORM.** If a particular kind of information is considered vital for description of the aid, it must be made available for every entry in the catalog.

It is clear from what has been said before that consistent information is not available in manufacturers' literature. The literature therefore can not be used as an exclusive source of information for the proposed catalog. Manufacturers must be contacted, or aids inspected to obtain the required data.

Since the catalog will be used mostly to aid in the search for a suitable aid, it was felt to be very important that the same information be not only present in the catalog but also be located in the same part of it for each entry. Due to diversity of aids it is difficult to assign a permanent space for very many of the parameters; some of the spaces would be left empty, which should be avoided in a situation when there is, inevitably, a shortage of space. All candidates for this privileged group of information were carefully considered and it was decided that the most important ones will be placed on the first page (with its structure permanent) and the others will be on the second and third page (with the number but not the size of the blocks fixed).

**INFORMATION OVERFLOW.** It was felt that the catalog should not only supply all the information required but also record all the information offered by the literature, even if it was not considered vital enough to be included in the basic structure. It was decided to publish a list of notes which would contain the "overflow" of information. A table is included with each catalog entry, containing addresses of the notes pertinent to that particular entry.

**DRAWINGS INSTEAD OF PHOTOGRAPHS** throughout the entry but particularly for the main picture introducing the aid. This picture showing a typical configuration of the aid with its transducers, displays, etc. was considered to be one of the most important features of the catalog. It is a drawing based on photographs, drawings or personal inspection of the aid.

The picture should be clear, showing all important parts of the aid and ignoring the unimportant details, labels, signs, etc., that make a photograph too "busy". The perspective is always the same and there is some information on relative size of different aids contained here. The main picture of the aid is considered to be the dominant factor in remembering and understanding the aid and is considered to be

of help in scanning through the catalog. It should be the first bit of information checked when studying the aid; there is supporting information in other drawings on pages one and two, and in the text.

**DRAWINGS INSTEAD OF TEXT** especially on the first and second pages. It is felt that some of the advantages of a picture instead of a verbal description are:

- it contains more information in a given space.
- the information is absorbed more quickly; the description is forming a mental picture while here the picture is already available.
- remembering the aid is easier.
- after a while some features of the aid are forgotten; it is easier to refresh the memory by looking at pictures than reading text.
- some facts, difficult to describe in text, (the aid in relation to the rest of the room, etc.) are easily described with a picture.
- searching through the catalog is easier if a person is looking at pictures than if a text is to be read.
- comparison of aids is easier.

All the illustrations are black and white, line drawings. Half-tone and colored pictures were avoided to facilitate copying on standard office copy machines. The pictures are rather informal and as simple as possible. As mentioned above, some of the details are not shown; the objective was not to reproduce accurately photographs and formal drawings but to convey a "feeling" for the aid, emphasize main features and make the drawing easy to remember. Thus the drawing made for the purpose of the catalog would not be valid without the rest of the entry and does not represent accurately the aid in its entirety.

In an effort to leave the main picture as clear as possible the obviously needed identification of parts is done in a separate space. The main picture is repeated, scaled-down, with a legend attached to each of the parts to be identified.

**USER - AID MATCHING ON A MORE RATIONAL BASIS**, improving speed of the process and its accuracy.

Very efficient systems could be devised by use of machine processing of the data but it was felt that it should not be required of the person working with the catalog to leave the realm of the catalog to get the answers. To simulate, in a simplified way, a punch card, the edges of pages two and three were used to code the data. The rim of the page two contains information on the aid, the rim of page three contains information on abilities required to operate the aid. There are two extra fold-out pages used to decode the information (as described

later).

The device works "inside out" as well as "outside in". When a particular aid is studied, the code can be used, in conjunction with the fold-out pages, to retrieve more information about the unit, transducers, etc., and also about the type of abilities the user must have to operate it. If, on the other hand, the prospective user is known and the question is what aid would be the best selection for him, the particular ability can be located on the fold-out page and the catalog can be scanned for a mark in the corresponding location of the page-rim code. This quickly eliminates the aids unsuitable for the particular application and speeds up the selection.

It should be understood that this feature of the catalog is not intended to be a substitute for the intelligent work of a person engaged in the user-aid matching. Its value is in separating those aids which are clearly impossible to use from those eventually feasible for the application.

**DISTINCTIVE HIERARCHY OF INFORMATION.** It is inevitable, with the amount of information involved and various schemes of accommodating it, that the catalog entry may appear too complicated and discouraging. This is the very thing that was to be avoided; yet leaving out information is not the right way to make the catalog more acceptable.

It was decided to organize the catalog entry very rigorously in such a way that it could be used in any depth desired. Thus not only the first page is most important and answers most often asked questions, but even the top of the page contains more important information than the bottom. A person can use the catalog by merely glancing over the first page of the entry, and would get meaningful information. The information on the second and third pages is of a second order, the information on the rim of pages two and three is next (and is more difficult to retrieve) and information in the Information Overflow is on details of the aid and is hardest to retrieve.

Some parts of the catalog may be completely ignored and the catalog would still function as a useful tool.

The phrase to be emphasized is: "USE AS MUCH OF THE CATALOG AS YOU WANT".

**EQUIPMENT/USER CODE NUMBER.** The code on the rim of the second and third page can be expressed as a number. If those numbers were listed in a table, together with a name of the aid, the information contained on the rim of the two pages would be available even without the catalog. It could be decoded (using the fold-out pages) or the table could be scanned for an aid suitable for a required application.





The Equipment Code Number and the User Code Number are shown in the table on the first page.

### Catalog

The first page is divided into six parts:

Part A: The main picture of the "typical aid". What the typical aid would consist of (considering the extensive range of transducers, output devices, etc. possibly available from the manufacturer) is discussed with the manufacturer or determined from experience and in consultation with workers in the field.

The picture itself is a drawing constructed from photographs of the aid or from the aid itself. The perspective of the pictures of all the aids is the same. There is a degree of size differentiation among aids shown in the drawings, although pictures too small were avoided and a logarithmic scale had to be used for scaling the drawings. The size differentiation between aids is not considered too important here, since information on this aspect is contained elsewhere on the page.

Some details of the aid are excluded from the drawing whenever it was felt that they would be detrimental to clarity of the picture. All essentials, however, are included.

Part B: The main picture needs a description of various parts and their functions. To keep the picture as clear as possible, a smaller copy of the same drawing was situated in part B with description of various parts, controls etc. included.

Part C: Another picture, considered to be important to the catalog user shows a typical installation and use of the aid. The user, the aid, transducers and appliances are shown in a relationship which is considered to be typical for an average installation. The drawing also contributes to a "feeling" for relative sizes of the user and the equipment.

Part D: A verbal description complements the picture of typical installation and use in the part C above. The description is abbreviated to contain as much information as possible in the small space available. The two parts of the description - "Installation" and "Use" are separated by a space in order to be easily distinguished.

Part E: Two of the important parameters of an aid are its size and weight. In this part of the first page the sizes of the main parts of the unit are shown graphically in two views. The silhouette at the left-hand side of the picture allows quick estimation of the size; more accurate information can be obtained by using scales and grids (the actual numeri-

cal values are given on page three). The weight scale at the right-hand side of the picture is a logarithmic one, which makes it useable for a wide range of aids.

Part F: The table in the upper right-hand corner of the first page contains condensed information on the aid. The entries are, from top to bottom:

NAME OF THE AID

CATEGORY which classifies the aid as belonging to one of several major groups such as Communication Aids, Environmental Controls, Hearing Aids, etc.

TYPE OF DISABILITY of the potential user; as with the category of the aid, this information should narrow a selection of potential users that would "match the aid".

EQUIPMENT CODE NUMBER AND USER CODE NUMBER are explained with the third page of the catalog.

AVAILABILITY/DELIVERY should separate aids that are under development or discontinued from those actually available, and should supply the information on delivery time.

PRICE RANGE gives three figures:

- a. The first figure is a price of the least expensive working combination of the aid, transducers, etc. In the case when manufacturer-supplied appliances are necessary for the operation of the aid, these are also included (that is, if a special television set is necessary as a display, its price is included, while a price for a commercially available television set to be operated by an environmental control is not).
- b. The second figure is a price of the most expensive working combination of the aid, transducers, etc. It may be an aid with extra outlets, a pneumatic transducer instead of a mechanical one etc.
- c. The last figure is a price of an aid with all available peripherals. While the first two figures represent a working aid, with nothing that would not be essential for a typical operation, this last figure includes a price, for instance, of a whole set of transducers, out of which only one will be used at a time. It was felt that the last figure would be of interest to technical aids centers considering buying a whole system.

The prices are shown in U.S. dollars, converted at a rate in effect at the time the entry was prepared. Explanation of what is included in the price is available in the third page's entries.

DATE ENTRY PREPARED

NAME OF THE MANUFACTURER AND COUNTRY WHERE MANUFACTURED with a full address, etc. available on the third page.

### Second Page:

This page is divided into three parts, assigned to description of transducers,

feedback and output devices.

**Transducers:** drawings of transducers are combined with descriptions of their function, parts description, etc.

**Feedback:** systems of feedback from the machine to the user are described by drawings, comments.

**Outputs/Appliances:** where appropriate, particular appliances are described with environmental controls, output devices with communication aids, etc. Information of immediate interest about outputs of the system is given also here, although it is expanded on the third page.

#### Third Page:

The third page contains more detailed information on the particular catalog entry and on the aid described. It is divided into four parts, A to D.

**Part A:** More information of a general nature is available in this space, allocated to further description of the aid.

**Part B:** Information on some aspects of preparation of the particular catalog entry is given here.

**Part C:** Front page information is expanded in this space; exact sizes, explanation pertinent to prices of the aid, availability, etc.

**Part D:** Information Overflow, organized into groups marked A to Z (e.g. transducers, displays, etc.) with possible number of entries in each group up to 99. A letter may be situated at the upper or lower edge of the table. The numbers under or above the letter belong to the group described by the letter. If there are different letters at the top and the bottom of a particular column, an empty space separates the two groups. A letter/number combination represents an address under which the particular information is found in the accumulative List of Information Overflow.

#### Equipment/User Definition and Code Numbers.

The edges of pages 2 and 3 are used to code additional information on the equipment and the user respectively.

At the top and bottom of each of these two pages are located code strips, each divided into 21 rectangles, organized in groups of three. A similar strip on the outer edge of each of the two pages contains 27 rectangles, for a total of 69 rectangles per page. Each "digit" of the code strip represents a bit of information on the equipment or the user. For decoding, two additional pages are supplied with a set of entries. Each of these pages carries three flaps containing information on each of the code-strip digits. The pages are placed in front and behind the entry (or a set of entries). When the flaps are unfolded, the informa-

tion corresponding to the code for a particular aid can be read directly over the code strip.

Each group of three digits can be treated as a binary number and can be expressed as an octal number for easier handling. A set of octal numbers is formed from each code strip and is entered as an Equipment Code Number or User Code Number on the first page. The numbers contain all the information available in the code strips. The information can be retrieved from those two numbers even if the rest of the catalog is not available; the code numbers can be organized in a table with just names of aids added. A strip of paper with a desired aid's code number marked on the edge can be used to scan the table for matching digits in a fast search through an extensive list of aids.

#### Fourth Page.

Informal Comments available on this last page could be more important than the name would suggest, for the following reasons:

In the catalog organized in a relatively rigid way it is inevitable that some of the entries will not be as clear as desired. If further explanation in the information overflow is not enough to clarify the data, the Informal Comments Page is the place to do so.

Some compromises accepted in the process of preparing the catalog entry should be mentioned. A device described as a transducer may actually be capable of operating a simple aid etc. Although it will be mentioned in the Information Overflow, an explanation is also possible on this page.

It may be desirable to supplement some entries with additional information. If, for instance, a T.V. set or a Teletype is specified as an output device of a communication aid, it may be of interest to users of the catalog to know what are the advantages and disadvantages of one or the other.

There are some features in various aids that are worth noting. Since they can not be emphasized and explained in the main body of the catalog, the information appears in the Informal Comments space.

In many cases the author of the entry will have had experience with operating the aid. This is the place to share his knowledge with the reader.

And lastly, the author of the entry may have some interesting information on the company manufacturing the aid, may have visited the company and may feel that there is something interesting to be said about the experience. A short note on this subject may appear here.

It is hoped that through this last page some of the expertise available in a large center could be channeled to the user of the catalog. It should also add a "human touch" to the catalog which is essentially trying to be as impersonal and machine-like as possible.

#### Conclusion

The catalog as presented here is an attempt to contribute to dissemination of information on aids and to elevate a catalog from a mere collection of incompatible information to a valuable working tool.

With the information organized in a rigid form (user definition numbers, etc.) a feeling may easily be created that a mechanical application of principles shown here will replace informed worker's judgement. It is not so. The catalog is not trying to replace a person involved in selection of aids - it is trying to make the work faster, less demanding and more accurate.

Undoubtedly a need will arise for changes in some of the features of the catalog, adding some or discarding others. Metric system should be considered, when it can be reasonably expected that information presented in that manner will be clearer to the user. Some names, controversial now (suck-puff vs. puff-sip vs. blow-draw) will be standardized or replaced. Information overflow code may be renumbered. Other features should, however, remain without changes: the hierarchy of information, a rigid form of the front page, basic criteria for drawings, etc.

It is hoped that the basic concepts of the catalog will be found useful.

#### Acknowledgements

This project has been supported by: Social Services Program of the Department of Health and Welfare Canada, through the Canadian Rehabilitation Council for the Disabled.

Queen's University, Kingston, Ontario.

The help of the following people is gratefully acknowledged:

Ms. Jan McLean, Occupational Therapist, Department of Rehabilitation Medicine, Kingston General Hospital for cooperation and valuable contribution.

Professor Denis W. Lywood for continuous support and encouragement.

Ms. Jo-Ann Gallagher for preparing the manuscript.

REVIEW OF TECHNICAL AIDS FOR HANDICAPPED CHILDREN PROVIDED  
BY SHRINERS HOSPITAL, WINNIPEG UNIT

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Technical aids vary in design, complexity, application, and success. This paper summarizes several years of successful experience in providing handicapped children with technical aids.

The objectives of this paper are:

1. to compile an itemized list of standing devices, mobility aids, special seating, aids for activities of daily living, and some educational aids;
2. to share this information with other professionals and the interested public;
3. to use this list as a reference for future research and further development.

CATEGORY:	INTENDED USER GROUP:
Device Development <input checked="" type="checkbox"/>	Handicapped children
Research Study <input type="checkbox"/>	AVAILABILITY OF DEVICE:
STATE OF DEVELOPMENT:	Some are commercially available
Prototype <input type="checkbox"/>	AVAILABILITY OF CONSTRUCTIONAL DETAILS:
Clinical Testing <input checked="" type="checkbox"/>	Blueprints available for most devices
Production <input checked="" type="checkbox"/>	FOR FURTHER INFORMATION CONTACT:
AVAILABLE FOR SALE:	R. L. Daher
Yes <input checked="" type="checkbox"/> No <input type="checkbox"/>	Shriner's Hospital for Crippled Children
Price: Under negotiation	633 Wellington Cres., WPG., Man Canada R3M 0A8

#### Standing Devices

A number of standing devices are routinely used. They differ in size, stability, and application.

The patient derives many benefits from the upright position: stimulation of bone growth; control of joint contractures; facilitation of better trunk and head control; better chest expansion in respiration; better kidney drainage. Change of position and being at peer-height have definite psychological benefits.

1. The Standing Frame permits upright positioning of non-ambulatory patients. It is intended to keep the lower limbs in a proper weight bearing position, and to aid in gaining trunk and head control. The standing frame can accommodate slight hip and knee flexion contractures. Regular use helps in stretching out these contractures. Leg length discrepancy can be accommodated by raising one of the foot receptacles. The addition of a pommel can regulate weight bearing from none to nearly full weight bearing, depending on the patient's tolerance. The addition of a tray provides a good working surface for play, school, and daily living activities.



Figure 1: Standing frame adapted to accommodate leg length discrepancy.

Wheels permit easy transportation of the upright child from room to room.

The standing frame is an important tool in evaluating a child's readiness for standing and further bracing.

2. The A-frame is a smaller, lighter, and more mobile version of the standing frame. It provides the same support and allows crutchless standing for work and play. Using a parallel walker, a pivoting or swing-to gait can be taught. The use of the walker contributes to arm strengthening, better co-ordination, and balance.

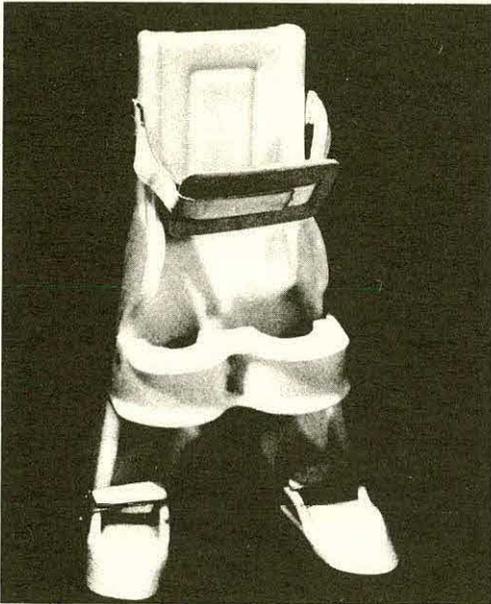


Figure 2: Plastic A-frame

3. The Parapodium is also used as a standing and mobility device for children with lower limb paralysis. The parapodium is more versatile than the A-frame, as it has locking hip and knee joints, permitting sitting down without taking off the device. Usually a child graduates to a parapodium after successfully using an A-frame. Of course, the child must have adequate hip and knee flexion. The parapodium also allows crutchless standing which free the arms for other activities. Walking can be done with a parallel walker, underarm or elbow crutches, using a swing-to or swing-through gait. Good users of the parapodium learn to manage ramps, curbs, and stairs. The parapodium is growth-adjustable. If necessary, extra trunk support can be added.

The standing frame can accommodate children of all sizes, from very small to adult size. The A-frame and parapodium are more limited in this respect; the A-frame can be used by children from 1 to 4 years of age (approx.), the parapodium by children from 4 - 10 years of age.



Figure 3: Child in parapodium using a parallel walker.

4. The stand In Box is intended for children with poor balance. It is used by fully weightbearing children (with or without braces) with the aim of increasing their strength, standing tolerance and balance. Children can rest periodically by leaning against the box. The stand in box is used together with a table of appropriate height to encourage upper extremity use.

5. The Prone Board allows better accommodation of hip and knee flexion contractures than the standing frame. If necessary, the angle of hip abduction can be selected by adding abduction pads to the pommel. The prone board is a maximum support standing device, and can relieve virtually all weight bearing. The child on the prone board can gradually be brought up to a nearly full standing position. This and the frontal trunk support are reassuring to a child who may be frightened by a trial on a standing frame. The arms are in a good functional position for play and work.



Figure 4: Prone board.

### Mobility Devices

1. The Pommel Walker was developed for children who are unable to walk with any of the conventional walking aids. The principal user-group includes children with cerebral palsy, seizure disorders, and mental retardation. The pommel walker has proven to be a useful and versatile piece of therapeutic equipment. Independent mobility through voluntary muscle action is added to the benefits of the upright position.

The essential parts of the pommel walker are a chest pad for frontal trunk support and a pommel for weight relieving and abduction. The pommel walker is open posteriorly so that the child does not have to be lifted into the walker. A removable pad gives support in the back and keeps the hips from sliding off the pommel.

Pommel walkers are adjustable and can accommodate patients from infant to adult size. Various modifications of the walker are possible to suit each patient individually. The pommel and chest pad may not provide sufficient trunk support; chest straps and back pads at various heights are often added. Some pommel walkers are so extensively modified that they resemble a moving orthosis. The chest pad and pelvic support can be shaped to fit the patient. The castors can be shaped to fit the patient. The castors may be modified to suit the walking style of the particular patient. Larger castors give easier motion over irregular terrain, such as gravel, grass, or deep shag carpet. If the walker moves too fast for the child, locking or unidirectional castors can be used. Walkers with locking castors are also finding application in classrooms, in place of other standing aids.

A removable tray is often provided with the pommel walker as a working surface for hand activities. Some children support themselves when walking by holding on to the sides of the tray. Patients with drop-seizures are given padded trays to avoid injuries.



Figure 5: Adjustable pommel walker modified for increased trunk support.

2. Pick-up Walkers There are many commercially available walkers on the market today. This discussion will be limited to the styles routinely used at Shriners Hospital.

a) The Parallel Walker is intended for use by children in A-frames, parapodiums, with maximal bracing, and/or poor balance. The patient stands within the device and transfers much of his weight through the arms when swinging or sliding forward. The parallel walker is very stable and sturdy, but less mobile than the following two walkers. Parallel walkers can be made any size. Most of them are made adjustable to grow with the child. The standard crutch tips can be substituted by gliders or skis for children who cannot manage to pick the walker up to advance it.

b) The Aluminum Adjustable Mini Walker is commercially available. It is smaller, lighter and easier to manoeuvre than the parallel walker. However, it is less stable, requiring better balance. It is a good all purpose walker and routinely prescribed for children who can manage it.

c) The A-Walker is a push walker with wheels in the front. The wheels permit easy advancement of the walker and contribute to stability, while the back pegs prevent the walker from sliding back or running away from the patient. Because it does not have to be lifted fully to be advanced, the A-walker is faster and easier to use than the other two.

3. The Shuttlebug is a hand-propelled mobility device which provides transportation, exercise, and recreation. It can be used by children wearing an A-frame or a parapodium. The Shuttlebug is currently in the development stage and its availability is quite limited.



Figure 6: Shuttlebug

4. The Castor Cart was developed to encourage independent mobility and good seating in very young, non-ambulatory children. The seat is close to floor level so that the child can get in and out of the cart by himself. A back support and a seat belt stabilize the trunk and free the hands for wheeling the cart and for other activities. Using the castor cart is a good pre-wheelchair activity, and contributes to upper extremity strengthening, improvement in co-ordination, trunk control, and balance. The castor cart is mostly used by children with spina bifida. It motivates them to move around at floor level which is appropriate for their age. Being in the castor cart eliminates a lot of skin problems which these children frequently develop from dragging their legs along the floor.

For children with very poor trunk and/or head control a molded back and head support can be incorporated in the cart. Legs can be held in a good position with a simple plastizote splint which clips onto the shoes.

A removable handle is supplied with the castor cart so that an adult can push the cart around without bending down.

#### Seating Devices

Good seating is important for children of all ages. Several aspects have to be considered in seating a handicapped child. The seat should give maximum support where needed. On the other hand, it should not be restrictive for children who show potential for good trunk and head control. The seat should be comfortable and enable the child to be at the same height as his peers for socialism, education, and play. Positioning of the child in a seating device depends on the child's condition and requirements. Most seating devices are used in conjunction with a table or tray. It is very important that this working surface is at the right height for each child to aid in the development of upper limb co-ordination and dexterity.

1. The Floor Seat is intended to provide children, young spastics in particular, with a good seating position. The back is supported, and adjustable abduction-wings prevent scissoring of the legs. The floor seat, and occasionally the castor cart, are used in conjunction with a low table.

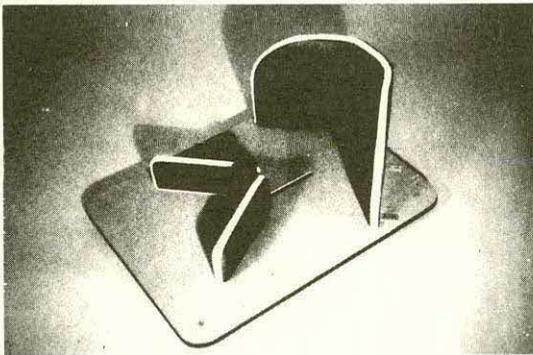


Figure 7: Floor Seat.

2. The Bolster Seat is popular in pre-school settings. The child's trunk is supported anteriorly by the chest pad, and the hips are placed into abduction by the bolster. Using a bolster seat is beneficial for children with cerebral palsy, mainly the athetoid type, as it holds the trunk and places the arms in the best functional position. Sitting on a bolster seat also facilitates good head control.



Figure 8: The Bolster Seat.

3. The Wheelchair A wheelchair will be required by a partially or non-ambulatory child as he becomes older and larger. A standard wheelchair is not always a satisfactory seating device, particularly for severely involved and deformed children. Wheelchair seating would then be supplemented by an insert. We have provided a number of inserts with a great variety of supports. Custom is the key word. Each insert is affected by a number of considerations, including the patient's medical requirements, likes and dislikes, home and school environment, transportation modes, parent's attitudes, and available technology. There are usually several options available for any desired modification of the seating position. For example, a firm curved back, in conjunction with bolsters or a chest pad as needed, will improve trunk position. Hip extension can be controlled by a lap belt, or knee-blocks, or groin straps, or a pommel depending on the severity of involvement.

In some cases it is desirable to have an adjustable reclining seat. This, for example, is beneficial for muscular dystrophy patients, spastics, hydrocephalics, and all those children who need a change in position quite frequently (e.g. patients with lung congestion).

Over the past year we have devoted a lot of time to the development of an insert frame, on which the upholstery components can be mounted. The latest model reclines, and also permits ready adjustment of the seat-back angle, shank angle and length, footrest angle, and head-support position. The foot rest folds under the seat for transferring and toileting. The entire insert can be removed from the wheelchair frame by undoing two bolts.

4. The Stand-up Wheelchair is custom made to

fit a particular child. It provides good seating, independent mobility, and self actuated standing and sitting. A stand-up wheelchair is used mostly by children who have outgrown the parapodium and do not have sufficient muscle power for further bracing. A child using a stand-up wheelchair continues to benefit from upright positioning.



Figure 9: Reclining insert with shaped back.

5. Car Seats The subject of seating would not be complete without reference to commercially available car seats. Not only are they safe and convenient for transporting a young child in an automobile, but they can also serve as a seating device for a handicapped child at home. Extra bolsters and belts can be attached if necessary. We recommend and use the "Travel Guard" at the moment as it meets Canadian safety standards.

Once the child has outgrown a commercially available car seat, some other form of restraint during auto travel may be needed. Frequently inserts are lifted from the wheelchair into the car and secured by the lap belt. Special harnesses have also been made. They are put over top of the child's clothing before the child is lifted into the car. Clips on the shoulder part of the harness are connected to belts which are installed in the car. The regular seat belt is also used to hold the child securely.

We do not have the facilities for safety-testing these devices. They are intended as a convenience to the parent, and have proven very useful for handicapped children travelling in an automobile.

#### Aids for Activities of Daily Living

Aids for daily living are intended to enable the handicapped to perform specific tasks, or to make the management of these tasks less difficult for the parents or attendants of these children. Some of the areas for which aids have been developed include personal hygiene, education and communication.

1. A Bathseat allows very young children to play safely in the bathtub with a minimum of parental attention. Side bolsters provide lateral support

for those with poor trunk and head control. A pommel and chest strap prevent the child from sliding out of the bathseat, which is firmly attached to the tub by suction cups. Other bathseats and boards allow or can be adapted to provide varying degrees of support or mobility, and are readily available commercially. These are generally used with larger children when lifting becomes a problem or when modesty dictates greater independence in personal hygiene.

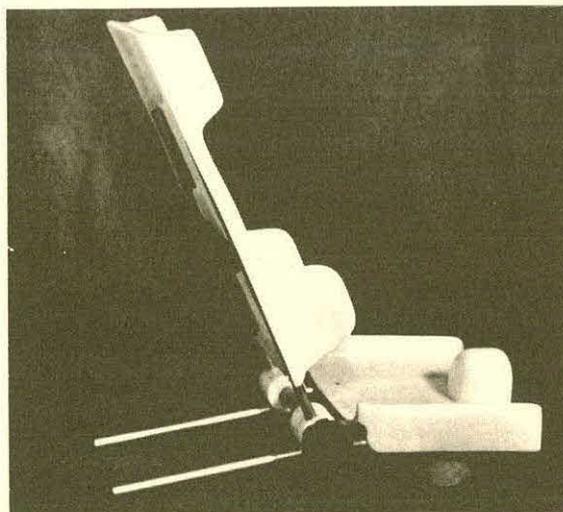


Figure 10: Adjustable bathseat.

2. The Bathframe takes over for the bathseat for larger, heavier children. It sits over the tub and is used in conjunction with a telephone-style shower attachment or rubber hose. Because bending and lifting are kept to a minimum when the child is on the bathframe as compared to being in the bottom of the tub, this device reduces the amount of strain placed on the parent's back.

3. The Toilet Frame was designed to support a child with poor trunk control, spasticity, etc. With the security of side supports, and a seat belt if necessary, the child is able to remain on the toilet for an adequate length of time to encourage toilet training. The toilet frame is made of washable plastic and chromed steel, and simply clips onto a standard toilet bar. Free standing floor commodes have also been made.

4. A Toileting Aid was designed to assist those with short arms and/or limited range of motion. It can be folded up and carried in a pocket or purse.

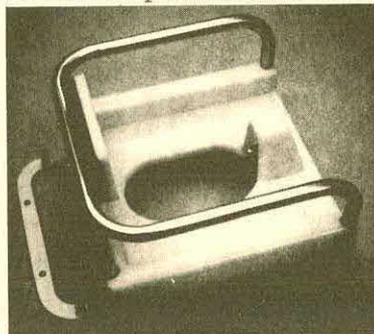


Figure 11:  
The toilet  
frame

5. Special Desks A handicapped child entering public school may encounter problems not faced by other children. Several special desks have been made for these children. One is a mobile desk for crutch-walkers. The crutches clip onto the side of the desk, which is rolled from classroom to classroom as the student's timetable dictates. Storage space is available for books, lunches, and so on. Another style of desk allows a dwarf to participate at the same eye and desk level as his peers. The slanted, curved desk and pencil box help to compensate for short reach. The demand for this type of device will likely increase, because more handicapped children are being integrated into regular schools.



Figure 12: Special school desk for midget.

6. Headsticks can be custom-made or purchased commercially. One such headstick (The Enabler) features easy and fine adjustability, and a selection of pointing attachments to suit individual educational and recreational needs.

7. Communication Aids Adequate seating position was mentioned as a basic prerequisite for education in that the child is able to concentrate his efforts on the learning material presented. A large part of education consists of the communication methods in the classroom. Bliss symbols, which pictorially represent words and ideas, are one of many communication aids frequently used by the verbally handicapped. A tray and a clear plastic shield have been developed to protect the symbol display from accidental degradation while allowing the user full access to the symbols. The shield clips onto the tray, allowing easy exchange of symbol displays. The symbols can be used along with hand pointers and headsticks for those with inadequate hand function.

Some of the more sophisticated communication aids are electronic devices. These vary from fairly simply controlled display units to very complex lighted units. One simple device that has proven useful in assessment of communication ability is "The Communicator", a commercially available unit. The displays in the kit include the alphabet, numbers, colors, and a green felt board for providing individualized communication modes. The pointer speed can be controlled, as can its direction of motion (clockwise and counter clockwise).

The control switch is operated by applying a small amount of pressure by almost any body part - hand, foot, chin; or using devices such as the headstick.

#### Conclusion

The provision of suitable technical aids to handicapped children is a very important function of Shriners Hospital, Winnipeg Unit.

The diverse resources of the Therapy and Rehabilitation Engineering Departments combine in the prescription and modification of special aids. These devices are derived from a number of sources, especially other rehabilitation centres and commercial suppliers.

Only by sharing ideas is it possible to provide the best technical aids to enable a handicapped child to achieve maximum function.

#### Acknowledgments

The authors wish to acknowledge the work of Mr. D. A. Hobson, University of Tennessee, Memphis, Tennessee, who initiated the Special Devices Program at Shriners Hospital, Winnipeg.

We are particularly grateful to Mr. R. L. Daher, Director of the Rehabilitation Engineering Department, Shriners Hospital, Winnipeg, for his encouragement and support.

We also wish to acknowledge the co-operation and support of the Winnipeg Health Sciences Centre, Rehabilitation Engineering Department, and the Manitoba Cancer Foundation.

Appreciation is also extended to all co-operating institutes.

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THE USE OF THERMAL PLASTICS IN THE DESIGN  
AND FABRICATION OF ADL DEVICES FOR CHILDREN

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Many children and adults with severe physical handicapping conditions have need for a wide variety of devices to assist them in their activities of daily living (ADL). A major obstacle to providing these devices is that the low volume and individuality required makes manufacturing and distribution cost prohibitive in many cases. The plastic vacuum forming (PVF) process is an industry based method of producing complex shapes in plastic which can be economically feasible in low volume production. This paper presents a series of ADL devices for children that have been designed for fabrication using PVF process.

CATEGORY:	INTENDED USER GROUP:
Device Development <input checked="" type="checkbox"/>	
Research Study <input checked="" type="checkbox"/>	AVAILABILITY OF DEVICE: Limited.
STATE OF DEVELOPMENT:	
Prototype <input checked="" type="checkbox"/>	AVAILABILITY OF CONSTRUCTIONAL DETAILS: Metal
Clinical Testing <input checked="" type="checkbox"/>	component drawings only.
Production <input type="checkbox"/>	
AVAILABLE FOR SALE:	FOR FURTHER INFORMATION CONTACT:
Yes <input checked="" type="checkbox"/> No <input type="checkbox"/>	D. A. Hobson, P. Eng.
Price: Various	Technical Director
	Address above.

#### Objective

Many children with severe handicapping conditions have need for a wide variety of devices to assist, either them, or their parents in activities of daily living (ADL). It is often possible to quickly define the problem and design a prototype device from wood or metal, and thereby successfully fill the needs of an individual child. However, if these aids are to meet the needs of a larger population, techniques must be developed to design and fabricate devices using economical industrial processes, combined with modern day materials. The purpose of this project has been to demonstrate the feasibility of the plastic vacuum-forming process as a means of economically providing ADL devices in low production quantities.

#### Methodology

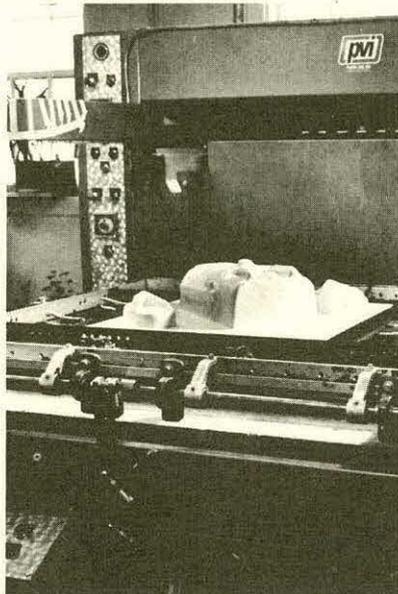
The plastic vacuum-forming process has been used in industry for many years. For example, most of the plastic signs we see blinking at us are fabricated using this process. More recently plastic vacuum-forming of polypropylene and polycarbonates has been used in the fabrication of orthotic and prosthetic appliances, respectively. For small parts, such as plastic ankle/foot orthoses, a small inexpensive vacuum-forming machine will do the job.

However, when the parts are larger industrial equipment is usually required. This paper concentrates on the use of a larger vacuum-forming machine (PVI-4' X 4') to economically fabricate a series of devices for a wide variety of purposes.

The primary advantage of the vacuum-forming technique is the ability to quickly fabricate complex shapes from a variety of high strength plastics. To fabricate similar shapes on a low volume basis using other materials, such as metals, would be cost prohibitive. The process involves the use of flat sheets of plastic of varying thicknesses (1/8", 3/16", 1/4") which are heated to a molten stage. After heating, the plastic is lowered over a mold designed to duplicate the desired shape of the final product. Then, air from around the mold is evacuated into a large vacuum tank. Atmospheric pressure then forms the molten plastic around the mold thus giving the shape of the final product (Fig. 1). The part is cooled for about five minutes after which time it can be removed from the machine and the process repeated.

The choice of plastics is fairly critical and it is related somewhat to the intended use of the final product. A wide variety of possible choices exists. However, after considering factors such as shrinkage, warping, impact and fatigue strength,

surface textures, color selections, ease of handling and finishing, availability and cost we have chosen ABS (Acrylonitrile Butadiene Styrene) plastic as the one best suited for our purposes. Other common uses of ABS include canoes, luggage, camper-trailer tops, aircraft interiors, toys, etc.



Results

The results of this project can best be demonstrated by presenting a number of devices that have been designed and fabricated using the plastic vacuum-forming process. Although the final products may seem simple, considerable attention must be paid to the design of the mold, taking into account shrinkage factors, part removal, and mold durability.

#### A. Plastic Caster Cart

The freedom to explore one's environment is a vital part of the learning and developing process of every child. Often this freedom is denied the severely handicapped child that does not have normal use of their lower limbs. The concept of the Caster Cart "originated at the Chailey Heritage School in Sussex, England. It was modified and introduced on this continent by the Ontario Crippled Children's Centre in Toronto, followed by the Shriner's Hospital, Winnipeg. This device has not received wide-spread use in the United States largely due to its unavailability. Our purpose has been to simplify the fabrication process so that it can be made available to others through stimulation of the commercial process.

The latest version of the Caster Cart is simply a plastic vacuum-formed shell that is set on three wheels, one of which is castered (Fig. 2). Two larger wheels allow children with paralyzed lower limbs to propel themselves independently with much greater ease than is possible by hitching along with their hands dragging their legs behind them. In

some cases, it has been necessary to add a removable foam-lined knee piece which serves to hold flaccid lower limbs in correct alignment.

The child is totally confined within the cart which prevents abrasion to anesthetic skin due to bumps, etc. which may be experienced in play situations. A removable handle is also provided to allow parents or therapists to assume control of activities at the appropriate time. Most children with good upper limb function can maneuver in and out of the Caster Cart independently.



#### B. Adapted Commode Seat

Children with cerebral palsy often lack sitting balance or trunk stability and must be held on the commode. This not only strains the parent's back but deprives the child of privacy. A similar situation occurs at school where not only must the child be held on the commode, but staff must be designated to perform this function. To resolve this problem, an adapted commode seat has been designed in two sizes (Fig. 3).

The small one fits children from three to seven years of age, and the larger one accommodates children from seven to twelve years of age. The seat attachment bracket is fit permanently on the standard home commode. The seat itself is secured in place by slipping the two protruding bars into the receptacles on the attachment bracket and screwing the side knob to lock the seat in place. The plastic device is light, easy to handle, and to keep clean.

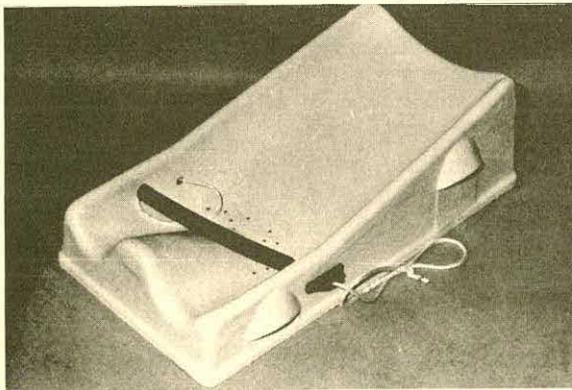
Most important, the commode seat is safe and gives the children a feeling of security and holds the child's pelvis firmly with their legs in slight abduction. The back height can be adjusted to meet the needs of the individual child. Also, a slight amount of flexion is built into the seat design to prevent an extension pattern from dominating the child's sitting position. Presently there are 12 units being field tested.



C. Plastic Bath Aid

Many parents of severely involved younger children request some assistance for bathing their child. It usually requires two hands to hold the child in the tub and two more to wash him. This means waiting until there are two family members present, or it can be accomplished by one parent getting in the tub with the child.

The plastic vacuum-formed Bath Aid was designed with the head portion raised 10" from the bottom to allow about six inches of water to be placed in the tub (Fig. 4). A safety belt further provides security as it holds the pelvis down into the Bath Aid. Holes in the bottom of the Bath Aid allow drainage so that water can be let out of the bathtub and the child dried before being lifted out of the tub. At present there are six of these devices undergoing field testing. Initial results indicate that this device is ready for wider distribution.

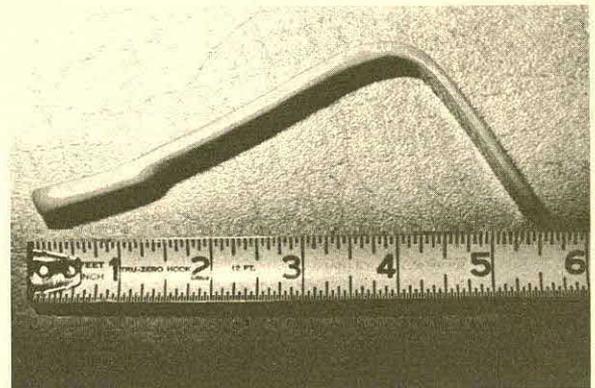


#### D. Feeding Spatula

There are many children with cerebral palsy that have severe involvement of their oral mechanism. For these children, the regular teaspoon is an inadequate feeding utensil. There is little opportunity for food placement as parents tend to put too much food on the spoon at one time and to scrape the food off the spoon onto the child's upper teeth. If the child has a bite reflex, biting down on the metal spoon can be quite painful. Furthermore, it has been shown that the anterior pressure on the tip of the tongue helps to decrease a tongue thrust. This is nearly impossible with the standard metal spoon as it is too large to localize pressure.

A plastic vacuum-formed Feeding Spatula (Fig. 5) has been designed to help in the feeding of children with severe oral problems. The shape of the blade helps to encourage lip closure and its underside can be used for therapeutic exercises such as tongue walking. The plastic is less painful than the metal in a regular spoon if the child bites down due to a hyperactive bite reflex. The thin elongated shape of the bowl allows for accurate food placement. Finally, due to the shallowness of the bowl limited amounts of food can be given that can adequately be managed by the child.

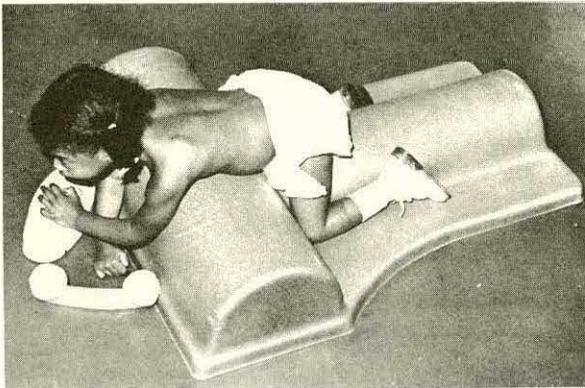
Approximately 30 of these Feeding Spatulas are now in use by therapists and parents throughout the Mid-South Area. More recently a number of these spatulas have been sent to several centers treating large numbers of cerebral palsied children. Hopefully these tests will indicate that this item is ready for wider distribution.



### E. T-Bolster

Many therapist are familiar with the Bobath rolls which are used to treat the child with cerebral palsy in the manner designed to reduce spasticity. The T-Bolster (Fig. 6) was developed to provide prone positioning of children in such a way to encourage normal back extension, particularly in the neck and upper trunk regions. Extensor patterns are broken up by abduction and flexion of the hips as the child straddles the stem portion of the bolster. By placing toys in front of the T-part of the bolster young children are encouraged to reach forward and up when playing. As they lift their heads, normal back and neck extension occurs which strengthens these muscles in preparation for standing or sitting postures. The T-bolster has been vacuum-formed from 1/4" ABS plastic and covered with 3/8" expanded polyethylene foam, which is also vacuum-formed in place. The vacuum-forming process makes this particular item very practical to fabricate and once the trimming process has been completed the item is essentially completed.

The T-Bolster has undergone clinical evaluation in several centers in the Mid-South Area over the past year and one-half. Although the demand for this item may not be large, we feel that it is ready for at least a low volume production run for purposes of wider distribution.



Several other items which appear elsewhere in this publication, i.e., The Molded Plastic Insert seating system and the Plastic Upright Positioner (PUP) are further examples of the successful use of the plastic vacuum-forming process utilized at the Rehabilitation Engineering Program at the University of Tennessee.

### Significance

Commercial availability of research and development devices is one of the major obstacles

restricting the delivery of technology to the handicapped population. The plastic vacuum-forming technique is one process that can be used to economically produce a variety of low volume devices. These devices may be produced with complex shapes, have appealing aesthetic lines, and have attractive surface textures with good durability. Of most importance is that the cost of fabrication should not be prohibitive, even in cases of relatively low volume production. Ultimately, the wider acceptance of this industrial-based process will mean that a larger number of handicapped individuals will benefit from the commercial availability of a larger number of new assistive devices.

## A MODULAR SEATING SYSTEM FOR PHYSICALLY HANDICAPPED CHILDREN

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A modular seating system for Cerebral Palsied children has been developed. It was designed to encourage motor development, to provide a stable, comfortable sitting posture, to be lightweight, collapsible and cosmetically attractive. The system includes modular components of an insert; parts of which can be fit into one of five possible bases. The insert can include any one or more of the following component parts; roll seat, moulded back, foot pods, neck support, head rest or anterior shoulder restraints. Different variations of the system have been found to meet the needs of over sixty percent of the children referred to the Rehabilitation Engineering Program for seating problems.

CATEGORY:	INTENDED USER GROUP:
Device Development <input type="checkbox"/>	
Research Study <input type="checkbox"/>	
STATE OF DEVELOPMENT:	AVAILABILITY OF DEVICE:
Prototype <input type="checkbox"/>	
Clinical Testing <input type="checkbox"/>	AVAILABILITY OF CONSTRUCTIONAL DETAILS:
Production <input type="checkbox"/>	
AVAILABLE FOR SALE:	FOR FURTHER INFORMATION CONTACT:
Yes <input type="checkbox"/> No <input type="checkbox"/>	
Price:	

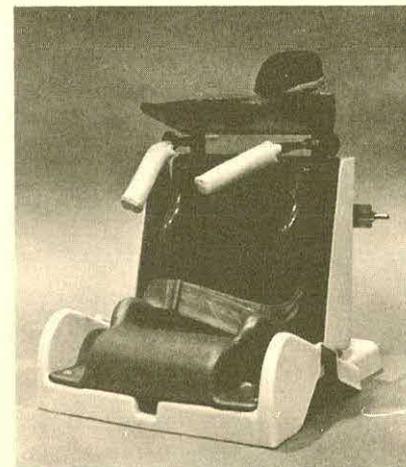
The technical needs of the Cerebral Palsied child are tremendous. If the child is not a functional ambulator usually the most immediate concern is that of appropriate seating.

Whether the goal is to attempt to encourage motor development, to provide a stable sitting posture as a prerequisite to hand skills, communication activities or ADL skills, or strictly for positioning for transportation, the seat designed should fulfill certain criteria. First, it should meet the developmental needs of the child. It should be lightweight, portable, collapsible and easy to propel. It must be comfortable and at the same time stable. Finally, it should be cosmetically acceptable both to the child and his family and the community in which he lives.

Meeting the developmental needs of children with Cerebral Palsy is not simple, especially when the aim is to develop a standardized seating system which is flexible enough to meet the individual needs of children with a wide range of complex physical problems. The children can exhibit extensor hypertonicity, floppy postures, a tendency to pull into flexion, dislocated hips, scoliotic curves, kyphotic curves and so on. Of course no child exhibits all these clinical signs but then

no two children exhibit the exact same ones either.

In designing our seating system we have incorporated modular components to meet the needs of individual children and at the same time tried to make the component pieces standard enough to be commercially manufactured and distributed.



Using the components of the moulded plastic insert (MPI system) we are now able to fit over sixty percent of the children we evaluate for seating needs. We also have designed the system so that there is a choice of five different bases into which the modular components can be fit depending on the size and functional needs of the child. The insert portion of the seat is comprised of one or more parts, mostly fabricated from plastic. All plastic parts of the insert are vacuum formed out of ABS plastic.

First there is a seat. It follows the design of a roll seat which helps hold the child well back in the chair as well as reduce adductor spasticity. There are pelvic blocks on the sides of the roll to hold the pelvic firmly in the midline. The seat comes in three sizes ranging from a width of seven inches to a width of eleven inches. The thigh length of the seat can be adjusted simply by cutting off portions of the moulded plastic. For comfort and friction a layer of expanded polyethylene foam is pulled over the plastic seat.

Next there is the back portion of the seating system. It is made in six sizes and its main purpose is to attempt to centralize the spine. The anterior projections of the moulded back are moulded so as to allow for full shoulder movement.

There are several options concerning head positioning. If the child has no head control then a moulded head piece is added. Whenever possible a neck piece is used. It is so designed that it discourages extensor thrusting and yet the head and neck are held central. The head pieces are made out of urethane foam and pigmented in fabrication to give improved aesthetics.

A third option is the anterior shoulder restraints. These are metal with a layer of foam as an interface. They can be adjusted so as to hold the child from falling or pulling forward into a kyphotic position. As sitting balance improves the position of the shoulder restraints can be adjusted or completely removed.

There are adjustable removeable foot plates. They adjust in distance from the floor and can also be adjusted to accommodate deformities of plantar flexion. Seat belts are always a part of the system and chest belts are added when necessary.

Finally, the child can receive a lap tray, which is also vacuumed formed out of ABS plastic. If the child is in a communication program the top of the tray can be vacuum formed out of V-Vex, which is clear plastic that will accommodate a communication sheet.

As mentioned previously we have five bases into which the MPI insert can be fit. For each base a standardized plastic interface has been designed which permits the attachment or removal of the MPI components from the base.

Some children have Hogg Chairs. They are not collapsible and are seldom the base of choice. They are used only occasionally when the family is unable to obtain one of the other bases.

Second is the commercially available stroller base. These are excellent for small children who are unable to push themselves. They are lightweight, collapsible and inexpensive.

We quite often use a wheelchair as the base, particularly when the child is able to push their own chair. Also, wheelchairs can easily be accommodated on school buses.

The fourth base is the McLaren Buggy. It is light, collapsible and much less expensive than a wheelchair. It is often recommended for children who do not have potential to wheel their own chairs. Several families have both the McLaren Buggy and wheelchair as bases. The wheelchair is used for school, and the lighter buggy is used on family outings.



Finally we have a four wheeled base which is made at the Rehabilitation Engineering Center. It is used for larger children who do not push their own chairs. It is collapsible, lighter, and less expensive than the wheelchair. As mentioned previously a thorough evaluation of the child's functional needs is performed before the base is prescribed.

One of our initial difficulties in fitting the children related to taking accurate measurements. The measurements obtained by measuring the child while sitting in their wheelchairs or on a table were inaccurate due to the poor body alignment as compared to that in a proper sitting position. The measurements taken in the lying position were even more inaccurate. For this reason a measuring seat was designed. It accommodates all sizes and component parts of the MPI system. At the same time the angle of the back in relation to the seat is adjustable. The depth of the seat and height of the back are also adjustable. Using the measuring chair the child can be assessed using the component pieces that will ultimately comprise his seating system when fit into the appropriate base.



A modular seating system has been presented. We look forward to finding a manufacturer and being able to provide the component parts to different centers around the country so they can in turn provide the MPI system to those children for which it would be appropriate.

We have been using the MPI system for almost a year. As mentioned over sixty percent of the children referred to the Rehabilitation Engineering Center for seating can now be fit with an MPI system. It is now our goal to refine the system so that we can measure, fit and provide a child with a seating system within a day.

We feel the MPI system meets the criteria set forth at the beginning of this paper. It is designed to encourage motor development, it provides a stable comfortable sitting base. It is lightweight and collapsible. We feel it is cosmetically acceptable. The MPI system is relatively inexpensive and easy to fit. However, not all children can be accommodated with the MPI system. Some require less seating, others have such marked scoliotic curves or orthopaedic deformities that a more custom designed system is required. We are currently working on improved techniques to manage the seating needs of this difficult group.



PROGRESS REPORT  
A COMPLETE SYSTEM FOR MEETING THE SEATING REQUIREMENTS FOR THE MULTIPLY HANDICAPPED

R. L. Daher, R. N. Holte, I. T. Paul  
Rehabilitation Engineering Department  
Shriners Hospital for Crippled Children

Maintenance of spinal alignment and prevention of muscular contractures is recognized by all medical personnel dealing with the physically handicapped. Unavailability of components, facilities, and information result in the nonambulatory handicapped being placed in inadequate seating, usually commercially available wheelchairs. This lack of adequate seating induces additional medical complications. The following is a Progress Report of the concept for seating described at the 1976 Conference on Systems and Devices for the Disabled (Ref. 1).

CATEGORY:	INTENDED USER GROUP:
Device Development <input checked="" type="checkbox"/>	Physical Medicine Personnel
Research Study <input type="checkbox"/>	AVAILABILITY OF DEVICE:
STATE OF DEVELOPMENT:	Anticipated 1 year
Prototype <input type="checkbox"/>	AVAILABILITY OF CONSTRUCTIONAL DETAILS:
Clinical Testing <input checked="" type="checkbox"/>	No
Production <input type="checkbox"/>	FOR FURTHER INFORMATION CONTACT:
AVAILABLE FOR SALE:	R. L. Daher, Director, Rehab Engng. Program
Yes <input type="checkbox"/> No <input checked="" type="checkbox"/>	Shriner's Hospital for Crippled Children
Price:	633 Wellington Cres., WPG., Manitoba R3M 0A8 CANADA

### Background

The concept as reported at the 1976 Conference involved three sub-divisions of the entire program, namely, a clinical fitting or measurement seat; an assembly of prefabricated functional basic components; and custom fitting by either hand shaping or foam casting techniques. Experience gained through custom fitting by hand shaping or foam casting indicated the possibility of standardizing the supportive foam shapes. Consequently, the measurement seat was re-designed for purposes of defining the dimensions of the supporting foam modules required. The immediate emphasis of this study is to scientifically correlate the clinical measurements obtained from the assessment seat, thereby, defining the shapes of the modules.

#### Clinical Assessment Seats Figures 1 and 2

In the 1976 presentation (Ref. 1) the fitting chair described, for clinical assessment was multi adjustable with a compliment of various bolster and head support configurations. To date this unit has been successfully applied in fitting 10 patients. The limitation

in the use of this assessment seat has been the bolster shapes and configuration of the adjustable back support. Experience gained using the custom foaming seat (Ref. 1) which intimately duplicated the contours of the back to at least AP midline has verified the necessity of extending the lateral support from immediately below the shoulder level to the iliac crest region. Also, noted was the similarity of shape required in this region. Consequently, a seating arrangement which would allow accumulation of specific measurements was designed and developed as shown in Figure 1.

The measurement unit consists of an adjustable seat (both angle and depth) and adjustable leg support (length and ankle). Supporting for the back consists of elastic straps webbed onto a frame. Each supporting post allows individual adjustment so that severely lordotic/kyphotic, and/or rotated spines may be accommodated. The entire assembly is mounted on a Mooney base supplied by Canadian Wheelchair Manufacturing, Toronto.

After positioning the patient as required, measurements are taken using the peg board arrangement shown in Fig. 2. The pegs are 5/8 inch delrin rods all of equal length. Note that the positive points of the patients back are duplicated behind

the frame allowing complete molding possibilities by draping orthoplast or similar material over the pegs. The resulting form can be filled with plaster of paris, modified and used to obtain the positive duplication of the patient.

An alternate method presently being considered for obtaining and banking data is the Shadow Moire technique developed by Takasaki and adapted at University of British Columbia in a project to automate shape definition for prosthetics/orthotics. (Private communications with James Foort, Department of Surgery, University of British Columbia).

#### Basic Components

Supporting Foam Modules: As shown in Fig. 3, the back consists of three foam modules held and supported by a light gauge aluminum tray. Each module is molded separately in a preshaped form using polyurethane foam which is injected in liquid state and expands to completely fill the cavity prescribed by the mold. The polyurethane foam used is of the self-skinning variety and forms a water resistant skin of approximately 1/16 inch thickness. The material can be pre-colored for improved cosmesis. However, heat dissipation is a problem and direct contact with the patient could produce skin breakdown.

Figure 4, demonstrates the removable cover designed to fit over the modules. The material is double knit allowing enough stretch to accommodate the curvatures of the modules. The complete back of the module is covered with velcro molded directly to the foam. By sewing on half-inch velcro hook to the bottom inside of the cover, the cover is attached to the underside of the module. The module itself varies from three to four inches in width and the remaining area is used to attach the complete section to the supporting tray, which has the corresponding hook backing.

The versatility of this system in accommodating the various deformities is directly dependent on the number of pre-shaped modules available. Data collection and scientific analysis cannot be over emphasized as a prerequisite in defining the shapes. The shape definition of the seat modules is less critical and can readily be defined on the basis of functional requirements, ie. abduction or lateral support.

Central Frame: Figures 5 & 6: The frame is designed to fit standard size wheelchairs, in particular the Everest and Jennings models. In terms of function, the frame has the following features:

- 1) easily removable from the base. This is achieved by removing two knobs from the slider attached to the wheelchair handles.
- 2) minimal modification to the basic wheelchair. Only four small parts are attached to the wheelchair; two slider-retainers to the handles, and two stops to prevent the wheelchair from spreading.



Figure 1

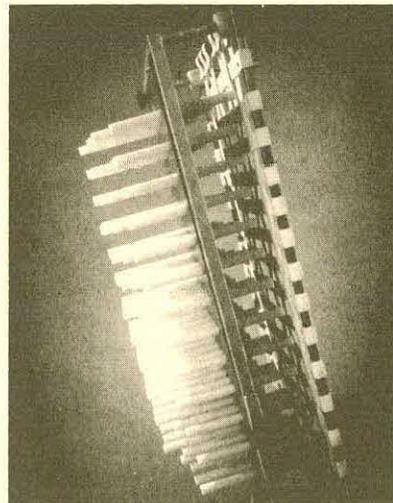


Figure 2

3) portability of the insert. The insert can be folded into a package of approximately 30 inches long by 16 (18) inches wide, by 8 inches deep.

4) adjustability of the seat to back angle, leg rest length and angle, plus adjustable leg rest to foot plate angle.

5) fold-away foot rest (Fig. 6) for transferring the patient and maneuvering in tight quarters.

6) tilting of the entire unit to a maximum of 45°.

A series of basic frames will be available to accommodate the ranges in size from child to adult. The measurements of each size range will dictate the overall measurements of the foam modules. As shown in Fig. 5, included in the accessories are adjustable head rests and supporting straps to maintain postural position. Where possible any remaining functional motion should be retained, in particular, the ability of changing position in the seat.

#### Conclusions

This project has demonstrated the feasibility of providing custom seating for the multiply handicapped using modular components. As experience is gained, and the range of available components is extended, it will be possible to seat the majority of cases effectively, and efficiently. Future expectations are to make available on a central fabrication basis the entire system to all centres dealing with the needs of the handicapped.

#### Acknowledgments

This project is supported under Canadian National Health Research and Development. Project No. 607-1117-41 of the Department of National Health and Welfare.

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Figure 3

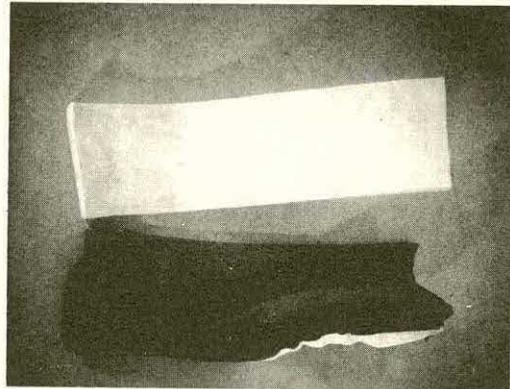


Figure 4



Figure 5

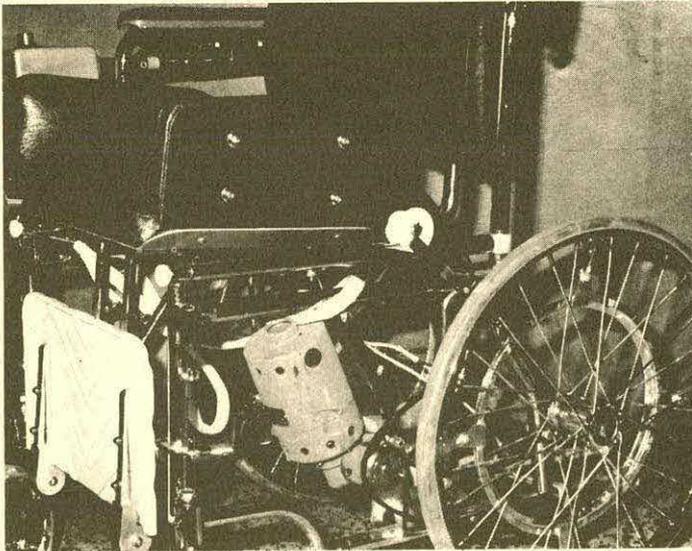


Figure 6

## SESSION B WEDNESDAY, JUNE 1

- |     |  |       |
|-----|--|-------|
| B-1 | THE QUANTITATIVE MEASUREMENT OF<br>ABNORMAL CHILDHOOD GAIT<br><hr/> A.O. QUANBURY, FOLEY, LETTS, & STEINKE<br>SHRINERS HOSPITAL, WINNIPEG              | P. 51 |
| B-2 | ASSESSING DEVELOPMENT OF INDEPENDENCE<br>IN CONGENITALLY PARALYZED CHILDREN<br><hr/> J. SOUSA, TELZROW & SHURTLEFF<br>UNIV. OF WASHINGTON, PEDIATRICS  | P. 55 |
| B-3 | SYSTEMS AND DEVICES FOR THE DISABLED'S<br>OCCUPATIONAL THERAPIST<br><hr/> M.A. CULLER, BROOKS & ROEMER<br>SANTA BARBARA GENERAL HOSPITAL               | P. 53 |
| B-4 | AN AUTOMATED NERVE CONDUCTION<br>VELOCITY METER<br><hr/> J.E. FREAL, KRAFT & ROUNDS<br>UNIV. OF WASHINGTON, REHAB. MEDICINE                            | P. 64 |
| B-5 | EFFECTIVENESS OF A TRAINING PROGRAM<br>IN DENTISTRY FOR THE DISABLED<br><hr/> D.J. STIEFEL & R.D. KINNE<br>UNIV. OF WASHINGTON, DENTISTRY              | P. 67 |
| B-6 | AIDS TO MINIMIZE BACTERIURIA IN<br>PATIENTS WITH ILEAL DIVERSION<br><hr/> E. NEWMAN & M. PRICE<br>UNIV. OF MINNESOTA HOSPITALS, PM & R                 | P. 71 |
| B-7 | DESIGN OF BATHROOM FIXTURES AND CONTROLS<br>FOR THE ABLE-BODIED AND DISABLED<br><hr/> P.M. MALASSIGNE & J.A. BOSTROM<br>VIRGINIA POLYTECHNIC INSTITUTE | P. 75 |
| B-8 | PNEUMATIC PRODUCTION AIDS<br>FOR THE HANDICAPPED WORKER<br><hr/> D.E. COOK & M.B. HAYES<br>KANSAS ELKS TRNG CENTER, WICHITA                            | P. 73 |

## THE QUANTITATIVE MEASUREMENT OF ABNORMAL CHILDHOOD GAIT

A. O. Quanbury, C. D. Foley, R. M. Letts, T. Steinke  
Shriners Hospital for Crippled Children, Winnipeg

The quantitative measurement of gait patterns is important for the assessment of therapy programs, orthopaedic procedures, and for accurately following the progression of neuromuscular disorders that influence walking. The Locomotion Laboratory at the Shriners Hospital can provide the necessary quantitative information using high speed cine techniques, video image processing operations by computer, and multichannel RF transmission of electromyographic and footswitch signals. In the three years that we have been studying the walking patterns of patients at the hospital, assessment techniques have been established for cerebral palsy patients and amputees. In addition, the techniques of gait analysis have been applied to muscular dystrophy patients, congenital dislocated hip patients, tendon transfer patients and scoliosis patients.

CATEGORY:	INTENDED USER GROUP:
Device Development <input type="checkbox"/>	Rehabilitation Centres
Research Study <input checked="" type="checkbox"/>	AVAILABILITY OF DEVICE:
STATE OF DEVELOPMENT:	Not Available
Prototype <input type="checkbox"/>	AVAILABILITY OF CONSTRUCTIONAL DETAILS:
Clinical Testing <input checked="" type="checkbox"/>	Available
Production <input type="checkbox"/>	FOR FURTHER INFORMATION CONTACT:
AVAILABLE FOR SALE:	A. O. Quanbury, Acting Head
Yes <input type="checkbox"/> No <input checked="" type="checkbox"/>	Bio Med Engng Research Dept
Price:	Shriners Hospital, Winnipeg, Canada

## Introduction

The quantitative measurement of gait parameters has progressed from the area of pure research to that of providing clinically useful information on a number of walking disabilities. The early studies done some 30 years ago, by the research group at the University of California (1) and more recently by the Biomechanics Unit at the University of Strathclyde, (2&3), to name only two research centres, showed the valuable information that could be obtained and a number of clinical centres that are now involved in gait studies for routine clinical assessment as evidenced by the papers to be found in the literature, (4,5,6). Although each centre has a somewhat different emphasis, based on facilities and the philosophies of the directors, there is full agreement of the importance of the data obtained from gait studies to the medical treatment of certain types of patients. This presentation will attempt to describe the facilities, capabilities and applications of the Locomotion Laboratory of the Shriners Hospital in Winnipeg.

## Equipment and Methods

A complete gait assessment involves recording

kinematic information using a video system or a high speed movie camera as well as the telemetered information and this requires the subject to walk along a 5 meter walkway in front of a black background. The telemetry system is a 6 channel FM-FM unit modified, to allow transmission of the envelope of the EMG signal (7). The unit, which weighs 450 grams is worn on a belt that fits the waist of all except our smallest patients who must wear it diagonally over one shoulder and across their chest.

The electromyographic signals are picked up with silver-silver chloride surface electrodes or occasionally with fine wire indwelling electrodes, which are connected to the belt via one of two cable harnesses of different lengths in order to minimize the amount of excess slack cable that might otherwise result on a small subject. Fig. 1 shows the telemetry belt worn by a four year old patient, an example of the lower limit of our patient population size. Temporal information is obtained from one of two types of footswitches. If the subjects can wear normal footwear and walk without excess valgus or varus foot deformities, they are fitted with "Hush Puppy" shoes which have small switches mounted in the heels and soles and resistor networks on the sides (8). If the subject must wear their own shoes because of a

special design or if there are braces attached to them, flat switches made from two layers of phosphor bronze are taped to the bottom of the shoes over the evident wear patterns of the heels and soles. Figure 2 shows the Hush Puppy shoe with footswitches. These switches give an accurate indication of the time of initial contact of the foot with the floor and the end of weight-bearing and allow the walking cycle to be divided into the swing phase and the stance phase. From this temporal information the muscle activity patterns can be related to the different phases of the walking cycle. Permanent records of the muscle activity patterns and the footswitch signals as shown in Figure 3, are obtained on an eight channel ink recorder and added to the patient's medical file.

Kinematic information can be obtained in two different forms. Quantitative information is obtained from a video recording of the limb movement that is processed and analyzed using a TV-computer interface and various software programs. Small lightweight reflective markers are attached to bony landmarks as illustrated in Figure 4, to provide bright targets of light for the video processing system. The basic kinematic information can be used to obtain a wide range of kinetic information that is important in the assessment of joint forces and power requirements of prostheses. A more qualitative form of kinematic information can be obtained from a high speed cine camera filming at 96 frames per second. This data provides not only very detailed movement information of a qualitative nature but also allows the quantitative measurement of ranges of joint motion and pace period and stride length. This is accomplished using the stop action feature of the movie projector that permits individual film frames to be viewed.

#### Applications

Over 100 patients from the following groups have undergone gait studies to date: cerebral palsy, muscular dystrophy, scoliosis, amputees and hemiplegic (adult). The EMG studies have proven very valuable in the assessment of cerebral palsy dysfunction although research work is progressing on its application to other study areas. The biomechanical information from the video data has been most valuable in the assessment of prostheses, but it is being applied to other gait abnormalities as well.

#### Muscles Transfers

In cerebral palsy patients and sometimes in other specific motor dysfunction (spinal cord lesions, etc.), reduced deformity and/or improved function can be achieved by a surgical procedure to change the function of a muscle. For example, tibialis posterior, a plantar flexor and invertor of the foot may be transferred to produce a dorsiflexion action to assist the dorsiflexor, tibialis anterior. This operation, which prevents serious inversion of the ankle, may improve gait by providing the patient with some dorsiflexion action to prevent the toe from dragging on the floor during swing phase. EMG studies performed pre-surgery can show the current action state of the

muscle and post-surgery studies can show whether or not the muscle is working in the proper phase to suit its new role

#### Spasticity

Cerebral palsy patients often have limited range of joint motion because of dynamic spasticity of various muscle groups. The spastic muscle often exhibits prolonged periods of activity as though once the muscle begins contracting it cannot easily be turned off. The resulting joint contracture is often alleviated by reducing the muscle action surgically through tendon lengthening or muscle release. EMG patterns obtained during gait can provide positive information on muscle spasticity to strengthen other clinical findings on the state of the neuromuscular system. Figure 5 shows the overactive pattern of the muscle in a cerebral palsy patient along with the normal period of activity for the same muscle. In addition to the prolonged phase of activity at initial contact, there is also an additional period of activity at toe off.

#### Lack of Control

Lack of muscle control may be exhibited in EMG studies by gross over-activity, lack of activity, or the presence of primitive reflex activity patterns. Telemetered muscle activity patterns during walking serve to confirm abnormal muscle patterns of this type.

#### Prostheses Evaluation

The video data portion of the locomotion laboratory has been used to study, in detail, the biomechanical considerations of prostheses. Two specific projects that have been studied in most detail are:

- a) power requirements and energy flows in hip disarticulation subjects
- b) evaluation of two different knee joint designs

From these studies we can answer basic questions about the energy requirements and power flows associated with different prostheses such as the power flow across the hip, shown in Fig. 6, for two different knee joint designs.

#### Conclusions

The locomotion laboratory has proven valuable not only as a basic research tool but also as a means of clinical gait assessment especially in cerebral palsy patients. It is anticipated that in future, as other abnormal walking patterns are better understood the results of gait studies will provide clinically useful information in these areas as well.

#### Acknowledgments

The authors wish to acknowledge the support of the Shriners Hospital, Winnipeg and the Medical Research Council of Canada (Grant MT4343).

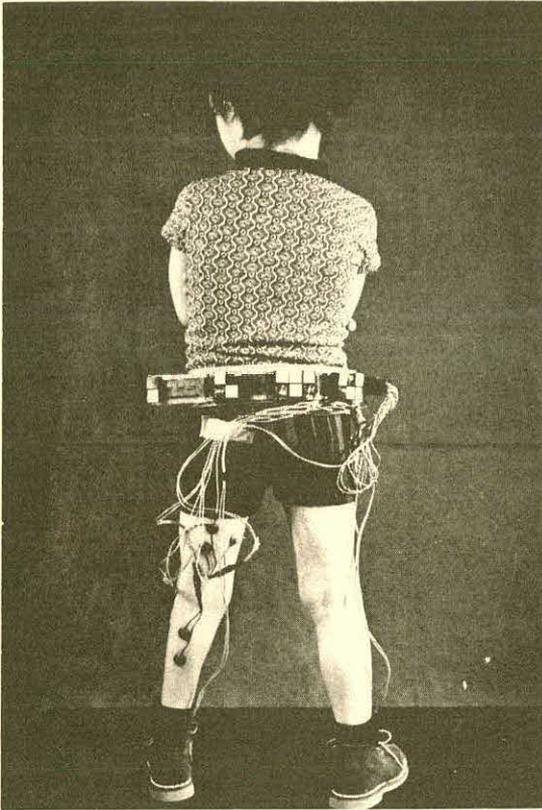


Figure 1  
Four year old subject fitted with telemetry belt  
and surface electrodes

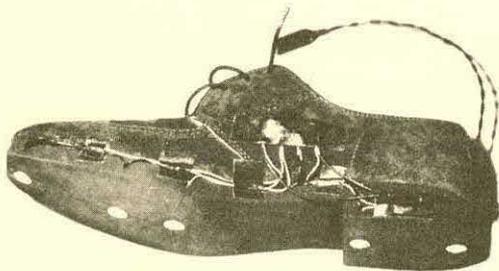


Figure 2  
Microswitch shoe for determining phases of walk  
cycle

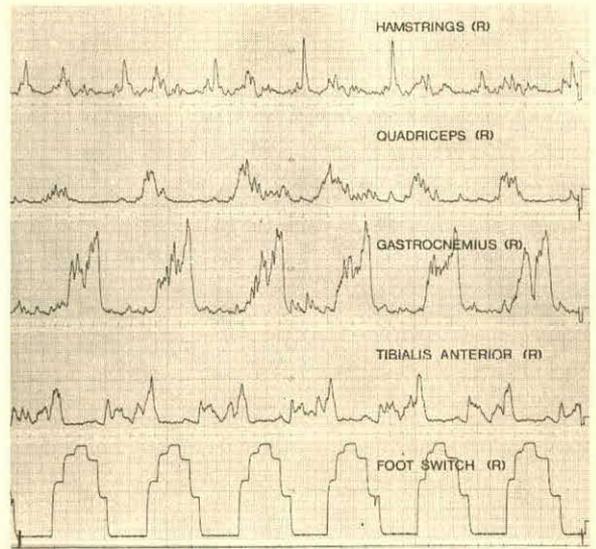


Figure 3  
EMG and footswitch signals from a normal gait



Figure 4  
Reflective body markers for kinematic analysis

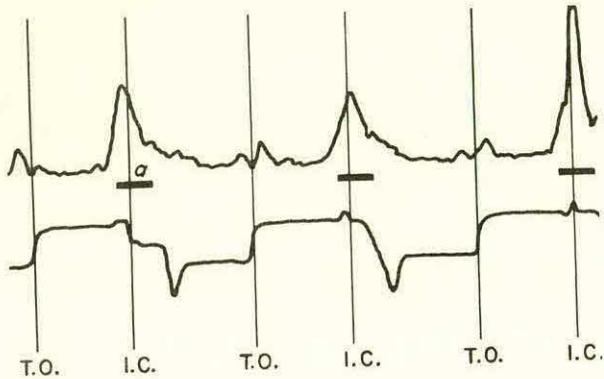


Figure 5  
Spastic activity of medial hamstring muscle related to normal patterns of activity. (Horizontal bars (a) indicate periods of normal activity)

T.O. - Toe off I.C. - initial contact

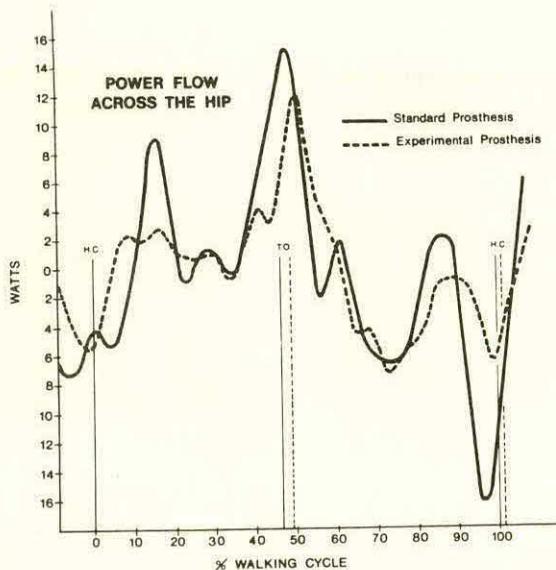


Figure 6  
Power flow comparison of two different prostheses worn by the same subject

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NEW MEANS TO ASSESS THE DEVELOPMENT OF INDEPENDENCE OF  
CHILDREN WITH CONGENITAL PARALYSIS

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The development of daily living skills of 256 patients with myelodysplasia was displayed graphically by means of a new Functional Activities scoring system. This scoring system assigns points for achievement of increasingly more difficult steps toward independence. Scores were derived from computerized data of patients' functional status over time in nine categories of daily living, which include self-care, locomotion and socialization activities. Different patterns of development based on the type of activities being learned are presented. The difference in overall achievement among patients with varying levels of paralysis is discussed as well as the variation between patients with similar degrees of paralysis. This mode of quantifying on-going functional status provides both a research and clinical tool for use in better understanding the special development of children with congenital handicaps.

CATEGORY:	INTENDED USER GROUP:
Device Development <input checked="" type="checkbox"/>	Clinicians, therapists, teachers, parents
Research Study <input type="checkbox"/>	AVAILABILITY OF DEVICE:
STATE OF DEVELOPMENT:	Pre-publication form from authors
Prototype <input type="checkbox"/>	AVAILABILITY OF CONSTRUCTIONAL DETAILS:
Clinical Testing <input checked="" type="checkbox"/>	A hand-out is provided
Production <input type="checkbox"/>	FOR FURTHER INFORMATION CONTACT:
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Yes <input type="checkbox"/> No <input checked="" type="checkbox"/>	
Price:	

Self-sufficiency and eventual economic independence, common goals for all young people, are becoming an increasing concern for those who are involved in the care of children with acquired and congenital handicaps. As modern medical advances make it possible to preserve the life of more children born with severe defects, it is becoming apparent that habilitating these children, many of whom have a multitude of associated physical, psychological and social complications, is not a simple task. This is because it still is not well understood how a totally independent and self-sufficient adult develops from a congenitally handicapped infant. No one can explain why some individuals with severe disabilities attain complete independence, while others with apparently less severe handicaps require a continued sheltered existence. Surprisingly, there are no age and degree of disability related guidelines to assess development. While there are numerous scales and standards of development for non-handicapped children, clinicians and therapists must depend upon memory of past experiences with other patients to assess the developmental rate of each child. Too often perceptions are off and children are allowed to lag so far behind their true potential that feelings of competence and self-worth may never be allowed to develop.

#### Purpose

The purpose of this study was to develop a model that would display graphically the average development of congenitally handicapped children and could be used to assess functional status as well as to select an ideal population to study for factors relevant to good adaptation. Once average development is outlined and the reasons for accelerated development are better understood, the task of helping parents set realistic goals and create more appropriate environments for their handicapped children will be made easier. Hopefully, more children will be helped to reach their true potential.

#### Methodology

For this pilot study, the records of 256 individuals with myelodysplasia were selected from a data pool containing semi-yearly and yearly evaluations conducted during a period of 19 years. For 17 of those years data had been collected prior to the initiation of this study, and for the last 2 years, data was recorded prospectively. Those patients not included in the study had upper extremity spasticity, I.Q.'s less than 80 or incomplete computer records. There was a total of 649 examinations for an average of 2.5 per patient. At least 20 individuals were seen over 10 years and had as many recorded examinations. Age ranged

from birth to adulthood.

Patients' functional status in daily living activities recorded at periodic evaluations were stored on computer tapes and provided the data for a new Functional Activities scoring (FAS) system. Activities in nine categories were chosen for their relevance to handicapped children's habilitation. In each case, what the individual actually was doing, and not what he was capable of doing was the recorded information. Five of the nine categories related to learning self-help skills: dressing, eating and meal preparation, hygiene, bowel control, and urinary appliance self-care. In the area of locomotion, the type of locomotion (whether braces and crutches or wheelchair were used), its effectiveness (the type of gait, or ability to do transfers), and the degree of independence in the community were evaluated. The last category was that of social interaction, that is, did the individual have an opportunity for social contacts and were they age-appropriate. To derive the FAS, points were assigned for increasingly more difficult activities within each category. Zero points were given for total dependence and a maximum of 50 points were given for complete independence in each category (1). A Functional Activities Score was calculated by computer for each patient by summing the points earned in each category, multiplying by 10 for comparability with computer analyses, and dividing by the number of appropriate categories. Not all categories were appropriate for all ages or were always known on every patient record.

Hypothetical norms for the FAS were determined using developmental sequences described by Alpern-Boll(2), Gesell (3) and Frankenburg(4). For each age, the expected stage of development was determined from these standards for normals and the appropriate points summed and divided by the number of categories.

A recorded yearly functional muscle exam was used to place each patient in a motor level group. The relative small number in the study and the desirability of also grouping children by age did not allow dividing the patients into more than three groups based on motor level. Patients in the first group had motor level paralysis at or above L<sub>3</sub>, the second group included those with L<sub>4,5</sub> paralysis, and patients in the third group had motor loss in the sacral nerve roots only.

### Results

When the mean Functional Activities scores were plotted for each motor level group by age, the average development of daily living skills by children with varying levels of congenital paralysis was graphically portrayed (Fig. 1). Note that children with only sacral root paralysis learned daily living skills at a rate approximately near that of normal children in the first two years of life. Non-handicapped children continued to learn at a very rapid rate, reaching near maximum independence in these daily activities by age six. (When the mean scores of those patients with minimal or no motor loss (S<sub>2,3</sub>) were compared to the curve for normal development, they even more closely approximated this hypothetical normal curve.) Individuals with L<sub>4,5</sub> paralysis learned the same skills at a more gradual, but steady rate, while those with the most severe

paralysis described the most delayed developmental curve.

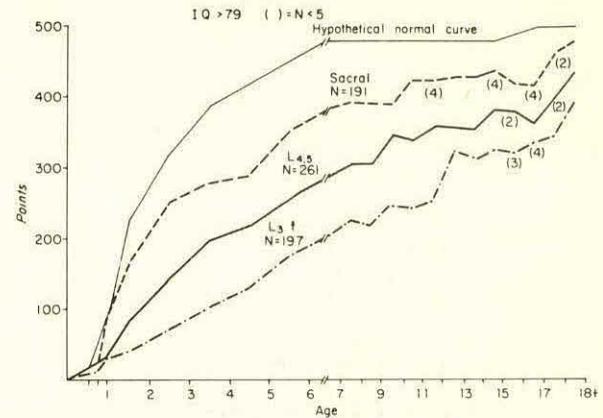


Fig. 1. Developmental curves of patients by level of motor paralysis. Mean Functional Activities scores (ordinate) are plotted by age (abscissa). Patients older than 18 are grouped together.

The variability of individual achievement within groups was considerable, indicating that these three mean curves represent trends in development rather than the average level of achievement by three statistically different groups.

The reliability of the first 17 years of retrospective data was supported when developmental curves from the additional two years of prospective data could be analyzed. The curves described by data collected since early 1974 were basically the same curves as those plotted using retrospective data.

When an individual's serial FAS's are plotted along the appropriate group mean curve, it is possible to demonstrate individual peaks and plateaus as well as to assess his development relative to others with similar paralysis (5). When staff members in one clinical setting who were unfamiliar with the tool were asked to compare children's function to others of the same age and with similar paralysis, there was a high congruence between these subjective opinions and the tool's objective placement of patients relative to others like them.

When the total population mean scores for single categories were plotted, different patterns of development were demonstrated depending on the activities being learned. However, in all categories but one, mean scores increased with age. In the self-help categories of hygiene, dressing, eating and meal preparation, mean scores described a very gradual, upward sloping curve similar to that of the L<sub>4,5</sub> mean curve in Fig. 1. In Fig. 2 the mean scores for activities in three categories have been plotted. The social interaction curve described a gradual upward progression until the pre-teen years, then teen-agers in the study

population actually began receiving lower social interaction scores than the pre-teens, and the adults' social scores were only as high as those of the pre-teens. The achievement of skills by this population in urine appliance care and self bowel regulation described very flat curves until the late pre-school years, when the average non-handicapped child is completely toilet trained. Once begun, however, these self care skills improved rapidly.

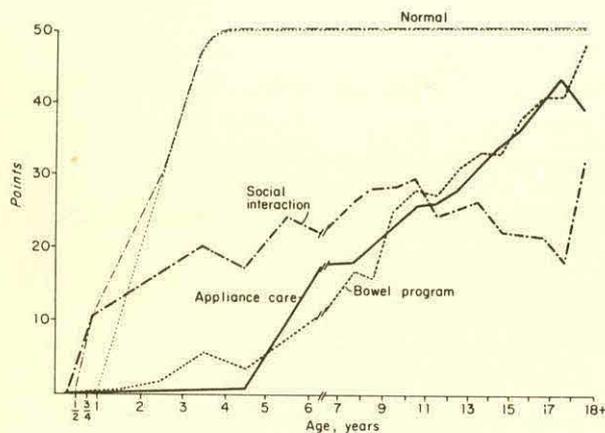


Fig. 2. Total population mean scores by age for 3 self care categories compared to normal expectation.

Plotting individual patient's achievement for a single category along the mean curves for that category provides information in isolated areas that might otherwise be lost if only the total functional activity scores were used.

#### Discussion

The different rates of acquisition of daily living skills by variously paralyzed groups of children was not unexpected. The rate of gross-motor learning is affected by the degree of paralysis. The wide within group variation may, in part, be reduced when larger numbers allow categorizing patients by more homogeneous groups, with exactly the same motor level of paralysis. Social and environmental factors are probably also responsible for the abnormally wide variation in achievement by handicapped children who have an increased dependency on people in their environment to make adaptations for them.

The similarity between the hypothetical standardized norms for the FAS and the actual achievement of individuals in this study with minimal or no motor paralysis suggests the validity of this scoring system for these activities.

The right skewed curves of the bowel and urine self-care activities indicate, perhaps, a lack of physiological readiness to use the necessary adaptive equipment (5). It also has serious implications for education programs for parents who must be emotionally and psychologically ready to transfer the responsibility of this care as

soon as the child is physiologically ready.

At this time we have only supposition to explain the reduced social activity scores of the teens in this study. Young children with handicaps need to be more adequately prepared to understand and cope with the stresses that commonly interfere with a smooth transition from childhood to the teen years. Physiological complications that may also affect this social interaction score have been discussed elsewhere (6).

This pilot study serves as a model in the use of computerized record keeping for defining the developmental patterns of groups of children with similar types and degrees of handicaps as well as for assessing individual patient progress. It is one objective method to screen for children achieving below average as well as a research tool to use to select individuals performing above the mean to study for factors contributing to their good adaptation.

This particular method of record keeping does not provide certain data or allow some analyses we think important. Collecting data only at yearly or semi-yearly intervals does not provide the age of first acquisition of skills, but only what groups of children are doing at any given age. Valuable information is lost in this way, especially in the early years when developmental change is so rapid. A new Developmental Milestone Inventory (DMI) has been completed and is currently being used by parents to record their child's developmental milestones as they occur. It was designed to provide the earliest age of acquisition as well as the age in which each skill is consistently independently performed. One hundred and forty five items include most of the FAS activities and result in more narrowly spaced intervals. When compiled, these data will provide parents, therapists and clinicians with age specific developmental expectations for children with varying degrees of congenital paralysis.

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## SYSTEMS AND DEVICES FOR THE DISABLED'S OCCUPATIONAL THERAPIST

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For many years occupational therapists have improvised various evaluation tools and treatment implementation equipment to provide care for the physically, emotionally, and learning disabled. Through application of advances in engineering and an improved definition of specific therapy needs by Occupational Therapy Clinicians, it is possible to develop devices which will enable improved, more efficient, quantitative and safer patient treatment. Additionally, such devices should make it easier for new therapists to understand the obviously useful equipment at the same time that the therapist frustration which is caused by poorly designed or makeshift equipment would decrease. This paper outlines several specific problem areas in occupational therapy and briefly discusses a few examples of solutions to those problems.

CATEGORY:	INTENDED USER GROUP: Occupational therapists
Device Development <input checked="" type="checkbox"/>	
Research Study <input type="checkbox"/>	AVAILABILITY OF DEVICE: N/A
STATE OF DEVELOPMENT:	
Prototype <input checked="" type="checkbox"/>	AVAILABILITY OF CONSTRUCTIONAL DETAILS: N/A
Clinical Testing <input checked="" type="checkbox"/>	
Production <input type="checkbox"/>	
AVAILABLE FOR SALE:	FOR FURTHER INFORMATION CONTACT: Authors
Yes <input type="checkbox"/> No <input checked="" type="checkbox"/>	
Price:	

### Introduction

It is a widely accepted belief in the rehabilitation professions that occupational therapists are proficient at constructing "makeshift" gadgets to solve the myriad of problems which they face on a daily basis. While this ability to improvise is an admirable trait which is to be encouraged, and which facilitates cooperation between engineers and occupational therapists, yet it points to a problem area which calls for solutions - occupational therapists need more engineering systems and devices for solving their problems. That is, makeshift solutions may temporarily solve an individual problem, but such solutions are often temporary, time consuming, frustrating to construct and use, and are often inaccurate when accurate quantification is needed. Put in another perspective, there are many sophisticated technological aids for the physically handicapped person, the physiatrist, the rehabilitation nurse, and the physical therapist, yet there are relatively few such devices for the occupational therapist. At the same time, somewhat ironically, occupational therapy is a profession which covers a wide range of problems and has a large number of variegated, diverse needs. This is due to two main reasons. First, occupational therapists work with a wide variety of

patient problems which impede an individual's ability to function within the environment, such as perceptual motor dysfunction, range of motion deficits, sensory dysfunction, mentation deficits, incoordination, personality problems, resocialization problems, and adaptive behaviors. Second, occupational therapists approach patients with a dual emphasis, one on rehabilitation, the other on habilitation. For example, the homemaker who has had a stroke leaving her right arm paralyzed may have incorporated into her therapy regime not only arm exercises, but also instruction on how to cook with one hand.

### Occupational Therapy Needs

Because of these diverse needs and approaches occupational therapists use a variety of evaluation tools, treatment modalities, and therapeutic equipment to facilitate remediation of problems. It is in the solving of these problems that there is a need for engineers to collaborate with occupational therapists in developing new technology. In particular, devices are needed for therapists to use in the administration of patient treatment and evaluation. Such devices could result in general improvements in patient care and decreased costs for individual treatments. The following are

specific areas in which occupational therapists could be benefited by more sophisticated tools.

1. Time and energy could be saved by the application of easy-to-use equipment, allowing the therapist additional time available for patient treatment.

2. Levels of therapist frustration involved in using poorly designed or makeshift equipment are often high. Technology could eliminate many of these problems and hopefully decrease job stress.

3. Improved technology could have a tremendous effect on the quantification of therapy, making more effective and appropriately individualized treatment programs available to patients. Such quantification would also allow much needed clinical research to be performed, and the standardized results of that research could be more readily communicated to and used by all clinicians.

4. Technology also offers the therapist better tools for instructing new staff and students in methods of treatment and evaluation. It is much easier to understand well designed and obviously useful equipment which have quantifiable measures of performance than makeshift gadgets.

5. Improved safety records could be achieved by safe, reliable, and easy-to-use equipment in clinics.

The above benefits could be realized for a wide variety of problem areas. Table 1 contains a description of several such areas. The items contained in this list were arrived at from discussion with the occupational therapy staff at Memorial Rehabilitation Foundation. It can be considered a partial, initial list which will hopefully be both expanded by contributions from other occupational therapists with different needs and decreased by better communication concerning existing and future solutions to these problems. The problems identified in that table cover a range from the simple to the complex. Many problems are almost purely engineering tasks while others could require years of basic and applied research before successful solutions are realized. The table is broken down into the two major areas of evaluation tools and treatment equipment, while within these areas are outlined; (1) the devices needed, (2) their purpose, and (3) the problems of currently used devices. The patient population for which such devices would be used includes persons with the following problems; spinal cord injuries, neurological diseases, traumatic head injuries, peripheral nerve injuries, and amputations.

#### Solution Examples

As examples of solutions to some of these types of problems, we will briefly discuss three devices designed to facilitate easier and more sophisticated treatment of the physically disabled. One item of equipment (Fig. 1) is a semi-automated, motorized skateboard and skate system for use in progressive resistive arm exercises



Fig. 1. Upper Extremity Resistive Exercise System.

which has been found to be valuable in the treatment of patients with impaired upper extremity motor function. It provides the following features: adjustable load (force), adjustable range of motion limits, an automatic method of counting the correct repetition of the prescribed exercise, and visual feedback to patients regarding their performance. After using this device in our clinic for almost two years we have found its advantages to be; 1) a decrease in the amount of therapist/attendant time needed for the exercise program, 2) improved performance by the patients, and 3) a better, quantitative measure of the patient's progress.

Another piece of equipment (Fig. 2) now being developed is a finger exercisor to enable a therapist to carry out a muscle re-education program to the extrinsic finger muscles with less stress to his/her own hand joints. The device stabilizes the patient's joints proximal and distal to the joint being exercised - a task that was previously performed by the therapists hands and which generally caused tendon and joint problems for the therapist.

In the preliminary development stages is a perceptual motor trainer to be used to assist occupational therapists in the evaluation and training of visual problems in left hemiplegics. The currently used method involves a large amount of therapist time, is not motivating to the patient, and yields poorly quantified results so that progress is difficult to measure. One proposed solution to this problem is to replace the traditional pencil and paper media with a television CRT display and a light pen hooked up to a microprocessor system. The patient would

TABLE 1  
 EXAMPLES OF DEVICES NEEDED BY OCCUPATIONAL THERAPISTS

DEVICE	PURPOSE	CURRENT DRAWBACKS
EVALUATION TOOLS		
1. Sensation measurement gauge including a dermatome sleeve	To measure position, temperature, and tactile senses in upper extremities.	Present time consuming tests are not always reproducible or accurate due to non-standardized techniques and equipment; measurement techniques give undesirable sensory inputs to patient; and tests are often psychologically disturbing to patients.
2. Grip and pinch measurement	To provide serial grip and pinch measurements.	Equipment is difficult and unsafe for patients to use and is not calibrated to measure weak grip and pinch; isometric exercises unsuitable for some cardiac patients.
3. Quantified gross muscle tester	To provide accurate consistent measurement and reading of gross arm muscle strength.	Subjective measurement by therapist providing manual resistance varies over time and between therapists.
4. Upper extremity goniometer.	To provide an accurate assessment of upper extremity range of motion.	Current methods are difficult and time consuming to apply.
5. Hand edema gauge	Accurate assessment of hand edema.	Water displacement systems are inaccurate and inconsistent.
6. Spasticity measurement gauge	To accurately measure spasticity in the upper extremity.	Subjective measurements by therapists vary over time and between therapists; accurate measurement could improve assessment of pharmacological effect on spasticity.
7. Device to measure hand for Jobst glove	Measure individual finger, wrist, and thumb joint circumference.	Time consuming with tape measure.
8. Hand function test	To evaluate and record functional hand usage quantitatively.	Present tests are large, bulky, not easily portable, difficult to quantify, and difficult to utilize.

TABLE 1 (continued)

DEVICE	PURPOSE	CURRENT DRAWBACKS
9. Subluxation test	To measure amount and direction of a subluxed shoulder.	Inaccurate measurement using therapists fingers is used now.
10. Ataxia measurement gauge	Monitor and record ataxia during evaluation and daily activities.	The visual observation and hand function tests which are used now are difficult to quantify.
11. Arousal level gauge	To assess the arousal level of a comotose patient from various stimuli during therapy.	Visual observations currently performed by therapists are extremely subjective and could delay recognition of potential communication channels with patients.
12. Device to produce positive model of patient's hand.	Needed for use in splinting	Time consuming and expensive when plaster and alginate are used.
13. Frustration gauge	Needed to determine patients' and therapist's gadget tolerance.	Therapists and patients are too frustrated to notice sophisticated engineering solution to problems.
TREATMENT EQUIPMENT		
1. Deltoid aid replacement	Exerciser to assist weak deltoid muscles and resist motions of shoulder adduction, shoulder extension, and shoulder depression.	Current equipment is unsafe and difficult to use.
2. Arm exerciser	To exercise antigravity shoulder and elbow exercises.	Velcro wrist weights currently used are time consuming to put on and often slide on patient's arm during exercises.

TABLE 1 (continued)

DEVICE	PURPOSE	CURRENT DRAWBACKS
3. Wrist flexion and extension exerciser	To exercise wrist musculature.	An inclined board over which patient's arm is placed is difficult to position, Weights attached to a wrist cuff are time consuming to apply and dangerous if dropped.
4. Writing trainer	To provide patients with writing exercises.	Therapist must devise exercises and spend much time with a patient completing exercises. Present techniques are not quantified.
5. Visual perception training	To provide standardized perceptual motor training for the adult.	Assorted pediatric developmental activities are currently used which were not developed for the adult. These are not only rejected by some patients but they are not quantified and are time consuming to apply and evaluate.
6. Head positioner	Needed for the comatose patient to provide head stability in wheelchair during therapy.	Currently there are no good devices to position a spastic head without causing skin problems.
7. Therapeutic games	Needed for patients with mentation, perceptual motor, and coordination problems.	Currently assorted children's games and pediatric perceptual motor training activities are used. More challenging activities aimed at the adult are needed.
8. Upper extremity positioning device	To position the upper extremity to prevent deformity and increase function.	Currently used overhead suspension slings, mobile arm supports and radial arm supports are time consuming and frustrating to install.

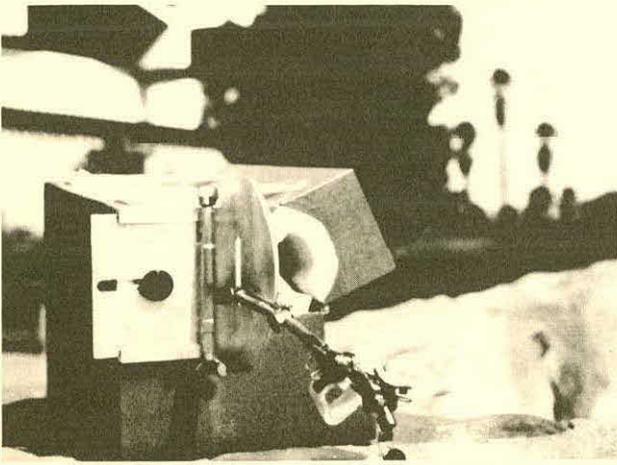


Fig. 2. Photograph of Finger Exerciser. Set up is shown for one finger only.

write on this screen with the light pen, and his performance would be monitored by the microprocessor system which would be able to numerically evaluate and record his scores. Additionally the microprocessor can generate figures and patterns on the screen, and can also "self prompt" the patient through a short series of tasks.

#### SUMMARY

Due to the myriad of complex problems which occupational therapists are involved in there is a need for a significant engineering contribution to their profession. For example, while the successful development of the devices listed in Table 1 would represent a significant contribution to the needs of the occupational therapist, yet there are several other problems which either exist now or will arise in time.

## AN AUTOMATED NERVE CONDUCTION VELOCITY METER

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## Abstract

A prototype motor nerve conduction velocity meter has been designed and built. The device can measure motor nerve conduction velocities and nerve latencies without the use of an oscilloscope. The main components of the instrument are two nerve stimulators, a detector which determines when muscle contraction has occurred, a time interval counter, a position encoder for determining the distance between the nerve stimulators, a computation unit, a sequence controller and a power transformer. The device has the potential of reducing considerably the error associated with the method currently used to measure motor nerve conduction velocities.

CATEGORY:	INTENDED USER GROUP:
Device Development <input checked="" type="checkbox"/>	Physicians and patients with end stage renal disease
Research Study <input type="checkbox"/>	
STATE OF DEVELOPMENT:	AVAILABILITY OF DEVICE:
Prototype <input checked="" type="checkbox"/>	Not available
Clinical Testing <input type="checkbox"/>	AVAILABILITY OF CONSTRUCTIONAL DETAILS:
Production <input type="checkbox"/>	Not available
AVAILABLE FOR SALE:	FOR FURTHER INFORMATION CONTACT:
Yes <input type="checkbox"/> No <input checked="" type="checkbox"/>	George H. Kraft, M.D., University Hospital
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The development of the nerve conduction velocity meter began in the late 1960s following the development of the artificial kidney at the University of Washington. Measurement of motor nerve conduction velocity (NCV) is perhaps the most useful means for detecting uremic neuropathy in patients with end stage renal disease (ESRD) (1). Since uremic neuropathy is usually a primary complication for ESRD patients undergoing artificial dialysis and since there is no blood chemistry test which can measure the build-up of unknown uremic toxins, motor NCV can also be a good indicator of the adequacy of dialysis if the NCV value is accurate.

However, there is a considerable amount of error associated with current electromyographic techniques used to measure NCVs (2). Techniques for determining motor NCV using an electromyograph are the following: a recording electrode is placed on the skin over a muscle in the distal portion of an extremity. This electrode records the electrical activity generated by that muscle when it contracts and transmits this change in electrical potential through an amplifier to be displayed as an "M" response on an oscilloscope screen. The nerve innervating that muscle is stimulated electrically at two points along its course, one proximal and one distal (fig. 1).

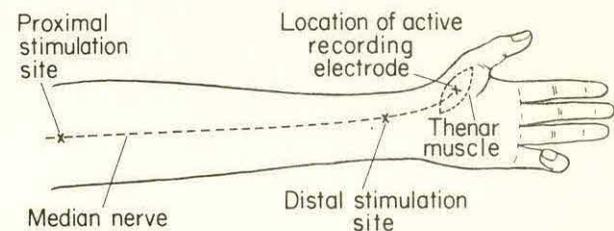


Figure 1. Stimulation and recording sites for determining the conduction velocity of the left median nerve.

The occurrence of the electrical stimulus is displayed together with the "M" response on the oscilloscope and the electromyographer measures the time interval (i.e., distance on the oscilloscope screen)

between the onset of the stimulus and the onset of the "M" response (fig. 2). This time interval,

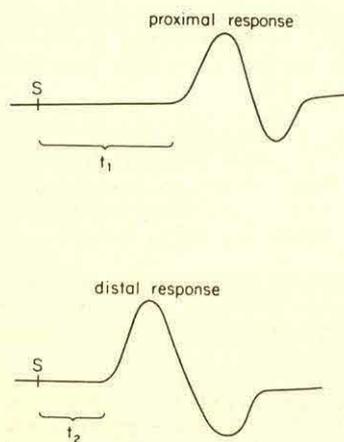


Figure 2. Diagrammatic representation of the trace of the "M" response on an oscilloscope screen when a peripheral nerve is stimulated proximally and distally. The time of the nerve stimulus is indicated by S, and times elapsing between the stimulus and the beginning of the "M" response are indicated by  $t_1$  and  $t_2$ .

known as the nerve latency, is determined for both proximal and distal sites. The major source of error in this technique is in the visual determination of the time of onset of the "M" response (3). A secondary source of error is in the measurement of the distance between the two points of nerve stimulation.

In 1970 McPhee, Koepke and Bauer (4) reported a device which automatically determined the conduction time by means of a computer analysis of the beginning of the "M" response. Subsequently, at the University of Washington electromyography laboratory this computer technique was modified and used with a fixed-distance (proximal and distal) stimulation template (5). We were encouraged by the results but found the technique cumbersome.

From this research we have developed our present motor nerve conduction velocity meter which combines electronic determination of conduction times with an automatic measurement of distance. The automated NCV meter was designed to reduce sources of error and improve the ease of determining nerve conductions. This device measures 46 x 15 x 13 cm (fig. 3) and is used with a power converter which can be plugged into a standard 110v socket. The automated nerve conduction velocity meter electronically measures the proximal latency, distal latency and the distance between the two cathodes and calculates and displays the nerve conduction velocity. The time involved in measuring conduction velocity with the automated device is less than when using a standard electromyograph.

The functional electronic equipment of the automated device consists of two stimulators, a variable evoked response detector, a position encoder for determining the conduction distance, a

time interval counter, a computation unit and a sequence controller. The proximal and distal stimulators are mounted on an I-beam. The distal stimulator is attached to one end of the instrument and the proximal stimulator is able to slide along the I-beam making contact with a copper grid (fig. 3).

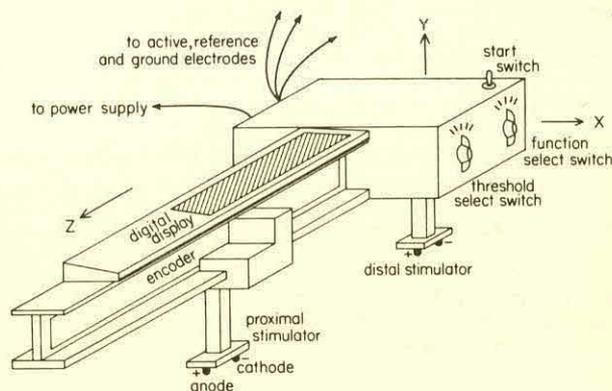


Figure 3. The nerve conduction velocity meter, measuring 13 cm in the X direction, 15 cm in the Y direction and 46 cm in the Z direction.

From the pattern of contact between the proximal stimulator and the copper grid the device is able to determine the conduction distance. The distal and proximal latencies are measured by a 1 MHz crystal clock and counter which measures the time between the nerve stimulus and the initial deflection when a threshold voltage difference between the active and reference electrodes is exceeded. The threshold voltage can be set at 20, 30, 40, 60, 80, 100, 200, 300, 400 or 500 microvolts. From the conduction distance and latency measurements the instrument calculates the nerve conduction velocity (6). The components of the instrument are represented schematically in figure 4.

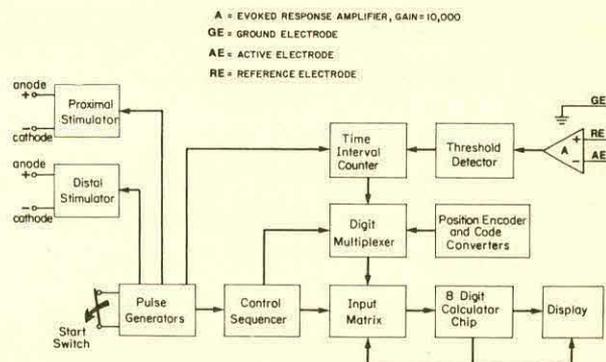


Figure 4. Schematic representation of the components of the nerve conduction velocity meter.

To determine nerve conduction velocity the physician attaches active, reference and ground electrodes to the patient at the appropriate sites, places the instrument so that proximal and distal stimulators are on the skin directly over the stimulation points of the nerve, and deflects the stimulus trigger. The nerve is stimulated at the proximal point and 1.3 seconds later at the distal site. The stimulation pulse is a square wave of 150, 200 or 250 volts amplitude and 200 micro-seconds duration. Distance information is automatically recorded; approximately 1.5 seconds after the trigger is deflected by the electromyographer the conduction velocity is displayed on the digital display panel. By changing the position of a "function" switch, the instrument can also display conduction distance or proximal or distal latency.

Table 1 indicates the reproducibility of the measurements made by the instrument on three median nerves. These data were collected by placing the instrument on normal volunteers and recording successive readings. Further clinical testing of the NCV meter is now in progress.

Table 1. Consecutive Determinations of Median Nerve Latencies and Conduction Velocities in Normal Subjects as Measured by the Automated Nerve Conduction Velocity Meter.

	Nerve A	Nerve B	Nerve C
NCV	55.39	53.64	57.91
(m/sec)	56.13	53.72	58.17
	55.83	53.38	58.19
	56.02	53.71	58.24
	56.40	53.88	58.42
Proximal Latency ( $\mu$ sec)	-----	8606	7857
		8527	7843
		8551	7835
		8507	7840
		8543	7838
Distal Latency ( $\mu$ sec)	-----	3902	3754
		3902	3762
		3919	3766
		3898	3761

The principal disadvantage of the instrument is that it does not allow the electromyographer to observe the evoked muscle response, which may be necessary for complete assessment of peripheral nerve function. However, the outputs of the evoked response amplifier and level detector can be connected to an oscilloscope so that the amplitude, duration and shape of the evoked response can be visually displayed.(7).

#### References

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## EFFECTIVENESS OF A TRAINING PROGRAM IN DENTISTRY FOR THE DISABLED

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A program of Dental Education for Care of the Disabled, Project DECOD, is designed to provide more dentists and auxiliaries, qualified and willing to treat the disabled. The program encompasses didactic and clinical instruction, in-service and continuing education; and evaluative research. Monitoring methods include specific records, surveys and computer information services. Patient treatment is supervised by experienced faculty, a social worker provides support services. Under these conditions the integration of DECOD patients into the general School clinics has proved practicable. Preliminary data indicate significant increases in student confidence in treating disabled patients as a result of specific didactic and clinical courses. No corresponding effect on attitudes toward the disabled was observed; however, interclass comparisons showed variable attitudinal differences. Further studies are in progress. Supported by a grant from The Robert Wood Johnson Foundation.

CATEGORY:	INTENDED USER GROUP: Educators and Providers of Health Care for the Disabled.
Device Development <input type="checkbox"/>	
Research Study <input checked="" type="checkbox"/>	AVAILABILITY OF DEVICE:
STATE OF DEVELOPMENT:	AVAILABILITY OF CONSTRUCTIONAL DETAILS:
Prototype <input type="checkbox"/>	
Clinical Testing <input checked="" type="checkbox"/>	
Production <input type="checkbox"/>	
AVAILABLE FOR SALE:	FOR FURTHER INFORMATION CONTACT:
Yes <input type="checkbox"/> No <input checked="" type="checkbox"/>	Dr. D.J. Stiefel, Admin. Director
Price:	Project DECOD SB-22
	University of Washington, Seattle, WA 98195

## Introduction

Our concerns for the disabled are based on the principle that every individual should have the opportunity to develop his or her potential to the maximum extent possible. Fundamental to the concept of normalization is the achievement of optimum total health, an integral part of which is a clean and healthy mouth. If the teeth are decayed and broken down, the gums infected, and the mouth generally neglected, the individual will be avoided by his or her peers, associates and society in general.<sup>1</sup> Moreover, the risk of serious systemic involvement which may result from dental and oral infection should not be added to the multiple problems which burden disabled persons.

A number of factors have been identified as responsible for the general neglect of dental care of the disabled: financial barriers, lack of mobility, perception of dentistry as a low priority need, and lack of training and sensitivity of dental professionals to deliver care.<sup>2</sup> In efforts to correct the last named deficiency, the University of Washington School of Dentistry is one of ten schools nationwide currently training dental and dental hygiene students in dentistry for the disabled. These programs are supported by 4-year grants from the Robert Wood Johnson Foundation.

The purpose of this paper is to report on selected aspects of the UW program and to provide preliminary data relating to its potential effectiveness in improving the delivery of dental services to the disabled.

## Outline of Project DECOD

At the UW a comprehensive program of Dental Education for Care Of the Disabled, Project DECOD, is now in its third year. It comprises a didactic and clinical curriculum for all dental and dental hygiene students; faculty and staff in-service training; continuing education courses; University and community interdisciplinary endeavors; and extensive evaluation and research activities.

Didactic instruction is given in both specific courses on disabilities and as an integral part of general courses, e.g. Clinical Medicine. Clinical training is provided both at extramural facilities for the disabled, and within the School's clinics. The integration of treatment of disabled patients into the general clinics of the Dental School was deemed to offer the greatest long-term benefit in terms of "normalization" of dental care. Such a system, in order to operate effectively within a School situation requires extensive monitoring and follow-up at each stage of treatment.

An outline of the protocol and the controls adopted are indicated in Figure 1. The methods used range in sophistication from simple forms to comprehensive record cards, surveys and a computerized clinical information service.

A core of hospital-trained instructors and other faculty experienced in disability management, supervise patient screening, treatment planning and treatment. The large majority of patients seeking treatment are accepted for comprehensive care; those not accepted are referred to other clinics or private practitioners. Patients are assigned to student teams, termed vertical groups.

A social worker has been involved in approximately one third of the cases, and has provided valuable support services by facilitating initiation of treatment, making referrals, identifying and obtaining transportation and financial assistance and resolving other patient and student problems relating to treatment.

Figure 1: Outline of DECOD Patient Protocol and Monitoring

Patient Intake	
Rate	
Reason for Participation	
Past Dental Experience	
Patient Screening	
Disability	
Dental	
Age, Sex	
Method of Payment	
Source of Referral	
Acceptance	Referral
Classification	
Assignment to Vertical Groups	
Patient Treatment	
Tx. Progression	
Problems	
Patient Survey	
Faculty Survey	
Student Follow-up	
Termination	
Inactivation	
Referral	

The monitoring of treatment progress has been simplified by a computerized system now in general use in the School. Data is based on information students provide for each clinic appointment. Thus for Autumn Quarter 1976, information was readily obtained for: no. of patients seen (99); mean no. of procedures performed/patient (4.1); mean no. of clinic sessions/patient (2.9); percentage of student groups treating patients (72). Those students not seeing their disabled patients within a given period are contacted.

Table I presents the total number of patients screened, treated and inactivated.

The collection of background information on the patient pool is considered important in assessing the Project as a model for future programs. It is, however, realized that the sample population is

limited to those disabled individuals seeking care at the School of Dentistry and therefore may not be representative of the disabled population at large.

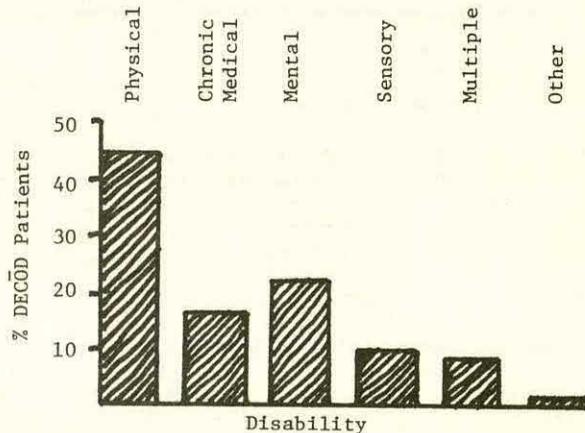
Table I: Number of Disabled Patients Serviced

Patients currently in treatment in Vertical Group System		248
Patients Inactivated		
Referred to private DDS	29	
Inactivated by School	46	
Withdrawal by Patient	27	
Total patients screened in Vertical Groups, but not currently treated		102
Total patients screened		350

Figure 2 gives the disability profile of the patients in treatment. Qualification as a DECOD patient is based on the criterion that the disability must require significant alteration in dental management or treatment. It is evident that the largest group is that of the physically disabled, comprising a spectrum of conditions.

Table II indicates the characteristics of the group with respect to age, sex, referral source and financial arrangements. The age range is fairly uniformly distributed, extending from 4-96 years. Males have consistently outnumbered females; this is probably related to the predominance of the physically disabled, including a relatively large number of spinal cord injury patients. The principal referral sources are agencies for the disabled. Slightly more than one-third of the patients use public assistance to pay for dental care.

Figure 2: DECOD Patient Disability Profile



An analysis is currently being made of the existing dental condition and treatment needs of the first hundred disabled patients compared with a group of non-disabled patients matched by age and sex.

Reasons for seeking treatment and past dental experiences are shown in Table III. For a group of 66 patients responding to a survey, the overwhelming reason for seeking treatment at the School was financial. Slightly more than half reported good previous dental experiences; by the same token, slightly less than half had inadequate care in the past. Barriers to past care were also primarily

financial. At least 29% of the group listed difficulties directly related to their disabilities.

Table II: DECOD Patient Characteristics

Characteristic	#	%
SEX		
Male	147	59
Female	101	41
AGE		
20 or less	40	16
21 - 40	93	38
41 - 60	64	26
61 and over	39	15
Unknown	12	5
SOURCE OF REFERRAL		
Agency	90	36
Media	30	12
Health Professionals	72	29
Friends	14	6
Unknown	42	17
METHOD OF PAYMENT		
Cash	93	38
Medical Coupons	88	36
Third Party	24	9
Other	10	4
Unknown	33	13

Transportation appears to pose only a secondary difficulty, as was substantiated by our subsequent experiences whereby transportation problems were solved relatively easily through use of available volunteer services and funding resources.

Table III: Patient Participation in DECOD

Reasons for Participation	#	%
Financial	24	52
No Private DDS	9	19
School's Reputation	8	17
Miscellaneous	6	12
Total	47	100
Past Dental Experiences		
Excellent, Satisfactory	22	56
Extractions, Exams Only	7	17
Unsatisfactory	6	15
None, No Care	4	12
Total	39	100
Obstacles to Past Dental Care		
High Cost, Lack of Money	19	33
My Disability	6	11
Dentists Unwilling	6	11
No Proper Office Facilities	4	7
No Transportation	2	3
Fear, Anxiety	8	14
No Barriers	6	11
Miscellaneous	6	10
Total	57	100

#### Program evaluation

The effectiveness of the program has been evaluated at various levels of participation: patient, faculty and student.

Questionnaires were sent to 199 active patients to determine their reaction to treatment. Of the 79 respondents: 78% expressed satisfaction, with frequent comments on student and staff helpfulness

and concern; 14% had complaints, centering chiefly on delays in treatment, a not uncommon by-product of the rigorous clinical requirements at the School. The remaining answers were unclear. A survey of patients who were inactivated is in progress.

A survey of full-time faculty, to which 25 members responded, indicated a favorable reaction by 72%; favorable, with some reservations, 24%; and no comment, 4%. The program is perceived as a means of introducing a new kind of patient, resulting in increased student and faculty awareness and acceptance of the disabled.

Extensive evaluations are being conducted with respect to student attitudes and confidence in treating the disabled. Tests are administered at given intervals of the students' dental schooling; namely, as part of orientation, as part of an all-day didactic course on disabilities in Autumn Qtr., and in conjunction with ETS tests given at all participating schools in Spring Qtr. The purpose of the tests is to determine the relative effects of specific courses, length of general exposure to the program and class level in School, on expressed attitudes and confidence. Analysis of the data is in progress; the studies are in part, longitudinal and results presented are preliminary.

Table V indicates the responses on the attitude test for three different classes of students, before and after a one-day course on disabilities. The course produced no significant changes in attitude.

A small, but significant interclass difference in attitude (on pre-tests) was, however, noted in September, 1975, the beginning of Project Year 2. The more senior students with clinical experience, appeared less willing to treat the disabled than the more junior students without clinical experience. Such a trend is consistent with other data indicating that the degree of altruism is highest for entering students and subsequently declines.<sup>3</sup>

No such overall interclass difference in attitude was evident in September, 1976, the beginning of Project Year 3; however, interclass differences in specific areas were present. Whether the DECOD program accounts for the change in observations between the two time periods is uncertain at present. Longitudinal studies are in progress.

Table IV shows that in contrast to lack of effect on student attitude, the one-day didactic course had a significant impact on student's reported confidence. Confidence increased in all areas covered by the course and also extended in some cases, e.g. cancer, to those not specifically mentioned. Other areas, e.g. alcoholism, not taught in the course had no effect on confidence expressed. A parallel increase in confidence has been reported by students as a result of clinical instruction in care of the disabled.

Table IV: Students' Confidence\* in Treating the Disabled as Expressed Immediately Before and After a One-Day Didactic Course on Disabilities.

DISABILITY	**Class of '76 (N=77)					°Class of '78 (N=79)					°Class of '79 (N=78)				
	Pre-Test		Post-Test		+ lvl. of sig.	Pre-Test		Post-Test		+ lvl. of sig.	Pre-Test		Post-Test		+ lvl. of sig.
	Mean	S.D.	Mean	S.D.		Mean	S.D.	Mean	S.D.		Mean	S.D.	Mean	S.D.	
Quadriplegia	2.60	1.07	3.53	0.74	0.00	3.04	1.13	3.78	0.86	0.00	3.23	0.95	3.68	0.83	0.00
Alcoholism	3.64	0.74	3.68	0.72	0.05	3.73	0.95	3.85	0.86	0.05	3.78	0.89	3.83	0.80	0.05
Mental Retardation	3.40	0.85	3.66	0.66	0.01	3.66	0.90	4.11	0.60	0.00	3.73	0.87	4.03	0.60	0.00
Deafness	3.38	1.06	3.47	0.87	0.05	3.79	1.00	4.48	0.53	0.00	3.73	0.94	4.29	0.60	0.00
Cerebral Palsy	2.59	0.88	3.22	0.84	0.00	2.81	0.91	3.25	0.81	0.00	2.75	0.85	3.26	0.71	0.00
Cancer	3.21	1.02	3.57	0.90	0.00	3.73	0.85	4.00	0.76	0.00	3.78	0.92	3.95	0.80	0.04
Schizophrenia	2.58	0.95	2.87	0.78	0.00	2.56	0.99	3.10	0.77	0.00	2.98	0.85	3.30	0.76	0.00
Emphysema	3.27	0.91	3.61	0.80	0.00	3.75	0.88	3.93	0.66	0.02	3.49	0.91	3.74	0.82	0.00
Blindness	3.51	1.00	3.83	0.68	0.01	3.93	0.95	4.54	0.52	0.00	3.80	0.94	4.39	0.60	0.00

Scale: 1 = completely inadequate      4 = somewhat confident      \*\*tested in Sept. '75  
 2 = somewhat inadequate      5 = completely confident      °tested in Sept. '76  
 3 = uncertain      †according to the paired T-Test

Table V: Students' Attitude Toward Treating Disabled Dental Patients as Expressed Immediately Before and After a One-day Course on Disabilities.

EXPRESSED ATTITUDE	**Class '76 (N=71)		*Class '78 (N=78)		*Class '79 (N=85)	
	Pre-Test (%)	Post-Test (%)	Pre-Test (%)	Post-Test (%)	Pre-Test (%)	Post-Test (%)
1) Will work c Pts. I feel capable..	5.6	6.5	7.8	2.5	3.5	2.4
2) Will make an extra effort..	2.8	6.5	6.5	10.1	9.4	10.7
3) Will work c pts. requiring no special equipment..	67.6	58.1	67.5	70.9	60.0	58.3
4) Feel a res- ponsibility, but am un- comfortable..	11.3	22.6	14.3	16.5	20.0	25.0
5) Am indif- ferent, un- certain..	0.0	0.0	0.0	0.0	2.4	1.2
6) Will include all but most difficult..	11.3	4.8	2.6	0.0	2.4	1.2
7) Will work c pts. where financially feasible..	1.4	1.6	1.3	0.0	2.4	1.2

\*presentation given in Sept. '76, Project Yr. 3.

\*\*presentation given in Sept. '75, Project Yr. 2.

## Conclusions

Our experience with Project DECOD to date indicate that a training program for dental and dental hygiene students in dentistry for the disabled is feasible. The majority of disabled patients seeking care can be treated successfully in the general clinics, with the support of adequate instruction, social services assistance and appropriate monitoring. The chief barrier to patient care is financial.

On the basis of preliminary data, student confidence in treating the disabled increased as a result of specific didactic and clinical courses. No corresponding changes in expressed attitude were observed. General evaluation of the Project awaits the conclusion of the on-going studies. If increased confidence will counteract attitudinal resistance and increase the probability of care delivery, an educational approach to the problem of dentistry for the disabled will have proved beneficial.

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## AIDS TO MINIMIZE BACTERIURIA IN PATIENTS WITH ILEAL DIVERSION

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M. Price; Renal Function Laboratory, Dept. Physical Medicine and Rehabilitation, University of Minnesota Hospitals, Minneapolis, MN.

The high incidence of bacteriuria, multiple species of organisms, and the constantly changing patterns of organism isolation occurring in urine cultures from patients with ileal diversion suggests external sources of contamination. This study was conducted to identify sources and to develop aids that would reduce this contamination. To obtain reliable urine specimens for culture, a double lumen telescopic catheter technique was used and an illustrated procedure manual prepared. Aids include an ileostomy bag anti-twist device and a supply kit. An illustrated Urinary Care Manual is of value in teaching and training patients in good care procedures. Preliminary results indicate a reduction in the incidence of bacteriuria and the occurrence of multiple species of organisms in patient cultures.

<b>CATEGORY:</b>	<b>INTENDED USER GROUP:</b>
Device Development <input type="checkbox"/>	Patients with urinary ileal diversions
Research Study <input type="checkbox"/>	Allied Health personnel
<b>STATE OF DEVELOPMENT:</b>	<b>AVAILABILITY OF DEVICE:</b>
Prototype <input type="checkbox"/>	Manuals available, Department of Physical Medicine, Univ. of Minnesota Hospitals
Clinical Testing <input checked="" type="checkbox"/>	<b>AVAILABILITY OF CONSTRUCTIONAL DETAILS:</b>
Production <input type="checkbox"/>	Mrs. Ellen Newman, M.S., Dept. P.M. & R., University of Minnesota Hospitals.
<b>AVAILABLE FOR SALE:</b>	<b>FOR FURTHER INFORMATION CONTACT:</b>
Yes <input checked="" type="checkbox"/> No <input type="checkbox"/>	Mrs. Ellen Newman
Price: Double Lumen Catheter Manual \$2.00	
Urinary Tract Care Manual \$3.00	

## Introduction

The ileal conduit has been used as a method of urinary drainage with increasing frequency. Many authors have reported complications including symptomatic urinary tract infections, pyelonephritis, and renal calculi (1,2). The significance of asymptomatic bacteriuria is controversial although it is known that the presence of bacteria in the urine is potentially dangerous, particularly in patients with ileal diversions because of the possibility of ureteral reflux.

Needham(3) reported in 1970 on the high incidence of positive cultures, multiple species of organisms in positive cultures, and changes in organism isolation patterns in follow-up cultures from patients with ileal diversions.

We found a similar high incidence of bacteriuria and multiple species of organisms when studying urine cultures from spinal cord lesion patients with ileal diversions(4). Follow up studies demonstrated constantly changing patterns of organism isolation and a high incidence of *Pseudomonas aeruginosa*, an organism generally attributed to exogenous sources. The

reported incidences of pyelonephritis, calculi, and urinary tract infection plus the increasing concern about the potential dangers of asymptomatic bacteriuria suggested the need for study of the sources of bacteriuria in patients with ileal diversions and methods which might minimize the occurrence of potential pathogens in the urine of these patients.

Studies are being conducted on the relationship of pre-diversion cultures to post-diversion cultures, however, this paper will report on some external sources of bacteriuria and methods of reducing contamination from these sources.

When evaluating the presence of bacteriuria, it is important that the urine specimens used for culture be obtained in such a manner that they represent the true bacterial population of the ileal loop. Bishop(5) in 1971 described the effective use of a sampling catheter with a protective metal sleeve to obtain urine specimens free from contamination by bacteria present on the stoma or in the urine pooling just inside the stoma. In 1972, Spence, Stewart and Cass(6) described the use of flexible telescopic double lumen catheter. We have

adapted this method and used it to obtain all urine specimens.

#### Methods

The double lumen telescopic catheters used to obtain all urine specimens is made from a No.8 polyethylene infant feeding tube and a No.16 French whistle tip catheter. The whistle tip catheter is cut at the proximal end, so that it is about 1 ½ inches shorter than the feeding tube. The feeding tube is inserted into the catheter before sterilization (fig 1). For use the feeding tube is retracted so the tip is protected well inside the outer catheter. The catheter is then inserted into the ileal conduit through a carefully cleansed stoma. When the tip of the catheter is well inside the conduit (about 2 ½ inches) the feeding tube is advanced into the pool of urine and a specimen is withdrawn through the feeding tube with a sterile syringe.

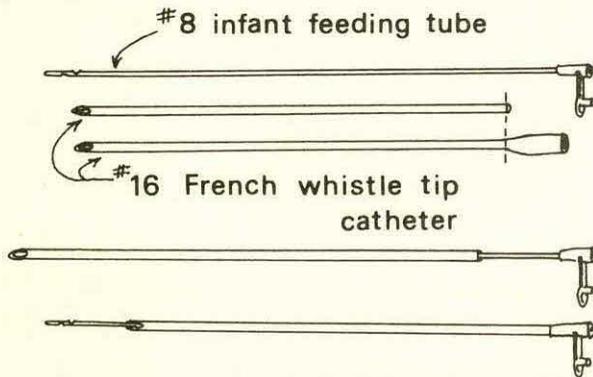


Fig. 1 Double Lumen Telescopic Catheter

To assess the reliability of this method, culture results from urine specimens were compared with results of cultures taken from the stoma area. Stoma cultures were obtained by passing a sterile swab over the stoma before it was cleansed for catheterization. All urine and stoma cultures were taken to the University of Minnesota Hospitals diagnostic laboratory for culture within 1/2 hour or refrigerated for delivery within the hour. Standard culturing procedures were followed.(7) Stoma culture results were also used to demonstrate a potential source of bacteriuria.

Cultures were obtained from the urinary drainage collecting appliances. The outer surface of pieces of drainage tubing used by patients were vigorously scrubbed with 10% alcohol to eliminate external contamination. A one inch piece was then cut from the tubing, placed in a sterile container and sent to the microbiology laboratory for culture(7).

#### Results

Comparison of the results of simultaneously obtained stoma swab cultures and urine cultures demonstrated the reliability

of the double lumen catheter technique, since it was possible to obtain sterile urine specimens, even with many bacteria present on the stoma (Table 1). To encourage the use of this technique to provide reliable urine specimens, we have published an illustrated procedure manual that is available to health personnel(8).

Table 1

Stoma Swab	Loop Cultures*
<i>Pseudomonas</i> , <i>Streptococcus</i>	Sterile
<i>Proteus mirabilis</i> , <i>Pseudomonas</i> , <i>Escherichia coli</i> , <i>Alpha streptococcus enterococcus</i>	<i>Proteus mirabilis</i> , <i>Citrobacter freundii</i>
<i>Klebsiella</i>	<i>Klebsiella</i> , <i>Escherichia coli</i>
<i>Providencia</i> , <i>Proteus mirabilis</i> , <i>Alpha streptococcus enterococcus</i> , <i>Escherichia coli</i> , <i>Enterobacter</i>	<i>Enterobacter</i>
<i>Escherichia coli</i> , <i>Providencia</i> , <i>Pseudomonas aeruginosa</i>	Sterile
<i>Proteus morgani</i> , <i>Pseudomonas</i> , <i>Proteus rettgeri</i> , <i>Alpha streptococcus enterococcus</i> , <i>Alpha streptococcus non-enterococcus</i>	<i>Proteus morgani</i> , <i>Proteus rettgeri</i> , <i>Pseudomonas aeruginosa</i>
<i>Pseudomonas aeruginosa</i>	<i>Pseudomonas aeruginosa</i>
<i>Candida albicans</i>	Sterile
<i>Proteus mirabilis</i> , <i>Klebsiella</i> , <i>Pseudomonas aeruginosa</i> , <i>Alpha streptococcus enterococcus</i> , <i>Proteus rettgeri</i> , <i>Alcaligenes</i>	<i>Alpha streptococcus enterococcus</i> , <i>Proteus morgani</i> , <i>Pseudomonas aeruginosa</i>
<i>Proteus mirabilis</i> , <i>Alpha streptococcus enterococcus</i> , <i>Pseudomonas aeruginosa</i> , <i>Proteus morgani</i> , <i>Escherichia coli</i> , <i>Serratia marcescens</i>	<i>Escherichia coli</i>

\*Specimens obtained using double lumen catheter procedure

Sixty-five cultures were obtained from spinal cord lesion patients with ileal diversions at the time of annual follow-up visits from 1973 through 1975. No antibiotics had been used for 48 hours prior to culturing. Sixty-eight percent of the cultures were positive. A culture was considered positive if bacteria were present in any concentration.

Fifty-nine percent of the positive cultures contained more than one species of organisms, with 21% containing four or more species, 9%, three species, and 30%, two species. The average number of species per positive culture were 2.1, and the range was 1 - 5.

The organisms occurring most frequently were *Proteus non-mirabilis*, 23%, *Proteus mirabilis*, 17%, and *Pseudomonas aeruginosa*, 18%. The high concentration of these organisms is of interest because of the relationship of urea splitters to the production of alkaline urine which can lead to the formation of renal calculi and inhibition of ileal peristalsis(2).

Follow up cultures from a number of patients demonstrated constantly changing patterns of organism isolation.

For example, thirty post-diversion cultures were taken from one patient be-

tween 1972 and 1975. All of these cultures were positive, except the first post-division culture.

The number of species per culture from this patient varied from one to five, with ten different species of organisms occurring in different combinations. The organisms occurring most frequently were *Proteus mirabilis* and *Proteus morgani*, each occurring in twelve cultures, and *Pseudomonas aeruginosa* present in eleven cultures.

Although it was demonstrated that bacteria growing on the stoma do not necessarily contaminate the urine in the loop, the constantly changing patterns of organism isolation demonstrated by us, by Guinan(9) and Needham(3) implicate the stoma as a means of entry. The high incidence of *Pseudomonas*, an organism generally attributed to exogenous sources, further suggests contamination of the ileal conduit from external sources.

We have identified three areas as contributing to this probability (fig 2): the stoma area, the bag-tubing union, and the collecting appliances. The presence of potential pathogens in the stoma area has been demonstrated by the stoma cultures (Table 1).

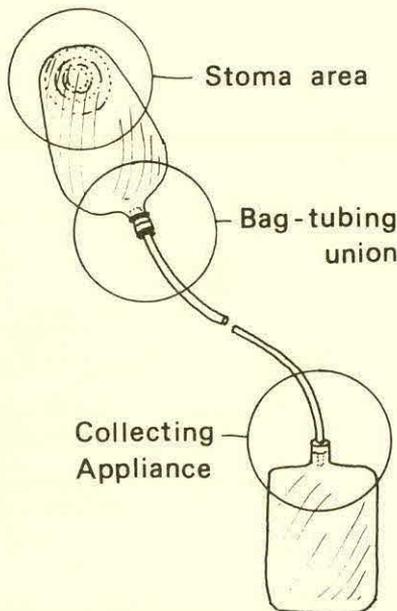


Fig. 2 Danger Areas

Frequently patients allow their ileostomy bag to become twisted, permitting the pooling of contaminated urine around the stoma. Occasionally patients reported that their ileostomy bags became so full that they separated from the skin. Such conditions can cause sufficient back pressure against the stoma to prevent the ileal conduit from emptying efficiently and allow bacteria to migrate through the stoma into

the loop, up the ureters and into the kidneys, or actually force contaminated urine back through the stoma into the ileal conduit.

To minimize twisting of the bag we developed an anti-twist device which consists of lightweight cardboard or 1/8 inch adhesive foam that is cut to fit the end of the ileostomy bag (fig 3). This unit is attached to the bag by adhesive or tape.

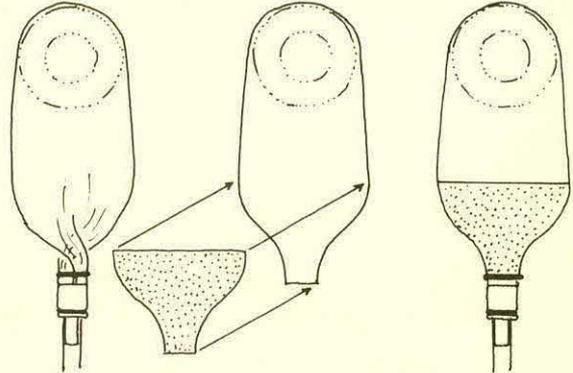


Fig. 3 Anti-Twist Device

The ileostomy bag with attached anti-twist device is then joined to the drainage plug in the usual manner making sure that the rubber band or tape used to secure the bag to the plug encompasses the attached device. The device thus holds the bag in a flat position, preventing twisting and allowing the urine to flow freely away from the stoma area.

We found that the care of collecting appliances after a patient's discharge from the hospital was often inadequate. Cultures taken of drainage tubing used by patients demonstrated large numbers of potential pathogens. To aid patients in using an effective method of appliance disinfection and self care, an illustrated manual has been prepared(10). This manual is used as a teaching workbook and a reference guide to help the patient and staff work out a feasible method of appliance care. It contains illustrated step by step procedures that can be adapted to individual needs and information concerning other aspects of good urinary tract care.

One of the most common reasons given by patients for lack of good self care is the poor availability of supplies. They frequently do not know where to obtain supplies and once they have them lack convenient storage space. The Urinary Tract Care Manual and a supply kit help alleviate these problems. The manual contains a description of the usual supplies needed and can be individualized with the sources of supplies and approximate cost. Before discharge from the hospital the patients are assisted in obtaining this information. The supply kit is a metal carrying case and the patient is assisted in fitting the

case with all the items needed for short term use at home or for traveling. A check list inside the cover helps the patient when replacing used items (fig 4 and 5).



Fig. 4 Supplies and Carrying Case



Fig. 5 Supply Kit

Preliminary results suggest that the use of these aids with a better education training program is reducing the incidence of bacteriuria. Forty-eight cultures taken at the time of annual follow-up during 1976 demonstrated a decrease in the number of positive cultures from 68% in 1973 - 1975 to 42% in 1976. The number of positive cultures with multiple organisms has dropped from 59% in 1973 - 1975 to 50% in 1976.

The number of positive cultures containing four or more species of organisms went from 21% in 1973 - 1975 to 10% in 1976. These studies are being continued, as are follow-up studies on individual patients.

## Summary

The incidence of pyelonephritis, urinary tract infection, and calculi in patients with ileal diversions has been documented in the literature. Knowledge of these complications plus the high incidence of bacteriuria which could lead to these conditions prompted this study. We have reported on the constantly changing patterns of organism isolation and multiplicity of organisms occurring in positive cultures. The potential for contamination of the ileal urine with bacteria from external sources through the stoma was demonstrated. An anti-twist device placed on the ileostomy bag minimizes the retention of urine in the ileostomy bag, the pooling of urine around the stoma, and the creation of back pressure on the stoma area. An illustrated manual serves as a teaching aid and reference to help patients maintain better urinary tract care, including care of urinary drainage appliances. A supply kit serves as a ready available source of needed supplies.

To promote the use of a double lumen catheter for obtaining reliable urine specimens for culture, an illustrated procedure manual has been published.

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## Design of Bathroom Fixtures and Controls for the Able-Bodied and the Disabled

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 College of Architecture and Urban Studies  
 Virginia Polytechnic Institute and State University

The need to design proper facilities to enable the disabled to achieve personal hygiene in a normal, safe and comfortable manner is an urgent task and a requirement that our society must meet. It is our belief that in designing bathrooms and bathroom fixtures accessible to and usable by the least capable, everybody else can be accommodated at the same time.

CATEGORY:	INTENDED USER GROUP:
Device Development <input type="checkbox"/>	The able-bodied and the disabled
Research Study <input checked="" type="checkbox"/>	
STATE OF DEVELOPMENT:	AVAILABILITY OF DEVICE:
Prototype <input checked="" type="checkbox"/>	No--needs further research and development
Clinical Testing <input type="checkbox"/>	
Production <input type="checkbox"/>	AVAILABILITY OF CONSTRUCTIONAL DETAILS:
	No
AVAILABLE FOR SALE:	FOR FURTHER INFORMATION CONTACT:
Yes <input type="checkbox"/> No <input checked="" type="checkbox"/>	Pascal M. Malassigne, I.D.S.A.
Price:	101-D Cowgill Hall, VPI & SU
	Blacksburg, Virginia 24061

The thrust of rehabilitation today is to help the disabled achieve independence. Independence for self care, living, employment, travel, etc. The dream of each disabled person (I am sure) is to be able to do as much as everybody else, in other words, to feel like an active member of our society.

But how can we help the disabled achieve independence? A large part of the responsibility for making a barrier-free environment lies with the architect, engineer and industrial designer. These professions must be aware of the wide range of physical disabilities, knowing exactly what the physical and functional capabilities of the disabled are and how they vary. This knowledge of physical and functional capability includes the awareness of the various movements that the disabled are capable of.

Unfortunately, the only people who currently possess this knowledge are the individuals who are deeply involved with rehabilitation of the disabled. The collaboration between the design professions and the rehabilitation profession has only recently begun. Continuation and expansion of

this collaboration is a critical step in the achievement of independence for the disabled.

The cause: what is handicap?

The Department of Health, Education and Welfare defines a handicap as "being a chronic or permanent defect representing a decrease in, or loss of ability to perform various functions, particularly those of the musculoskeleton system and sense organs."<sup>1</sup>

How many disabled  
and what are they capable of doing?

It is difficult to identify the full disabled population, but an indication of its magnitude can be estimated. In the United States 85 million (approximately 45 percent of the population) were reported over the last ten years to have had one or more chronic disease or impairment. Of this group, some 23 million were limited in their activities, such as the ability to work, keep house, etc. While we cannot presume that all of these individuals have difficulties with personal hygiene, the proportion is likely to be substantial.

The disabled are often subjected to reduced physical activities resulting from a disease or an injury, but the reduction in these activities is also a resultant of the man-made environment. Our environment has been designed primarily for those with normal abilities and this results in what is known as "the architectural and transportation barriers." For many disabled, our man-made environment is the beginning of the end of their dream to independence, or their road to freedom.

#### The architectural barriers

Fortunately, major effort is underway to remove many architectural and transportation barriers from the environment. Many new buildings, products, and modes of transportation are being made accessible and usable by all. These correcting measures are taking place under the auspices of the federal and state government. New laws require that public facilities funded by the federal or state government be accessible to all.

To help architects, designers and engineers design a better environment, design accessible buildings, the Department of Housing and Urban Development in Washington has sponsored the revision of the outdated ANSI Standard 117.1, dealing with the accessibility of buildings by the disabled.

The new ANSI Standard, prepared by Syracuse University, goes a long way to update the design guidelines necessary to provide a barrier free environment. However, the study fails to adequately assess the needs of the disabled relating to specific product design or existing products. Providing accessibility to a building or room is definitely necessary, but the safe usage of products or equipment within the building or room is also very important. The new ANSI Standard recommends the usage of some special products and specific locations for these products but there are certain parts of the building that remain inaccessible or unsafe for usage by the disabled.

#### The design of bathroom fixtures

One problem area is the bathroom. We hope that this new ANSI Standard provides for accessibility to the bathroom, but the nature of the existing bathroom fixtures often prevents or restricts their usage by many disabled people. Some are able to use the existing fixtures when they are properly located, but they often risk physical injury due to the fact that the functional requirement necessary to use the fixture exceeds, or nearly exceeds the functional capability of the user. The present design of bathroom fixtures reflects the needs of the able-bodied, and as a result are sometimes unsatisfactory to many disabled people.

The design of universal fixtures is a challenge that has been confronted by my colleagues, students and me for almost three years. With the help of the College of Architecture (Virginia Polytechnic Institute and State University), the Rehabilitation Services Administration, and the Woodrow Wilson Rehabilitation Center in Fishersville, Virginia, a complete design and development of universal fixtures is now underway.

#### Bathtubs and showers

Bathtubs and showers are the most dangerous fixtures in the bathroom. I am sure you have experienced as I have many times, slipping or almost falling in the tub, and being saved from injury by the curtain.

A great number of individuals do not have such luck, according to the Consumer Product Safety Commission, "there are 110,000 bathtub and shower area accidents every year."<sup>2</sup> These accidents are caused by slipping and falling while entering or leaving the bathtub or when changing from a standing to a sitting position. It has been found that the hardness of the tub causes injury when a person slips or falls. Drowning and burning have also to be added to the list of accidents.

Industry has responded to this problem by providing a texturized bottom as well as adding grab bars in or adjacent to the bathtub. Nevertheless, the 1977 standard bathtub is still unsafe, uncomfortable and inaccessible to many of the disabled.

#### The universal bathtub

The universal bathtub will be more comfortable, with a sloped and texturized backrest for the able-bodied, and will also be equipped with various options to help the disabled. First of all, when transferring from the wheelchair, a seat often needs to be incorporated into the bathtub. Grab bars along the sides will then help the disabled during transfer to lower themselves into the tub. The same grab bars are necessary for rising from the bottom of the tub and transferring to the wheelchair. Another model has a transfer seat adjacent to the bathing area to permit disrobing prior to and drying after the bath.

#### The shower

The shower stall features a fold down seat to enable disabled users to sit down while showering. The seat may be folded up when the shower is used by a person who wishes to stand. The same fold up shower seat is also being developed as an accessory to a standard shower stall. This would be a valuable addition for those who already have a shower but are unable to use it in the normal manner. The controls for the tubs and shower

are located within easy reach of the user. The shower also has a movable shower head to enable a seated user to have control over the shower spray, and to move it closer to him.

#### Lavatory

Existing bathroom lavatories often fail to meet the needs of the non-ambulatory disabled because of their inadequate size and excessive depth. The non-ambulatory user depends on the sink as an alternative to a daily bath or shower and uses it for the cleansing of scalp, face and arms. Existing sinks prevent close approach by a wheelchair by not providing sufficient clearance for the arm rest, and for the knees. In addition, these sinks also fail to provide adequate bowl area to shampoo hair or to wash the user's arms.

Research and testing indicate that the lavatory should satisfy the following design criteria:

- Room for the wheelchair armrests under the washbasin.
- Clearance for the knees; this includes isolation of the drain pipe to prevent burns to the user.
- Proper bowl contour to allow cleansing of face, arms, and scalp.
- Interchangeable faucet controls that would allow use by those with little hand and finger function.
- A water faucet that does not restrict the use of the bowl area or risk injury to the user's head.
- A flexible spray to rinse face and hair.
- Integrated towel and soap areas within easy reach of the user.

#### The toilet

The existing toilet is another inadequate fixture for the disabled in terms of access, usage and overall design. Most disabled transfer to a toilet from the side, positioning the wheelchair against the toilet. The armrest of the wheelchair is then removed and the transfer is accomplished with or without the help of adequately positioned grab bars. This maneuver is unfortunately not as easy as described. First of all, the wheel of the chair protrudes about 6 inches above the seat, and the person has to clear this wheel which causes an unsafe condition. In many instances a severely disabled person has to use a raised seat to enable manual stimulation of their bowel. This raised seat's height is about 6 inches higher than the wheelchair, sometimes requiring the use of a transfer board in order to reach the toilet and adding another unsafe condition to the transfer. A safer alternative to the side transfer to the toilet would be a forward approach. Research and design of several prototypes have shown the need to modify present fixtures. An elongated and narrower rim would enable the disabled person to

straddle over the toilet and provide the necessary space for bowel stimulation.

Adequately positioned grab bars would also assist the disabled reaching and transferring to the toilet. Such a model could also be used by every one else, including the elderly. This toilet could offer many advantages over existing models, when the disrobing problem could be solved.

#### Conclusions

Throughout our research on bathroom fixtures for the disabled, we have relied on information obtained from physical therapists, the disabled and observation of these people using existing bathroom fixtures. This has shown the wide range of capabilities of the disabled population and we hope to use this information to design better bathroom fixtures.

#### Bibliography and footnotes

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- <sup>2</sup> The Consumer Product Safety Commission, Executive Summary, A Systematic Program to Reduce the Incident and the Severity of Bathtub and Shower Area Injuries, June, 1975.

## PNEUMATIC PRODUCTION AIDS FOR THE WORKER (WHO IS PHYSICALLY HANDICAPPED)

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 Kansas Elks Training Center for the Handicapped, Wichita, Kansas

Pneumatic production aids are designed for and utilized by multiply handicapped workers to improve and maintain work skills. The goal of aids is to channel the lack of gesture control and bring it into total coordination for production. Jigs were designed specifically for the task and the individual. To create a specific jig the task must be studied, each step catalogued and then simplified. The aids described are made of practical, inexpensive materials, e.g., scrap aluminum, hammer tip, door hinge, foot pedal, washers, etc. Historically, physically handicapped persons' involvement in meaningful work has been minimal. The aids described have enabled physically handicapped workers to perform tasks previously impossible for them. Improved gesture control is gained through use of these jigs and workers attain confidence and an opportunity to succeed.

CATEGORY:	INTENDED USER GROUP:
Device Development <input checked="" type="checkbox"/>	physically handicapped, e.g. cerebral palsied
Research Study <input type="checkbox"/>	individuals or others with similar muscular control
STATE OF DEVELOPMENT:	AVAILABILITY OF DEVICE: difficulties.
Prototype <input type="checkbox"/>	KETCH (contact below)
Clinical Testing <input type="checkbox"/>	AVAILABILITY OF CONSTRUCTIONAL DETAILS:
Production <input checked="" type="checkbox"/>	KETCH (contact below)
AVAILABLE FOR SALE:	FOR FURTHER INFORMATION CONTACT:
Yes <input type="checkbox"/> No <input checked="" type="checkbox"/>	Dwight E. Cook
Price:	Ks. Elks Trng. Cntr. for Handicapped
	619 So. Maize Rd, Wichita, Ks., 67209

## Introduction

The following describes four relatively simple production aids designed for specific jobs and individuals with absolutely no previous work experience. Each aid was constructed with a minimal expense in material and time. The most important element is each aid was designed with a person and his specific task in mind. However the aids are versatile and the jig can be redesigned for other people and different tasks.

## The spring depressor

The first picture, Fig. 1, shows a spring depressor in operation. This aid is operated by a cerebral palsied woman who averages 600 knob assemblies per day with the help of her tailor-made jig.

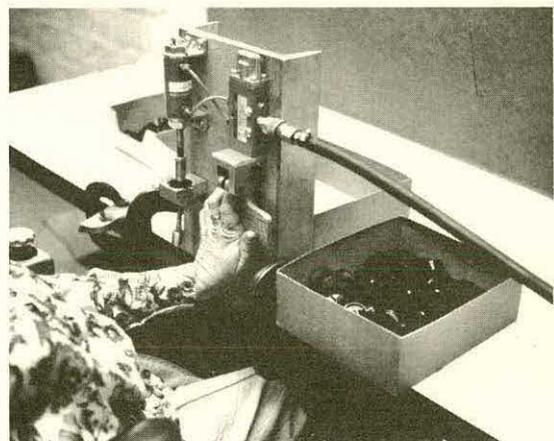


Fig. 1

The spring depressor is a pneumatic device, made of an air cylinder with a 2-inch stroke, a foot-operated air control valve and a spring-loaded knock-out pin, all mounted on an 8-inch piece of aluminum channel

#### Method of operation

The worker places partially loaded control knobs in jig and trips the pedal with the palm of her hand, which activates the air cylinder that presses the spring in place per specifications. This aid runs 40 lbs. of air pressure when in operation. The entire procedure is done by the worker with the use of only one hand.

#### The airstone depressor

The next three production aids were designed for specific tasks involved in aquarium filter assemblies, which is an on-going subcontract that provides continuous work suitable for our disabled population. The first aid in this series is an airstone depressor, shown in Fig.2.

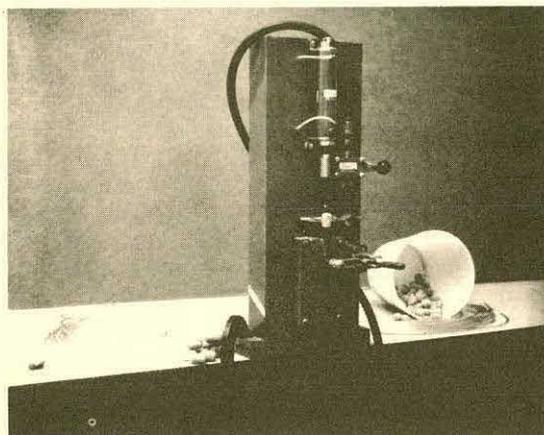


Fig. 2

This aid is also operated by a cerebral palsied individual who was unable to complete this assembly prior to construction of her jig. This pneumatic aid consists of an air cylinder with a 4-inch stroke, an air control valve operated by hand, one door hinge, one 90 degree bracket, one toggle clamp, one 4" x 6" base plate and one piece of 5/16" x 1 1/2" tubing all mounted on a piece of 8" aluminum extrusion. Located on the air cylinder shaft is a lathe turned part to fit size of the air stone.

#### Method of operation

To operate her aid the worker inserts 1/4" plastic tubing into the 5/16" x 1 1/2" tube, she activates the toggle clamp by hand and sits the air stone in the door hinge. Then she's ready to activate the cylinder with the air control valve, releases the toggle clamp and extracts the air stone attached to tubing.

#### The tube cutter

Fig. 3 shows the production aid used to cut plastic tubing for the aquarium filters. The operator of this particular aid has cerebral palsy and is extremely athetoid. Before the construction of his jig this worker was unmotivated and generally unproductive. At present he cuts an average of 400 pieces of tubing per day. He is very proud of the progress he has made and the new interest he has found in work. The cutting device is made of an air cylinder with a 4-inch stroke, an air control valve, one teflon hammer tip, 2 pieces of 5/16" tubing mounted to aluminum milled or sawed to suit proper height. Attached to the air cylinder shaft is a 3" piece of copper round bar stock slit on one end to accommodate a blade which protrudes 1/2" for cutting purposes. A guide (slide) holds the shaft in its proper position. As a safety measure the entire device is enclosed by a plexiglass cover.

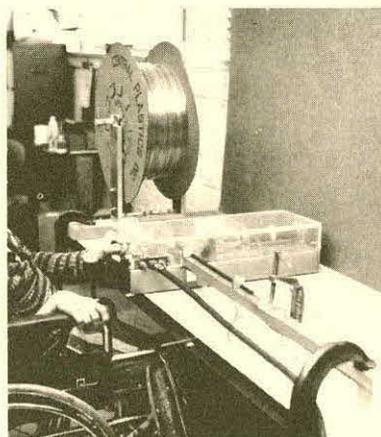


Fig. 3

#### Method of operation

To cut a piece of plastic tubing the worker simply slides the 1/4" tubing into the 5/16" tube, set stock for desired length and activate the cylinder by using an up and down motion of the hand.

### The drill press

The fourth and final production aid is a pneumatic drill press, Fig. 4.

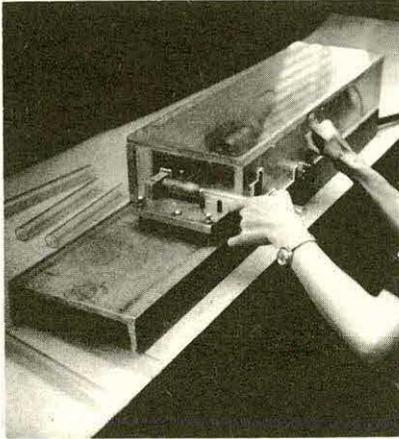


Fig. 4

This device is currently used to drill holes in 1" or 7/8" plastic tubes. It involves an air cylinder with a 6-inch stroke, an air control valve, an air adjustment valve, a micro switch, a 180 degree drill motor, a 4" section of a broomstick handle, and a jig to suit desired hole size. This device is also enclosed by a plexiglass cover and is completely safe. This aid is usually operated by a blind woman. She drills an average of 700 tubes per day using this air-operated device.

#### The method of operation

To put the drill press in operation the worker simply fits the 7/8" or 1" tube over the broomstick handle (jig). She then activates the air control valve which thrusts the air cylinder forward, activating the drill motor which, in turn, activates the micro switch as it passes. After the hole is drilled the worker removes the tube from the jig.

#### Conclusion

With the help of production aids like these, a physical handicap need never prohibit a person who wants to work from doing so. It has been demonstrated the worker who is physically handicapped can have the opportunity to stay busy, be productive, increase his earnings and feel a sense of accomplishment with the use of a tailor-made pneumatic production aid.

## SESSION C THURSDAY, JUNE 2

- |     |  |        |
|-----|--|--------|
| C-1 | COMMUNICATION SYSTEM USING MORSE CODE<br>TO PRINTED ENGLISH TRANSLATION<br><hr/> A. ROSS & K. FLANAGAN, UNIV. WASH.<br>CHILD DEVELOPMENT & M.R. CENTER   | P. 83  |
| C-2 | DEVELOPMENT OF FLEXIBLE TEACHER<br>MODIFIABLE COMMUNICATION AIDS<br><hr/> G.C. VANDERHEIDER, KELSO, HOLT &<br>RAITZER, TRACE CENTER, U. OF WISC.         | P. 36  |
| C-3 | A BREATH-CONTROLLED COMPUTER<br>DATA ENTRY SYSTEM<br><hr/> C.D. TRAYNOR<br>UNIV. OF CALIFORNIA, IRVINE   | P. 92  |
| C-4 | VIDEO COMMUNICATOR FOR<br>THE SEVERELY DISABLED<br><hr/> E.H. DENYS & J. MORTELMANS<br>MICRO COMMUNICATION DEVICES, CAL.                                 | P. 96  |
| C-5 | THE BLISS-COM: A PORTABLE SYMBOL<br>PRINTING COMMUNICATION AID<br><hr/> H. SILVERMAN, BLISSYMBOLICS, TORONTO<br>D. KELSO, TRACE CENTER, U. OF WISC.      | P. 99  |
| C-6 | AN EXPERIMENTAL EVALUATION OF SELECTED<br>COMMUNICATION TECHNICAL AIDS<br><hr/> C.A. MOOGK-SOULIS, TECHNICAL AIDS<br>CONSULTING SERVICES, CALGARY, ALTA. | P. 103 |
| C-7 | A MICRO-PROCESSOR-BASED GESTURE ENTRY<br>NON-VOCAL COMMUNICATION SYSTEM<br><hr/> J.E. HENKEL, THE VALLEY INSTITUTE<br>HILLSBORO, NEW HAMPSHIRE           | P. 107 |
| C-8 | REPRESENTATIONS OF LANGUAGE SPACE IN<br>SPEECH PROSTHESES<br><hr/> J.B. EULENBERG, ARTIFICIAL LANG. LAB.<br>MICHIGAN STATE UNIVERSITY                    | P. 109 |

AN INNOVATIVE COMMUNICATION SYSTEM FOR THE DISABLED  
USING MORSE CODE TO PRINTED ENGLISH TRANSLATION

A. Ross and K. Flanagan  
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This paper describes the development of a communication system for one cerebral palsied individual which may be useful for other physically handicapped people who have a need for maximum communication capabilities, but who can provide only a limited amount of physical input. The communication system utilizes Morse Code to English translation which is achieved through the use of a relatively inexpensive translation machine. The addition of a translation device alleviates one of the primary disadvantages of Morse Code communication systems-- the need for the receiver to know the code. This investigation shows that a Morse Code communication system containing a code sending key, a translator, and a television display or hard copy option may offer increased communication capabilities to the handicapped.

CATEGORY:	INTENDED USER GROUP: physically handicapped people who lack vocal and gestural methods of communication.
Device Development <input checked="" type="checkbox"/>	
Research Study <input type="checkbox"/>	
STATE OF DEVELOPMENT:	AVAILABILITY OF DEVICE: components of system available directly from manufacturers listed below.*
Prototype <input checked="" type="checkbox"/>	
Clinical Testing <input type="checkbox"/>	AVAILABILITY OF CONSTRUCTIONAL DETAILS:
Production <input type="checkbox"/>	A. Ross or K. Flanagan, Child Development and Mental Retardation Center, U.of WA.Seattle, WA. 98195
AVAILABLE FOR SALE:	FOR FURTHER INFORMATION CONTACT:
Yes <input checked="" type="checkbox"/> No <input type="checkbox"/>	*HAL Communications Corp. Urbana, IL 61801
Price:	Atronics, Escondido, CA 92025

#### OBJECTIVES

This paper describes the development of a communication system designed for use by physically disabled people for whom speech is not possible. Like all individuals, these people have a need to communicate in a normal fashion utilizing words to develop complete thoughts. This system of communication involving the use of electronic Morse Code to English translation is consistent with the often limited physical capabilities of these individuals. It requires only one controllable movement in order to produce printed language.

#### METHODOLOGY AND PRELIMINARY RESULTS

The investigation was the result of an effort to design a communication system to meet the unique physical capabilities of one individual. When first seen, the subject was twenty (20) years old, and had been diagnosed as cerebral palsied with mixed (spastic/athetoid) quadriplegia. As such the young man did not have functional use of his arms or legs nor could he communicate in a vocal or gestural fashion. When observed in the classroom, the subject used a head wand to depress the keys on an electric typewriter fitted with an elevated typewriter guard. (See figure 1).



Fig.1. Use of head wand and electric typewriter.

His typing rate was 2.05 words per minute. An extraordinary amount of time and effort was required to type each letter. As a result, the subject was able to type for only a few minutes at a time. This observation indicated that an alternative method of communication would need to be found.

Upon learning that the subject knew Morse Code, an hypothesis evolved: Could the subject use Morse Code to communicate more rapidly,



## SIGNIFICANCE OF RESULTS

The results and data obtained thus far for one individual suggest that a Morse Code communication system may be an effective approach to solving the needs of some handicapped individuals. The use of Morse Code as a basis for communication is commensurate with the physical disabilities of many individuals who need maximum communication potential, but with a minimum of physical input. Previous restrictions upon the use of Morse Code as a language tool have been alleviated through the availability of relatively inexpensive Morse Code translation devices. For this reason, adaptations of Morse Code communication systems appear to warrant further investigation as they seem to offer increased communication capabilities to handicapped people.

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DEVELOPMENT OF FLEXIBLE TEACHER MODIFIABLE COMMUNICATION AIDS  
FOR THE SEVERELY AND EXTREMELY MOTOR IMPAIRED

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University of Wisconsin-Madison

Recent years have seen great advances in the development of special communication aids for the non-vocal, severely physically handicapped children, including the development of portable aids and aids which can be used with pre-spelling and pre-reading children. These aids, however, were usually quite inflexible with little room for teacher/clinician modification to meet specific needs of individuals. To address this problem, a project was initiated to develop a highly flexible control system which could be used as the basis for a very wide range of communication aids. A module was developed which could enable aids to operate in any of the different modes of scanning and encoding and direct selection. The particular operational mode for an aid need not be defined until the aid actually reaches the hands of the teacher in the classroom. In this manner, the aid can be more closely fitted to the abilities of the individual and can be changed as the child develops.

CATEGORY:	INTENDED USER GROUP: severely and extremely motor impaired individuals
Device Development <input checked="" type="checkbox"/>	
Research Study <input type="checkbox"/>	AVAILABILITY OF DEVICE:
STATE OF DEVELOPMENT:	AVAILABILITY OF CONSTRUCTIONAL DETAILS:
Prototype <input type="checkbox"/>	
Clinical Testing <input type="checkbox"/>	
Production <input checked="" type="checkbox"/>	
AVAILABLE FOR SALE:	FOR FURTHER INFORMATION CONTACT:
Yes <input type="checkbox"/> No <input type="checkbox"/>	Trace Center
Price:	922 ERB, 1500 Johnson Drive
	University of Wisconsin, Madison, Wisconsin 53706

The last few years have seen a development of a whole new range of communication aids for the severely physically handicapped children and adults. Portable aids, as well as aids which can print whole words, phrases and sentences are now becoming available to meet the needs of non-vocal, severely physically handicapped individuals. These aids use a variety of different techniques, including scanning, encoding and direct selection (Vanderheiden, Grilley 1976; Raitzer, et. al. 1976; Luster, Vanderheiden 1975) in order to meet the needs of individuals having different problems and abilities. Although these aids represent significant advancements in the development of communication aids, there are still several areas where significant advances were still needed. A good example of these aids was the original Autocom developed at the University of Wisconsin. Although the aid did provide a portable means to communicate, the ability to print out messages independently and the ability to be used with pre-spelling children, the aid was not correctable, was relatively inflexible, operated in only one mode (direct selection) and was limited in its adaptability in that its adaptability was limited to the varying of its input interface. In addition, the Autocom also suffered from the other common characteristics of communication aids of its class in that it was a low-volume and therefore high-cost item and that it was maintainable only by its developer.

Finally, the aid had only limited ability to function in a developmental manner; to start out very simple and to expand to meet the growing needs and skills of the child as he developed.

The universal control module concept

Because of shortcomings such as these which were expressed by teachers/clinicians in the field, the Trace Center established a program to explore the development of a control module which could serve as the core for a whole range of very flexible/adaptable and compatible communication aids. It was hoped that this "universal control module" could be designed such that it:

- would be able to serve as the control section for most any type of communication aid, scanning, encoding, direct selection or combination
- would be part of a universal control system which would comprise the bulk of the needed electronics for any given aid
- would be very flexible and allow for maximum adaptability by the manufacturer, teacher/clinician and the user himself

- would allow the design of "developmental" aids which could grow and expand function with an individual as he/she grew
- would allow for easy access to and changing of a large vocabulary of words, phrases and sentences
- would lower the cost of an aid below its cost if it were designed using discrete logic (by reducing number and complexity of subassemblies)
- would lower costs of various different aids using the system since it could be produced in larger quantities
- would allow for lower maintenance cost and wider availability through self-diagnostic capabilities and common subassemblies and electronics across aids
- would provide other researchers as well as research clinicians/teachers with a flexible core mechanism around which they could implement their new ideas and develop new types of aids for specific users without having to develop all the support materials, documentation and production/maintenance mechanisms
- would allow for the use of a common set of accessories and materials across a wide range of fully compatible aids.

#### Universal control (UCM) design

Because the universal control system and the modules connected to it will comprise about ninety percent of any communication aid designed around it, most of the features and capabilities of an aid would be defined by the control system. For this reason, a major portion of the design considerations were centered around the design of the universal control system. The principle design consideration for this system centered around the areas of power consumption, size, cost, versatility, adaptability, reliability and maintenance.

The power consumption and size of the module were principle concerns because of the need for the aid to be portable and battery operable. In addition, it was necessary to design a module which would have an extremely low power consumption when left turned on, but in a stand-by mode so that it would be "asleep" but always available to the individual. For these reasons, a low power COS/MOC microprocessor made by RCA (the "Cosmac") was chosen as the core for the system and C-MOS digital logic was used throughout the rest of the system design. The only exceptions were the programmable read-only memories which are only turned on for the brief instant in which they are being used. By using a simple microprocessor based system, the cost of the total electronics was reduced to about two-thirds of the cost of a similar but less flexible design which used discrete C-MOS digital logic.

To provide for maximum adaptability (the ability of the UCM to be used in the design of different types of aids) the universal control module was designed to operate with an octopus-like struc-

ture (Figure 1). With this structure, the universal control module would form the hub and directly control each of the peripheral accessories or features of the communication aid. In this manner, features, output modes, or input modes could be added or deleted easily without changing the basic structure of the system. Figure 2 A and B show how the universal control system could be used with various input formats to develop very different types of communication aids. In all of these applications, no physical modification of the module itself is needed. The only change would be in the program which is fed to the module and the mechanisms controlled by it.

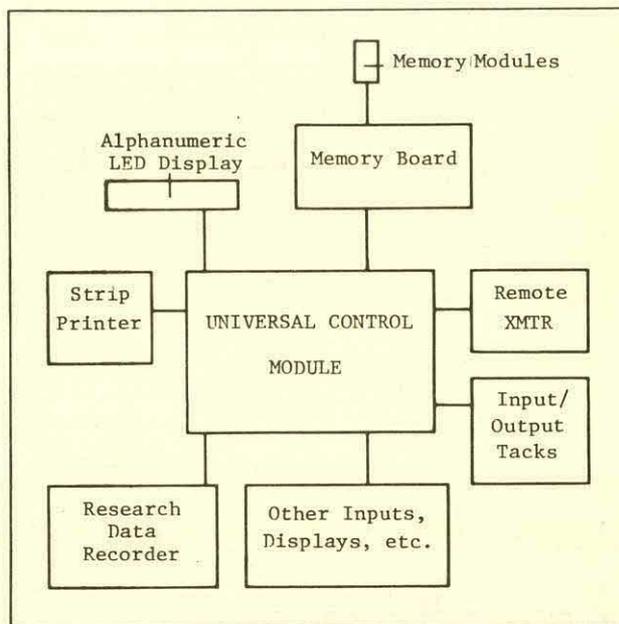


FIGURE 1 UCM: OCTOPUS DESIGN

Because of the importance of having the aid always available for the handicapped individual, the reliability and ease of maintenance were a prime concern in developing the system. The design team attempted to maximize the reliability of the system through: 1) minimization of electronic parts, 2) elimination of mechanical parts wherever possible, 3) failure of localization techniques which ensured that failure in one section could not cause damage in other areas, 4) the implementation of an auto-reset system. Ease and speed of maintenance were maximized primarily through the modular construction by containing all the major electronics on two easily replaceable printed circuit boards. In addition, the octopus design (Figure 1) makes localization of the problem fairly simple.

Perhaps of greatest importance to the teacher in the classroom were the considerations made in the design to ensure the versatility of the communication aid. The versatility is defined as the ability of the aid to be adapted by teacher/parent/clinician to meet the particular needs and abilities of an individual. The ability to specify particular words, sentences or arrangement of the letters and words on the aid; the ability of the teacher/parent/clinician to specify the number and

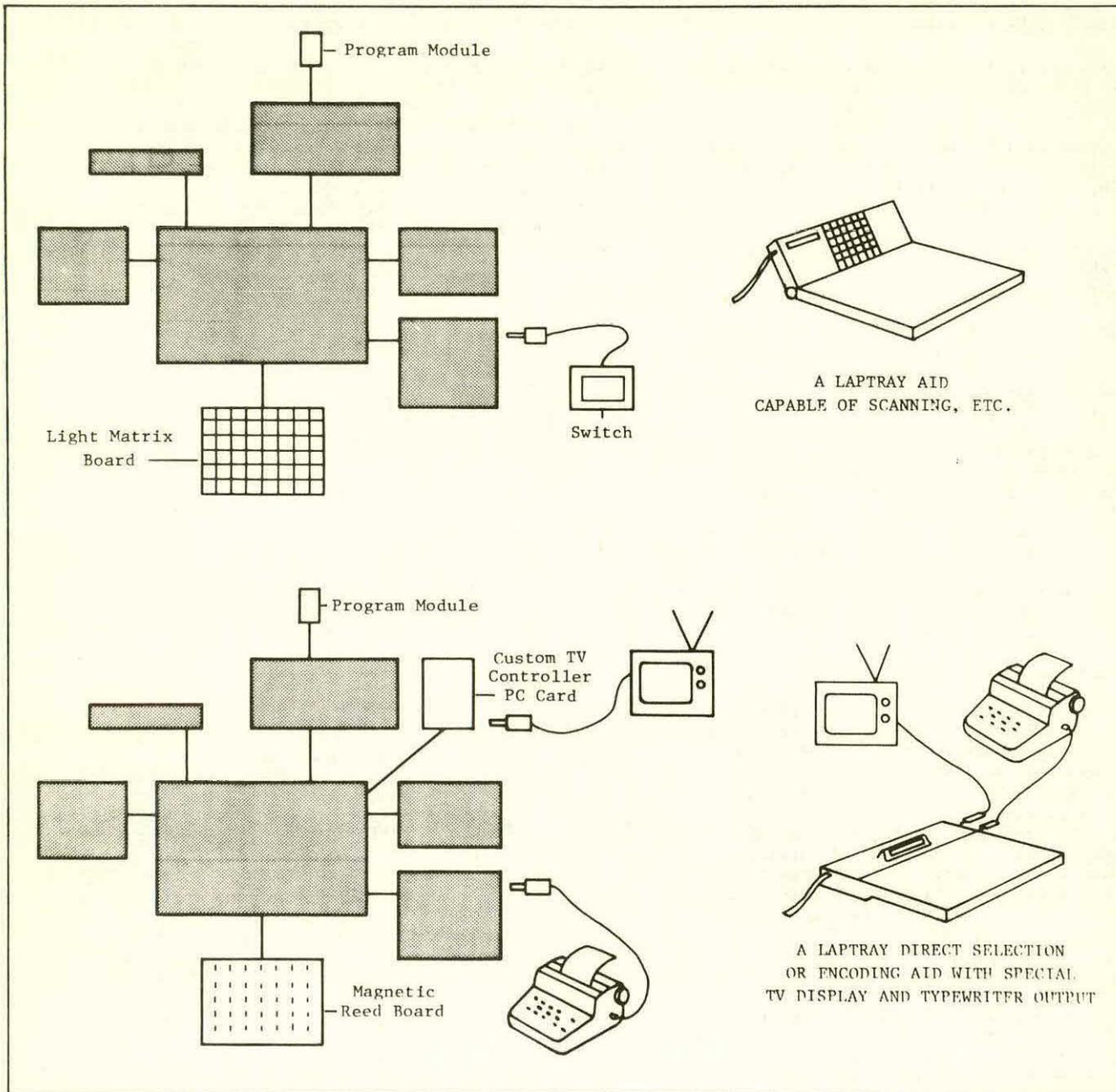


FIGURE 2 UCM WITH VARIOUS INPUT FORMATS

type of switches to be used; and their ability to specify the particular mode of operation (different types of scanning, encoding or direct selection) which would be best for their particular individual are all examples of aid versatility. The ability to re-specify or change all of these variables and others to accommodate the growth and development of the child is also a most important aspect of versatility.

To provide a mechanism for this type of versatility, an externally accessible memory plug-in board was included in the design of the system. This board has sockets into which matchbox-sized

memory modules can be inserted. In designing a communication aid, this card would be placed directly in front of a sliding door which would allow the teacher direct access to the plug-in memory modules. In this manner, the teacher would be able to easily change memory modules as necessary to change the operation of the aid to meet the current needs of the handicapped child.

#### *Results of UCM design*

The result of the universal control system project was the development of a universal control system which could function as the heart of a large

number of different types of communication aids. The features and capabilities of these different aids would essentially all be identical with the only difference being their package and their input form (i.e., different scanning, encoding or direct selection input/control techniques). Some of the features of the universal control module developed, which would also be features of an aid incorporating the module, are:

- 1) Portability - the unit has its own self-contained rechargeable battery pack. The entire universal control module with the subassemblies shown in Figure 1 weighs approximately 3 pounds (batteries = + 3 lbs.) and would fit in a box approximately 5 x 13 x 50 cm (2 x 5 x 20 in.)
- 2) Highly visible display - the characters on the LED display have an effective image height of .16 in. and with normal vision, can be read up to a distance of 3 m. (10 ft.). The character format is presently that of a standard 16 segment display. Part of the field test procedure will determine whether or not this letter format is a problem for very young children. (Other displays could be substituted as they become available.)
- 3) Correctable display with printed copy - because of special programming, the LED display which does not normally allow for correction, is able to do both back space and back-word functions to enable the individual to correct any errors in spelling or sentence construction as he sees them displayed. The letters are printed on the display from left to right in typewriter fashion. When the display is full, with each additional selection, the letters "drop off" the left end of the display onto the paper tape on the strip printer. This allows very long messages to be constructed and preserved using the strip printer without losing the ability to make corrections. In an alternate mode of operation, the letters enter the display from right to left. As each new letter is added, the contents of the display shift to the left. When the display is full, with each additional selection, letters "drop off" the display onto the paper tape. This shifting mode can be completely avoided if it poses a problem for some children.
- 4) The ability to print out words, phrases or sentences - In addition to printing out single letters, the universal control module has the ability to print out entire words, phrases or sentences with a single signal from the handicapped user. Commonly used words, phrases and sentences can, therefore, be programmed into the unit to provide more rapid and timely communication for the handicapped individual. This feature can also be used to store and output a series of commands to the aid or to other devices. The universal control module has the ability to hold up to approximately 2,000 words.
- 5) The ability to be used with pre-reading and pre-spelling children - Because of the ability to print out words and phrases, etc. the aid can be used with pre-spelling children having a sight word vocabulary. By using pictures or symbols in conjunction with the words on the child's display, the non-reading child would also be able to construct messages which could be subsequently read back to the child providing him with oral feedback as well as a motivating mechanism for providing associations between the picture and the corresponding word(s). Connected to a voice synthesizer such as the Votrax, the aid could both say and spell out the words on a display as the child pointed to the word/picture/symbol.
- 6) Versatility needed to adapt the aid to the specific needs of the child - The universal control module itself is capable of operation in almost any type of scanning, encoding or direct selection mode. Aids which incorporate the module would be extremely flexible due to the program-ability of the module and would allow for extensive modification of the particular operational mode chosen even after the aid is placed in the field.
- 7) Ability to function as a Developmental Aid. Because the aid can be easily modified even after placement, the aid can be adapted to develop slowly with the child. The aid can be easily programmed to operate very simply when placed with a young child. Then as the child develops the aid can be modified by the parent or teacher by simply changing the plug in modules to meet the advancing communication and control needs of the child as he grows and to take advantage of developing physical and conceptual abilities in the child.
- 8) Ability to have the child himself change words/phrases in the word-master. Up to 64 words can be added or changed from day to day by the handicapped user (or teacher) to meet the changing communication needs of the handicapped individual. Frequently used words, seasonal greetings, favorite quips, emotional expressions and prepared remarks are some uses for this feature. It can also be used to easily alter his permanent word store and to store series of commands for the aid or for control of devices in his environment or employment situation.
- 9) The ability to easily interface with a wide range of accessories. Since the output of the aids are under software control, any length serial output string using any code can be easily programmed. Some examples would be 8 bit ASCII, used by most computers, 5 bit Baudot used by the deaf teletypers, 9 bit EBCDIC used by IBM, and special codes such as the 6 + 2 bit code used by VOTRAX.

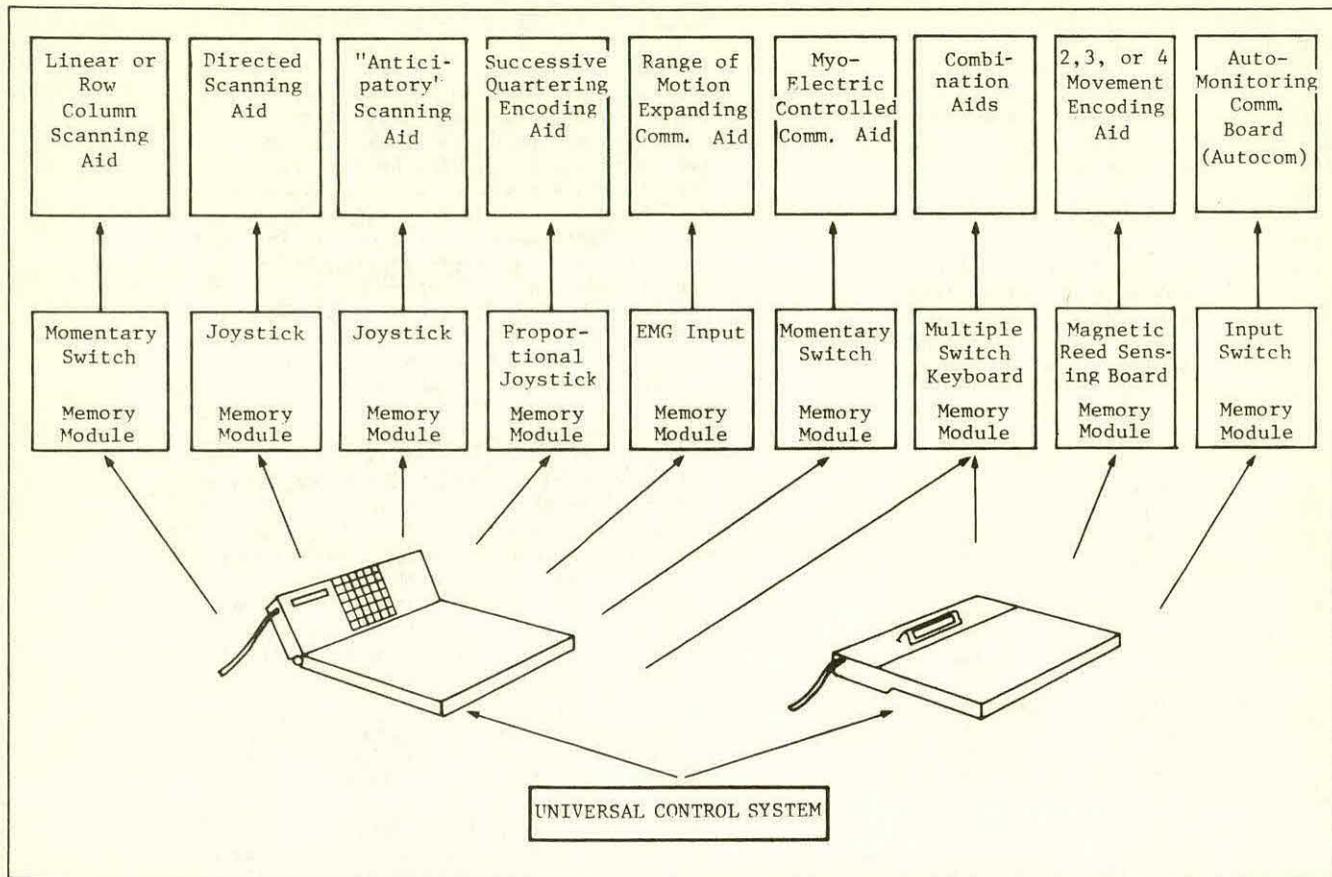


FIGURE 3 TWO COMMUNICATION AID FORMATS

- 10) The ability to be programmed by researchers or applications engineers to incorporate their own special features/capabilities. The COSMAC is a very easy microprocessor to learn and use. Because of the design of the UCM software, programs can easily be written by other researchers to expand the function of the aids or to develop new aids using the UCM system.
- 11) Ability for limited self-diagnostics and ease of maintenance. Because it is a "smart" aid, special diagnostic programs can be prepared to aid the technician in locating problems in the aid. Because it is a static processor, the aid can be stepped through its programs further simplifying maintenance. Since a large number of different types of aids could all use the same basic system, populations of users could be denser allowing for the setup of local or regional maintenance centers.
- 12) Ability to provide special functions for education, recreation, independent living creativity and employment. Special functions such as calculators, sequence programmers, games and device control could be easily added to the aid by simply plugging in special program modules. A special accessory could also be developed which would allow handicapped individuals to write their own programs for their aids.

- 13) A lower cost than comparable non-micro-processor based aids - the cost of the aid would be less than a non-flexible and (having features described in this list as items 1, 2 and 4). Aids which have only a single mode of operation and spelling only (no significant word output) could however be more inexpensively designed with discreet logic and would not benefit from the UCM approach.

Use of the UCM in two communication aid formats subsequent to the development of the UCM system, two very flexible communication aids were developed around the system. The objective in the development of the aids was to minimize the number of different package forms needed to provide a wide range of different communication aids. Since the various different techniques explored could be generally broken down into two categories (those that require active selection displays such as the scanning techniques and those that do not - the least common denominator arrived at was two. As a result, two package forms were developed, dubbed the Versicom and the Autocom-E. Figure 3 shows some of the modes of operation for which the aids can be programmed as well as the accessories needed to implement them.

Thirty five of the Autocom-E or Versicom aids have been built and purchased by centers or individuals in the United States and Canada. In addition, the Blissymbolics Communication Foundation has had one of the aids adapted to print out Bliss

Symbols for use with children in their program  
(see paper in this volume).

#### Summary

A new coordinated approach to the design of compatible communication aids has been explored and found successful based upon the concept of a general flexible control module. This module has been used to develop two new aids capable of operating in scanning, encoding and direct selection modes. Through cooperative development of this concept, it is hoped that a wide range of compatible aids with resulting widespread maintenance availability can be achieved. The Trace Center solicits and welcomes input on the further development of the UCM concept to better meet the needs of the severely handicapped. The Center also welcomes the development of cooperative programs to facilitate other researchers as well as teachers, clinicians, parents and handicapped individuals themselves in implementing their ideas using the UCM or UCM aids.

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## A BREATH-CONTROLLED COMPUTER DATA ENTRY SYSTEM

C. D. Traynor

University of California, Irvine

This work involved designing a device that allowed a spastic, quadriplegic woman to type with the aid of a computer. The subject was taught to operate pressure sensitive switches with her breath, sending a modified Morse code of high and low tones. This was converted to a format a computer could use. The feedback system included several parameters which were adjusted to accommodate the characteristics of the subject. The code was enlarged to include all characters on a computer terminal keyboard. By using a standard interface the device was compatible with a wide range of computer equipment.

The user obtained control of the device immediately and with limited training was sending characters as fast as a hunt-and-peck typist. The system functioned as a simple typing machine. Future possibilities for the device include text editing and computer programming.

CATEGORY:	INTENDED USER GROUP: any individual with reasonably good control of their breathing
Device Development <input checked="" type="checkbox"/>	
Research Study <input type="checkbox"/>	
STATE OF DEVELOPMENT:	AVAILABILITY OF DEVICE: not available (developing second prototype)
Prototype <input checked="" type="checkbox"/>	
Clinical Testing <input type="checkbox"/>	AVAILABILITY OF CONSTRUCTIONAL DETAILS: complete details should be available late in 1977
Production <input type="checkbox"/>	
AVAILABLE FOR SALE:	FOR FURTHER INFORMATION CONTACT: Charles Traynor 754B W. 12th St. Eugene, OR 97402
Yes <input type="checkbox"/> No <input checked="" type="checkbox"/>	
Price: \$ 300 (estimate)	

Purpose

In bringing members of the handicapped community into the mainstream of society it is absolutely essential that they be provided with the means of acquiring skills that exercise their full potential as people. This must include the necessary tools to achieve these goals.

The present research focuses on providing one such tool for a young, cerebral palsied woman. The woman, diagnosed as a spastic quadriplegic, is verbal, very intelligent, and intent on pursuing a college education and a career. To do this effectively, she must be capable of writing without the assistance of others. Until now she has had to dictate her work, leaving herself totally dependent on those who do her writing. She finds she is constrained by her writers' schedules and suffers from a complete lack of privacy. Dictation does not provide her with the advantages of written composition: organizing and editing large papers proves to be particularly difficult.

To write independently she requires more power than a typewriter provides. She must have the means of creating a rough draft of her work, correcting it, editing it, and typing a polished

copy. She requires a means of juggling text without juggling paper. Timesharing computers are ideally suited for that application. Many of the timesharing computer systems employed in government, education, and industry contain text editing facilities, complete with printers that produce high quality typewritten output. Communicating with a timesharing system via a computer terminal, a user can move from an idea to a finished document without ever touching a piece of paper.

To provide the subject with such capabilities it was necessary to find a way she could use a timesharing system. To do this she had to be provided with a means of controlling a computer terminal. This research was aimed at designing a device which she could control that emulated the function of a computer terminal keyboard.

Method

## The switch and feedback system

The subject operates pressure sensitive switches with her breath, as she exhibits good neuromuscular control there. Generating a distinct audio feedback, the switch closures are translated into computer character codes.

To operate the system the user blows or sucks on a mouthpiece, generating high or low tones, respectively. The technique closely resembles Morse code with the high tones (H) corresponding to Morse code dots and the low tones (L) corresponding to Morse code dashes. Characters are created by pausing after sending desired combinations of high and low tones. By maintaining the pressure in either direction the tones automatically repeat, sparing the user from having to operate the switch successively in the same direction. One can illustrate the technique with the following examples.

To send the letter "S", the user blows in on the mouthpiece until she hears three consecutive high tones (HHH). By releasing the mouthpiece an "S" is transmitted. To send "T", the user sucks in on the mouthpiece until she hears a single low tone (L). She then releases the mouthpiece and "T" is transmitted. To send "R", the user blows on the mouthpiece for one high tone, sucks on the mouthpiece for one low tone, and blows on the mouthpiece for another high tone (HLH). She then releases the mouthpiece and "R" is transmitted.

Because the user's timing is critical to her success at manipulating the system, I included several features which I felt might help us avoid possible pitfalls. One such pitfall involves delimiting characters incorrectly. If the user takes too long in switching from blowing to sucking, or vice versa, the circuitry delimits a character prematurely. The example for "R" (HLH) could be sent as "A" (HL) and "E" (H), or as "E" (H) and "N" (LH), or as "E" (H) and "T" (L) and "E" (H). To adjust for that, the system contains a variable timing element which controls the length of the delimiting pause. The pause can be made very short for people who are quick at operating the switches and long for people who operate the switches slowly. As people gain skill at operating the system the delimiting pause can be shortened.

Another potential problem stems from sending symbols (high or low tones) accidentally through inadvertent switch closures. A number of circumstances contribute to this problem, including the sensitivity of the switches and the neuromuscular control of the user. Someplace during the length of a tone the device must record what symbol is being sent. If the symbol is recorded at the very beginning of the tone an accidental switch closure may register a false symbol. If the symbol is registered at the end of the tone there is little chance that a false symbol may be sent, but this also increases the possibility of dropping intended symbols. Unable to foresee what the user might require, I added two timing elements that enable her to specify where, during the tone, she wants the symbol registered. The two parameters set the length of the tone before the symbol is registered and the length of the tone after the symbol is registered. The duration of each timing element can be adjusted relative to a master timing signal which functions as the speed control. In this fashion one can increase or decrease the overall speed of the system without having to alter the length of individual timing elements.

## The coding technique

My coding method differs from Morse in two major aspects. The first difference concerns the mode of feedback. Morse code contains two symbols made up of short and long bursts of a single tone. This code contains two symbols of equal duration, but with distinctly different tones. The second change in the code deals with the treatment of spaces. In Morse code, words are delimited by long pauses: no code for space exists. I felt I should employ a separate code for space (versus using a pause) for several reasons. Computers deal with spaces in a larger context than that of just delimiting words. Multiple spaces are common in all formal text, whether written on a computer or not. A second, more dramatic, reason for treating space as a character concerns the stamina of the prospective user. Work on this system could be quite frustrating if for every time the user paused the equipment dutifully typed a space. It could make typing a long word a real challenge.

Letters and numbers in my encoding are identical to Morse, using the high tone (H) as a dot and the low tone (L) as a dash. The Morse encoding scheme is unusually efficient as it assigns the shortest codes to the most common characters in English. With all the letters and numbers assigned, there remain a few unused codes of length four, and many unused codes of length five. These unassigned codes are used for the space character, miscellaneous punctuation, standard terminal characters (backspace, carriage return, line feed, break, etc.) and special codes that change the internal mode of the machine. This last group will be discussed in detail later.

There are no legal codes more than five symbols long in this system. Any time the user generates a code of length six, or greater, an overrun error light comes on. Although the user continues to receive to receive audio feedback during an overrun, the system will ignore that code when the delimiting pause occurs.

The circuitry converts the user's codes into ASCII (American Standard Code for Information Interchange) characters. Although other computer codes exist, ASCII is the most widely used in dealing with computer terminals. This system only uses a subset of the ASCII code, leaving out all lower case alphabetic characters. As many terminals use this subset, this omission should not create great hardships for the user.

## Special terminal modes

Many of the characters in the ASCII character set are not directly available on a computer terminal keyboard. These characters can only be sent by pressing two keys simultaneously. On most terminals there are two such subsets: shift and control characters. These characters are sent by depressing either a "shift" key or a "control" key while striking a second key. For example, most computer terminals have a bell, which can only be operated by pressing the control key and "G" at the same time.

This device incorporates a control code (HHHLH) and a shift code (LLLH) to achieve the same results. When the user sends either code a light will come on indicating that the terminal is in either control or shift mode. The user then sends a second code which represents the character to be "controlled" or "shifted." The circuit sends the modified character and switches the terminal out of the special mode. If the user sends the control or shift code accidentally she can send it again to switch the terminal back out of that mode. In this way, the user is not forced to have her next character modified just to reset the system. A shift-lock code (HHLHH) also exists. This enables the user to send several shifted characters in a row without having to send a shift code for each one. After sending the characters, the user must send shift-lock again to reset the terminal to its standard mode.

I felt I should include the function of a repeat key in this device, as most computer terminals have one. To repeat a character on this system, the user sends the desired character once, then sends the repeat code (LLHLL). A light on the front panel indicates the terminal is in repeat mode. Repeat mode changes the basic operation of the system. When the user blows in on the mouthpiece she generates a string of special tones, occurring at the standard rate. For each tone sent the previous character is repeated once. The overrun circuitry is disabled so the user can send as many consecutive tones (repeating characters) as she wishes. The system remains in repeat mode until the user sends a single low tone.

#### The terminal configuration

This system takes advantage of the full duplex format of computer-to-terminal communications. In the full duplex mode, a computer terminal can be thought of as two distinct units: a keyboard and an output device. In the case of a cathode ray tube terminal the output device is a TV screen; in the case of a teletype it is a printer. In a full duplex configuration characters typed at the keyboard are sent directly to the computer. The computer then sends those characters back to the terminal's output device. When typing at the keyboard one gets the illusion that the characters are being sent directly to the output device, rather than being "echoed" by the computer.

Computer-to-terminal connections usually have a standard format known as the EIA RS-232C. The connections for this device have been designed to meet this standard. To hook the device up to a machine, we need only pull the existing connectors between the standard terminal and the computer, inserting a special adapter between them. With this adapter in place the terminal's keyboard is locked out. Characters sent by our device are echoed by the computer to the output device of the standard terminal. In doing this we can use any available output device, whether they be printers or TV screens. This can be done without disrupting existing equipment.

#### Physical description

The mouthpiece for the system, a hollow plastic tube with an inside diameter of 1/8 inch, is suspended from a simple wire stand which can be bent to any position. Rubber tubing connects the mouthpiece with a small box which holds the pressure switches (Fairchild PSF 100A's). This enclosure also holds the speaker and an earphone jack (for private listening). A cable runs from this enclosure to the cabinet which holds the electronics. The front panel of the cabinet contains a power switch, a calibrated dial for the speed control, and various indicator lights (overrun, shift, shift-lock, control, and repeat). A cable connects the main electronics with a small adapter which connects the computer and the standard terminal. The device is quite portable.

#### Results

My initial experiences at having the user operate the system were instructive. When she first attempted sending characters she thought in terms of blowing or sucking on the mouthpiece. She emphasized the switch operation, paying little attention to the feedback. By approaching it in this way she found she had very little control of the switches. This lack of success made her quite nervous. The anxiety led to a marked increase in involuntary muscle activity which made things harder yet.

I intervened, suggesting that she should approach it from another angle. I asked her to play with the switches for a few minutes, ignoring anything being typed. I added that it might help if she thought in terms of making tones rather than thinking about blowing or sucking on the switches. Within the next few minutes she made a distinct improvement in her ability to control the system. After she had relaxed a little I proceeded with some new instructions. I demonstrated certain tonal sequences and asked her to mimic them using the switches. The results were dramatic. Within the next hour she learned to send all but a few codes in the character set. Her rate of error dropped steadily. By the end of the first session she was able to send complete words without mistakes.

This is not to say the technique was without its problems. I found that for the user to send a code reliably she had to hear it first, or sound it out in her mind. At first she had trouble conceiving what certain characters sounded like, these problems disappeared after a little practice. For reasons I never understood, she had serious problems sending two codes in the character set: space (HLHL) and "C" (LHLH). She would send the codes correctly for awhile, then make an error and lose control of them altogether. She even experienced problems in trying to mimic these codes. Although she finally learned to send them, she continued to make a large number of errors.

At first, the user paused constantly to catch her breath as she was not breathing while operating the switches. This ceased to be a problem after she discovered that she could breathe through her nose while operating the switches with her mouth.

I encountered another problem involving the switches and the mouthpiece. The user's saliva tended to be drawn up into the mouthpiece. The pressure switches were so sensitive that the capillary action of the liquid in the tube turned the switch on and kept it on until the tube was cleared. Although this proved quite annoying to the user, the continuous tones did not generate characters, due to their detection by the overrun circuitry. I later found that I could eliminate the problem altogether, by changing the angle of the mouthpiece with respect to the user.

The adjustable timing elements proved to be of benefit in tailoring the system to the characteristics of the user. In the first sessions the user operated the pressure switches very slowly. Only by making the delimiting pause quite long could she delimit characters correctly. I also discovered she was prone to making accidental switch closures of varying lengths. But by registering the symbol in the center of the tone most of the false actuations were ignored.

In our later sessions her average typing speed was about one character every two seconds. Because of her schedule we could not work for more than a single two or three hour period each week. Under such circumstances it was difficult for her to get the feedback she needed to master the codes. She spent a fair percentage of her typing time just trying to remember them.

As the training progressed it became apparent that the subject would require more instruction than I had anticipated. As she had never written before, she needed tutoring in spelling, punctuation, and basics of written composition. I was unprepared to provide such instruction. I discovered that it would be very difficult to teach her how to use the editing functions of the computer when she had not yet learned to write. In addition to this, she was unable to allocate the time needed for this training. For these reasons I was not able to evaluate the writing system as a whole.

#### Discussion

The results demonstrated the following: the subject successfully controlled a computer terminal, the audio feedback played a major role in this success, and the adjustable nature of the switch and feedback system compensated for problems that the subject experienced in operating the switches. I feel that the subject's average typing speed reflected her incomplete knowledge of the codes rather than a ceiling to the speed at which she could manipulate the switches. I believe that, with the proper training, she could type at speeds exceeding one character a second. I discovered that several levels of training would prove necessary to progress from the subject's controlling a computer terminal to her mastering a writing system. These levels would include learning the code, serious practice to increase typing speed, and instruction on the use of text editing systems. If the user had never written before it would probably be necessary to teach basics in written composition, including spelling and punctuation, before work could begin on

building up typing speed or teaching the subject how to use a text editor. This instruction is vital to the success of the system.

Although this paper has stressed its use as a writing tool, the terminal could be used for anything from providing an individual with a means of communicating to providing the same individual with a job as a computer programmer. It appears that this technology has an incredible potential, but the criteria is, as always: will it meet the needs of the individual? This can only be answered through personal experience.

#### Acknowledgments

This work was made possible by a grant from the University of California at Irvine and would not have been possible without the ideas and support of Fred Tonge and Ann McClellan.

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## VIDEO COMMUNICATOR FOR THE SEVERELY PARALYZED

E. H. Denys and J. Mortelmans

Micro Communication Devices\*

A video communicator consisting of electronic circuitry and a monitor screen enables the patient with a severe motor handicap to spell out messages; a single switch activation (mechanical, pressure, etc.) selects the desired character or special symbol from a sequential display at the bottom of the screen and adds it to the message. Storage is provided for 16 lines of 32 characters each; a two-page feature allows storage of one message while another is being displayed; an accelerator speeds up the flashing rate; an alarm call as well as three power outlets for additional devices are built in.

Initially designed for a patient with amyotrophic lateral sclerosis, the addition of a printer will expand its usefulness to any motor handicapped, unable to write and desiring a permanent record.

CATEGORY:	INTENDED USER GROUP:	Severely paralyzed with speech difficulties; quadriplegics.
Device Development <input checked="" type="checkbox"/>	AVAILABILITY OF DEVICE:	3 months
Research Study <input type="checkbox"/>	AVAILABILITY OF CONSTRUCTIONAL DETAILS:	Not at present
STATE OF DEVELOPMENT:	FOR FURTHER INFORMATION CONTACT:	Micro Communication Devices
Prototype <input checked="" type="checkbox"/>	2094 Anthony Drive,	Campbell, Calif. 95008
Clinical Testing <input checked="" type="checkbox"/>	Production <input type="checkbox"/>	
AVAILABLE FOR SALE:	Yes <input checked="" type="checkbox"/> No <input type="checkbox"/>	
Price: \$2,000.		

## Introduction

Very few devices are available for the severely handicapped with motor impairment involving the speech mechanism. Such a device becomes imperative when the intellectual functions remain intact as in amyotrophic lateral sclerosis, myasthenia gravis, the locked-in syndrome or Guillain-Barre syndrome.

A young patient with amyotrophic lateral sclerosis became totally paralyzed; artificial respiration, esophagostomy and total body support were necessary. Only eye movements and blinking were retained. In order to communicate, the patient would blink when the desired letter or word was pointed out on a traditional alphabet board. This method was not only time-consuming, but also frustrating for both the patient and her attendants and left the patient totally dependent on others. When a slight recovery occurred in one arm, special balancing of the movement allowed her to control an alphabet clock, but the necessity for an observer to be present remained.

With a humanitarian purpose in mind, a video communicator was developed and built which improved the quality of life of the patient and the ease of nursing care to such an extent that further refinements and additional features were incorporated. Details of this improved device, called VideoCom II, will now be presented.

## Mode of operation

Most of the screen area is used for message display. Characters and special symbols are flashed continuously in a preview and a selection window located in the center of the bottom edge of the screen. The message area allows for 16 lines of 32 characters and always contains the cursor (displayed as an underscore) which indicates the location on the screen where the next character will be written.

Four cursor movement symbols can be selected and move the cursor backward or forward one position or to the next line; all three movements are non-destructive, i.e. no displayed

\* Micro Communication Devices, 2094 Anthony Drive, Campbell, Calif. 95008, was recently formed to make the device available to patients.

information is changed by moving the cursor. The fourth cursor movement is an integral part of the Erase Page command which places the cursor in the top left hand corner of the screen after erasing it.

By activating the switch, the character or special symbol displayed in the selection window is processed. If a character is chosen, it is displayed in the location indicated by the cursor and the cursor moves to the next character position. If a special symbol was selected then the command represented by the symbol is executed and no cursor movement is involved unless the command is a cursor movement.

The preview window displays the character or special symbol next in line before it reaches the selection window. It appears then to the observer that the flashed symbols shift out of the preview window into the selection window. The time the symbols are displayed in the preview and selection windows can be adjusted by the patient; selection of a special symbol followed by number of switch activations (zero through 15) allows for 16 different speeds (0.3 s to 1.5 s exposure time).

#### Program modes

The sequence of the characters and special symbols in the windows is determined by the program mode. The maximum capacity of all program modes is 64 characters or symbols. There are two one-step selection modes (designated automatic) and two modes whereby the selection occurs in two steps (called self code).

Of the two automatic modes, one has the characters arranged in alphabetical, and the other in statistical order. The alphabetical sequence is easiest to understand and helpful mainly to familiarize with the device. Presentation of the characters in a statistical order, giving priority to the most frequently used characters, causes a marked reduction in the waiting time. Because certain infrequently used characters would increase the waiting time for more common characters too much, they have been stored in separate loops; a total of 4 loops accommodates all characters. The main loop contains 22 characters and two special symbols. The second loop has the remaining characters, punctuation marks, the alarm call, the page flipping symbol, the power outlet controls and the flashing speed symbol. The third loop has the numerals and the fourth loop has mathematical symbols and the least used punctuation marks. The last symbol of the first three loops is one cursor movement (backspace, forward and new line, respectively). When no selection is made, only the contents of the main loop are continuously displayed in the windows. After a selection (in any loop) is made, the program is reset and starts with the first character of the main (1st) loop which is a blank or space.

If a character or symbol stored in loop 2, 3 or 4 is desired selection of the shift-symbol at the end of loop 1 gives exit from loop 1 and entry into loop 2; the same applies for loops 3 and 4.



VideoCom II

Whereas many patients will be satisfied with the above described operation, the following mode, called self code, makes selection markedly faster. The characters and special symbols are divided over 8 loops of 8 characters each. The patient will need a visual display of the matrix, at least until he has it memorized. The loops are numbered 0 through 7 and presented by number in the preview window while the selection window is blank. Two switch activations are required before a character is displayed. The first one selects the appropriate loop 0 to 7, following which the characters of that loop are displayed as usual in preview and selection window until a selection is made; if no selection is made a particular loop is displayed over and over; in order to exit an erroneously selected loop, a special shift symbol identical to the one used in the automatic mode should be selected (available at the end of each loop), which resets the program to the presentation of loop numbers.

#### Special Features

If an additional switch can be activated by the patient (mechanical switch, sip in addition to puff, etc.) a built-in accelerator can be activated which causes rapid flashing (.13 seconds per symbol) of the symbols for as long as the switch remains activated. High speed flashing will only occur in the main loop unless the loop changing symbol is selected, which is difficult at this speed; therefore the following action will assure rapid flashing into the next loop: a single activation of the selection switch, while the accelerator is engaged, brings the next loop in the windows at high flashing speed. The same can be done to reach the following loops; when approaching the desired character or symbol, the accelerator should be released and selection made at the appropriate time.

All special symbols are typomatic, i.e. when the selection switch remains activated, after a short delay (approximately .27s) the circuitry will automatically generate repetitive actions at a fast rate of speed (.13s) as long as the switch is activated. For example, despite experienced

use, errors are unavoidable; if one has to back-space 20 times, it is sufficient to keep the selection of the reverse symbol depressed for about 3 seconds. This causes the cursor to shift in that direction without erasing and correction is then achieved by selecting the correct character. The typomatic feature is most useful in cursor movement commands but can also be used to give special meaning to the alarm call or power outlets, and will turn the device on and off at .26s intervals.

A two-page feature allows one message to be stored in memory for later recall while another is being prepared. The pages can be interchanged through a special page-flipping symbol. This allows for interruption of a longer message or letter for display of matters which require immediate attention.

A built-in alarm call with a connector for a remote alarm and three additional 110 V power outlets (12 A max.) are available for controlling such devices as a radio or TV set.

A special connector for a page-turning device is provided.

The page-erasing symbol has to be activated two consecutive times to prevent unintentional erasure of an entire message.

#### Print-out

In order to provide a copy of the message displayed on the screen, a printer can be attached to VideoCom II. On selection of the print symbol, the printer will copy the screen with exactly the same lay-out, i.e. 16 lines of 32 characters. A full page can be transcribed in approximately 12 s.

#### Performance

The fact that a 7-year old boy could operate VideoCom II with no difficulty after about five minutes shows how readily it can be mastered. The four different program modes were compared with respect to the time required in writing the following two sentences: "The quick brown fox jumped over the lazy dog" and "Now is the time for all good men to come to the aid of their country." The table below shows the number of flash times required to write the message without the use of the accelerator, provided no errors were made. In the self code statistical mode 169 and 205 represent 100%.

	"The quick brown..."		"Now is the time.."	
	Stat.	Alpha.	Stat.	Alpha.
auto- matic	431 255%	515 305%	454 221%	553 269%
self code	169	213 126%	205	223 109%

The use of the accelerator reduces markedly the time in the automatic mode, but is less helpful in the self code because of the two-step selection process and an already shorter access time. A moderately skilled operator can, with either method, reach a speed of 6 words per minute when the flashing speed is 0.75 s.

#### Conclusion

The VideoCom II may seem relatively slow compared to our standards of normal speech communication. However, its apparent slowness stems from the very limited trigger capacity in those patients with severe motor paralysis, for whom the device was originally intended. The development of a blink switch is currently under investigation, as well as multiple trigger features which would allow for faster communication in the less severely handicapped. For example, different levels of suction or puffing for decoding of the characters and symbols could be especially useful for quadriplegics. The flexibility of the screen, with its two-page feature and the possibility for correction before printing, are considered an advantage over the customary typewriter.

## THE BLISS-COM; A PORTABLE SYMBOL PRINTING COMMUNICATION AID

H. Silverman - Blissymbolics Communication Foundation, Toronto, Ontario

D. Kelso - Trace Research and Development Centre, Madison, Wisconsin

Use of the Blissymbol system with non-verbal physically handicapped children has proven to be a useful and effective alternate form of communication. One major barrier to more effective use of the Blissymbol system is the fact that with the existing communication aids, the child could not construct his entire symbol message before calling upon the recipient of that message to read it. He could assemble only short segments of the message, have the recipient read the segment, "erase" the segment and then construct the next segment. The purpose of this project was to develop a Blissymbol printing communication aid which would allow the child to construct his entire message and have it appear in print form for the recipient to read.

CATEGORY:	INTENDED USER GROUP:
Device Development <input checked="" type="checkbox"/>	Non-verbal physically handicapped children and adults.
Research Study <input type="checkbox"/>	AVAILABILITY OF DEVICE:
STATE OF DEVELOPMENT:	AVAILABILITY OF CONSTRUCTIONAL DETAILS:
Prototype <input checked="" type="checkbox"/>	Preliminary drawings available.
Clinical Testing <input type="checkbox"/>	
Production <input type="checkbox"/>	
AVAILABLE FOR SALE:	FOR FURTHER INFORMATION CONTACT:
Yes <input type="checkbox"/> No <input checked="" type="checkbox"/>	D. Kelso - Trace Research and Development Centre, Madison, Wisconsin.
Price:	

The ability to communicate is basic to human development and interaction and fundamental to any educational process. It is through communicative interaction that social adaptation is possible. It allows one to relate and to exchange thoughts, ideas, feelings, needs, and desires to learn and to share the experience of others. Through the function of the language system, humans not only adapt to their environment, but also exert control over it. For many severely handicapped children, however, effective communication is not possible through "normal" channels. These non-verbal motorially impaired children are unable to speak or write or finger spell and have only undifferentiated guttural sounds and gross gestures with which to relay their thoughts and feelings to others.

Without effective communication channels, these children have no means of interacting with their teachers or peers. They have no means of asking questions when tasks presented are unclear, nor can they respond to questions from their parents or teachers.

The education of non-verbal severely handicapped is greatly limited by their need for one-to-one tutorial attention, their inability to do

productive work independently, and their reliance on another's undivided attention and interpretation of their thoughts.

It becomes obvious then, that for the child for whom speech is not a functional means of meeting his communication needs, an alternate means of communication must be provided to compensate for the defective oral communication system.

There are a number of basic elements in developing an alternate communication system for the non-verbal severely physically handicapped child (Vanderheiden & Grilley, 1976):

1. Selecting or developing a symbol system which is appropriate for the child's communication needs and which is sufficiently extensive to allow for the development of more and more complex and sophisticated statements as the child grows and matures;
2. Developing a teaching methodology in order to assist the child to understand the alternate symbol system and to use it effectively and efficiently in his communication with others;

3. Developing and introducing a technical aid designed to provide the physically handicapped child with an effective means of indicating in sequence the component symbols of his communication.

All the elements mentioned above comprised the major focus of two earlier projects (Kates, McNaughton & Silverman, 1974; Silverman, 1976). These projects utilized Blissymbolics (Bliss, 1965), a pictorial and ideographic symbol system as the alternate to spoken language, developed a teaching methodology for Blissymbolics, and developed a series of increasingly more sophisticated technical aids culminating in a compact, portable electronic scanning device on which 512 Blissymbols were displayed. Eight different control switches were also developed for use by handicapped children with varying degrees and various types of physical abilities.

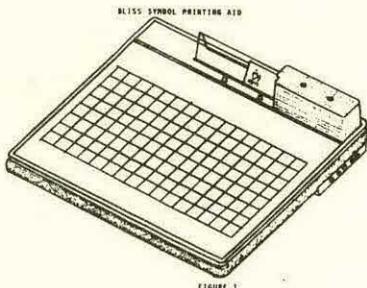
However, one major barrier to more effective use of the system by the children is the need to have a second person present to receive the symbol message, one segment at a time with each segment being followed by a period of time during which the child assembles the next segment of his message. For non-pointing children these time periods can be quite long, making classroom or other discussion very difficult and frustrating. In addition, the process must have negative effects on both the thinking of the child in his attempt to convey his message and the comprehension of the recipient of the message. Thus the child's ability to interact effectively with others is restricted and the benefit he derives from learning experiences is reduced.

A print out capability which would allow the child to construct his entire message in his own time would be one way of alleviating this problem.

The purpose of our study was to develop a communication aid which would provide the child with the means of producing his communications in print form thus enabling him to become more independent in the process of communicating.

#### Description of Aid

The Blissymbol printing communication aid is a modified Autocom-E, with the extra control electronics built into the original package, and the printer mechanism built onto its top surface (see figure 1).



The package measures 24-1/2 inches wide by 20-3/4 inches deep, and is 5 inches high at the printer housing.

The sensing area is the same as in the Autocom, and consists of 128 individually selectable squares. Each square is 1.35 inches on a side, making a total array of 10.8 inches by 21.6 inches. Because of the auto-monitoring technique, operation of the aid requires only gross pointing skills.

#### Features

The aid is portable and runs on rechargeable batteries. The batteries will last through a full day of normal use, and can be charged through a jack in the side of the aid, the same way a pocket calculator is recharged.

The Blissymbols are printed on a standard 100 foot roll of 2-1/4 inch wide thermal print tape, which can hold five to seven hundred symbols. The tape roll is changed by removing the printer housing via two quarter-turn fasteners, and replacing the empty roll with a new one. There is space inside the housing for a second tape roll, so the child should never be unable to communicate because of lack of print tape.

Printers are inherently non-correctable, but if the child makes a mistake, he can tell the aid, and it will back up the print tape and "cross out" the last character. The child can also adjust the speed of the aid (delay time of the sensing area) to compensate for variations in his physical abilities throughout the day.

In its present configuration, the aid can display up to 464 symbols on its top surface. The overlay is protected by a sheet of clear plexiglass, which can slide off to allow easy modification of the overlay. The aid is being programmed to print a set of 464 different symbols. This set could be considerably larger, but it is difficult to display any more symbols on the top of the aid. The symbol set can be modified by changing pre-programmed memory modules which plug into the back of the aid (behind a sliding door). This makes it possible to print any "standard" Blissymbol.

#### Operation

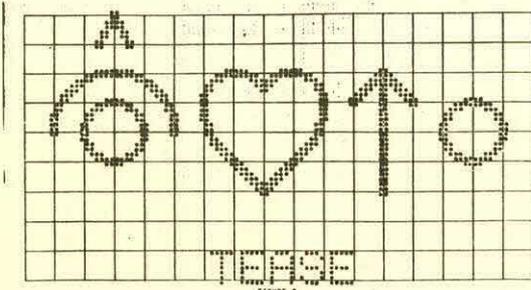
Twelve of the squares on the top of the aid are used for various control functions. Each of the other 116 squares contains four Blissymbols. To select a symbol, the child points at the group of four symbols (squares) that contains the symbol he wants. He then points at one of a group of four special squares (level selection squares) to indicate which of the four symbols he wants. The selected symbol is then printed.

#### Symbol Storage

This section describes the dot pattern format developed for printing the symbols, and the data compression and symbol reconstruction techniques which were developed for storing the symbols in memory.

### Dot Pattern Format

If one examines the geometry of Blissymbols, it becomes apparent that the symbols can be drawn on a square grid pattern such that a standard sized symbol like HOUSE is four cells wide and four cells high. The total height required for printing any Blissymbol is twelve cells, and each cell is represented by a 6 x 6 array of dot positions. A sample symbol is shown in figure 2.



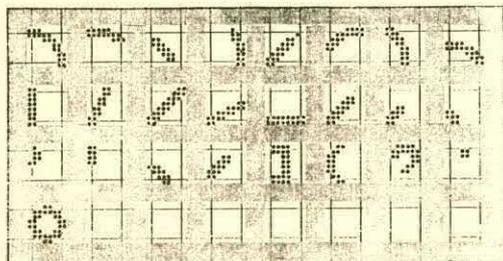
Note that one extra dot position is required around the edge of each "outside" cell. This makes the total dot pattern height of the Blissymbol printer equal to 74 dots.

### Data Compression

The typical Blissymbol requires about 56 dot positions in the horizontal direction. If the symbols were stored in memory as is, each symbol would require about 500 bytes, and a 464 symbol vocabulary would require about 230,000 bytes of memory!

Fortunately, this is not necessary. The symbols can be constructed from a set of symbol segments. Examination of a large set of symbols reveals that the total number of different basic symbol shapes is small. The number of basic shapes required for constructing any Blissymbol involves less information than is required for the standard set of 64 ASCII characters.

The actual symbol data is stored in eight byte blocks with each block corresponding to a single 6 x 6 cell of one (or more) symbol shapes. When vertical and horizontal reflections are eliminated, the total number of different data blocks (cells) is reduced to 25 (see figure 3).



This is the total amount of dot storage information required for printing any set of Blissymbols. The data blocks are 8 x 8, and include an extra dot position all around the edge of the actual cell. This facilitates the assembly of symbols from the basic data blocks.

### Symbol Reconstruction

The data blocks which are stored in memory must be assembled by the aid each time a symbol is printed. Each symbol is made up of a group of one or more symbol segments, and each symbol segment is made up of one or more simpler symbol segments (data blocks are also symbol segments). The rules for assembly are as follows:

1. Each symbol segment occupies a defined position in the symbol space relative to a reference point halfway between the earthline and the skyline. For data blocks this is the lower left corner of the cell.
2. A symbol segment can be flipped horizontally and/or vertically around its reference point.
3. A symbol segment (actually, its reference point) can be moved up or down relative to the reference point of a segment into which it is being assembled (by one cell increment).
4. A symbol segment (again, actually its reference point) can be moved to the right of the reference point of the segment which precedes it in the segment into which it is being assembled (also by one cell increment). If the symbol segment is the first one in the segment into which it is being assembled, then it is moved to the right relative to the reference point of that segment.
5. A symbol segment is assembled from one, two or three simpler symbol segments unless it is a data block, in which case the symbol segment is the data block.

When symbol segments are combined to form other symbol segments or actual symbols, two or more data blocks may occupy the same physical cell position. In this case, the data blocks are "ored" together to form the actual dot pattern for that cell. That is, if any data block has a dot in a particular dot position in the cell, that dot position gets a dot.

The aid contains instructions for the assembly of a total of 320 symbol segments (excluding data blocks).

In addition to these 320 symbol segments, there are a total of 128 data blocks. This makes a total of 448 available symbol segments (including some spares, shown as blanks).

Blissymbols are constructed by assembling symbol elements from the symbol segments, using the same rules as are used for assembling symbol segments. The symbol elements are used to "spell" the actual Blissymbol according to the usual rules of spacing.

Using this storage scheme, a total of 2304 bytes of memory are required for storing all 448 symbol segments (including the data blocks). An average Blissymbol can be assembled from this set of symbol segments using less than 3 bytes of memory (it takes about 5 or more bytes just to assemble the word), so a set of 464 symbols can be constructed with about 3700 more bytes of memory, making a total of about 6,000 bytes of memory for the entire process. That's a reduction of 40 to 1 over the simple method of storing the whole symbol as dots.

#### Print Mechanism

The thermal printhead forms the heart of the print mechanism. The printhead used in the Blissymbol printer has 84 fifteen mil square dots on 25 mil centers, giving 40 dots to the inch. Only 74 of the dots are used by the printer - the others are ignored.

A stepper motor was chosen because of its relatively small size (1.3 x 2.0 x 2.5 inches) and the availability of an integral gear train with the proper gear ratio. The geared down stepper advances by .75 degrees for each step, so four steps advance the tape by one print position (about 26 mils). The four step sequence for advancing the tape takes about 12 ms.

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## AN EXPERIMENTAL EVALUATION OF SELECTED COMMUNICATION TECHNICAL AIDS

C.A. Moogk-Soulis

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A method is evolved and applied to objectively compare the performance of six Communication Technical Aids (CTA's), including a standard electric typewriter, when used by representatives of three disability groups. User performance, defined by the rate and accuracy of typing, is presented for each of the CTA's and user characteristics (age, grade and I.Q.) are related to user performance. In general the standard electric typewriter with keyguard performed best for all three disability groups. The results of the evaluation show that sophistication of equipment does not guarantee superior performance and that objective information is needed to make decisions about optimum equipment/user matches. The results also demonstrate the need for better designs to mitigate the deficiencies of potential users.

CATEGORY:	INTENDED USER GROUP: N/A
Device Development <input type="checkbox"/>	
Research Study <input checked="" type="checkbox"/>	AVAILABILITY OF DEVICE: N/A
STATE OF DEVELOPMENT:	
Prototype <input type="checkbox"/>	AVAILABILITY OF CONSTRUCTIONAL DETAILS: N/A
Clinical Testing <input checked="" type="checkbox"/>	
Production <input type="checkbox"/>	
AVAILABLE FOR SALE:	FOR FURTHER INFORMATION CONTACT:
Yes <input type="checkbox"/> No <input type="checkbox"/>	Technical Aids Consulting Services
Price:	1620 - 24 Ave. S.W.
	Calgary, Alberta T2T 0Y2, CANADA

## Introduction

Technical Aids and their potential for use by the disabled are unknown or poorly known in many treatment facilities. This was the case in 1975 at the Alberta Children's Hospital (ACH), a 128 bed acute and rehabilitation treatment centre in Calgary, Alberta.

A number of very severely disabled children attend the school at the Alberta Children's Hospital. As staff gradually became aware of the existence of Technical Aids they began to consider the use of Technical Aids by these students. This consideration, however, led to the following problems.

First, Technical Aids were very expensive when compared to other items of school equipment such as books and desks, and it was necessary to strongly justify the high expenditure by showing the Aids did a much better job than the equipment currently in use.

The second problem was that the information about the Technical Aids needed in order to justify the cost of the equipment was unavailable. No objective analyses of performance or

reliability seemed to exist.

Consequently, in early 1975, five PMV Communication Technical Aids (CTA's) were borrowed by the Alberta Children's Hospital from Mid-Canada Medical, Mississauga for assessment and the following experimental evaluation was undertaken.

## Objectives

The objectives of the evaluation were to design a general method for use at ACH for objectively testing and comparing various types of CTA's when used by various disability groups and to test the method using the five borrowed CTA's and three disability groups selected from students at the ACH School.

## Equipment

Six CTA's were used in the experiment. To represent equipment already in use by students in the School, a standard IBM electric office typewriter (Standard CTA) fitted with a keyguard, was used. The typewriter was compared with the five PMV systems, described in detail by Moogk-Soulis (1976). Each consisted of a different interface connected to a solenoid unit which controlled an IBM Selectric typewriter.

The PMV Minimum had the smallest interface, with dimensions 12 cm X 9.5 cm (4.7 in X 3.2 in), and consisted of an alphabetical letter arrangement and a metal tipped "pen" which completed the circuit to the solenoid unit when a metal button under the desired letter was touched.

The PMV Combination interface was 44.8 cm X 24 cm (17.6 in X 9.4 in), produced in four sections which can be used in various combinations. During the evaluation, the sections were fastened together in a linear arrangement. The Combination had a standard typewriter arrangement of letters, each selected by depressing small raised buttons.

The PMV Medium was 62 cm X 25 cm (24.4 in X 9.8 in) and was operated by depressing 2.5 cm (1 in) diameter recessed buttons arranged in standard typewriter format.

The PMV Maximum, 77 cm X 49.5 cm (30.3 in X 19.5 in), was a larger version of the PMV Medium.

On the PMV Scanner letters and functions were arranged alphabetically in two horizontal lines behind which a variable speed light progressed from left to right. The system was controlled by two pressure switches, one to accelerate the light and the other to type the letter currently illuminated.

#### User Groups

The users for the experiment were drawn from the three largest disability groups in the School: spastic; athetoid/ataxic; muscle/joint weakness or lack of range. Pupils were chosen to participate if they were unable to print, write or type on a standard electric typewriter or if they did so at a non-functional speed compared with normal peers. At least seven individuals were included in each disability group. The individuals represented a wide range of age, grade, I.Q. and degree of disability.

#### Method

When evolving the method for objectively testing and comparing CTA's many parameters were considered, for example, reliability, machine characteristics, and speed of performance. However, rate of typing and accuracy of output, defined collectively as "user performance", were emphasized. They can both be objectively observed and easily recorded, and are influenced by the design and reliability of the machine so allow an indirect measure of these parameters as well.

Other information was recorded, such as machine failure and portability, but not rigorously enough to allow objective comparisons. Normally, this information as well as information about aspects such as cost, servicing, availability, and output are important considerations when making a final decision about equipment/user matching. However, they proved unnecessary in this evaluation (Moogk-Soulis, 1976).

Each user, in most cases, had one scheduled half hour test period per day. The same time of

day was used for each individual to minimize variations in performance so learning curves could be observed but the members of each disability group were spread randomly throughout the day.

Each user tested each CTA four times, copying material picked at random from his school reader. The CTA's were tested in rotation to balance learning on each machine. The date, amount of time spent typing, type of CTA used, number of words typed, number of errors performed and any problems with the CTA or for the user were recorded at the end of each trial. The trials took six weeks to complete. Thirty tests per group per unit were made to allow statistically significant conclusions in spite of the anticipated variability of performance.

User characteristics were related to observed performance as follows:

- i) A multiple linear regression analysis (Draper and Smith, 1965) was performed to correlate the user characteristics (age, grade, and I.Q.) to the observed user performance.
- ii) The t-values of each partial regression coefficient were examined to select the significant (>95%) user characteristics.
- iii) The multiple regression analysis was repeated using only the characteristics found significant in ii)
- iv) In cases where no user characteristics were significant at the 95th percentile, group averages were calculated.

#### Results

The accepted regression equations and their multiple correlation coefficients or the group means and their standard errors, SE, are shown for the Spastic group in Figure 1. Table 1 summarizes the results for all three groups evaluated. The rates shown are the actual numbers of words per minute typed by the user and have not been adjusted to exclude those words typed incorrectly. No significant increase in rates due to learning was observed.

#### Conclusions

The user performance parameters in Figure 1 and Table 1 show that in general none of the PMV CTA's had significantly better typing rates or accuracy than the standard electric typewriter with keyboard for any of the groups. In some comparisons, i.e. spastic group using the PMV Combination versus the Standard CTA and muscle/joint limitation group using the PMV Combination versus the Standard CTA, the PMV Combination had a slightly higher typing rate for younger children but very quickly the Standard CTA became faster.

The muscle/joint limitation group results show that for a user who was at his proper grade level in school none of the PMV CTA's were an improvement over the standard electric type-

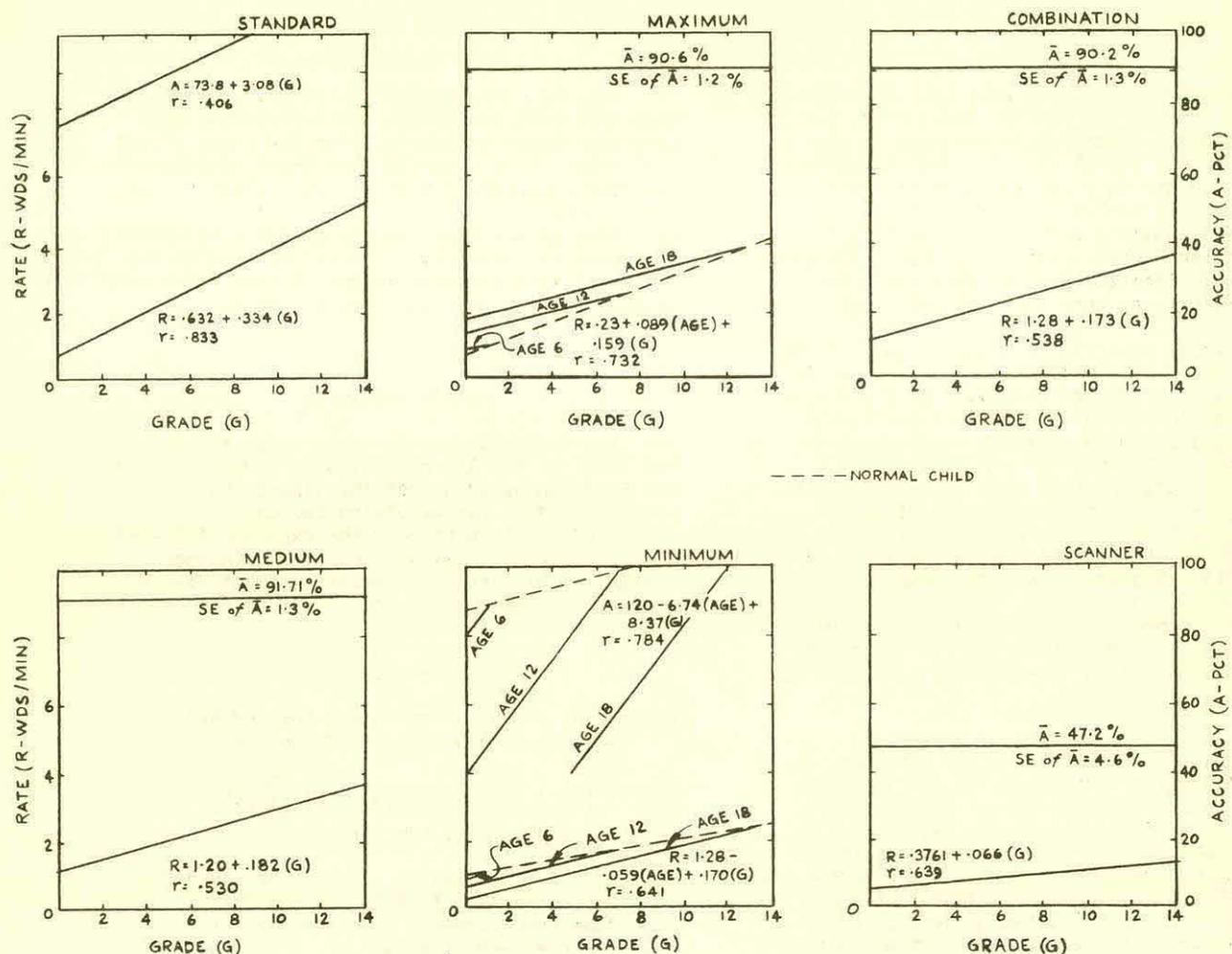


Figure 1. User performance for the spastic group

TABLE 1. Means of User Performance: Rate (R) in wds/min and Accuracy (A) in %.

				Standard	Maximum	Combination	Medium	Minimum	Scanner						
				R	A	R	A	R	A						
<i>Spastic</i>															
Grade	1	Age	6	1.0	77	0.9	91	1.4	90	1.4	92	1.1	89	0.4	47
			12	1.0	77	1.4	91	1.4	90	1.4	92	0.6	48	0.4	47
	10	1	18	1.0	77	2.0	91	1.4	90	1.4	92	0.4	10	0.4	47
		15	3.9	100	3.1	91	3.0	90	3.0	92	2.1	100	1.0	47	
		18	3.9	100	3.4	91	3.0	90	3.0	92	1.9	83	1.0	47	
<i>A thetoid/A taxic</i>															
Age	6	IQ	75	1.0	78	1.0	82	1.0	72	1.0	77	0.6	60	0.4	32
			100	2.5	78	1.6	82	1.6	72	1.5	77	1.0	60	0.7	32
	15	75	2.1	78	1.8	82	1.7	72	2.3	77	1.3	60	0.9	70	
		100	3.2	78	2.3	82	2.3	72	2.8	77	1.7	60	1.1	70	
<i>Muscle/Joint Limitation</i>															
Grade	1	Age	6	1.9	83	1.9	73	2.4	82	0.9	79	1.4	78	0.3	34
			12	0.5	64	0.6	73	0.9	82	0.9	79	1.4	78	0.7	54
	10	1	18	0.0	45	0.0	73	0.0	82	0.9	79	1.4	78	1.1	74
		15	4.4	100	3.8	96	4.0	82	3.2	79	4.1	92	1.7	75	
		18	3.8	96	3.1	96	3.3	82	3.2	79	4.1	92	1.9	86	

writer. However, all CTA's with the exception of the PMV Minimum and Medium showed a sharp drop in rate and sometimes in accuracy as the user fell behind in school. This relationship may have been due to a general physical deterioration in some members of this group which leads to an inability both to keep up in school and to use the larger interfaces. For individuals with severely limited physical abilities the smallest interfaces were the only ones usable.

With these results, in general, none of the PMV CTA's could be justified for use in the ACH School. Even in the one exception in the muscle/joint limitation group only a small portion of the total group showed a slight improvement in function on the PMV Minimum and Combination interfaces suggesting that only in extreme cases could these systems be considered. It was decided that, since on average the PMV CTA's were ten times the cost of the Standard CTA, the Standard CTA was a better economic choice. When factors such as portability, servicing, availability, etc. were also considered the Standard CTA became the obvious preferred choice for the three groups evaluated (Moogk-Soulis, 1976).

#### Discussion

The results of the evaluation reinforce the need for objective information on which to base decisions in providing Technical Aids to users. Initially many of the people who had contact with the sophisticated PMV CTA's assumed that they would be superior in performance for the disabled users. Even when the equipment malfunctioned or was difficult to operate, this opinion was generally maintained. It was not until the results were objectively analyzed that it became clear that the sophistication of the equipment was no guarantee of superior performance. Clearly more such comparisons are required to give a sound basis for equipment selection.

Finally, the results in Figure 1 and Table 1 show that none of the six CTA's evaluated had very high rates or accuracy for the three groups evaluated. This suggests that there is a need for more comprehensive objective evaluations of existing CTA's and more rigorous analysis of user deficiencies and needs by the appropriate medical and technical personnel in order to lead to the design of sophisticated Technical Aids which when objectively analyzed do produce superior performance.

#### Acknowledgements

The author wishes to acknowledge the help of the staff of the Alberta Children's Hospital and the staff and students of the Alberta Children's Hospital School for providing the physical facilities and participating in the experimental work and to thank Mr. Bill Webster of Mid-Canada Medical of Mississauga, Ontario, rehabilitation equipment distributors, for providing the PMV equipment.

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## A MICRO-PROCESSOR-BASED GESTURE ENTRY NON-VOCAL COMMUNICATION SYSTEM

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The object of the project is to develop a non-vocal communication system which replaces the keyboard entry with a gesture entry, video feedback method that emulates the audio feedback control system of vocal behavior. The system uses body motion in the form of gestures which are sensed by a small accelerometer. As the computer recognizes the digitally encoded sequence of gestures, it delivers video display feedback, graphic or symbolic, selected by the user, which acts to control and refine the gestures. The non-vocal communication system that uses a feedback-controlled natural behavior can approach the ease and flexibility of vocal communication.

CATEGORY:	INTENDED USER GROUP:
Device Development <input checked="" type="checkbox"/>	Cerebral palsied and stroke
Research Study <input type="checkbox"/>	AVAILABILITY OF DEVICE:
STATE OF DEVELOPMENT:	Manufacture is anticipated
Prototype <input checked="" type="checkbox"/>	AVAILABILITY OF CONSTRUCTIONAL DETAILS:
Clinical Testing <input type="checkbox"/>	Contact The Valley Institute
Production <input type="checkbox"/>	FOR FURTHER INFORMATION CONTACT:
AVAILABLE FOR SALE:	The Valley Institute
Yes <input type="checkbox"/> No <input checked="" type="checkbox"/>	Old County Rd., Hillsboro, N.H. 03244
Price:	

## Introduction

In the usual computer-based non-vocal communication system, the human must input data through a keyboard, digitally and in computer code. This concession to work 'on the computer's terms' is fundamentally unnatural and awkward. For the handicapped person it presents a severe 'bottleneck' in non-vocal communication.

A 'natural' data entry method would allow the computer to sense our most natural behavior, body movement. However, in order to be used as communication, movement must be choreographed into a rapid sequence of gestures, as in the deaf sign language. The sophistication of motion and motor coordination required to execute sign language are beyond the capabilities of a large majority of the handicapped. How then can the handicapped use gestures as a data entry mode?

## System Concept

If the computer is coupled to the human in a closed rapid feedback loop, the resulting man/computer 'psychofeedback' system can emulate the natural vocal system. In ordinary speech, immediate auditory feedback is required to close the speech control loop and allow properly articulated speech. The motor behavior of our vocal chords is controlled through auditory feedback. Note that this is a learned skill.

In the gesture data entry system, video display feedback substitutes for the audio feedback of the vocal system. Graphic gesture feedback format is variable and can be chosen by the system user to facilitate his learning a gesture language. Most important, the gestures themselves can be defined by the system user. Unlike the standard sign language used by the deaf, a private personal comfortable gesture language

can be developed by the system user. The computer can learn his arbitrary gestures as he builds motor skills for the gestures through the video graphic psycho feedback. As a consequence, even the motor-impaired handicapped can learn a large set of distinguishable gestures. Association of these personal arbitrary gestures or sequences of gestures with whole thoughts or complete conversational replies allows the gesture data entry system to become a true non-vocal communication system.

#### System Details

Mechanical motion is sensed by a small accelerometer of novel design, which can be attached to any convenient part of the body. Gesture acceleration signals are digitized and fed to the micro-computer. Computer output is video display of graphic and symbolic psycho-feedback and associated English conversational replies.

The first model uses a handheld two accelerometer transducer, allowing two dimensional gestures to be sensed. The first model uses a set of eight possible simple gestures: up, down, left, right, up and right (diagonal), down and right, down and left, and up and left. A small motion in one of these directions then selects one of eight possibilities. Immediate feedback CRT display indicates successful recognition of the gesture. Numbers 1 through 8 can be used as display or arrows pointing in the direction of the gesture could be used.

The first gesture of a session initializes the system and indicates which mode the user has chosen. Modes are divided into classes by the number of gestures to be interpreted as a single unit. Modes that use a single gesture constitute the 1 of 8 symbol class; modes that use double gestures constitute the 1 of 64 symbol class; modes that use triple gestures constitute the 1 of 512 symbol class, and so on.

For example, if the first gesture is up, this could select a single gesture mode, where one of eight complete phrases could be selected. This is called a one stage mode. This mode would be used for simple commands and stock conversational replies. The English phrase associated with the single gesture would immediately be displayed. Double and triple gesture modes can also be one stage modes, selecting complete phrases from 1 of 64 or

1 of 512. One stage modes are non-prompting and require memorization or external lookup tables.

When a mode using a large vocabulary is chosen, a two or three stage mode allows intermediate feedback in the form of prompting or menu display to aid in the synthesis of complex messages. For example, if a Basic English mode is chosen, parts of speech and subvocabularies can be displayed as 'work sheets'. This intermediate feedback aids in organizing thoughts and maintaining a rhythm in the process of synthesizing complex messages.

The prototype system uses a MOS Technology KIM-1 computer, augmented with additional RAM memory, an I/O board, with eight 8 bit ports, and an A to D converter board. Production models will use the 6502 processor chip used in the KIM with a few additional ROM and RAM chips.

#### Use Of The System

The handicapped user of the system is fitted to it with the help of a system operator. During this learning phase, personal gestures, graphic feedback format, and associated English phrases, etc. are chosen. Pattern recognition criteria are kept loose, so that successful matches to standard gestures are frequent, even for naive users. Later, as skill in forming and reproducing gestures grows, recognition criteria can be made tighter, while maintaining frequent successful matches. Tighter recognition criteria allow a richer set of distinguishable gestures within the motor coordination limits of the user.

#### Acknowledgement

This work was supported by a grant from the Stanley Olson Foundation.

REPRESENTATION OF LANGUAGE SPACE  
IN SPEECH PROSTHESES

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Modern computer technology, using voice synthesizers and dynamic displays, is ushering in a new generation of communication aids. These aids can access all relevant levels of linguistic structure. The proper representation of language space in a speech prosthesis system is essential to its effectiveness in terms of fluency and articulateness and the cognitive and intellectual demands made on the user. We describe several systems, representative of various levels of linguistic structures, which we have implemented in the Artificial Language Laboratory.

CATEGORY:	INTENDED USER GROUP:
Device Development <input checked="" type="checkbox"/>	Non-speaking
Research Study <input type="checkbox"/>	AVAILABILITY OF DEVICE:
STATE OF DEVELOPMENT:	Systems available on limited basis
Prototype <input type="checkbox"/>	AVAILABILITY OF CONSTRUCTIONAL DETAILS:
Clinical Testing <input checked="" type="checkbox"/>	Available
Production <input type="checkbox"/>	FOR FURTHER INFORMATION CONTACT: Mgr., Information Dissemination, Artificial Language Laboratory, Computer Science Department, Michigan State University, East Lansing, Michigan 48824
AVAILABLE FOR SALE:	
Yes <input type="checkbox"/> No <input checked="" type="checkbox"/>	
Price:	

### Introduction

In this paper we describe the work going on at the Artificial Language Laboratory at Michigan State University on the development of practical speech prostheses utilizing computers and speech synthesizers.

Our emphasis will be on the linguistic considerations which are central to the proper design and utilization of any communication enhancement system. Detailed technical descriptions of individual devices mentioned here appear elsewhere [1].

The objective of our effort has been to provide aids to those thousands of human beings who cannot command their bodies to produce the socially demanded patterns of the spoken word and the written word. Such individuals have always been excluded quite forcibly from participation in society. This exclusion, based solely on the bio-technological criterion of speech-based communication, is a burden which diminishes the quality of life for non-speakers and those who would interact with them. Recent attempts at many schools and institutions to include these individuals into the mainstream of activities have confronted

these institutions with a challenge which can be met only through the development of programs for the proper transfer of advanced technology [2].

The invention of writing did to a considerable extent provide humans with an alternative to speech which allowed the speechless at least limited access to the community of speakers. By providing a graphic representation of language space, writing gave persons physically unable to speak a means of expressing their thoughts to others. The technology of writing, however, has never been accessible to all non-speakers, either for socio-economic reasons or because of the dexterity required by writing instruments.

Modern technology now allows us to define and explore new mesotics [3] beyond speech and writing. Generalizing from current knowledge of human linguistic competence, we have defined language spaces appropriate to individuals with varying physical capabilities.

### Basic Linguistic Concepts

We distinguish between speech, the system which humans traditionally produce with the organs of the vocal tract, and language, the system of correspondence between human thought structures and their various physical embodiments, of which speech is but one.

By language space, we refer to a structured representation of linguistic elements and their relationships. Much of the content of modern theoretical linguistics has been concerned with the elucidation of such representations of human language for the purpose of explaining the phenomena of diachronic (historical) change, dialectical variation, first and second language acquisition, and synchronic constraints on grammatical and phonological well-formedness. In recent years, the availability of relatively inexpensive digitally driven voice synthesizers and advances in bioelectronics have challenged the field of rehabilitation engineering to consider the concept of language space from an entirely novel perspective: the design of practical speech prostheses.

#### Talking to the Blind versus Talking for the Speechless

Our efforts at the Artificial Language Laboratory in developing talking computer systems began with applications for the blind computer user. It was relatively easy to find ways in which a synthetic voice could be of immediate benefit to the blind. Besides our Laboratory, a number of centers have been active in this area, including Haskins Laboratory and M.I.T., where much of the pioneering work was accomplished. Both as an aid to interactive computing and as the output of reading machines, voice synthesizers are today starting to have a positive impact on expanding educational and vocational opportunities [4]. Manufacturing firms, sometimes with federal subsidy, have also become involved in delivering this talking technology to the blind consumer. As a result, talking calculators with limited vocabulary, using ROM-stored digitized speech, and a reading machine using an optical character recognition input device and a voice synthesizer under minicomputer control, are now commercially available and in use by growing numbers of blind persons.

Except for some obvious areas of commonality, the problems of designing a talking machine for a person who cannot speak are strikingly different from those encountered in designing a talking machine for the blind. First, the criteria of portability and intelligibility to strangers are more important, since the speech prosthesis is more closely linked psychologically to the user's own personality than is a reading machine or talking calculator. Second, a speech prosthesis demands much more active involvement on the part of the user,

who must constantly make choices about what to say and how to say it. Third, the non-speaking population includes many more who experience limited motoric ability, rendering standard keyboards impractical as input devices.

#### Evaluative Criteria for Speech Prosthesis

The success of a speech prosthesis can be measured by the degree to which it gives the user the freedom to express what he or she wishes to express. In practice, this freedom is constrained by a trade-off between articulateness and fluency. By "articulateness" we mean the precision with which linguistic units can be chosen, while by "fluency" we mean the rate at which a given utterance can be delivered to a listener. Typical speakers within any speech community vary, of course, in their articulateness and fluency, but each speech community establishes tolerances for these characteristics with respect to which people are classed as "normal" or "handicapped". An effective speech prosthesis is one which will bring the user within the accepted limits of normal articulateness and fluency, or at least significantly closer to these limits than he or she can attain without it. As in the case of barrier-free design of buildings, the attitudes and expectations of society with respect to the acceptability of prosthesis-aided speech are subject to modification by appropriate educational efforts. The successful utilization of a speech prosthesis therefore depends on the willingness of the general public to accept prosthetic speech. The most ingeniously designed vocal communication aid may disappoint its user if other people are not willing to listen.

It is also important that any prosthetic device should be cosmetically acceptable both from the standpoint of the psychological effect on the user and from that of facilitating social acceptance.

#### State of Technology

The development of microprocessor technology has been as important to the development of speech prostheses as has been the availability of voice synthesizers. The same technological revolution that has given us talking computers has also given us the means to produce dynamic displays capable of graphic outputs. This development allows the designer to incorporate flexible visual displays of language space and to experiment with various approaches to the user interface.

The technological developments of interest have several properties in common:

1. The cost of equipment is decreasing
2. The size and power requirements of equipment are decreasing
3. The capacity and flexibility is increasing
4. Programming-Language interfaces are becoming more human-oriented

### Linguistic Levels Accessed by Communication Aids

One of the fundamental insights of linguistics is that human language is structured at several levels. Language has syntactic, semantic, and phonological structure. All of these levels are represented in some way in the orthographic (writing) systems which have evolved. A look at communication boards in current use by non-vocal individuals reveals that all these levels have been invoked in an attempt to facilitate communication. At the semantic level, pictographic representations, whether ideosyncratic or systematized, such as Blissymbolics, are used to help the non-literate or pre-literate to express ideas where the orthographic image is too complex. Syntactic information is also

used in many boards to arrange words according to grammatical category: one column for nouns, another for verbs. The phonological level is represented by the letters of the alphabet, which approximate the phonetic units of language.

The many varieties of communication boards have this in common: they are all representations of language space. They are two-dimensional lay-outs of symbols for linguistic elements: letters, words, numerals, and ideograms.

In comparing existing language boards to the new generation of communication aids made possible by microprocessor technology, one can perceive a striking contrast. This is evident from the summary of salient features presented in the following table:

Feature	Language Board	Microprocessor-based Speech Prosthesis
1. Retention of utterance as communicated.	None. Depends on the memory and constant attention of the user and interlocutor.	Limited only by cost. Hard (printed copy) and soft (editable video display) available in addition to repeatable speech output.
2. Retention of previously assembled utterances.	None.	Substantial.
3. Accessibility to linguistic units.	Subject to some spatial constraints and limited to small vocabulary of words and symbols.	Essentially unlimited.
4. Incorporation of statistical structure of language to anticipate choices made.	Limited to a few principles of arrangement on a relatively small two-dimensional space.	Allows use of relations defined in many dimensions.
5. Multiple Page Access	None, except by use of multiple overlays which must be manually installed by someone else.	Substantial, limited only by memory available.
6. User programmability.	None.	Substantial.
7. Ease of teaching use.	Relatively simple.	Various levels of difficulty, subject to user interface language.
8. Cost.	Extremely low.	High limited cost.
9. Availability.	High, can be constructed by parents, teachers, or therapists with simple materials.	Restricted by access to money and expertise.

The cost and availability of communication aids will be the determining factors in the choice of such aids for the next few years. However, the rapid decrease in cost and increasing demand for effectiveness will, we feel, make the use of computer-based aids indispensable in the 1980's.

#### Examples of Systems for Speech Prosthesis

In the following paragraphs, we will describe a number of devices which we have implemented to access different levels of linguistic structure. ORTHOPHONE allows the user to operate at the level of English orthography, which is part phonetic, part morphemic. MNEMONOPHONE allows the user to access language by means of ideographic symbols of his own creation, usually a mnemonic abbreviation representing a phrase or sentence. SAY-ME-SCROLL gives the user access to a spatial arrangement of words through a dynamic display window. BABBLEBOARD lets the user range through an external representation of articulatory phonetic space.

These devices exemplify principles of language space arrangement which can be combined in multi-level communication aids suitable to the requirements of individual users. We are working to identify the appropriateness of each level to various communication tasks. Out of this work we hope to be able to determine the most effective combinations of language space representations.

ORTHOPHONE is the name of a computer software module that converts an orthographic image to its corresponding phonetic representation for immediate processing by a voice synthesizer. Similar computer programs have been developed at other centers [5]. The user enters the spelled words into the computer by means of a keyboard or adaptive input device, such as an alphabetic scanner, and the computer speaks it out. This method of speech prosthesis directly utilizes the language space defined by the orthography, and requires spelling ability on the part of the user. It allows a high level of articulateness, but subjects fluency to the constraints of the user's motoric ability. Intelligibility is dependent on the algorithm used to assign phonetic values to letters and letter combinations. For standard English orthography, the number of rules and exceptions which must be accounted for in such an algorithm is very large, and homographs (e.g. read [riyd], [red]) can never be entirely disambiguated. Variations in pitch contour and vowel length--so-called "suprasegmentals" are not adequately represented in the orthography of any language, and thus a strict orthographic-to-phonetic converter cannot by itself cover the range of expressiveness found in biological speech.

Greater control over expressiveness is attainable by using a phonetic-based orthography, especially one which contains symbols for specifying suprasegmentals. Phonetic notations, however, typically require longer strings of symbols than do standard orthographies, thus further retarding fluency. The added burden of learning a phonetic notation may or may not be a drawback, depending on the intellectual level and motivation of the user.

A potentially fruitful line of research is the exploration of analogic transpositions of articulatory phonetic space from the musculature of the vocal tract to more readily controlled sets of muscles. We are using myoelectric pick ups on the extremities and face as inputs to a computer model of the vocal tract. By training with auditory feedback, some individuals seem to be able to learn to associate particular "body dances" with the phonetic result. Although still in the experimental stage, this technique promises to give a direct channel from mental sound image to its acoustic representation. BABBLEBOARD is an implementation of a projection of English phonetic space onto the two-dimensional surface of a Graf/Pen tablet. The user moves a digitizing pen around on this surface to produce an utterance.

The SAY-ME-SCROLL is a system which extends the principle of conventional language boards by means of a microprocessor, TV display, and voice synthesizer. It was designed for use by individuals who can control a joy stick such as found on many electric wheel chairs. Just as a wheel chair user steers the chair along passageways and around corners, the operator of the SAY-ME-SCROLL directs the movement of a cursor within the display area of the video screen. On the right side of the screen is a vertical list of words and phrases. By putting the cursor in the control areas marked UP and DOWN, the operator causes the list to scroll respectively upwards or downwards. Pushing the cursor all the way up or down results in accelerating the movement of the list, while letting the cursor rest in the neutral area between the UP and DOWN control areas causes the list to remain stationary. When the desired word has been brought to the center of the display, a rightward movement of the cursor from the control section onto the list brings the word into a memory buffer. Moving the cursor back into the UP and DOWN areas causes the list to scroll again. In this way, words and phrases can be assembled into sentences. When the operator wishes to have an assembled sentence spoken out, he places the cursor into the SAY area. In a similar manner, the user can cause the assembled utterance to be printed out on a printer. A Backspace function is also provided for removing words from the buffer on a last-in-first-out basis. The buffer retains its contents until emptied by the clear function. A word-count numeral is displayed so the operator can keep track of the size of the buffer.

The SAY-ME-SCROLL has been implemented on a Motorola M6800 microprocessor, using a VOTRAX VS-6 voice synthesizer. The control program uses 256 words of RAM and 2K words of ROM. The vocabulary, containing orthographic and phonetic images of approximately 200 words, is held in 4K of ROM. The vocabulary may easily be expanded to several thousands words. A similar system, SWITCH-AND-SAY, uses a single switch input to access vocabulary items off a scroll.

The one-dimensional circular scrolls in these devices are subject to the limitations of any serial access memory structure. A second-generation SAY-ME-SCROLL now under development will use a paging feature to allow the user to go more directly to a desired vocabulary item. Since letters of the alphabet and phones are provided as accessible units of an output string, the user can produce novel utterances not already pre-coded on the scroll. An area of RAM memory is available for retaining such user-programmed vocabulary items on the scroll for future use.

MNEMONOPHONE is a software package which enables the user to access pre-coded utterances by means of short mnemonics. The main program allows the user to define situation sets of up to several hundred entries (words, phrases, or sentences) each, associating every entry with a mnemonic chosen by the user. Each such situation set may relate to a certain type of communication experience. An example is the set used to order a pizza by telephone, where the mnemonic "ID" stands for the utterance entry "I'd like to order a pizza", and where "PM" stands for the entry "pepperoni and mushrooms" [6]. The meaning of a given mnemonic is defined locally within each set, so that the same mnemonic can be used in another situation set to evoke a different utterance.

The MNEMONOPHONE principle maximizes fluency while restricting articulateness. To the extent, however, that the utterance requirements of regular human social interactions can be anticipated and scripted in advance, the limited number of immediately available utterances need not be a serious problem. For a discussion of a similar implementation, see the work of Kenneth M. Colby and his associates at UCLA [7].

### Conclusion

The ease with which microprocessor technology lends itself to portable dynamic displays will bring about a new generation of computerized "language boards" providing windows onto portions of language space. The manner in which this language space is represented will be crucial to the effectiveness of such devices to provide the user with the maximum measure of fluency and articulateness.

### Acknowledgements

The work described here received partial support from Wayne County and Jackson County Intermediate School Districts in Michigan. We wish to acknowledge the equipment support received from Federal Screw Works Company, Troy, Michigan, Science Accessories Corporation, Southport, Connecticut, and Electronic Products Associates, San Diego, California. We also acknowledge the collaboration of J.J. Jackson, Linda Chadderdon, Rochelle Danjuma, Gregory Turner, Steven Kludt, Eric Dilks, Kenneth Kawamura, Douglas E. Appelt, Hans Lee, James Renuk, Avi Assor, Donald Sherman, Mark Musial, Juha Koljonen, Joseph Gehman, Richard Carling, Harry Hedges, John Forsyth, Carl Page, Kathy Skinner, Marge Easto, Carol Summers, Jean Budde, Linda Gillum, Lucylee Neiswander, Tim Oren, Michael Bonkowski, Karen Gladstone, Richard Roppel, Oscar Tosi, Connie Supal, Mark Greenwald, Patricia Bainbridge, David Dwyer, and Carol Scotton.

### References

1. Technical reports describing the systems mentioned in this paper are available from the Artificial Language Laboratory Computer Science Department, Michigan State University, East Lansing, Michigan 48824.
2. Vd. Neiswander, L., Eulenberg, J.B., and Rahimi, M.A., "Administration and Management of a Computer-Based Communication Program", Annual Meeting of the American Academy for Cerebral Palsy and Developmental Medicine, October 5-9, 1977, Atlanta, Georgia, to appear.
3. The term mesotic, due to Larry Grandin, refers to "the means by which linguistic communication is transmitted from encoder to decoder". Cf. Marc L. Schnitzer, "The Role of Phonology in Linguistic Communication: Some Neurolinguistic Considerations", Chapter 4, Studies in Neurolinguistics, Volume 1, edited by Haiganoosh Whitaker and Harry A. Whitaker, Academic Press, Inc., New York, 1976, p. 140.
4. The Artificial Language Laboratory participated in 1975-76 with the U.S. Civil Service Commission and the Rehabilitation Services Administration in the Projects With Industry program of Arkansas Enterprises for the Blind to provide software and hardware development and training of personnel in the use of a talking computer system for use by both blind and sighted Civil Service Commission employees. The system uses a Votrax VS-6 voice synthesizer and provides real-time voice interactive capability. A reading machine developed by Kurzweil Computer Products, Inc., Cambridge, is currently testing its reading machine in schools and places of employment. Voice output for the Kurzweil system is also based on a Votrax synthesizer.

5. Cf. H.S. Elovitz et al., "Automatic Translation of English Text to Phonetics by Means of Letter-to-Sound Rules," Naval Research Laboratory Report 7948, Jan. 21, 1976; and M. Douglas McIlroy, "Synthetic English Speech by Rule", Bell Telephone Laboratories, March 1974.

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7. Colby, Kenneth Mark, Daniel Christinaz, and Santiago Graham, Jr., "A Personal, Portable and Intelligent Speech Prosthesis", Memo ALHMF-9, Algorithmic Laboratory of Higher Mental Functions, UCLA Department of Psychiatry, University of California School of Medicine, Los Angeles, California 90024; To appear in Brain and Language.

## SESSION D THURSDAY, JUNE 2

- D-1            EVALUATION & DESIGN CONSIDERATIONS  
FOR POWERED RECLINING WHEELCHAIRS  
C.G. WARREN & M. KO  
UNIV. OF WASHINGTON, REHAB. MEDICINE            P. 117
- D-2            HEAD AND BREATH CONTROLLED WHEELCHAIR  
FOR A HIGH LEVEL QUADRIPLÉGIC  
J. LEGAL, MANITOBA CANCER FOUNDATION  
N. PETELESKI, REHAB. ENG. WINNIPEG            P. 121
- D-3            TONGUE OPERATION OF A PROPORTIONAL  
CONTROL ELECTRIC WHEELCHAIR  
R.W. STOW, DEPT. OF PHYS. MEDICINE  
OHIO STATE UNIVERSITY, COLUMBUS            P. 126
- D-4            MODIFICATION OF E & J WHEELCHAIR  
CONTROL TO SEPARATE SPEED-STEERING  
J.L. COCKRELL & W. J. NELSON  
UNIV. OF MICHIGAN MEDICAL CENTER            P. 129
- D-5            SPEECH RECOGNITION AND CONTROL - A  
VIABLE AID TO PHYSICALLY DISABLED  
J. CLARK & R.B. ROEMER  
UNIV. OF CALIFORNIA, SANTA BARBARA            P. 132
- D-6            CURRENT STATE OF DEVELOPMENT AND  
TESTING OF AN OCULAR CONTROL DEVICE  
G.A. RINARD & D.E. RUGG, UNIV. OF  
DENVER, ELECTRONICS DIVISION            P. 139
- D-7            BREATH/VOICE CONTROLLED WHEELCHAIR  
PART 1 - EVALUATION AND TESTING  
M. ZIMMERMAN, STRATFORD & SELL  
NEW YORK UNIV. INST. REHAB. MEDICINE            P. 143
- D-8            BREATH/VOICE CONTROLLED WHEELCHAIR  
PART 2 - WHEELCHAIR CONTROL DESIGN  
M. YODIN, CLAGMAZ, LOUIE & SELL  
NEW YORK UNIV., INST. REHAB. MEDICINE            P. 147

## EVALUATION AND DESIGN CONSIDERATIONS FOR POWERED RECLINING WHEELCHAIRS

C. G. Warren  
M. J. Ko  
J. V. Imre

Department of Rehab. Medicine  
H.S.B. BB-805 RJ-30  
University Hospital  
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The severely paralyzed person uses a reclining wheelchair to allow him to alleviate pressure and to rest during his daily activities. Repeated cycling of reclining wheelchairs frequently causes shifting of the body segments in the chair, wrinkling of clothing and areas of pressure concentration. A modified reclining mechanism was evaluated which more closely aligns the axes of recline with the axes of rotation of the human body. This was found to produce significantly less displacement in the chair and significantly smaller residual shear forces after recline. Further study will attempt to determine optimal locations for the chair axes of rotation in relation to the trunk geometry of individual subjects.

CATEGORY:	INTENDED USER GROUP: Quadriplegic and/or severely paralyzed persons who require a reclining wheelchair for functional independence
Device Development <input checked="" type="checkbox"/>	AVAILABILITY OF DEVICE: Not presently available
Research Study <input type="checkbox"/>	
STATE OF DEVELOPMENT:	AVAILABILITY OF CONSTRUCTIONAL DETAILS: A technical bulletin will be prepared when the design is finalized
Prototype <input checked="" type="checkbox"/>	
Clinical Testing <input type="checkbox"/>	
Production <input type="checkbox"/>	
AVAILABLE FOR SALE:	FOR FURTHER INFORMATION CONTACT: Authors
Yes <input type="checkbox"/> No <input checked="" type="checkbox"/>	
Price:	

## Introduction

People who are quadriplegic or severely paralyzed often require a reclining wheelchair to be able to function for significant periods of time. They must frequently cycle to a reclining position to lessen the pressure distribution on their trunk and thighs and to rest the residual stabilizing and respiratory musculature. Many people using currently available powered reclining wheelchairs complain about problems encountered with repeated cycling of the chairs: it causes shifts in their body segments which may require them to be repositioned in the chair, and it causes wrinkling and bunching of clothing which causes areas of pressure concentration (See Fig. 1). These problems are likely the result of the difference in alignment between the axes of rotation of the chair and those of the body. This discrepancy theoretically causes relative motion between the body and the elements of the chair, and if motion does not occur, shear forces will be present. Many persons require straps to hold them in their wheelchairs, and the forces produced by the restraint of these straps during recline must be taken up in the body.

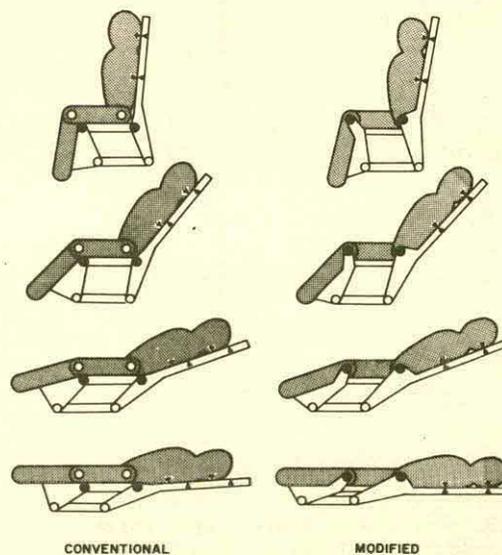


Figure 1 Conventional vs Modified Recline

## Methodology

Strain gauge instrumentation was developed to measure the shear forces between a patient's trunk and the back of his wheelchair. The instrumentation was applied both to the conventional reclining wheelchair mechanism and to a modified reclining wheelchair mechanism where the axes of rotation were moved to coincide more closely with those of the body. The axis of rotation on the modified design was placed 3" anterior and 3" superior to that of the conventional design. The strain gauge transducers measured the axial force applied to the back of the chair, and a potentiometer measured the angle of the back of the chair with respect to the horizontal. A marker on the body indicated displacement with respect to a grid on the back of a chair. Data was taken using a data acquisition system which was synchronized with a motor drive 35mm motion picture camera which made the displacement measurements.

Quadriplegic persons were seated in the wheelchairs and were positioned until they were satisfied that they were in a comfortable and normal position for them. The original position being similar in either chair. Shear force and displacement were then measured during descent from 80° to 5° from the horizontal and during ascent back to 80°. Comparisons of shear and displacement were made between the conventional and modified chairs. A block diagram of the test set-up is shown in Figure 2.

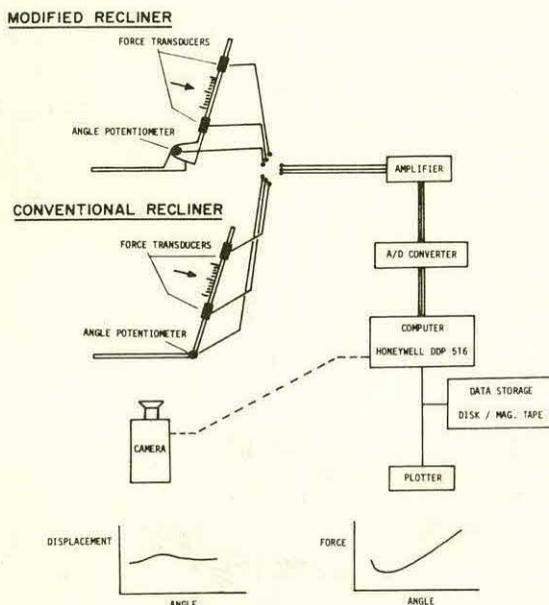


Figure 2 Data Acquisition System

The subjects for the evaluation were three quadriplegic persons (See Table 1). Each subject tested sat in the chair on a 4 inch foam pad. When they were positioned to their satisfaction in comfort and balance, the chair was reclined manually at a rate of 15° per second, which meant

SUBJECT	MOTOR LESION LEVEL	HEIGHT	WEIGHT
A	C7	6'0"	170#
B	C6-7	6'4"	165#
C	C5	6'0"	150#

Table 1 Subjects Used in Evaluation

the reclining or evaluating phase took five seconds in each direction. Four sets of measurements were taken with the subject being repositioned after each recline and evaluation. A set of data was taken for two conditions on each chair configuration, one with the knees restrained to eliminate motion of the buttock and lower limbs and the other with no restraint.

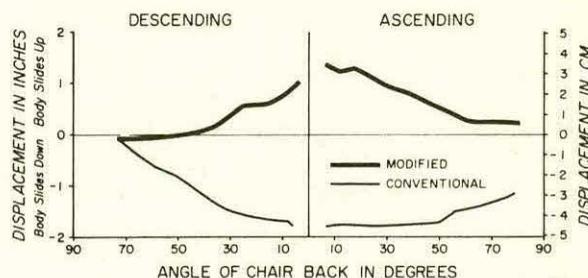


Figure 3 Body Displacement Without Knee Restraints

Figure 3 shows the displacement of the body with respect to each of the chairs when knee restraints were not used. This is a representative curve of the average of 4 runs for one of the subjects. As predicted in the model, the displacement found in the conventional chair was negative, the body sliding down on the chair during recline approximately 4 1/2 cm. In the modified chair there was some displacement, however it was in the opposite direction and occurred when the chair was close to the horizontal position, well beyond 30°, and was positive indicating that the body was moving upward slightly in the chair. In the ascending phase, gravity allows the trunk to come back down to within 0.5 cm. of its starting position in the modified chair. However in the conventional chair there was a residual displacement of approximately 3 cm. Figure 4 shows the displacement of the body with the knees restrained. Under these conditions the displacement of the body was of the same order of magnitude in the modified chair, again the displacement occurring as the body approached the horizontal position. In the conventional chair there was a slight increase in the range of displacement with the knees restrained, however there was less residual displacement after the cycle was complete.

Figure 5 shows the shear force between the body and the chair without knee restraints. The curves begin with the chair back vertical and a force in the negative direction on the chair due to gravity. During descent in the conventional

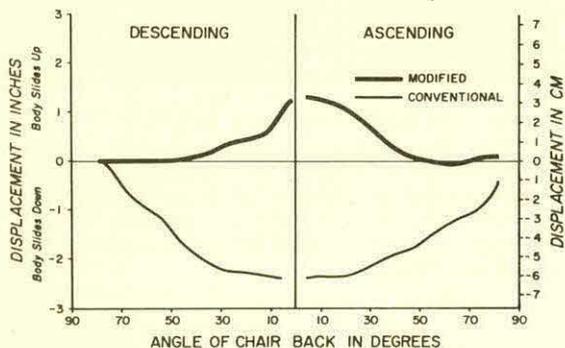


Figure 4 Body Displacement With Knee Restraints

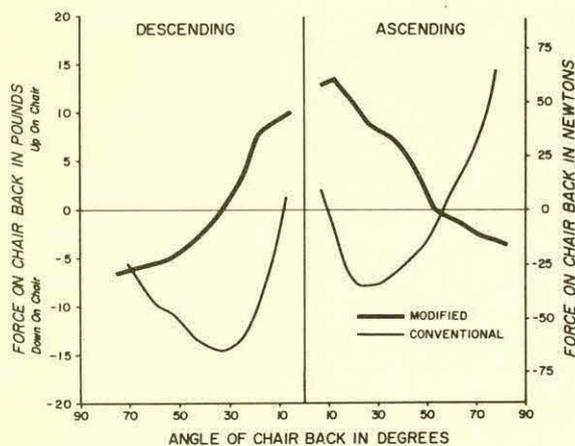


Figure 5 Shear Force Without Knee Restraints

chair, the body is pulled down causing an increasing negative force until the horizontal position is approached and the force relaxes to zero. During ascent, the opposite occurs as the body is pushed back up the chair towards its original starting position, resulting in a large residual force after completion of the cycle. In the modified chair the body tended to move with the chair, resulting in a smoother curve with fewer inflection points and a small residual force after completion of the cycle.

Figure 6 shows the shear force with knee restraints. Under these conditions, the force curves retained the same basic shape, however the order of magnitude of the forces increased, and in the conventional chair where knee restraints are commonly used to attempt to limit displacement, a large residual force was again produced. This residual force must be resolved through a combination of elastic deformation of the body tissues, motion of the body, and shifting of clothing.

The critical issues then are residual displacement and residual shear forces. The average forces which must be resolved and the average residual displacement in the conventional modified chair for each of the three subjects are shown in Tables 2 and 3. We found that the residual forces to be resolved ranged from 1.7 to 9 times greater in the conventional chair than in the

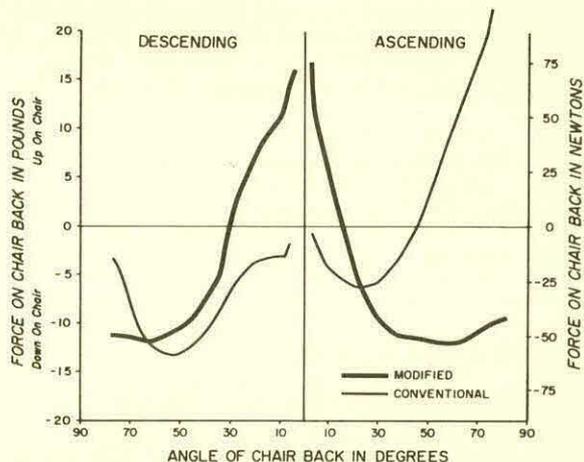


Figure 6 Shear Force With Knee Restraints

modified chair. Displacement ranged from 1 1/2 to 3 or almost 4 times greater in the conventional chair. When knee restraints were used, the forces to be resolved ranged from 2 1/2 to 21 times greater in the conventional chair, and the displacement ranged from 1.6 to 4 times greater.

	Subject	Conventional	Modified	Ratio Conv./Mod.
Δ Force (nt.)	A	58.3	16.5	3.5
	B	40.9	23.6	1.7
	C	61.4	6.7	9.2
Δ Displacement (cm.)	A	3.0	0.8	3.8
	B	3.0	2.0	1.5
	C	2.3	0.8	2.9

Table 2 Force & Displacement Data Without Knee Restraints

	Subject	Conventional	Modified	Ratio Conv./Mod.
Δ Force (nt.)	A	133.0	6.2	21.5
	B	55.6	23.1	2.4
	C	102.3	6.7	15.3
Δ Displacement (cm.)	A	1.5	0.5	3.0
	B	0.8	0.5	1.6
	C	2.0	0.5	4.0

Table 3 Force & Displacement Data With Knee Restraints

### Conclusions

The findings demonstrate that relocating the axis of rotation of the wheelchair 3 inches anterior and 3 inches higher on the chair significantly reduced displacement and shear forces between the chair and body. It was also found that there is some variability between the subjects which is likely due to body geometry (i.e. length of the limb segments and thickness of the trunk segment). These dimensions determine how closely

the axis of rotation of the chair approximates that of the body. Experiments were conducted with and without the knee restraints commonly used to hold a quadriplegic or severely disabled person in a wheelchair. Without the knee restraints, the relocation of the axis of the chair reduced the residual shear force produced by a recline cycle from 2 to 9 times and reduced the displacement from 1.5 to 3.8 times. With the use of knee restraints, the residual force interaction was reduced between 2.5 and 21.5 times. The displacement was reduced between 1.6 and 4.0 times. The conclusions can be summarized as follows:

For the conventional reclining wheelchair

1. while descending, the body slides downward with respect to the chair back.
2. while ascending, the body attempts to slide up the chair to its original position.
3. while ascending, the residual shear force produced is augmented as the chair resists the body's attempt to rise.

For the modified chair

1. while descending, the body remains stationary with respect to the chair until nearly fully reclined, when it moves slightly upward.
2. while ascending, the effect of gravity causes the body to return to its original position.
3. the residual shear forces are resolved to a greater degree since the chair mechanics and gravity tend to move the body back to its original position.

Conclusions of the study were

1. attempting to align the axis of rotation of the chair with that of the body significantly decreases both the displacement of the body and the residual shear force.
2. the use of restraints with the conventional chair increases the trunk displacement and causes considerably higher residual shear forces.
3. the use of restraints with the modified chair eliminates residual displacement and further reduces the residual shear forces.

These findings indicate that further definition of the axis of rotation of the chair must be made and is being conducted at this time. A mechanism is being developed which will allow the axis of rotation to be adjusted so that evaluation with patients can be conducted to determine the optimal location of this axis. This is necessary because it is evident from the data that considerable variability does exist; and at this point, the variability has not been directly correlated with optimum axis location with respect to body axis.

It is somewhat evident that the position or series of positions for optimal axis placement will probably be within the space through which the person must move his body when transferring from the chair. To avoid interference with transfer activities, we plan to design a mechanical linkage which will allow us to locate the recline mechanism out of the way of transfer activities while placing the axis of rotation in the region necessary for accomplishing reduced shear and displacement.

A POWERED WHEELCHAIR FOR A HIGH LEVEL QUADRIPLÉGIC INCORPORATING  
HEAD AND BREATH CONTROL AND A RESPIRATORY SUPPORT SYSTEM

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Abstract

A fourteen year old boy suffered a spinal cord injury at the C1-C2 level in an accident several years ago leaving him totally immobile from the neck down and totally dependent on a respirator. Self mobility being an important consideration, a wheelchair suitable for his needs was developed at this centre. This paper discusses aspects of the design of the wheelchair including patient interface, respiratory system, seating, control of accessories, safety and the incorporation of these features into a compact mobile unit. The result is a unique wheelchair that has given this individual considerable mobility and independence.

CATEGORY:	INTENDED USER GROUP: High Level Quadriplegics
Device Development <input checked="" type="checkbox"/>	
Research Study <input type="checkbox"/>	AVAILABILITY OF DEVICE: Not Available
STATE OF DEVELOPMENT:	
Prototype <input type="checkbox"/>	AVAILABILITY OF CONSTRUCTIONAL DETAILS: Limited
Clinical Testing <input checked="" type="checkbox"/>	
Production <input type="checkbox"/>	
AVAILABLE FOR SALE:	FOR FURTHER INFORMATION CONTACT: Above Authors
Yes <input type="checkbox"/> No <input checked="" type="checkbox"/>	
Price:	

Introduction

The possibility of self mobility for Kevin, a quadriplegic patient totally dependent on a respirator, evolved over a period of time as various aids were being adapted to suit his needs. Kevin now 14 years old was involved in an accident six years ago that virtually severed his spinal cord at the C1-C2 level. Despite this severe impairment he became proficient at using chin and head movement to operate several devices, but his remarkable skill in operating a toy road racing set was most impressive. If Kevin, by means of a breath-operated proportional pressure transducer, could control the precise speed of a toy car, perhaps one day he might be able to drive his own vehicle.

A commercial powered chair designed for the quadriplegic (1) was tried but was not suitable. Similarly, a new head control (2) and improved chin control (3), successfully used at our centre could not be adapted. It became apparent that a wheelchair designed with Kevin's special needs in mind was required. No suitable

chair was available commercially, so it was decided to design and build one here (Fig. 1). The multi-disciplinary team that evolved to carry out this project consisted of medical and technical personnel from the Physics Department - Cancer Centre, Rehabilitation Engineering Department and Intensive Care Unit of the Health Sciences Centre.

Patient interface

The most challenging aspect of designing mobility aids for the severely disabled is the interface between patient and machine. General considerations that we felt were important before proceeding with the interface design involved safety and simple operation.

To ensure fail-safe operation, no patient action should be required to cease the chair's motion. The number of controls, their adjustments and reproducibility must be kept simple to minimize the technical expertise required by the attendant, for example the tedious application of skin electrodes, optics and any switches that require fixation to the



Fig. 1. Kevin in his wheelchair

patient. With less severely handicapped people the control possibilities are quite extensive but with Kevin the choices were restricted. Brief consideration was given to tongue, sight, sonic operated switches and transducers (4,5) but these were judged unsuitable.

A head operated typewriter, although not totally successful, indicated that Kevin had precise head control in at least two directions but his neck muscles were extremely weak. In a sitting position he could not support his head unassisted. His range was severely restricted with lateral flexion-extension virtually non-existent, but he could rotate his head and nod slightly. Rather than adding controls in proximity to a

head rest, an articulating head support was designed that rotates through two axes. These axes intersect through a point in space that closely corresponds with the center of his head. This gimballed arrangement is virtually friction free (due to ball bearing pivots) enabling Kevin to rotate and nod his head for long periods with very little effort. Potentiometers, mechanically coupled to the two motions of this head support, were used during an initial training period to produce a visual display on an oscilloscope. It was felt that control of the nodding axis would be difficult while driving, particularly on rough and bumpy surfaces and, therefore, the nodding axis was temporarily locked.

Rotational head movement, although limited in Kevin's case to approximately  $\pm 20$  degrees, proved to be better than anticipated for the proportional steering of the wheelchair. It was now felt that an intimate coupling between Kevin's head and the articulating controller would be required, but following experiments with adjustable head bands and snug fitting cushioning about the temples, we found that a loose fitting "U" shaped headrest worked well and provided him with the added freedom to change the position of his head relative to the headrest to suit his comfort. A soft detent to indicate the null position keeps the wheelchair steering in a straight line.

Because of the patient's severe impairment it was decided that simultaneous control rather than sequential control of two axes was necessary (6). More recent work has shown that a near maximum performance capability is attained by quadriplegic subjects utilizing state-of-the-art two axis controllers (7). Other work indicates that breath control of a powered wheelchair is practical (8,9).

Further investigation with a breath-operated proportional control proved conclusively that positive pressure would make a very functional velocity control. Negative pressure (sip) is used only for selecting forward, reverse and initiating a scanner system for selecting accessories. The angular displacement signal from head rotation is used for proportional steering control. Kevin is free to rotate his head support when the chair is stationary. Positive (blow) pressure is required to initiate motion, increasing pressure to accelerate, and sustained pressure to maintain velocity.

While the concept of sustaining breath pressure to maintain motion assures a realistic fail-safe feature, we had doubts about Kevin's ability to comply with this requirement. Like many other initial concerns this presented no difficulty to Kevin. He quickly learned to sustain pressure by placing his tongue over the mouthpiece after attaining the desired speed. However, this type of control may prove too tiring for some patients (10).

In the event of component failure that might initiate or sustain motion of the chair with no breath pressure, a low pressure switch was pneumatically connected in parallel with the proportional air pressure transducer but electrically connected in series with the main power to the motors, providing an added safety feature.

#### Function selector scanner

The scanner is used to select forward reverse and neutral operation of the wheelchair as well as selection of accessories such as a call horn, power seat recliner, and an FM telemetry link to an environmental control.

The scanner combines single step and automatic scanning in a dedicated controller configuration and is operated by the same breath tube used for driving the wheelchair.

Referring to Fig. 2, initially the LED indicators are automatically sequenced. If the pneumatic tube is sipped when indicators "F", "R", or "N" are "on" then sequencing will halt and the wheelchair will be in the "Forward", "Reverse", or "Neutral" mode. Blowing then activates chair motion in the selected direction. Subsequent sipping will cause the display to step within the F-R-N loop making wheelchair maneuvering in tight places easier without having to sequence through the remaining indicators. When "N" is displayed, blowing will cause automatic sequencing to resume. Blow and sip operation can then be used to activate accessories 1 to 5.

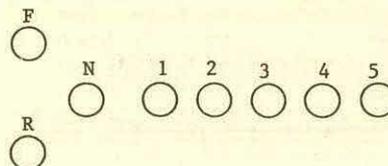


Fig.2. Layout of LED indicators on wheelchair display scanner.

#### Respiration

If Kevin was to be away from the hospital and achieve marginal independence, the most vital requirement which had to be incorporated into the wheelchair was the ventilator and alarm system. Several ventilators, humidifiers and alarms were tried before the wheelchair was considered, so that by the time serious design of the wheelchair began the choice of these components had been narrowed down.

Gas operated ventilators, although reliable, were eliminated as being too heavy and cumbersome. A diaphragm pump type ventilator was also eliminated because of a noise problem which proved too difficult to overcome. The final choice was a "Thompson Bantam" portable ventilator which operates on 12 V.D.C. or line voltage. It has proven very

suitable and reliable but for added safety a bag type resuscitator accompanies the wheelchair at all times. This ventilator enables Kevin to maintain nearly normal speech. A tracheostomy coupling to the ventilator does not interfere excessively with his daily routine.

An automatic switching capability for the ventilator supply was incorporated into the wheelchair circuitry. In the event of a malfunctioning or discharged ventilator battery the ventilator is automatically switched over to the wheelchair battery. A self contained pneumatically activated alarm sounds if for any reason there is a loss of positive pressure in the ventilator circuit.

Dual high rate battery chargers with automatic cutoff are built into the wheelchair. Opto-electronic isolation is used in the charging circuitry to ensure safety.

#### Seating

Seating was one of our greatest concerns. Kevin had by now become very flaccid, muscles had atrophied, scoliosis was developing and despite conscientious daily care given him, bedsores were a constant threat. Some consideration was given to an articulating seating arrangement that would hinge at the knees and hips. We thought this feature might be useful in that it would allow Kevin to sit nearly upright while driving and recline to a flat position while resting. From experience gained with our standing and reclining wheelchairs (11,12), orthotists advised against this type of seating for two reasons. Firstly, it was felt the transitory stage between sitting and reclining would create a shearing action that might be too much for Kevin's sensitive skin. Secondly, only limited support could be built into this type of articulating seat. As mentioned previously, scoliosis was developing and if we were to prevent this condition from worsening, considerable lateral support would be required.

A vacuum bag impression of Kevin's body was used to fabricate a one-piece fibreglass seat with minimal cushioning that extended from neck to toes. It was contoured to a semi reclining position for weight distribution over as large an area as possible while keeping in mind that an upright sitting position is more practical for driving. This compromise is greatly improved by the added feature that the seat can be angularly adjusted by means of a motor driven mechanism enabling the patient to rotate the seat through approximately 24°. This compact mechanism consists of 2 arc shaped tracks riding on rollers. The spatial axis of these arcs corresponds closely with the

patient's center of gravity resulting in a nearly balanced load. A single automotive accessory motor coupled through a unique timing belt configuration transmits adequate torque to rotate the seat. For more flexibility and servicing of the wheelchair, the fibreglass seat can be decoupled and removed in seconds, then placed into a standard collapsible chair adapted to accept this seat.

#### Mechanical considerations

From broad and basic requirements proposed early in the design phase we had progressed to firmer and more detailed concepts of what was physically required. We now knew the chair would have to accommodate a controlled ventilator, alarm, humidifier, contoured fibreglass seat, recliner mechanism, head control, breath control, scanner display, 2 electronic modules, 2 drive motors, 2 automotive type batteries, dual battery chargers, and emergency bag type resuscitator. All these components were fitted into a rigid chassis no larger than a conventional powered chair. A rigid rather than a conventional flexible chassis gave us the freedom to arrange the components very compactly but it also meant that a suspension system was required. An independent telescoping front suspension maintains 4 wheel contact over rough uneven surfaces. The rear wheels mounted firmly to the frame have low pressure tires providing a smooth ride and excellent traction. The front wheels are free swivelling pneumatic casters. Weight distribution proved quite critical. Maximum weight over the rear drive wheels was required for good traction while too little weight on the front impaired steering under certain conditions. The chair employs conventional drive consisting of 2 independent motors coupled to the rear wheels via toothed timing belts to ensure positive torque. Free wheeling for manually pushing the cart required release clutches between the drive motors and the wheels. Other refinements include bumpers, parking brakes, limit wheels to assist in curb climbing and anchors for securing the chair to the school van.

Size: 23.5" wide, 56" long with seat in driving position  
 Weight: 275 lbs. including respiratory support system and batteries  
 Weight distribution front to rear: 1:4  
 Speed: 3 - 4 m.p.h.  
 Range: 7 - 10 miles  
 Controller: simultaneous, proportional two axis  
 Drive: E. & J. Model 33  
 Batteries: 2 automotive type 90 amp. hrs.  
 Frame: 3/4" square steel tubing, all joints T.I.G. welded  
 Wheelbase: 18"  
 Front wheels: 8" pneumatic wheelchair casters  
 Rear wheels: 10" pneumatic low pressure

### Conclusion

Kevin enthusiastically became an expert driver within a couple of hours and is able to routinely maneuver in and out of elevators, through narrow doorways and even up the loading ramp of the van that takes him to school. He delights in leading friends through ice and snow, and evidence of dirt in the undercarriage suggests jaunts through mud as well. Although someone familiar with his special needs is never far away, the wheelchair gives Kevin a good measure of freedom and independence, enabling him to associate more fully with his family and friends.

Kevin has contributed to the development of his wheelchair with helpful ideas and criticisms. He confidently has asked for an increase in speed. His neck muscles have strengthened and his range of head motion has improved in the past year due to increased usage. Although the contoured seat provides good support, his scoliosis has actually worsened. Possibly the extra hours he now sits upright has contributed to this problem. Presently his condition is being reviewed.

Improvements that we anticipate in the near future include a new model ventilator called the "Thompson Minilung" which has an extended battery operating time. This unit also includes an improved high-low pneumatic alarm. A low powered 12 V.D.C. centrifugal type humidifier to replace the present line voltage model is currently being tested. To assist Kevin in his school work, a portable scanning tape recorder (Prenke-Romich) will be evaluated. Ultimately, Kevin expects to use the facilities of a computer. His expertise with a T.V. game adapted to the nodding axis of the head control indicates that a combination of three control inputs (namely the 2 axes of head control and breath control) could be used for a computer interface.

We feel that this project has not only been a technical success but has also resulted in a considerably improved quality of life, self dignity and significant rehabilitation of the individual. We hope that the various features of this wheelchair shall be of use in the design of similar systems for high level quadriplegics.

### Acknowledgements

We would like to acknowledge the contributions of every individual who cooperated to make this project a genuine team effort. Special thanks to those directly involved in the design and fabrication of the chair; also consultants from the Health Sciences Centre, Shriners Hospital and The Canadian Paraplegic Association who so freely offered their expertise and advice.

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## TONGUE OPERATION OF A PROPORTIONAL CONTROL ELECTRIC WHEELCHAIR

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The aim in design was to permit full operation of an Everest and Jennings proportional control wheelchair by a quadriplegic with limited neck motion due to arthritis. A tongue operated joystick is the control actuator. The transducer using changes in optical path length rather than sliding contacts greatly reduces the forces and deflections required to provide control signals. These are processed to substitute for the original control signals. Mounted on a swinging arm from the side of the chair, the bite held control box is loosely coupled to the chair reducing transmission of vibration to the head. A microswitch operated motor swings the arm into operating position. Spring return swings the arm away from the operator removes power from motor circuits when the bite on the mouthpiece is released. Testing is complete.

CATEGORY:	INTENDED USER GROUP: Quadriplegics with little or no use of upper extremities
Device Development <input checked="" type="checkbox"/>	
Research Study <input type="checkbox"/>	
STATE OF DEVELOPMENT:	AVAILABILITY OF DEVICE: None at present
Prototype <input checked="" type="checkbox"/>	
Clinical Testing <input type="checkbox"/>	AVAILABILITY OF CONSTRUCTIONAL DETAILS: Available
Production <input type="checkbox"/>	
AVAILABLE FOR SALE:	FOR FURTHER INFORMATION CONTACT: The author
Yes <input type="checkbox"/> No <input checked="" type="checkbox"/>	
Price:	

It is difficult or impossible for persons with severe upper extremity weakness to operate the conventional joystick control for an electric wheelchair. The control to be described was designed to be used by a post-polio quadriplegic with almost no functional upper extremity muscles and with limitations of head movement due to arthritis. An Everest & Jennings (E&J) proportional control chair was available and used in this development.

#### Design considerations

A central feature in the design of a new control was to reduce the force and displacement needed to actuate the control element, the conventional joystick being impossible to move with the tongue. To this end optically rather than mechanically produced signals were chosen. In the new control the joystick principle was retained since its motion and position are conveniently related to the direction and speed of the chair in any maneuver. Also the joystick motion is commonly used and well known for wheelchair control.

To assure precise intentional motion and position of the actuating elements it is necessary to tightly couple its mounting assembly to

that portion of the skeleton to which the activating muscles, in this case the tongue, are attached. To achieve satisfactory mechanical isolation of the head from the chair, the actuator assembly must be loosely coupled to, though supported by, the chair frame.

The E&J proportional control chair incorporates electronic control of speed and direction of the separate right and left wheel motors. In the original control, the joystick orientation determines the resistance between the wiper contact and the fixed terminal of two sets of two pairs of variable resistors. Each set is involved in the control of one of the two wheel drive motors and each resistor of one pair is concerned with forward or reverse motor rotation. For simplifying the task of modification the additional electronic circuitry devised for the present application was to produce output signals identical to the original signals, and substituted for them.

The final aspect of design was the incorporation of a failsafe mechanism which would allow the operator to promptly shut down all control and motor circuits if these should fail in any way.

## The Joystick-sensor assembly

The joystick assembly is mounted in an opaque box approximately 5 x 5 x 3 cm attached by a tube 3.5 cm diameter x 3 cm long to a mouthpiece<sup>(1)</sup> through which the tongue end of the stick protrudes. The joystick, shown schematically in Figure 1, is about 8.5 cm long. It is constrained by a ball joint about 5.5 cm from the tongue end by light spring wires passing through the stick near the ball joint. Rotation about any axis perpendicular to the axis of the stick itself is produced by deflection of the tongue end. The spring wires effect return of the stick to its rest position and prevent rotation of the stick about its own axis.

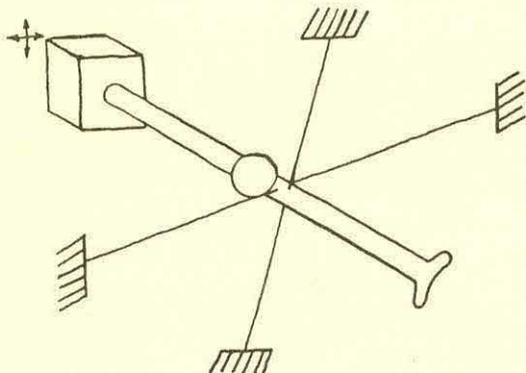


Figure 1 - Joystick and constraints

The outer end of the joystick, contained in the light tight box, carries a one cm acrylic cube. Plane mirrors are mounted parallel to the axis of the stick on two adjacent faces of the cube. A light emitting diode (LED) and photocell are mounted on the inner wall of the box opposite each of the mirrors as shown in Figure 2. Any motion

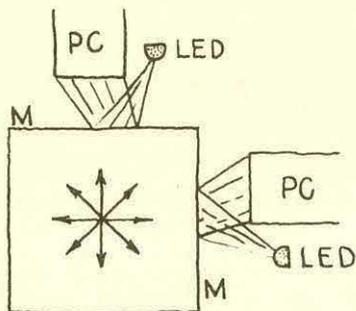


Figure 2 - Light source, mirror and receiver

of the stick causes one or both of the mirrors to move toward or away from its LED - photocell pair. Such motion changes the optical path length from the LED to its photocell thus causing a change in the light flux received by the photocell which in turn produces a change in the photocell resistance. See Figure 3. In a suitable circuit the change in resistance is translated into a change in voltage, the basic electric signal.

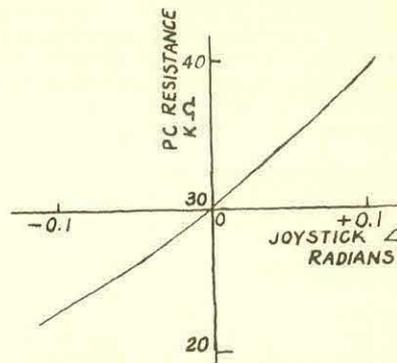
Figure 3  
Photocell resistance vs. joystick angle

Figure 4 is a schematic representation of the additional electronic circuitry, the output of which, in response to deflection of the joystick is essentially identical to that produced by motion of the joystick in the original manufacturer's control box. The latter signal is illustrated in Figure 5. The dead zone is required so that the

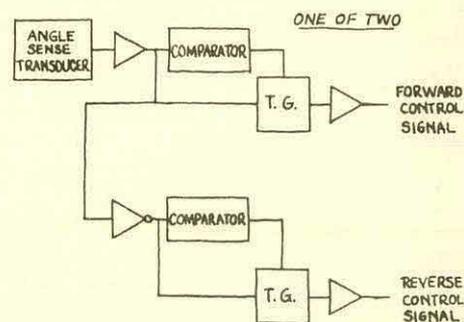
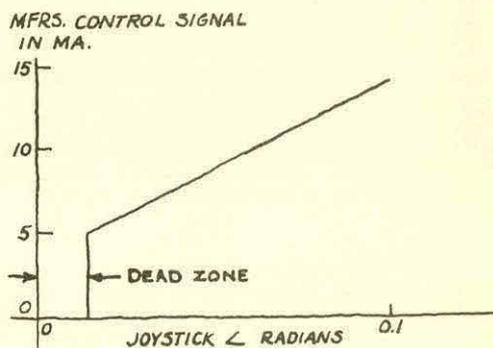


Figure 4 - Signal processing circuit

Figure 5  
Original control signal vs. joystick angle

unavoidable uncertainty in the rest position of the stick due to friction in the joystick mounting will not result in motor activation when none is wanted. Referring again to Figure 4, the portion of the circuit involving the comparator and transmission gate (T.G.) produces the required dead zone. Forward and reverse control signals are

produced via separate pathways, as in the original control. The signal levels at which the two comparators switch prevent both forward and reverse commands from being present at the same time. Figure 6 shows how the motor speed and direction vary with the angle of inclination of the joystick.

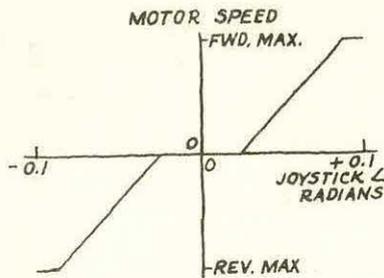


Figure 6  
Motor speed and direction vs. joystick angle

#### Control box mounting

The entire control box assembly is suspended from the end of a coil spring which in turn is suspended at the end of an arm mounted at the side of the wheelchair. The spring serves to isolate the control box, in use held rigidly by the mouthpiece in the operator's bite, from the chair proper. The suspending arm, a 1/4 inch diameter steel rod, is mounted in a ball bearing assembly with a vertical axis so that the control box can swing into the operating position or conveniently out of the way when desired. Stops limit the rotation of the arm and a return spring keeps the arm and box in the "out of the way" position when not in use.

The person for whom the chair control was designed has limited ability to flex the fingers of the right hand. This motion is sufficient, however, to operate a microswitch. Accordingly, a suitable microswitch was mounted on the underside of the front of the lap board. It is used to activate a motor driven eccentric pin which drives a cam on the swinging arm shaft. The control box swings into the operating position upon activation of this motor, bringing the mouthpiece into a convenient position to be grasped in the operator's bite. A second microswitch, operated by rotation of the swinging arm, closes when the arm is within 10° of the operating position and remains closed so long as the arm is in the operator's bite. Closing of this switch closes a power relay which makes battery power available to both control and motor circuits.

Release of the biting grip on the mouthpiece causes the control box arm to swing away toward its rest position; the microswitch opens as it swings thus removing power from control and motor circuits.

#### Testing

The tongue control mechanism, mounted on the E&J proportional control chair, has been tested under a variety of conditions by the author. In

order to achieve precision and a feeling of relaxed confidence in operating the chair, a learning period of a few sessions, was necessary. Direction, acceleration, speed and stopping proved to be under good control after a few hours of practice.

The chair has been operated under ambient temperatures ranging from -15° to +27° C and in light levels from near darkness to bright sunlight. At the time of writing, the person for whom this prototype has been built has operated the chair on two occasions. The second time she was able to maneuver the chair with considerable precision: avoiding obstacles, moving into tight quarters, turning around in restricted space, accelerating slowly, etc. Presently the specialized chair mounted braces required for this person are being constructed and mounted by an orthotics specialist.

#### Expense

No estimate has been made of the likely cost of reproducing the control mechanism which has been described above.

#### Other potential applications

Though this mechanism was designed for tongue operation, it incorporates two particular features which commend its consideration in other situations for operation by other muscle groups. First, the use of optomechanical rather than solely mechanical means of developing control signals reduces the necessary forces and deflections to a small fraction of those required in the original control. The forces required in the tongue control mechanism are only those needed to overcome ball joint friction and to deflect the light return springs. For full range displacement of the tongue end of the stick of 0.45 cm, a force of 0.083 newtons is needed; in the original control a force of 9.2 newtons is required to produce the 3.4 cm maximum displacement.

Secondly, the failsafe power switch, under convenient positive control of the operator, is an important safety feature which might avoid potentially serious consequences of an electronic or mechanical malfunction.

Finally, it is worth pointing out that the tongue is very well suited to function in control tasks. The precision of its motion and the variety of complex movements to which it is accustomed make it very easily and naturally adapted to the relatively simple task of holding or making adjustments in the orientation of the joystick.

- (1) The cast acrylic mouthpiece was made by Professor J. Wendell Lotz of the College of Dentistry of the Ohio State University

MODIFICATION OF EVEREST & JENNINGS MODEL 33B  
WHEELCHAIR CONTROL FOR SEPARATION OF SPEED-STEERING

\*James L. Cockrell, Ph.D.  
Wilbur J. Nelson

For some persons needing a self-propelled wheelchair, the luxury of X-Y (two dimensional) control at one site is not available. Coordination of two single-wheel controls at two sites is unnecessarily tedious. A straight-forward non-invasive modification to the E&J Model 33 Control System is offered to separate speed control (forward, stop, reverse) from steering. A single control for "on-off" (panic switch) of the entire system is included. A case study is presented.

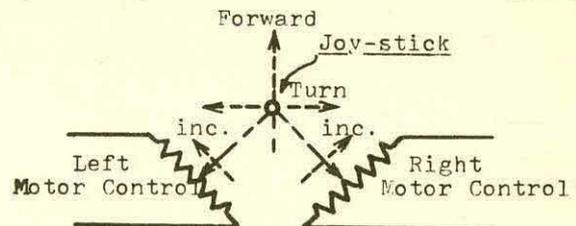
\*Department of PM&R  
U. of M. Medical Center  
Ann Arbor, Michigan 48109

CATEGORY:	INTENDED USER GROUP:
Device Development <input checked="" type="checkbox"/>	Powered wheelchair users not having conventional X-Y Control Capability
Research Study <input type="checkbox"/>	AVAILABILITY OF DEVICE:
STATE OF DEVELOPMENT:	Not commercially available now
Prototype <input type="checkbox"/>	AVAILABILITY OF CONSTRUCTIONAL DETAILS:
Clinical Testing <input checked="" type="checkbox"/>	Herewith
Production <input type="checkbox"/>	FOR FURTHER INFORMATION CONTACT:
AVAILABLE FOR SALE:	Authors
Yes <input type="checkbox"/> No <input checked="" type="checkbox"/>	University of Michigan Medical Center
Price:	Ann Arbor, Michigan 48109

#### INTRODUCTION - The Problem

In the control of a self-powered wheelchair the designer's concept generally has been the availability of an X-Y (two dimensional) control mode, - associated with some single anatomical site. The hand is the choice in the overwhelming majority of cases simply because that is how we are used to causing things to happen. When either hand is unavailable other sites of X-Y control have emerged - such as chin, cheek, and head. Symmetry of elbow positioning has even been used. In all of the control situations the location of the two dimensional control at the single site has allowed the designer to convert one mechanical motion (nominally fore and aft; the X direction) to symmetrical angular motion of two electrical control potentiometers controlling the angular velocity of two electrical motors - one powering each side of the wheelchair. The steering action is imposed at the same site by the other mechanical motion (nominally side-to-side; the Y direction) mechanically generating differential angular motion of the same two electrical potentiometers. The familiar joy-stick is the single connecting link to the patient. The mechanical coupling to the control potentiometers is an elegant example of design which is simple, trouble-free, economical, and effective.

The associated electronics in the Everest & Jennings Model 33B proportional control, - so commonly seen in self-powered wheelchairs today provide adequately for a dead-band in the neutral position of the joy-stick -- to turn off all motor motion. This dead-band is achieved mechanically by return springs if the joy-stick is released. The general layout of control is shown in figure 1.



INPUT SIGNAL TRANSDUCER  
Figure 1

So now, what more can be asked? There are some patients who either have so few control motions left or so spotty a distribution of these motions that there are neither X-Y sites, nor any two sites that could use anatomical symmetry to initiate control of the left and right motors separately. It is this group to whom the substance of this paper is addressed.

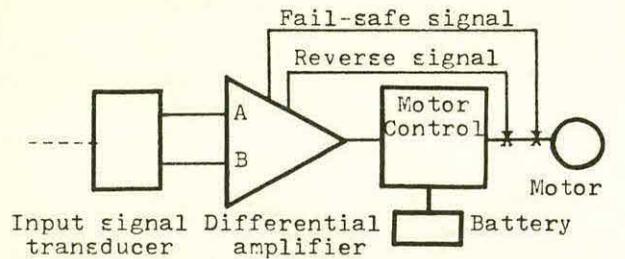
Form of Solution

Using a different starting point the problem was encountered and presented a number of years ago.<sup>1</sup> The essential idea is that one control device be used to control the proportional "forward-off-reverse" action of both motors. The other control device is used to control proportional "steering" by speeding up one motor and slowing down the other. When the chair is stopped (i.e. forward-reverse control is "off") the steering control allows the chair to turn on its own axis, one wheel turning each way. In this mode the coordination required between the two controls is quite different. Straight forward or straight reverse motion requires the use of only one control element, - the other used only for minor corrections of the relative wheel speeds.

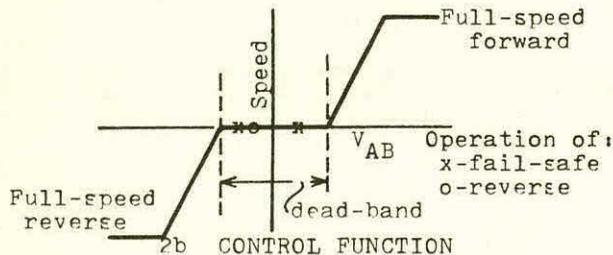
For the particular patient to be presented here, a new Everest & Jennings self-powered wheelchair incorporating the 33B Series Power Drive (Proportional Control) was available. Although the details of what follows pertain to that particular chair, the approach is applicable to any control scheme.

How It Is Done

The 33B Series Power Drive Control of each of the traction motors is accomplished by the electronic components shown in the block diagram of figure 2a. Pulse-width is the primary variable for lossless conversion of the battery energy at constant voltage to a controlled average current having a pulsating voltage. Two relays accomplish separately the "fail safe" (motor disconnect) and reversing functions. The control information required from the input transducer (coupled to the patient) is a voltage differential between the two input terminals of the amplifier. The particular control function built into the differential amplifier is a key to the possible control modes.



2a BLOCK DIAGRAM (each motor)



2b CONTROL FUNCTION

MOTOR CONTROL COMPONENTS - 33B SERIES  
Figure 2

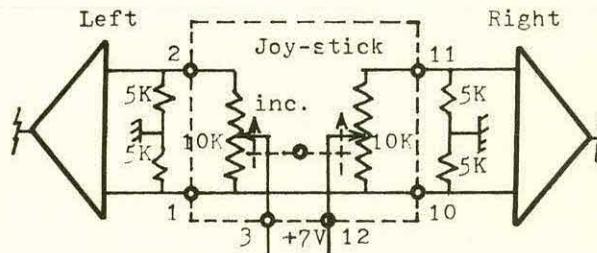
Figure 2A shows a significant band in the region of zero voltage difference between points A & B where the fail-safe relays are open and the motors are both off. As a voltage difference between A & B develops the fail-safe relay applies voltage to the control circuit and then the speed increases with increasing control signal voltage difference.

The original connection to the two mechanically connected potentiometers is shown schematically in figure 3A. The numbers located on the wires coming from the joy-stick box are the terminal numbers associated with the cable connection. As the two potentiometers are advanced (forward) by the joy-stick control both motors increase in speed in the forward direction. Thus we observe:

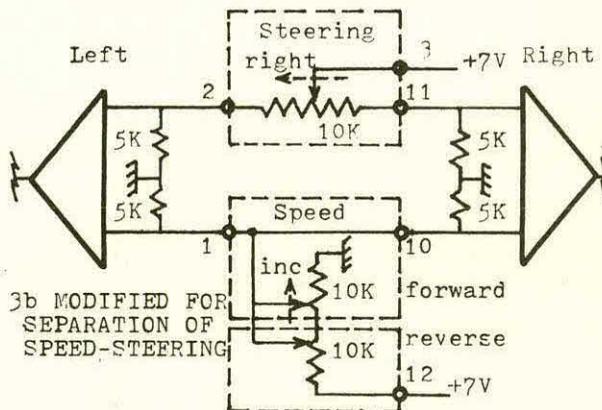
Table 1

Control Voltage	Left Motor	Right Motor
	Terminal # Speed	Terminal # Speed
decrease	1 increase	10 increase
	2 decrease	11 decrease

The normal control scheme causes terminals #1, to #10 to decrease in absolute voltage at the same time terminals #2 and #11 are increased. But we observe that it is not necessary to do both (e.g. decrease #1 and increase #2) to cause the left motor to increase in speed in the forward direction. In fact variation of either of the two alone can accomplish the entire control function.



3a ORIGINAL JOY-STICK CONTROL



3b MODIFIED FOR SEPARATION OF SPEED-STEERING

Figure 3 MOTOR CONTROL DETAILS

This suggests, then, a solution to the control problem. If the two terminals (#1 on left motor and #10 on right motor) which will cause the motors to increase in speed in the forward direction are connected together and energized by a single control element then the speed function is set by that single element.

For steering the other two terminals (#2 on left motor and #11 on right motor) are connected at opposite ends of a potentiometer, producing differential voltages at these points for the two motors (as the connection had done when applied to one motor). Thus departure from a center position of the steering potentiometer will cause steering by increasing the speed of one motor and slowing down the other, as in Figure 3b.

Note that no connection inside the main controller is altered to accomplish this. Rather, only the external connections to the new control potentiometers are made through a new cable. The essential notion is that separate control sites are identified with the patient, supplied with appropriately sized potentiometers (10K here) (linear, rotary, optical, etc. or any combination) and then connected according to the terminals identified.

#### Related Problems

Variants of the suggested modification will arise; a situation which is almost inevitable as the degree of disability increases and such parameters as available range of motion, or available torque at a joint become limitations. One such variant is the discovery that a patient has only one-half a control degree-of-freedom. For example, only extensors may be available for a proportional control. An "up scale" zero is possible to implement - but this becomes highly questionable in an emergency situation - and certainly does not lead to relaxation for what is probably already a marginal control situation.

The amount of control action - that is linear motion or rotary motion will seldom exactly match the requirements of the controller, - and accordingly either mechanical or electrical adaptations would have to be made.

The addition of an emergency "on-off" switch, accessible to the patient, - and particularly to the more disabled patient is urgent. These problems and others, as they occur, are the usual lot of the orthotist and rehabilitation engineer although the solutions are seldom simple.

#### A Case Study

Miss A is a post-polio quadriplegic patient. Her breathing difficulty precluded successful adaptation to a chin control. She has limited extension at her right wrist. At her right thumb she could move the distal joint smoothly through about 60 degrees. There were other spotty motions or forces but these seemed to be the best ones. In short, control potentiometers were attached to appliances mounted to her right foot, and right hand. The thumb controlled a potentiometer directly for steering while the foot and wrist were combined to supply the full range of speed control - as in figure 3b. To gain adequate angles of motion mechanically amplifying linkages were devised for

the foot and wrist sites. Miss A. requires assistance for attachment of the appliances each time she is placed in her chair. After that she is off and running.

The panic button used for Miss A. is a push-on - push-off electronic switch (Radio Shack) connected in series with the panel switch of the E&J 33B Series hardware. After some trial and error the switch was located behind the extension head rest of the wheelchair and operated through the fabric of the head rest. The switch demounts with the head-rest and is an integral part of the system. Miss A. uses the switch in the process of assuring proper zeroing of her controls - and on occasion uses the switch to avoid catastrophe. Our admonition to her as she glided away from us after final fitting was that there is tremendous power in the wheelchair, controlled through cables and connectors which, of necessity, are vulnerable. The failure mode (and failures will occur) is uncertain, - and the risk is that the failure may be hazardous. Therefore, learn to use the panic switch and be ready! She has learned to use it, - she did use it, and in her words "I wouldn't give up that chair for anything"!

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1. "The Electric Wheelchair - An Experimental Orthosis"  
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## SPEECH RECOGNITION AND CONTROL - A VIABLE AID TO THE PHYSICALLY DISABLED

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Speech recognition and control systems for use by the severely physically handicapped are currently being tested in both laboratory and clinical situations. A variety of applications are being investigated, including environmental control systems, wheelchairs, remote manipulators, and specialized vocational applications such as computer programming. This paper discusses the advantages and disadvantages of speech recognition and control systems, with particular emphasis on laboratory and clinical experiences. The practical, clinical aspects of various applications are also discussed.

CATEGORY:	INTENDED USER GROUP: High Level Quadriplegics
Device Development <input checked="" type="checkbox"/>	
Research Study <input checked="" type="checkbox"/>	AVAILABILITY OF DEVICE: Commercially Available
STATE OF DEVELOPMENT:	
Prototype <input type="checkbox"/>	AVAILABILITY OF CONSTRUCTIONAL DETAILS: Not available
Clinical Testing <input checked="" type="checkbox"/>	
Production <input type="checkbox"/>	
AVAILABLE FOR SALE:	FOR FURTHER INFORMATION CONTACT: Authors
Yes <input checked="" type="checkbox"/> No <input type="checkbox"/>	
Price:	

## Introduction

One of the major problem areas in rehabilitation engineering is that of the patient/device interface<sup>1,2,3</sup> - assisting the physically handicapped individual in controlling devices in his surroundings. The devices available to be controlled cover the gamut from motorized wheelchairs, hand splints, telephones and televisions, to remote manipulators, automobiles, and large computers. Essentially, the problem is that the devices are there but the currently available control systems are inadequate for all of these tasks. Many commercially available control systems very successfully meet some of the commonly occurring needs of these patients (e.g., puff and sip environmental control systems, chin or breath controlled wheelchairs, etc.), yet for several reasons they are not sufficient for the control needs of the more complicated devices which a high level quadriplegic would find useful. For example, applications such as control of (a) a wheelchair mounted remote manipulator, (b) a large number of environmental devices (e.g., TV, radio, light, phone, etc.), (c) peripheral devices on a specially equipped van, and (d) computer systems for vocational applications<sup>4</sup> can be expected to increase in numbers in the future. To meet these

needs, new control modes are needed which surpass the capabilities of the existing approaches and eliminate their drawbacks.

Two of the most promising new techniques are voice control and EMG control. They are widely different approaches which can serve different needs. For the high level quadriplegic, EMG control could be used to provide proportional control of a remote manipulator for manipulating objects during ADL and recreational and vocational situations. Such manipulators, particularly for fine control of position, benefit from a proportional control mode. EMG control of devices has become commonly used in control of on/off modes for prosthetic devices and is currently being applied to prosthetic devices for proportional control - the Boston Arm<sup>5</sup> being the most well known application. Future applications of EMG for proportional control can be expected to be investigated for use by high level quadriplegics controlling several degrees of freedom through the use of shoulder, upper back, neck, and/or residual upper extremity muscles. It is only with extensive research and development that such control will become practical.<sup>6</sup>

On the other hand, for applications where some form of discrete control can be applied,

then voice control is an established, commercially available means of control which has distinct advantages over other methods. Such voice control systems, in which a patient verbally commands a device in his environment through the use of natural language commands ("television" "on", "wheelchair" "forward", etc.), are currently undergoing laboratory and clinical testing in rehabilitation settings, and the preliminary results are encouraging. The application of voice control to meet the needs of the physically handicapped can be expected to increase as the costs of voice control systems are lowered.

#### Voice Control - Main Characteristics

The main characteristics of voice recognition and control systems for use by the severely physically handicapped are summarized in Table 1, while Figure 1 is a block diagram of such a system.

Table 1  
Synopsis of Main Characteristics  
of Voice Recognition and Control System

##### Requirements

- Ability to Consistently Repeat Sounds
- Relatively Low Noise Environment

##### Advantages

- Random, Immediate Access to Any One of A Large Number of Devices
- Complex Procedures Performed By Simple Commands
- "Natural" Means of Control
  - low "gadget factor"
  - psychologically acceptable to patient
  - no mechanical connection to patient
  - easy to learn

##### Disadvantages

- Not 100% Recognition Rate
  - failure to activate occasionally (especially in noisy environments)
  - substitutions possible
- Occasional Erroneous Triggering
  - low probability
- Presently Expensive

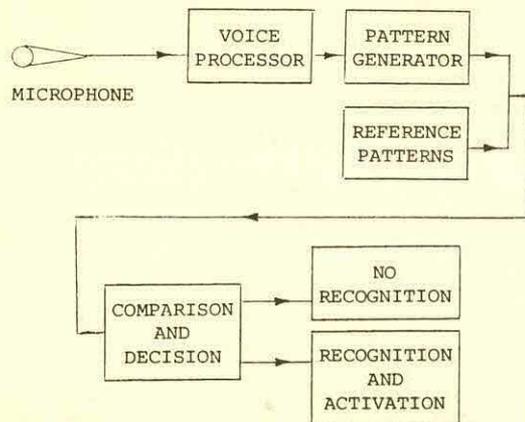


Fig. 1. Block Diagram of Speech Recognition and Control System

First, there are two requirements for the use of this control mode. The most basic of these is that the user must be able to consistently repeat the sounds used for commands. These sounds need not be normal English speech, but could be any foreign language, or even "non speech" sounds such as the difficult-to-understand vocalizations of cerebral palsy individuals. As long as enough distinct command sounds can be consistently repeated, then voice is a possible control mode. The second requirement is that the environment be relatively quiet. That is, the noise level must not be so loud that the spoken commands are masked by the noise.

Next, given a situation wherein voice control could be used, there are several advantages to this control mode. First, it gives the user immediate, random access to any one of a large number of commands. That is, upon saying the words "arm" "up", those commands are immediately activated, as would be any other sequence of commands such as "wheelchair" "forward". This is as opposed to available puff and sip systems, etc., where the user must sequentially pass through a list of possible commands until the desired command is reached, and then activate that command.

Next, given the above random access feature, one is capable of controlling very complex procedures such as the direction control of a computerized remote manipulator.

Last, a very important feature of voice control is that it is a very "natural" means of control. That is, it has a low "gadget factor", and is easy to learn. There are no mechanical connections to the patient, and he remains physically separate and autonomous. The only training one needs is to learn to speak a normal vocabulary consistently. This is no problem for most people. This control mode is also very psychologically acceptable since it is obvious that the patient is in control. He does not need to subserve himself to the machine, or make his disability more conspicuous by performing some "unnatural" or out of the ordinary action (the use of a microphone is a normally accepted - even a prestigious - activity).

It should be pointed out, however, that there are some characteristics of voice control which are not desirable. Again referring to Table 1, note that there is less than a 100 percent recognition rate for command words. This is due to the fact that some words are not recognized (especially in noisy environments), and also that occasionally one command word is spoken and a different command is recognized (e.g., "right" is pronounced and "light" is recognized) - i.e., substitutions are possible.

Another potential problem source is that of erroneous triggering caused by ambient noise being recognized as a command - i.e., the system being triggered by normal conversations of the user or other persons, TV sets, etc. The effect of this problem can be minimized by the use of command words with more complex structures (i.e., replacing "on" by "start") and/or by requiring two-word sequences to activate any device (i.e., "TV" "on" rather than just "TV"). These strategies can

effectively eliminate the problem. As a last resort, a master on/off sensitive head switch can be used as an emergency switch to terminate all functions.

#### Applications of Voice Control

There are two basic categories for devices aimed at increasing a patient's independence: (1) those aimed at increasing his "mobility" (the ability to move himself around within his environment, and (2) those aimed at increasing his "manipulability" (the ability to manipulate or control other objects within his environment). Mobility aids include such typical devices as wheelchairs and specially equipped vans, while manipulability aids include (1) the traditional environmental control system for controlling TV's, radios, etc., (2) more specific aids aimed at vocational (or recreational) needs such as a conveyor belt control systems, computer programming, and visual inspection accompanied with data input, and (3) the much more generally useful devices such as remote manipulators and orthotic arms.

#### Performance Requirements

Environmental devices, wheelchairs/vans, manipulators/arms, and specialized systems place different technical requirements upon their control systems. For voice control, these requirements can be broken down into the following six categories: 1) size, weight, and power consumption; 2) vocabulary size; 3) response time; 4) miss rate; 5) substitution rate; and 6) erroneous triggering.

Size, weight, and power consumption are of critical importance in any portable situation except for vans. Wheelchair systems (Fig. 2) and remote manipulator systems that are wheelchair mounted both require that these three variables be minimized. The voice control system must be small enough to fit on the chair without increasing its overall dimensions significantly. Weight and power consumption requirements of the voice control system should not exceed 10 percent of the chair's own values. For a standard Everest and Jennings electric wheelchair, this means that power consumption should be less than 12 watts, and weight should not exceed approximately 25 lbs.

These are stringent requirements for an electronics package capable of recognizing speech.

For stationary systems such as environmental device control and conveyor belt control systems, the size, weight, and power consumption are not critical considerations. Power is readily available from the building wall socket, and the bulk of the control system can be tucked away in some unused space.

The motorized van application lies between these two extremes in that space, power, and weight are of consideration, but are not as constrained as in the wheelchair situation.

Vocabulary size requirements are totally dependent on the number and type of devices involved in the system.

A minimal environmental device control system with a TV, radio, light, nurse call, and electric bed would need the following 14 word vocabulary:

Table 2

TV	Volume	On
Radio	Channel	Off
Light	Head	Up
Nurse	Height	Down
Bed	Foot	

If a phone were added, the vocabulary would jump up to the following 27 words:

Table 3

TV	Volume	On
Radio	Channel	Off
Light	Head	Up
Nurse	Height	Down
Bed	Foot	Zero
Phone	Answer	One
	Dial	Two
		Three
		Four
		Five
		Six
		Seven
		Eight
		Nine

The most extreme case for an environmental control system would be one that included a typewriter. This device alone would require an additional 40 words over the minimal vocabulary, and this only for individual character control.

Depending on the complexity of a wheelchair, the necessary vocabulary can range from 8 to about 15 words. An example of the basic 8 word vocabulary is shown below.

Table 4

Straight	Faster
Reverse	Slower
Left	Drift
Right	
Stop	

A very basic manipulator control system would require the following 9-word vocabulary:

Table 5

Arm	In	Stop
Wrist	Out	
	Up	
	Down	
	Left	
	Right	

Some manipulators may be equipped with a form of coordinate control in which a command of "4" "6" "2" would move the terminal device to a position 4 units out, 6 units over, and 2 units up from a known reference or null position. The unit of movement could be either feet or inches depending on whether coarse or fine control has been requested by the user. This mode would allow the user to easily send the terminal device to a de-

sired location - such as close to a refrigerator door handle. In these cases, the vocabulary would be expanded to something like the following 21-word vocabulary

Table 6

Arm	Coarse	Stop
Wrist	Fine	Zero
	In	One
	Out	Two
	Left	Three
	Right	Four
	Up	Five
	Down	Six
		Seven
		Eight
		Nine

If preprogrammed control in which, for example, a command of "mouth" would send the terminal device to a preprogrammed position close to the patient's mouth were used, then the vocabulary requirements would increase again.

The categories of response time and miss rate can be treated the same in most respects. Both affect the amount of time required before proper or corrective action is taken. The basic dividing line between the four groups listed above is whether or not movement of a physical object is being performed.

Applications such as wheelchair or manipulator control demand as fast a response time as possible in order to prevent collisions and accidents. A partial solution to this problem is to provide the patient with a microswitch which he can activate quickly to stop the motion. The response time and miss rate are constrained mainly by the limits of delay that make it too difficult to maneuver. The response time of a speech recognition system is theoretically limited to approximately 0.1 sec., since dropouts of this duration can occur in the middle of a word. Hence, the recognizer must wait at least this long after the end of a command utterance before making a decision. Our experience with a voice controlled wheelchair system showed that a response time of 0.4 sec. was acceptable, as long as a microswitch stop was available.<sup>7</sup>

Systems such as environmental device controllers have much less stringent requirements. Unlike the wheelchair or manipulator system, there is no danger or even inconvenience in having the system take up to 1.0 sec. to respond. The miss rate, as with response time, should be as good as possible, but does not have to be perfect. One hundred percent recognition is essentially not achievable anyway due to human inconsistency, so the system must be designed with this in mind. Hence, the microswitch panic button.

Substitution errors are an entirely different story. In systems such as the wheelchair or manipulator controller, substitution errors are highly undesirable. An intended right turn that instead goes left into an obstacle is dangerous. The substitution rate in systems such as this could be less than 1%.



Fig 2. Photograph of Voice Controlled Wheelchair. Speech Recognition System is Mounted Behind Wheelchair

In systems such as environmental device controllers a substitution error is more of an inconvenience than a danger. However, it is still a serious concern since an inappropriate action can be activated.

In general, a speech recognition system should be set up such that it is more likely to make no decision rather than an incorrect one. A miss is less costly in time, as well as being less dangerous.

#### Interfacing Requirements

As may be evident from the preceding discussion, a speech recognition system can seldom be considered separate from the actual control system which interfaces the speech recognizer to the controlled devices. There are very few applications where all that is needed is an electrical code that identifies the word just spoken. It is also seldom just a matter of decoding the signal and turning on or off the device identified. That is, for practical, clinical applications a considerable amount of engineering design must be concerned with interfacing the speech recognizer to the controlled devices.

Environmental device control systems illustrate this point well. Note that in all of the vocabulary tables above there are at least two columns. The task of turning the TV on would require the two commands "TV" "on". The task of changing the TV channel would require "TV" "channel" "up". We refer to this as multiple level coding, and it is a very important technique. It necessitates at least two commands for every action and thus drastically reduces the possibility of erroneous triggering by environmental noise.

Another consideration in interfacing requirements is the specific nature of the device being controlled. An example of this is a TV set. Most remote control TV's, especially the typical clinical TV, can only perform a "channel up" function. In order to provide for the proper response to "TV" "channel" "down", the interface must step the TV up N-1 times, where N = 13 is the number of channel positions on the VHF tuner.

Wheelchair interfaces have to provide multiple level coding also, but in addition they must provide feedback control for the chair motors, and some form of proportional control from the "discrete" input of spoken commands. Feedback enters in that when the user says "straight", it is the task of the feedback control system to make sure that the chair indeed goes straight despite differences in motor characteristics, wheel load, etc. The proportional control, which is activated by commands such as "faster" and "slower", is necessary to give the user some way to regulate his speed. The task of the interface is to recognize these commands and begin changing the speed of the chair until the user says "straight" whereupon the speed is set at that new level until the next command.

Remote manipulators require very complex interfaces. A typical manipulator may have five or more motors that require torque/speed control as well as on/off control. The interfaces can be broken down into two major parts: (1) manipulator supervision and, (2) feedback control. Figure 3 illustrates the tasks of these

two parts. Depending on the geometry of the arm being controlled, fairly complex mathematical calculations may be necessary just to get the terminal device (i.e., hand) to move "left", or "in", etc. If the arm is to have a coordinate control mode as well, this necessitates another level of mathematical calculations in order to convert the coordinate input into net movement for each of the arm's degrees of freedom. This level of complexity requires that a computer be implemented in a manipulator interface. Modern microprocessor technology makes this feasible in terms of size and power consumption, but not cheap or simple.

#### Experiences with Voice Control Systems

First, concerning wheelchair applications, in order to determine the feasibility of controlling a wheelchair using voice, we undertook extensive maneuvering tests through an obstacle course which simulated the close quarters found in a typical home. The prototype recognizer used for these tests was 10" x 11" x 14" in size, weighed 22 lbs, and required 20 watts input power. It used an eight word vocabulary (Table 4 above), and gave recognition rates ranging from 74% to 96% during the tests. In order to determine the effects of environmental noise, we exposed the system to various intensity levels of background music and speech (tape recordings). The results indicated that sound levels up to 70 db spl\* (average) had little or no effect upon the system performance (55 db spl corresponds to a room where only air conditioning can be heard).

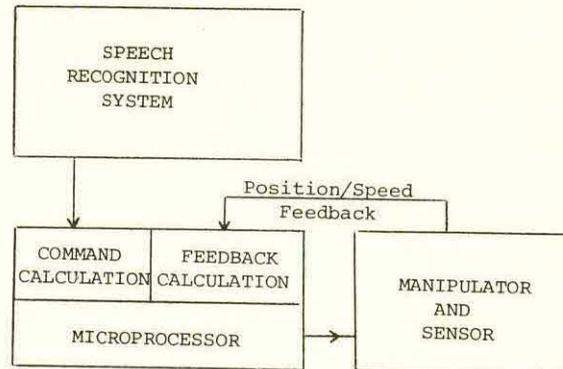


Fig. 3. Block Diagram of Remote Manipulator Control System

However, the limit of usefulness for our prototype system appeared to be around 77 db spl.

Subjects who drove the chair using voice control stated that they had good control of the chair and felt they could go anywhere they wanted. Recognition rates down at the 74% level were somewhat frustrating, though manageable. The average recognition rate for tests run below the 77 db noise limit was 85% (for experienced users). Of the 15% error rate, 1.1% came from substitutions. This level of performance proved quite adequate for maneuvering the chair conveniently.

Because this chair system was equipped with a head switch, collision problems were minor (a few bumps into the walls of the obstacle course). Most of the bumping resulted from trying to maneuver in extremely tight spaces.

Extraneous triggering did occur occasionally when subjects were conversing while sitting in the chair. This happened about three or four times a day during our testing sessions (about six runs per day). Note that this wheelchair system required only a single command to be activated, and thus did not have the screening effect of multiple word commands.

Next, concerning environmental control system applications, for the past year and a half, we have had a prototype environmental device control system installed in the Long Beach Veterans Administration Hospital. This clinical application has given us a chance to gain real-

\* spl = sound pressure level, 0 db =  $2 \times 10^{-4}$   $\mu$  bar

life experience with our early prototype voice control system. Based on limited, periodic evaluation, the average recognition rate over this last year has been 81%, with a range of 70%-96%. The highest substitution rate was 2.1%, so most all errors were misses. The average noise level encountered was 71 db spl, with a range of 65 db to 78 db. Thus, as with the wheelchair system, the recognizer was able to maintain an average recognition rate of 81% despite noise levels greater than 70 db. Since these average recognition rates are close to the performance of the prototype machine in quiet surroundings, it can be surmised that noise levels up to 70 db are not at all deleterious to the performance of a good speech recognizer.

It should be noted that in both the wheelchair system and the clinical system we did not use a noise-cancelling microphone, but rather just a simple cardioid microphone placed 4"-6" from the patient's mouth. For even better ambient noise rejection, a Telex type head-gear mounted microphone could be used. This arrangement, in which the microphone remains a small fixed distance from the speaker's mouth, would certainly yield better performance in noisy environments. For some applications, this would definitely be the approach to take. However, the drawback to this arrangement is a slightly higher "gadget factor" for the patient in that he has to have an apparatus placed on him. This is cosmetically and physically undesirable, and could be restrictive in some situations such as eating.

In summarizing the recognition rate results for commercial and industrial uses Herscher and Cox<sup>8</sup> have recommended a 98.5-99.5% recognition rate. Our experience in both a laboratory and a clinical setting indicates that recognition rates as low as 80% are acceptable - for environmental control systems in particular since clinical trials have demonstrated this point. The level of recognition rate which defines acceptable performance seems to be a function of the application and the individual user. Substitution errors are rare in good recognition systems, and thus do not represent much of a problem.

As pointed out in Table 1, there should be significant psychological advantages in using voice control systems. This indeed proved to be the case in our clinical experience. These advantages are best summed up in the written evaluation (in response to a questionnaire) of a quadriplegic who has used this clinical system for over a year. He states that "...the system gave me greater independence than I could of enjoyed normally," and he "...felt it was more sanitary and mentally exhilarating, in that you would actually command the functions, compared with the puff and suck system." Regarding any recommended changes, he stated "Yes, I would like to see more commands implemented in to the system to insure more independence to the disabled. Its potential is limitless." In general, both patients who have used the system found the system quite workable, despite the rather low recognition rate (81%).

In addition to these patient comments, written evaluation were solicited from the nurses and attendants who had utilized that same system. Their comments were almost all favorable, and aside from a few requests for structural changes, indicated that there were no serious interface or human factor problems. For example, (1) they could easily operate the system, and (2) the spoken commands from the patient did not disturb the other patients in his immediate surroundings.

Last, it should be re-emphasized that these current applications of voice control are the initial efforts to bring this technology into the clinical environment. Thus, it is to be expected that there will be some failures and bad experiences as the proper applications for voice control systems are determined. Indeed, it appears from our personal experiences and our conversations with others that these problems will arise mainly from the need for proper interfacing with the devices to be controlled, and not from any limitation in the speech recognition process itself. This statement is true for patients such as high level quadriplegics, but does not apply to cerebral palsied persons who appear to have much more difficult to recognize speech patterns.

#### Present and Future System Availability

Presently, commercial firms offer speech recognition systems with 32 word vocabularies for approximately \$10,500<sup>9,10</sup>. These systems weigh 50 lbs or more, and consume 125 watts or more. Their performance is good (96% or better), but their size and power requirements make them unsuitable for portable applications.

The prototype system developed at UCSB is in a somewhat different class from the presently available commercial system. The present prototype is a successor to the one referred to in this paper. It is intended as a minimal speech recognition system for applications that do not require large vocabularies or extremely high accuracy. Recognition rate is 90% or better on 20 words. It requires 20 watts to power, weighs 22 lbs and is about half the size of the commercial systems mentioned above. Commercial firms have estimated they can manufacture and sell this unit for approximately \$6,000.

It should be kept in mind that interface hardware is not included in the above cost information and that present companies do not normally offer any special interface work. Cost of this work is wholly dependent on the nature of the application. The market cost of a simple environmental device controller (TV, light, radio, bed, phone) would be approximately \$1,000.

During the next decade, the cost of these systems should decline steadily as the market expands and the overhead cost of development is ameliorated.

#### Summary

Based on the successful, but limited, clinical and laboratory experience which is available, it appears that voice control has the

potential to become a practical means of control for many severely physically disabled persons. Applications such as control of large centralized computers for vocational needs, environmental devices, wheelchairs, and wheelchair-mounted remote manipulators are currently being investigated both in the laboratory and the clinic. These trials indicate that the advantages of voice control definitely overshadow the disadvantages in several applications. Perhaps the most serious current drawback to voice control is its high price tag. This limitation can be expected to be overcome in the not too distant future.

#### Acknowledgements

We would like to thank the following individuals and organizations for their invaluable contributions to this program: Dr. Harris Meisel, and Brian McGann for their valuable assistance, and the National Easter Seal Research Foundation, the Santa Barbara Chapter of the Easter Seal Society for Crippled Children and Adults, the Everest and Jennings Corporation, and the Prosthetics Research Service of the Veterans Administration for their encouragement and financial support.

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CURRENT STATE OF DEVELOPMENT AND TESTING OF  
AN OCULAR CONTROL DEVICE

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Abstract

The principles of operation of an ocular transducer which tracks corneal reflection and details of a system for controlling an electric wheelchair are given. The system allows the user to select either drive or recline modes of operation and to turn the system on and off all using only the ocular transducer. Typical use of the system is described and results of clinical testing are given. Applications to non-vocal communication and environmental control are indicated.

<p>CATEGORY:</p> <p>Device Development <input checked="" type="checkbox"/>    Research Study <input type="checkbox"/></p> <p>STATE OF DEVELOPMENT:</p> <p>Prototype <input type="checkbox"/>    Clinical Testing <input checked="" type="checkbox"/>    Production <input type="checkbox"/></p> <p>AVAILABLE FOR SALE:</p> <p>Yes <input type="checkbox"/> No <input checked="" type="checkbox"/>    Price:</p>	<p>INTENDED USER GROUP:</p> <p>High level Quadriplegics</p> <p>AVAILABILITY OF DEVICE:</p> <p>Not available</p> <p>AVAILABILITY OF CONSTRUCTIONAL DETAILS:</p> <p>Available</p> <p>FOR FURTHER INFORMATION CONTACT:</p> <p>George Rinard, Denver Research Institute, P.O. Box 10127, Denver, Colorado 80208</p>
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### Introduction

A transducer designed to detect the corneal reflection of an infrared source and produce coherent signals for control purposes has been developed [1]. This has proved to be more reliable for ocular control purposes than other techniques that have been investigated [1], [2]. During the past year, the transducer has been interfaced to an Everest and Jennings proportional drive, full recliner wheelchair. The wheelchair has been modified to make it suitable for use by high level quadriplegics and has been used for clinical testing of the ocular transducer. Mode select capability has been developed so that the device to be controlled may be selected by the user. The ocular transducer has also been interfaced with video display devices in order to investigate non-vocal communication and environmental control applications.

#### Acknowledgment

This project was supported by National Institutes of Health Grant 5 R01 AM 10763.

### Ocular Transducer

The configuration of the eye position monitor is shown in Figure 1. The infrared light emitting diode, LED, is attached to the nosepiece of the eyeglasses. The inside surface of the lens of the eyeglasses is coated to form an infrared mirror, yet it is transparent to visible light. The image sensor unit, near the outside corner of the eye, is mounted on the bow of the eyeglasses.

Figure 2 is a sketch of the optics used to monitor eye position. The infrared LED has an illumination angle of about 35 degrees. The infrared mirror which may be flat or a prescription lens is mounted in the frame of the eyeglasses. The eye is illuminated by the infrared source reflecting from the infrared mirror.

The sclera and cornea have radii of curvatures of about 13.3 mm and 8 mm respectively. A virtual image of the LED is formed about 4 mm behind the spherical surface of the cornea. The virtual image, or corneal reflection, moves about half the distance that the pupil moves since the eye rotates on an axis through point O as illustrated in Figure 2.

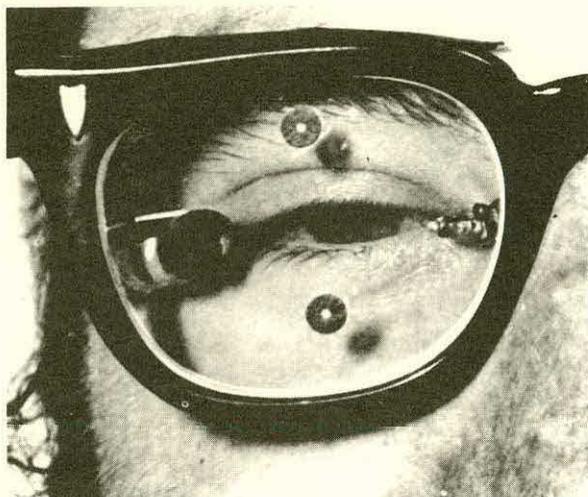


Figure 1. The Ocular Transducer

The corneal reflection is detected by the image sensor unit via another reflection from the infrared mirror. The lens produces an image of the corneal reflection on the photodiode array. The array is about 3.8 mm square. The filter which may be a visible light absorbing filter or an interference type infrared bandpass filter reduces the ambient light which would interfere with eye tracking if it reached the photodiode array. Since the corneal reflection moves with eye motion, its location on the photodiode array can be used to derive signals for control purposes.

#### Applications of Ocular Transducer

The ocular transducer has been used for the proportional control of an electric wheelchair and the operation of a wheelchair recliner. Figure 3 is a block diagram of the ocular control circuitry that was used. Each element of the 32 x 32 photodiode array is sequentially addressed

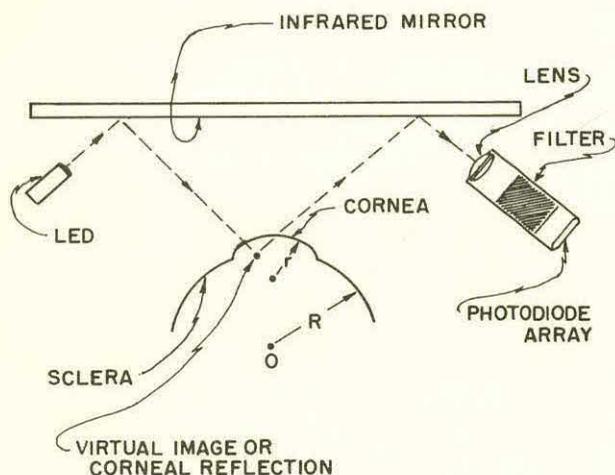


Figure 2. Optics Used in the Eye Position Monitor

by the image sensor scanning circuitry to determine if its video signal is a low or high state. The video signals and corresponding addresses are processed by the corneal reflection signal detector circuitry. The corneal reflection is assumed to be detected if two adjacent elements are illuminated and if the total number of illuminated elements is sixteen or less. If these conditions are met, the x and y position coordinates of the corneal reflection are stored in the address latch registers. The x and y digital addresses are converted to proportional control signals which are used to drive an electric wheelchair. The y digital address is also converted to a control signal which is used to operate the wheelchair recliner. If the corneal reflection is not detected for a period of 0.25 seconds, the device being controlled is momentarily turned off; and if loss of signal continues for 2.5 seconds, it is latched off (null mode). Since closing the eye results in loss of signal, the user can stop any operation in 0.25 seconds. A coded sequence of eye blinks was selected as the means of activating the desired mode of operation. A low level audio tone is used to inform the user of the mode of operation and to assist in activating the desired mode. The circuitry, as presently developed, allows the ocular transducer to be used to drive and recline a wheelchair. However, additional modes to operate other equipment can be added.

The ocular transducer, mounted on eyeglasses, is adjusted to the individual by displaying the image sensor output on an oscilloscope and adjusting the position of the image sensor unit. The sensor unit is adjusted so that the bright corneal reflection is near the center of the array when the eyes are in the central-gaze position. The user should be able to move the bright spot from side to side and top to bottom of the array when adjustment is completed. This requires about 25 degrees of eye motion from the central-gaze position. This adjustment usually requires about a half hour to complete. During the initial training period an override switch, is plugged into the control circuitry box to allow the instructor, at any time, to stop operation of wheelchair or recliner.

The ocular controlled wheelchair and associated equipment for a high-level quadriplegic are shown in Figure 4. The Everest and Jennings proportional control unit was remounted in front of the cross-member of the frame. This allowed the battery to be moved forward and a portable volume ventilator to be placed behind the battery. A reclining unit and compatible arm rests were added to the wheelchair, and the ocular control circuitry was mounted on the wheelchair back. Addition of the associated equipment was made without increasing the length or width of the wheelchair.

In Figure 4, the eyeglasses have been put onto the user and the wheelchair is ready for operation. Figure 5 shows the wheelchair as reclined by the user without assistance. At the start of the procedure the control circuitry is always in the null mode. A low amplitude audio beep occurs at a 1 Hz rate to indicate the null

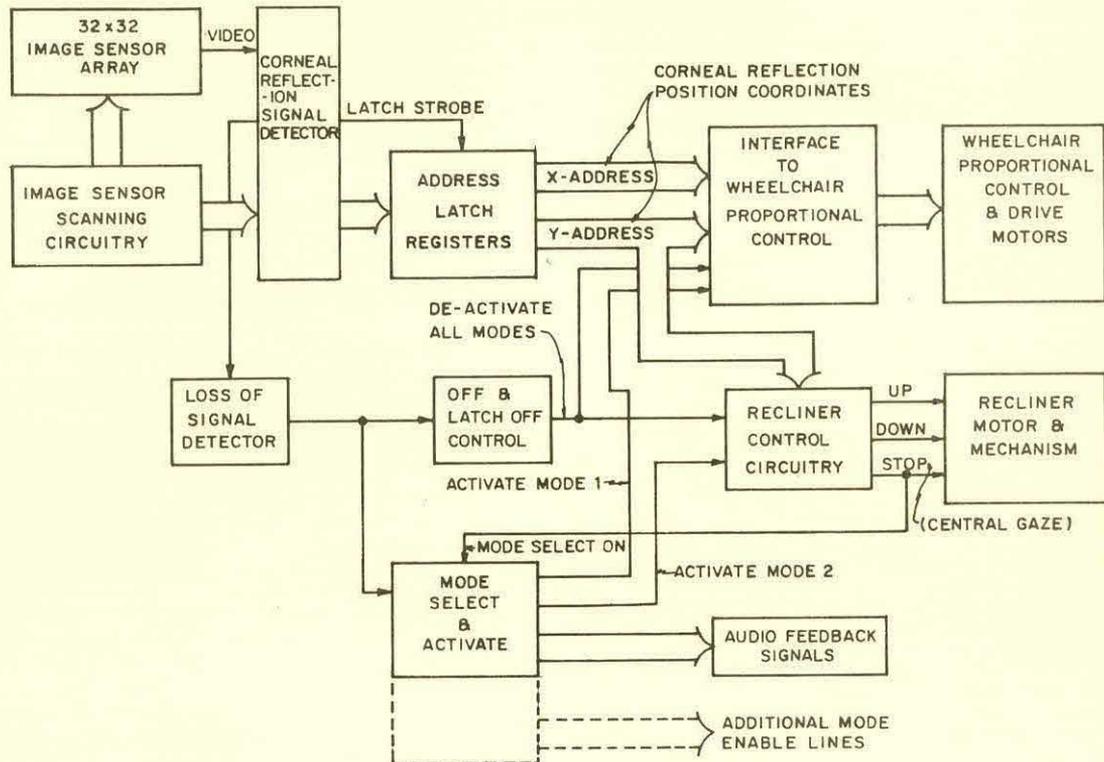


Figure 3. Ocular Control Circuitry Block Diagram

mode and to indicate that the eyes are in a defined central-gaze position. To activate the recliner mode requires that a particular sequence of eye blinks be performed in synchronism with the audio beep. When the recliner mode is activated a 2 second staccato tone is heard followed by silence. At this time no motion occurs because the eyes must be in the central-gaze position during the selection of any mode. In the recline mode, looking above the central-gaze position causes the chair to recline and looking below central-gaze position causes the chair to return to the upright position. The recliner can be stopped in any position by returning the eyes to central-gaze or by closing the eye.

Turning on the drive mode is achieved by a different sequence of blinks performed in synchronism with the audio beep. When the drive mode is selected a 2 second tone is sounded followed by silence. If the eyes remain in the central-gaze position, the wheelchair does not move. The velocity of the wheelchair is controlled by the direction and distance that the eyes are moved from the central-gaze position. The wheelchair can be stopped by returning the eyes to central-gaze or by closing the eye. The drive mode is turned off, just as the recliner mode, by closing the eye for 2.5 seconds or longer.

The ocular transducer may also be applicable to control of non-vocal communication systems. Preliminary development in this area has included interfacing the ocular transducer with TV games and a video displayed typewriter. In addition to

being a source of amusement, the TV games teach the user to control the position of a cursor on a video display. The typewriter unit consists of a display of an alpha numeric keyboard, a cursor which can be steered to any character by ocular control and a display of the characters selected. This unit is not completed to the point of testing at the present time.

#### Testing

The initial testing of the ocular transducer for wheelchair and recliner control was made by non-handicapped individuals to identify and correct obvious technical problems. More extensive testing was performed by a post polio quadriplegic who has been associated with this project for an extended period of time. Several problems were identified and corrected.

The next phase in testing is being conducted with the assistance of high level spinal cord injury quadriplegics at Craig Hospital. The most important aspects of the testing are to determine if eye motion is an acceptable means of device control and to determine if the ocular transducer is a practical wheelchair control for some quadriplegics.

The first SCI participant was a C4 quadriplegic with no arm motion but good head motion. About 15 minutes were required to adjust the image sensor unit for tracking the corneal reflection. It did not need readjustment after this time. He spent about 30 minutes operating the



Figure 4. Ocular Controlled Wheelchair and Associated Equipment

the wheelchair during the first session. Driving up/down a hallway presented no problems, but he required assistance in turning around in the limited space. During the third testing session he learned to activate each of the two modes of operation. Throughout the fourth and final session his ability to use the ocular control was still improving. After a total of about 3 hours practice he was able to maneuver the wheelchair in limited spaces, operate the recliner and use eye blinks for off-on control.

The first participant's comments on the ocular transducer as a means of controlling a wheelchair and a recliner included: (1) The sequence of eye blinks was a practical means of mode selection and he preferred this to switches mounted on a collar or the headrest. (2) The eyeglasses seemed less conspicuous than a chin operated joystick control box. (3) The eyeglasses would not interfere with transfers to and from the wheelchair or with other activities as much as other types of controls. (4) The ocular control was equally useful compared to the sip/puff control and better in some respects. (5) The chin-joystick proportional wheelchair control seemed more positive and precise than the ocular control.

The second SCI participant was also a C4 quadriplegic with no arm motion but good head motion. An unexpected problem was encountered when an attempt was made to adjust the image sensor unit. The desired size of the corneal reflection and the range of eye motion which could be tracked was not obtained. The same ocular transducers had been readily adjusted for at least six other individuals without encountering this problem. This participant operated the ocular controlled wheelchair for only about one hour since most of the sessions were spent working on the optical problem. The desired range of eye tracking was accomplished but reduction in the size of the corneal reflection was not achieved. Even with the unsatisfactory image, she was able to drive through doorways, turn and back up. With continued practice, her ability to use the ocular

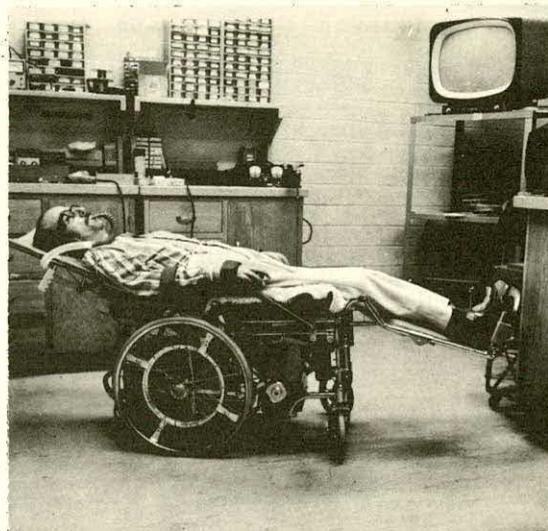


Figure 5. Wheelchair in the Recliner Mode

control would have improved but also would have remained limited until the optical problem was solved.

A C2 SCI quadriplegic who requires a respirator and has limited head motion will be a future participant in testing the ocular control. His ability to use ocular control and his opinions about it will be valuable since other control means are limited.

#### Concluding Remarks

The testing of the ocular control device by high level quadriplegics revealed that some problems still exist in the ocular transducer. Several factors which affect the operation of the ocular transducer are being investigated and modifications which should improve performance are being made. Safety of operation was of primary concern in the development of the ocular control circuitry and will remain a primary factor in the evaluation of all modifications.

At this time, the testing indicates that equipment can be controlled by eye position after about 3 or 4 hours of practice. It appears that the ocular control device may become a viable option for the high level quadriplegic to consider when selecting a means of control.

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A CONTINUING PROGRAM OF DEVELOPMENT AND EVALUATION OF A BREATH AND/OR VOICE CONTROL  
FOR A POWERED WHEELCHAIR FOR THE SEVERELY DISABLED  
PART I - EVALUATION & TESTING

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**Abstract:** Testing results of breath operated wheelchairs includes both previous and new data to provide an overall evaluation perspective. It covers comparison of data compiled from factors of patient operation, mechanical and electronic functioning of interface and wheelchair, and handling of patient and chair during testing. Findings are analyzed and used to set forth requirements for a breath and/or other interface and design of unit for compatibility with existing power driven wheelchair. Need for inclusion of a tape recorder operated with the same interface system is discussed.

<b>CATEGORY:</b>	INTENDED USER GROUP: High Level Quadriplegic and other severely physically handicapped individuals.
Device Development <input type="checkbox"/>	
Research Study <input checked="" type="checkbox"/>	AVAILABILITY OF DEVICE: Not applicable
<b>STATE OF DEVELOPMENT:</b>	AVAILABILITY OF CONSTRUCTIONAL DETAILS: Not applicable
Prototype <input type="checkbox"/>	
Clinical Testing <input checked="" type="checkbox"/>	
Production <input type="checkbox"/>	
<b>AVAILABLE FOR SALE:</b>	FOR FURTHER INFORMATION CONTACT: Muriel E. Zimmerman
Yes <input type="checkbox"/> No <input checked="" type="checkbox"/>	Institute of Rehabilitation Medicine
Price:	NYU Medical Center
	400 E. 34th Street, New York, New York 10016

Object

In previous presentations (contained in a Beginning<sup>1</sup> and an Interim<sup>2</sup> report) descriptions and results on evaluation of electronic devices for the high level quadriplegic - including the breath operated wheelchair - were covered. Continued testing and evaluation of the wheelchair has added both reinforcement and dimension, especially with findings included from testing of chairs at home after discharge. A combined capsuled summary of both old and new is offered first for the sake of perspective, and in setting forth a set of requirements as a basis for design criteria and resultant fabrication as presented in Part 2.

Method

Statistical parameters of the study are as follows:

Table I - Equipment Parameters

The testing of breath operated interfaces has all been done utilizing standard Everest & Jennings power driven wheelchairs. Four different interfaces have been used on four standard E & J models. The five different interface/chair combinations are described in Table I and for this discussion will

Table I - Equipment Parameters							
Chair Descriptors					Interface Descriptors		
Chair	E&J mod #	type of speed	Power	max. speed	inter-face design	no. of drive tubes	breath pressure mode
A	34	4- speed	12V	3 1/2 mph	1-tube	1	inter-mittent
B	33	fixed proportional	12V	5 mph	2-tube	2	sus-tained
C	33	variable proportional	12V	"	4-tube	2	inter-mittent
D	33	"	12V	"	1-tube	1	"
E	32	"	24V	6 1/2 mph	1-tube	1	"

be referred to as chairs A,B,C,D, and E. (Chair E is only in the beginning stages of testing, having just recently been designed and completed - report in Part 2 - but positive results have led to including data on it in all the Tables for purposes

of comparison).

Chair	total time tested	tot. # pat.	age range	cord level	post-onset	length of time tested individual patients
A	5 yrs	21	16-22 (16) 26-45 (3) 51-63 (2)	C2-5	1 mo. to 6 yr.	5-12mo (3) 1- 4 " (6) 1- 3wks(4) 1- 2day(6) ½- 2hrs(2)
B	20 mo	5	16-20 (5)	"	5 mo. to 5 yr	2mo (1) 1-10day(3) 20min(1)
C	20 mo	7	17-21 (7) 63 (1)	C3-5	3 to 14 mo	1mo (3) 1- 2wk (2) 1day(2)
D	12 mo	5	20-22 (4) 45 (1)	"	5 mo to 2½yr.	2mo (1) 1- 2hrs(2) 15min(2)
E	4 mo	4	21-22 (4)	"	5 mo to 2 yr.	1mo (1) 1day(1) 2hrs(2)

Table II - Patient Parameters

The period of time covered in these in-hospital tests ranges from five years to four months. The length of time in which any one patient tested any one chair ranged from 15 minutes to 12 months, with half the patients testing from 1-4 months. The total number of patients involved in the testing is twenty-three, some having used several of the test models. Generally, the age group ranges from 16 to 22; four were in a middle-aged group, and 2 were older, the oldest being 63. Injury levels range from C2 to C5, the majority being C4, 5. Half were 2-5 months post-onset, 2 were less than 2 months, 4 were 7-10 months, and 2 were 5-6 years.

Table III - Summary of Test Findings

A - Patient Operation

Chairs A,D, and E have provided the greatest amount of operation satisfaction. The main difference in these models is in speed - in amount and/or patient independence. Chair D improved over Chair A in giving the patient the ability to change the speed himself. Chair E has added an increase of speed, which was preferred, although jerk on starting and stopping while in high speed was undesirable and a potential danger. Chairs A, D, and E, the one-tube drives, were and are preferred over chairs B and C, the two-tube drives, because of the simplicity in input, ease, and cosmesis.

The breath requirements, discussed previously at length<sup>2</sup>, now show that the pressure levels themselves are not as much a problem as the range of levels when using more than one input with either negative or positive pressure, especially

Chair Model	A	B	C	D	E
<b>A. Patient Operation</b>					
breath - capabilities and tolerance	+	-	+	+	+
drive mode - learning	+	+	-	+	+
- ease	+	-	-	+	+
input errors	x+	+	-	+	+
speed variation - control	-	-	+	+	+
- results	+/	+/	-	+/	+/
<b>B. Mechanical/Electronic Operat.</b>					
<b>Interface</b>					
tube support mechanism	+/	+	-	+	+
emergency switch	+/	+	+	+/	+/
reliability control module	x+	+	+	+	+
<b>Wheelchair</b>					
speed available	-	-	+/	+/	+
driving smoothness	+	+	+	+	-
chair drift	-	-	-	-	-
driving ease	+/	+	+	+	+
<b>C. Handling and Service</b>					
<b>Interface</b>					
tube support mechanism	+	+	-	+	+
size of control module	+	-	-	+	+
<b>Wheelchair</b>					
battery and charger	-	-	-	-	+
constructional comfort	+/	-	-	+/	+/

▼ adjusted                      ● repaired  
 ✕ corrected                      + to be corrected

the negative which requires a greater range. Most patients can easily achieve the levels which are needed, particularly when the proper techniques of breath are mastered.

B - Mechanical/Electronic Functioning

**Control Mechanisms** - The supports on chairs A,B,D and E being superior indicates that flexibility along with stability is preferable to the rigid types used on C. The original small gooseneck used on A was too flexible. Use of one larger gooseneck to accommodate 2 tubes offered better stability and more cosmesis. The control box modules were reliable after repairs and a design change. Emergency switches on chairs A,D and E are still not without their problems.

Many patients are a little negligent in assuring that the emergency stop is in functional position, possibly due to the protected hospital environment. But because of the spasticity or a spasm of the driver which can occur at any time, an emergency stop must be present and operational at all times.

Another feature not mentioned in the testing results is the tip of the breath tube which comes in contact with the operator. This tip when separate sometimes pulls off or deteriorates. So far no satisfactory type of replacement tip has been determined.

Wheelchair Characteristics - The construction and operating functions of the wheelchair itself still cause several problems regardless of the type of breath control interface used.

The higher the speed available, the more ease there is in driving, especially where pneumatic tires are used on the chair. In low speeds, necessary for maneuvering in close quarters, friction from the pneumatic tires is difficult to overcome. The availability of a momentary burst of speed will overcome this problem. The ability to adjust speed also makes it easier to go up inclines and to cover more territory.

On the other hand, higher speed decreases driving smoothness as there is more jerkiness in accelerating and in stopping. When the operator is able to increase and decrease speeds just after starting and just before stopping then smoothness and comfort are improved, but skill is required to learn this coordination. The gliding factor, sometimes present during stopping, will also increase smoothness, but can be dangerous when it is too long.

Both smoothness and ease of driving are also affected by motor imbalance which necessitates constant course correction.

#### C - Patient Handling

Interface Mechanisms - Flexible tube supports on chairs A,B,D, and E, and the smaller-sized control boxes on A,D, and E were responsible for minimizing patient handling problems, especially during transfer.

Wheelchair Characteristics - There have been problems with batteries and battery chargers - factory defects and product life - but more frequently problems were due to the part played by those people responsible for the maintenance of the products. Patient comfort due to wheelchair construction has not been terribly satisfactory, but has been improved in chairs A,D, and E through use of modular components which permit individual fitting.

Home Testing (Operation, Mechanical/Electronic and Handling) - Chair A is the only one which has been used in the home environment. Five units are being tested. Periods of time range from 8 to 24 months (8,10,15,18,24). One chair has been entirely free of all problems. Four out of the five have had minor problems, but are being used satisfactorily. Areas of trouble were due mainly to battery and/or battery charging difficulties and to environmental restriction (curbs, transport, etc.). One had the breath unit attached temporarily to a chair loaned from nursing service which turned out to give seating problems that resulted in discouragement in use. Later, when unit was installed on patient's own chair, comfort

and operation were satisfactory. One or two minor mechanical breakdowns occurred. There were no actual difficulties with operation by the occupant of the chair, and acceptance of unit by patient and family was good.

The fifth patient experienced unit failure from day of delivery. After attempting to solve problems via telephone, chair was returned for check-out. Batteries proved defective. Also, the relays in the control module were not satisfactory. This unit was one of a newer design, the purpose being to reduce size of the box on back of chair, resulting in use of smaller relays (rated OK for desired performance, but functionally not adequate). Patient was also beginning to express dissatisfaction with chair itself (and all other equipment). As patient was scheduled to begin work very shortly, his concern heightened reaction to all or any problems, large or small.

Breath Controlled Tape Recorder - In as much as the use of breath control has increased the independence of the severely disabled high level quadriplegic in the rehabilitation center and at home, its introduction into school and work environments is a logical development. In anticipation, provision of a tape recorder, to be operated by the same breath system, was considered highly desirable and has been made available. Testing has been minimal as use of breath does not add additional demands. Use in actual educational or vocational settings will undoubtedly show some mechanical or hook-up needs due to handling aspects.

#### Results

##### General Requirements Determined From Testing

The results of the testing of the breath operated wheelchair as discussed above, have indicated the following requirements as of the present time:

##### A. Patient Operation

1. One-tube drive with intermittent breath control for ease of driving and cosmesis. Breath pressure levels and range (when 2 or more inputs) determined by patient potential and avoidance of unintentional signals. Average for 2 inputs is 3-6 inches of pressure for positive and 3-8 inches of pressure for negative.
2. Speed adjustment through breath operation, using a second tube.
3. An emergency stop system of some nature.

##### B. Mechanical Functioning of Interface

1. Firm but flexible support mechanism for the drive and speed adjustment tubes such as a gooseneck. Size important for cosmetic acceptance.
2. The size and positioning of the power control box are just as important as its reliability. How large it is and where it is attached great-

ly affect the ease of patient transfer and, ultimately, how much the chair will get used. This is also important as a cosmetic factor.

3. If interface comes in contact with patient, this piece must be easily exchanged or renewed for hygienic purposes and for maintenance of material.

C. Wheelchair Functioning and Handling

1. Sufficient speed to overcome chair inertia, friction of surface over which wheelchair is driven, and inclines.
2. Ability to adjust speed for adequate control in all environments, for safety and for comfort.
3. Control or elimination of drifting. No solution at present.

D. Wheelchair Structural Design

1. Fit and comfort. This requirement is being achieved through complete modular design. (Examples of this are the 4-post construction and the Postura backs.)
2. Battery with good life expectancy and charging systems with minimal maintenance problems.
3. Speed limiters. It is probably desirable to have two speed limiters, one which can be adjusted by the chair operator as a general safety measure, and one which is adjustable by a non-operator as a back-up safety measure.
4. Continued provision of the manual joy stick control or a standard interface. Dual interfaces, such as the breath control and manual control, should be considered essential in order to meet rehabilitation improvement changes, varying environmental demands, and fluctuating medical conditions. It is also sensible to maintain the manual system as a back-up to the breath control or other system in case of unexpected malfunction.

The above requirements determined from testing have been utilized in design of chair E, which is described in Part 2 of the presentation, as mentioned before. Observations of testing data reported show conclusive evidence of its superiority over other models.

As a result of success with breath control for wheelchairs, we must give attention to the newer voice control interface. The advances and development of this interface now allow us to consider its use. It would overcome one of the main factors remaining, which results in "less than 100% perfect" use of breath interfaces - that of

the actual physical contact. Some may consider it to be more cosmetic as well. Probably, however, it will not be without its problems. One that has been suggested is that of voice recognition when changes occur in volume or pitch due to such factors as fatigue, stress, or excitement. Another is the necessity for voice recognition re-training necessitated by such factors as hoarseness resulting from colds. It may also be necessary to determine the amount of distance and the amount of change in direction which can be permitted without affecting the quality of operation. And it must be determined how this operation will be affected by the onset of spasms or spasticity. Requirements for operation and handling of this interface have already been compiled according to guidelines set by preceeding data on breath interface and wheelchair testing. When the voice control unit, which is presently being developed accordingly, becomes available for wheelchair operation, testing will be done to include this interface along with the present systems.

References

1. Zimmerman, M.E., "Preliminary Report on Evaluation of Various Electronic Devices to Increase Independence of the Very High Level Quadriplegic Patient." Presented at the American Congress of Rehabilitation Medicine, Nov. 8, 1975 (unpublished).
2. Zimmerman, M.E. & Stratford, C., "Interim Report: Evaluation of Various Electronic Devices to Increase Mobility and Independence of Very High Level Quadriplegic Patients." Proceedings of the 1976 Conference on Systems and Devices for the Severely Disabled, pp. 86-88.
3. Youdin, M., Clagnaz, M., Louie, H. and Sell, G.H., "A Continuing Program of Development and Evaluation of a Breath and/or Voice Control for a Powered Wheelchair for the Severely Disabled - Part 2 - Wheelchair Control Design." Conference on Systems and Devices for the Disabled, Seattle June, 1977.

Acknowledgments

This work was supported by:  
 RSA Grant No. 16-P-56801/2-15,  
 Rehabilitation Research and  
 Training Center RT-1 from the  
 Rehabilitation Services Administration,  
 Department of Health,  
 Education and Welfare, Washington,  
 D.C.

A CONTINUING PROGRAM OF DEVELOPMENT AND EVALUATION OF A BREATH AND/OR  
VOICE CONTROL FOR A POWERED WHEELCHAIR FOR THE SEVERELY DISABLED  
PART 2 - WHEELCHAIR CONTROL DESIGN

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Institute of Rehabilitation Medicine  
New York University Medical Center New York, N.Y. 10016

**Abstract** To provide maximum mobility for quadriplegic and other severely disabled individuals, a continuing program of development of control systems for powered wheelchairs is in progress. The goals are to accomplish greater reliability, versatility and user acceptability. The NYU variable speed breath controlled wheelchair has been modified to enable the patient to operate a portable tape recorder from the DIRECTION control switches when the wheelchair is not in motion. A compatible battery operated voice recognition system has been designed to control the same powered wheelchair. Early clinical results with the improved pneumatic variable speed control have been excellent. It is anticipated that the voice control, because of its great versatility, will receive even greater user acceptability.

<b>CATEGORY:</b>	INTENDED USER GROUP: Quadriplegic and other severely and physically handicapped individuals.
Device Development <input checked="" type="checkbox"/>	AVAILABILITY OF DEVICE: Not Yet
Research Study <input type="checkbox"/>	
<b>STATE OF DEVELOPMENT:</b>	AVAILABILITY OF CONSTRUCTIONAL DETAILS: Yes
Prototype <input checked="" type="checkbox"/>	
Clinical Testing <input type="checkbox"/>	
Production <input type="checkbox"/>	
<b>AVAILABLE FOR SALE:</b>	FOR FURTHER INFORMATION CONTACT: M. Youdin
Yes <input type="checkbox"/> No <input checked="" type="checkbox"/>	Institute of Rehabilitation Medicine
Price:	NYU Medical Center
	400 E. 34th Street, New York, New York 10016

### Object

In order to provide maximum mobility for quadriplegic and other severely and physically handicapped individuals, a continuing program of development and evaluation of control systems for powered wheelchairs is being conducted at the Institute of Rehabilitation Medicine of the NYU Medical Center. The results of clinical evaluation of our previously reported single tube breath control for powered wheelchairs indicate it to be favored by all patients. This system has now been further developed to accomplish greater reliability, versatility and user acceptability.

### Method

There are two versions of the control unit. The simplest operates at fixed low or high speed selected by manual switching (which is not within control of the patient). This unit can be attached to a commonly used wheelchair (Everest and Jennings Model 34) with minimal rewiring. The IRM/NYU pneumatic control is compati-

ble with the manual joy-stick control provided by E&J. Wheelchairs equipped with both the manual and pneumatic controls can operate in either mode and be used by patients with varying degree of disability. The IRM/NYU control operates in the following manner: A high level (6 inches max. of H<sub>2</sub>O) positive pressure pulse causes the chair to move in the forward direction; a high level negative pulse (8-10 inches of H<sub>2</sub>O) causes the chair to move in the backward direction. Forward or backward motion cease upon application of an additional positive or negative pressure pulse. A sustained low level (2-3 inches H<sub>2</sub>O) positive pressure causes the chair to turn to the right; an equal negative pressure causes the chair to turn to the left. Turning from a standstill position is accomplished by driving one wheel motor in the forward direction and the other wheel motor in the reverse direction. Once the chair is traveling either forward or backward, turning is accomplished by stopping one of the motors for an instant. The chair will stop instantaneously when the patient presses his head lightly against a momentary contact switch mounted at head level from an ad-

justable gooseneck tube. This switch interrupts all power to the relays and resets the control system.

The fixed speed pneumatic control system has been further developed to provide continuously variable speed as desired by the patient. This unit requires a wheelchair with permanent magnet motors (as on the E&J Models 32 and 33 in place of the wound field motors that are supplied on the Model 34). Both motors are energized from a single variable motor speed control whose output is varied by a motor driven potentiometer which is in turn controlled by the patient through two pressure switches. Evaluation by patients has indicated a marked preference for a separate breath control tube for this function. A recent prototype chair with the continuously variable speed control (utilizing an E&J Model 32 wheelchair chassis and motors) is shown in Figures 1 and 2. Two breath tubes are contained within the single flexible gooseneck which is terminated with a mouthpiece for two straws. A continuous increase in speed is obtained by a sustained positive pressure; decreased speed by continuous negative pressure. It is possible to accelerate from low to high speed (or decelerate from high to low speed) in 4 seconds. To avoid sudden jerks of the chair when starting, the patient should start at low speed and increase speed as required. To avoid a jolt upon stopping, the speed should be reduced gradually as one would do in bringing a car to a stop. Since the speed setting is continuously variable, it is important for the patient to have an indication of the exact power setting at all times. We have developed an indicator which mounts directly onto the breath control tube as shown in Figure 3a. The indicator consists of a ring of eight red LEDs which are illuminated one after the other in a clockwise direction as the speed setting is increased. When the speed is set for maximum all of the LEDs are lighted as shown. In Figure 3b the speed setting is reduced and only the first three LEDs are illuminated. We have found that some patients have difficulty discerning lighted LEDs in very bright sunlight. For them we have substituted the 1-1/2 inch voltmeter shown in Figure 3c.

Most patients tend to drive the chair too fast before learning to maneuver properly. At maximum speed the chair moves 6-7 miles per hour (9.5 ft/sec). To prevent accidents and possible injury during training, the speed can be limited to approximately 60% of maximum. (The limiter switch is not within the patient's control.) The entire range of the LED indicator is applied to the reduced range, i.e. all eight LEDs are illuminated at 60% of full speed. The chair cannot be braked while in motion. However, a resistive load is connected across each motor when

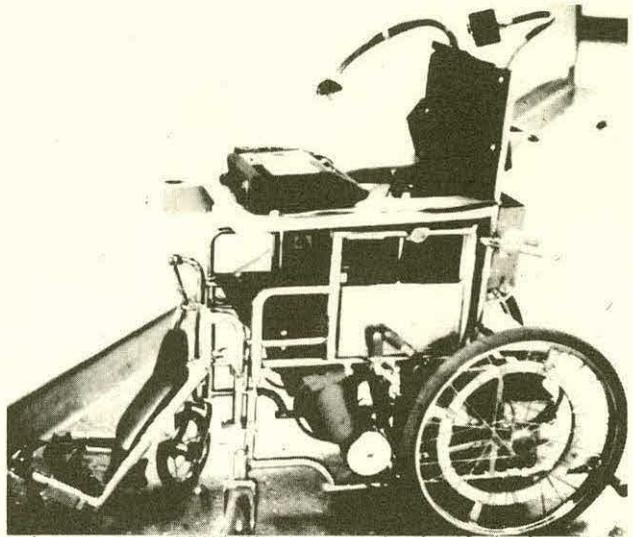


Figure 1. IRM/NYU powered wheelchair with pneumatic continuously variable speed control. Small black box directly over back is emergency stop switch.

a STOP pulse is applied. A block diagram of the breath operated control is shown in Figure 4.

We have also been concerned with providing the high quadriplegic student, writer, or potentially employable worker with a tape recorder/dictaphone system which is battery powered and small enough for use on a wheelchair lapboard. We have been able to adapt the Craig Model 2706A

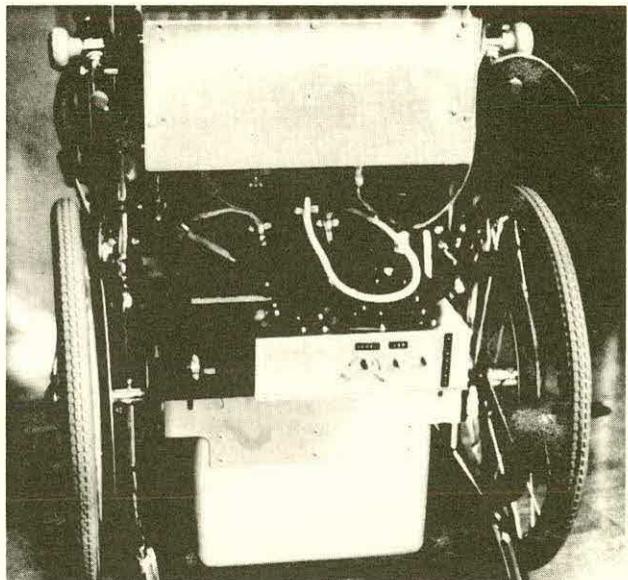


Figure 2. Rear of IRM/NYU chair. Top rectangular box contains DIRECTION pneumatic controls and power relays. Chair requires two 12 volt batteries. Rectangular box over batteries contains variable speed drive, speed limiter and switches required to transfer breath controls to tape recorder.

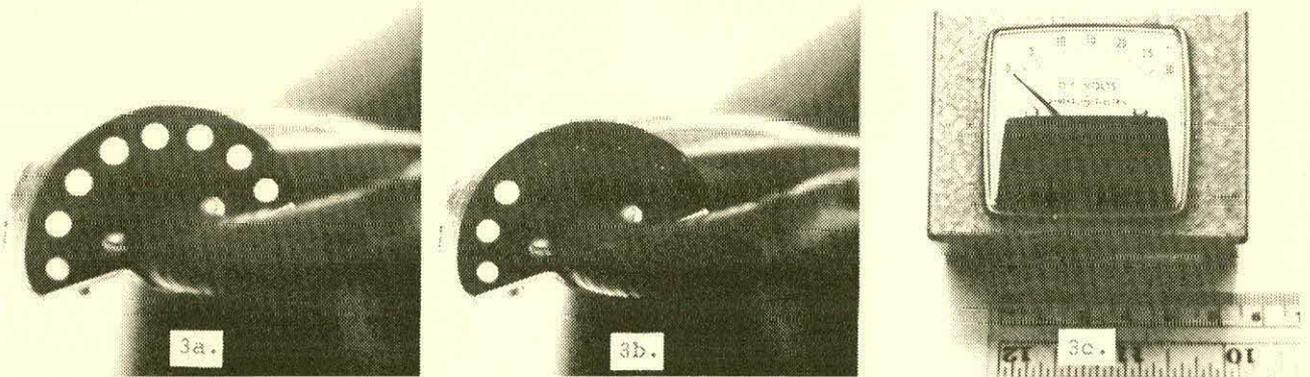


Figure 3. Speed Indicator has ring of 8 LEDs (light emitting diodes). Figure 3a. When speed is at maximum all LEDs are illuminated. Figure 3b. At lower speeds fewer LEDs are illuminated. Figure 3c. 1-1/2 inch voltmeter can be used in place of LEDs when bright sunlight makes it difficult to discern lighted diodes.

Dictator-Transcriber<sup>3</sup>, whose principal functions are solenoid operated, for breath control - see Figure 5. The tape recorder is operated from the wheelchair battery by means of a small inverter<sup>4</sup> shown mounted to the understructure of the wheelchair in Figure 6. When the wheelchair is not in motion, the DIRECTION control switches are used to operate the tape recorder. This is accomplished as follows (see Fig. 4): A sustained negative low pressure is applied to the speed control until the end of the speed range is reached. At the endpoint, the DIRECTION controls will be switched to control of the tape recorder and the green "Power" light on the tape recorder will be illuminated. A light positive pressure pulse will actuate the PLAY function. A second positive pressure pulse will STOP the tape. (It is necessary to apply a "STOP" pulse before proceeding to any of the other functions.) REWIND is accomplished by maintaining a light negative pressure for as long as is required to

reach the desired tape location. A digital counter is available for locating regions of interest. A high level positive pressure pulse will energize the RECORD function. (The switch on the hand microphone should always be maintained in the neutral position between DICTATE and REVIEW.) The red RECORD pilot light will remain illuminated for as long as the recorder is in the RECORD mode. A second high level negative pressure pulse will cancel the RECORD function and extinguish the red pilot light. Sound VOLUME and tape SPEED are not breath controlled.

A compatible battery operated wheelchair mounted voice recognition and control system has been developed for this same powered chair and is now being fabricated in its final form. All of the functions which are controlled by breath will also be controllable by voice. In addition there has been added a JOG control which will enable the patient to make incremental adjustments in direction and

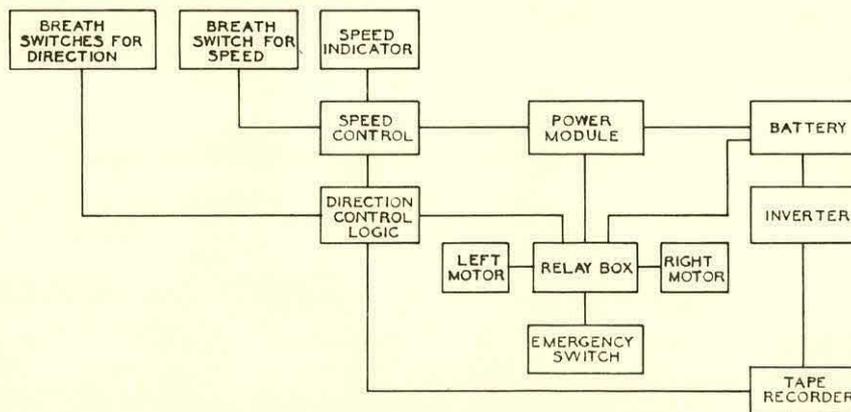


Figure 4. Block Diagram of Pneumatic Continuously Variable Speed Control with Inverter and Tape Recorder.



Figure 5: Dictator-Transcriber, shown on lapboard of wheelchair, is operated from breath tube top right.

speed. When not required for wheelchair control, the voice control system can be removed and operated from a 110 volt, 60 cycle AC power source to control an environmental control unit. The breath and voice controls are compatible and can be used interchangeably.

#### Results

Early clinical results with the improved variable speed breath controlled chair have been excellent. Patients master the control technique within a few hours. The Model 32 prototype (shown in Figs. 1 and 2) performs especially well on city sidewalks and hills. The balloon tires have been removed from the forward wheels because their increased friction contributes to a loss of indoor maneuverability. A detailed evaluation of the control is given in another paper from this Institute.

Since "voice" is the most natural form of communication available to patients, and because of the greater versatility and applicability of the voice control, it is anticipated that it will receive even greater user acceptability.

#### References

1. Youdin, M., Louie, H., and Sell, G.H., "A Proportional-Speed Breath Operated Motorized Wheelchair Control for Quadriplegic and Other Severely Disabled Patients", Proceedings of the 1976 Conference on Systems and Devices for the Disabled, June, 1976, pp. 86-88.
2. This unit will be available as a kit for installation on an existing chair or

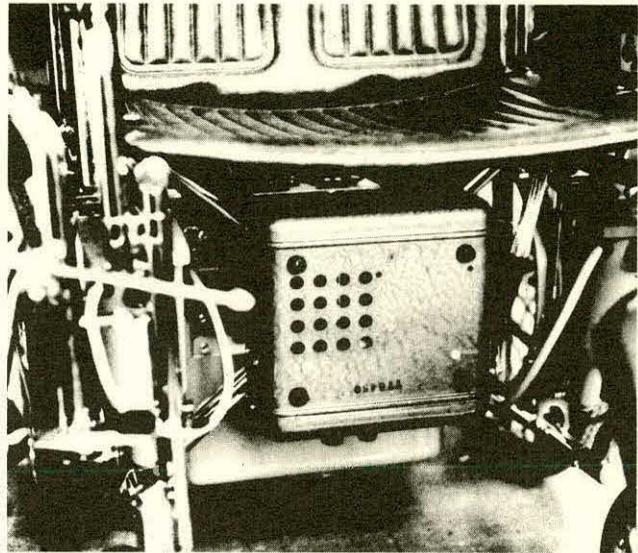


Figure 6: Inverter, shown mounted to understructure of Model 32 Wheelchair, supplies energy for Dictator-Transcriber.

as a control incorporated on chair at time of purchase from:

Everest & Jennings, Inc.  
1803 Pontius Ave.  
Los Angeles, Cal. 90025.

3. Model 2706A Dictator-Transcriber, operates from 120V, 50/60 Hertz, 20 watt supply. Manufacturer: Craig Corp., Compton, Cal. 90220.

4. Model 28V-RSF Universal Inverter, Input D.C. Volts = 28, A.C. Output 110V., 60 Hertz, 100 watts continuous. Manufacturer: ATR Manufacturing Co., Inc., St. Paul, Minnesota 55101.

#### Acknowledgements

This work is supported in part by:  
The Charles A. Dana Foundation  
The Hearst Foundation, Inc.  
Henry and Lucy Moses Fund, Inc.  
RSA Grant No. 16-P-56801/2-16,  
Rehabilitation Research and  
Training Center RT-1 from the  
Rehabilitation Services Administration,  
Department of Health,  
Education and Welfare, Washington,  
D.C.

## SESSION E FRIDAY, JUNE 3

- |     |  |        |
|-----|--|--------|
| E-1 | <p>SPEECH SYNTHESIS FOR NON-VERBAL<br/>CHILDREN - A PROGRESS REPORT</p> <hr/> <p>P. J. NELSON ET AL, OTTAWA<br/>CRIPPLED CHILDREN'S TREATMENT CENTER</p>                 | P. 153 |
| E-2 | <p>THE UTILIZATION OF AUDITORY FEEDBACK<br/>IN EXPRESSIVE LANGUAGE DEVELOPMENT</p> <hr/> <p>R.A. FOULDS &amp; H. GERTSTMAN<br/>TUFTS-NEW ENGLAND MED. CENTER, BOSTON</p> | P. 157 |
| E-3 | <p>VIDEO THERAPY FOR PHYSICALLY HANDI-<br/>CAPPED WITH PERCEPTUAL DISABILITIES</p> <hr/> <p>R.E. WARREN, CENTER FOR ADV. REHAB.<br/>ENG., DRAPER LABORATORY, MIT</p>     | P. 160 |
| E-4 | <p>MATCHING TRAINER FOR TEACHING<br/>DEVELOPMENTALLY DELAYED CHILDREN</p> <hr/> <p>A.M. COOK, MEYERS &amp; DEIGMAN<br/>CALIFORNIA STATE U., BIOMEDICAL ENG.</p>          | P. 163 |
| E-5 | <p>GRAPHIC &amp; WORD COMMUNICATION FOR<br/>THE VISUALLY HANDICAPPED</p> <hr/> <p>J.C. SHERMAN, DEPT. OF GEOGRAPHY<br/>UNIVERSITY OF WASHINGTON</p>                      | P. 166 |
| E-6 | <p>MOBILITY STUDIES WITH A TACTILE<br/>IMAGING DEVICE</p> <hr/> <p>C.C. COLLINS, SCADDEN &amp; ALDEN<br/>SMITH-KETTLEWELL INSTITUTE</p>                                  | P. 170 |
| E-7 | <p>TACTILE LEARNING DEVICES<br/>FOR THE BLIND-SENSORY QUILLS</p> <hr/> <p>D.R. TRAYLOR, JONES &amp; HEDGCOXE<br/>SOCRATIC EDUCATION, INC. TEXAS</p>                      | P. 175 |

## SPEECH SYNTHESIS FOR NON-VERBAL CHILDREN - A PROGRESS REPORT

P.J. Nelson, J.G. Cossalter, J.R. Charbonneau, and F.P. Orpana,  
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C. Côté and H.A. Warrick, Ottawa Crippled Children's Treatment Centre

A system is described which provides synthesized speech as auditory reinforcement on a Blissymbol communication matrix for non-verbal cerebral-palsied children. A study of five candidates over a period of five months determined that the addition of artificial speech resulted in improved attention span, emergent language, and interface manipulation skills for the children. The authors are proceeding to apply speech synthesis as an educational aid to the teaching of Blissymbols, the alphabet and numbers, and phonetics. A stand-alone classroom communication system is under development which will incorporate a speech synthesizer, a microcomputer, and a television display. The system has been designed to permit the addition of educational games which the children can play from their individual communication matrix boards. Future possibilities for speech-output aids for the non-verbal are discussed.

CATEGORY:	INTENDED USER GROUP: Non-verbal cerebral-palsied children
Device Development <input type="checkbox"/>	
Research Study <input checked="" type="checkbox"/>	AVAILABILITY OF DEVICE: Not applicable
STATE OF DEVELOPMENT:	AVAILABILITY OF CONSTRUCTIONAL DETAILS: Write to contact person
Prototype <input type="checkbox"/>	
Clinical Testing <input type="checkbox"/>	
Production <input type="checkbox"/>	
AVAILABLE FOR SALE:	FOR FURTHER INFORMATION CONTACT:
Yes <input type="checkbox"/> No <input type="checkbox"/>	Peter J. Nelson, P. Eng.,
Price:	Medical Engineering Section, M-50,
	National Research Council of Canada, Ottawa, Canada K1A 0R8

## Introduction

For nearly two years we have been experimenting with synthesized speech as an aid for severely handicapped non-verbal children. Feeling that a purely visual display of letters or symbols has some limitations, our objective has been to provide a multisensory learning experience for these children and to evaluate its effectiveness for communication and education.

Our initial equipment for this study was described at last year's Conference on Systems and Devices for the Disabled.<sup>1</sup> A conventional scanning display matrix and a commercially available speech synthesizer (VOTRAX<sup>TM</sup>) were coupled to a remote computer via telephone lines. Blissymbols were used on the display matrix. The computer provided the necessary memory and storage of control codes such that when a symbol was selected from the display matrix, the synthesizer would immediately speak out the name of the symbol. The computer would remember a sequence of selected symbols and, upon command from the subject, would cause the synthesizer to speak out the whole thought or sentence as often as is desired.

## An Evaluation of Audio Reinforcement

During the past year we have attempted to evaluate the effect of the audio reinforcement on some of the non-verbal children at the Ottawa Crippled Children's Treatment Centre. In particular we studied the attention span, emergent language, and interface manipulation skill of five subjects over a period of five months.

The candidates were cerebral-palsied children with various degrees of physical and mental handicap having an age range of 3 1/2 to 11 years. None of the children had reading skills. They were assessed as being able to relate to meaningful visual symbols, such as Blissymbols, but not to non-meaningful symbols such as the alphabet. The comprehensive skills of the 5 children, as measured with the Carrow Test of Auditory Comprehension, ranged from 3 years to 5 years 2 months.

The displays used for the evaluation period consisted of 32 and 64 Blissymbols. Since 4 of the 5 subjects were enrolled in a preschool and kindergarten setting, the 64-Blissymbol display was designed to meet the earliest level of comprehension and the specific vocabulary required for communication within the educational environment.

The display contained 3 pronouns, 7 human nouns, 8 verbs, 8 determiners and prepositions, 4 adjectives, 32 nouns, and 2 questions. Each child had the same basic display with him throughout the half-day school programme.

All the children used the joystick control for scanning the symbol display matrix. Three additional paddles were provided for the functions: SPEAK SYMBOL (memory record), SPEAK SENTENCE (memory read-out), and ERASE (clear memory). Each child received the same number of individual 30-minute training sessions using the audio reinforcement. Results of the study are summarized in Table 1. Explanations of the terms and methods of measurement are given below:

I Attention Span: This was defined as the time period during which each child showed total involvement with both the instructor and the equipment. The average attention span was ascertained over three, half-hour sessions without the audio. During the three subsequent sessions, the audio reinforcement was added and the average time of total involvement was measured again.

II Emergent Language: Each child was asked to respond to the question: "What is your news for to-day?" Responses were categorized as to parts of speech and to total number of words used. The children were limited, of course, to the 64 symbols in the display.

III Interface Manipulation: It took between 5 and 30 training sessions before the children understood the activation of the joystick and resultant scanning process. Once having achieved this under-

standing, however, each gained greater manipulative skills while exposed to the audio reinforcement.

#### Significance of the Study

Despite the limited scope of this study, the results of the use of audio reinforcement are encouraging. The children's attention span was increased significantly and their level of communicative skill generally improved. In fact, by the end of the study period, candidates 1 and 4 showed some attempts to use the equipment for spontaneous communication. The auditory feedback has had a positive effect on every child, emphasizing the relationship between the selected symbol, the concept it represents, and the spoken word for that concept. Thus the children were encouraged to learn more symbols and to increase their manual skills for more rapid selection of the symbols on the display matrix.

Our observations have been that all the children are fascinated by the "space-age" electronic quality of the synthetic voice. They listen to it attentively, understand it easily and frequently attempt to verbalize along with it. A note of caution is in order. The child's increased motivation to "talk" with the artificial voice, in conflict with his limited manipulative skill in selecting the symbols, can result in frustration and discouragement.

#### Speech Synthesis as an Educational Aid

Our work with synthetic speech began as an attempt to increase the effectiveness of communication aids such as a Blissymbol scanning matrix. From this work, it is becoming evident that the synthesizer is also a powerful

TABLE I Results of Five Months' Exposure to Audio Reinforcement

		CANDIDATES					Overall Average
		No. 1	No. 2	No. 3	No. 4	No. 5	
I Attention Span (minutes)	without audio	15	10	2	25	2	10.8
	with audio	25	30	30	30	12	25.4
II Emergent Language	initial exposure	single noun	single noun	single noun	single noun	single noun	1 word
	final exposure	pronoun, verb, noun	descriptive and noun	single noun	pronoun, verb, noun	single noun	2 words
III Interface Manipulation (minutes to locate one symbol)	initial exposure	8	15	3	1.0	10	7.4
	final exposure	0.5	0.8	1.5	0.5	7	2.1

educational tool.<sup>2</sup> The preschool children who started working with the synthesizer using Bliss-symbols on the display matrix are now progressing to alphabet and number displays and even to phonetics.

It is a simple matter to change the plastic overlay sheets on the display matrix and to call up different computer programs, so that the synthesizer will speak out the names of letters, numbers, or simple phonetic sounds. No matter what the characters are, the audio output provides immediate positive reinforcement for the chosen character. This objective feedback allows the child to learn by trial and error. The machine will patiently repeat the child's selection, whether it is right or wrong, as often as required. Mistakes made while working in this context do not upset the child. The relationship between the character and the spoken sound for that character is emphasized so that the child soon learns the correct character. These new programs are presented to the children, using the same equipment, with the same type of auditory reinforcement, as was used to teach Blissymbols.

In the classroom, the speech synthesizer holds the attention of the whole class, even of the verbal children. It appears to be an effective aid to the mastering of phonetic sounds. A further study is planned, therefore, to measure how much effect the synthesizer has on the teaching of phonetics to verbal and non-verbal children alike and to determine whether their vocabulary and reading skills are enhanced as a result.

#### Development of a Classroom Communication System

The original speech synthesis system was quite successful at holding the children's attention and giving them the independence to work on their own and at their own rate. Because of this we have proceeded to develop a classroom communication system which will permit more than one child to share the synthesizer and to inter-communicate with each other and with a teacher in the mediums of both Blissymbols and synthesized speech.

Our "Classroom Symbol Talker" is a stand-alone system built around a microcomputer and the speech synthesizer (see Fig. 1).

In this new system, two student display matrices are provided. Each will have 256 symbols, much like the communication matrix board used previously.<sup>1</sup> No link to a remote computer is necessary. The children will use the same interface controls which were adapted to them previously. The new boards will be different in that there will be a local loudspeaker in each board and special "control locations" on the symbol matrix to permit the child to select the destination for his or her message.

A graphic television display is planned as a low-cost additional feature. It will serve as a classroom "blackboard" onto which the teacher or either of the students can "write" a Blissymbol message. The teacher will use a numerical

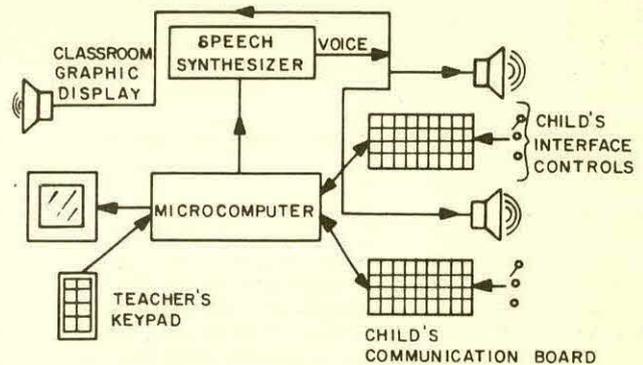


Figure 1

#### Block diagram of "Classroom Symbol Talker"

keypad to select the symbols from a code chart. The symbols will appear on the screen in "Times Square" fashion. By bringing the symbols together and displaying them in a serial string on the TV screen, it is hoped that a degree of connectedness will be conveyed which may be lacking in the way they are displayed on the individual symbol board.

The microcomputer is the component which provides all the necessary memory and electronic control. Sentences built up word-by-word on one child's board can be sent to the other board to be read out or to the TV screen for all to see. The audio from the speech synthesizer is also under computer control and can be directed to any individual board or to the whole class. As the symbol message is being displayed, the corresponding words are spoken by the synthesizer.

Technically, the microcomputer is based on the 8080 microprocessor. Since it has an 8-bit word length, it handles a 256-symbol vocabulary very nicely (each symbol can be identified by a unique 8-bit word or "byte"). The control programs are stored in Erasable Programmable Read-Only Memory circuits (EPROM's). This type of memory is ideal for this application because it allows the control programs to be changed by merely reprogramming the EPROM integrated circuits. The control codes required to direct the speech synthesizer to produce the spoken words are also stored in EPROM's. In this respect the synthesizer is an efficient device: it only requires about 1500 bytes of memory to store the codes for all 256 symbols. Each child's board is independent from the others and more "terminals" can be added to the system by interfacing them through additional parallel input/output ports in the microcomputer.

The speech synthesizer is the most expensive part of our Classroom Symbol Talker. By permitting several students and the teacher to share the synthesizer in a classroom setting, our system becomes more cost-effective. The synthesizer, the microcomputer, and the television display all can

be purchased as completely assembled and tested commercial products. This is a considerable advantage since it is always a serious problem getting small quantities of aids for the handicapped manufactured. The logic functions for our system are contained in the programmed EPROM's which can be simply plugged into the micro-computer. Only the individual symbol matrix boards and the interface controls need be custom made.

#### Additional Teaching and Recreational Programs

Additional programs can be plugged into the microcomputer to expand the capabilities of this classroom system beyond Blissymbols. We can now see the value of a graded series of programs, all with auditory reinforcement. Starting with the non-verbal children at the earliest preschool level, we would first introduce them to pictures of concrete objects on the scanning board, with the synthesizer speaking out the names of the objects. Blissymbols would not be introduced until the child was ready for them. After Blissymbols, programs to provide auditory reinforcement for the alphabet, numbers, and phonetics can be added.

The possibilities for other teaching and recreational programs are almost limitless. Each communication board has been designed to permit illumination of up to 25 of the lights simultaneously. Hence, by changing the overlay sheets and adding more preprogrammed memory circuits, interactive games such as Bingo, Tic-Tac-Toe, and Steeplechase can be played on the child's individual display. Alternatively, the game could be played on the classroom TV screen. The games must be chosen to match the children's developmental and functional capabilities and, ideally, to stimulate intellectual participation. The cost of additional EPROM memory circuits for each game is quite small.

#### The Future

The future of synthesized speech for the non-verbal physically handicapped looks very exciting. Because of the cost, educational applications appear to be the most practical at the present. Speech-output communication aids are most needed in group situations, where pointing on a display board is difficult for all to see. Hence, homes for the handicapped and other institutional settings will be logical places to implement multiple-user intercommunication systems similar to the one we have described.

The older non-verbal person who finds himself in social situations through employment and community activities, would find a speech-output aid a tremendous boost to his self image. (The "voice" must be clear and socially acceptable.) In fact it would be a psychological benefit to both the non-verbal person and the "listener" with whom he was trying to communicate. Since non-handicapped persons usually feel uneasy when confronted by someone using a symbol or letter board, speech would be a far more accommodating medium of communication for both. Speech output is also necessary for room-to-room communication

and for longer distance communication via telephone. Hence there will be a great demand for a portable artificial voice, whenever it can be developed. Cost, size and power consumption are the factors which prohibit the system described in this paper from being truly portable. Speech synthesizers will undoubtedly come down in cost, but their voice quality will still be price dependent.

There are techniques, other than the one described here, that can be exploited to produce artificial speech. In the near future, we can expect to see portable, speech-output communication aids, based on the technique used in the "talking calculator" for the blind. These devices will have a rather limited vocabulary, at least initially. For the severely handicapped, there remains a challenging problem of interfacing the device to permit reasonably rapid access to the desired words. Nevertheless, it shouldn't be too long until we have the non-verbal "talking" one way or another.

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## THE UTILIZATION OF AUDITORY FEEDBACK IN EXPRESSIVE LANGUAGE DEVELOPMENT

by

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Summary: This paper describes the preliminary rationale for the establishment of a laboratory for the investigation of synthesized speech feedback in a teaching program for non-vocal individuals. The study consists of the development of a computer augmented system that will be evaluated for its effectiveness in utilizing receptive language abilities to improve expression.

CATEGORY:	INTENDED USER GROUP:
Device Development <input type="checkbox"/>	Non-vocal severely
Research Study <input checked="" type="checkbox"/>	physically disabled.
STATE OF DEVELOPMENT:	AVAILABILITY OF DEVICE:
Prototype <input type="checkbox"/>	
Clinical Testing <input checked="" type="checkbox"/>	AVAILABILITY OF CONSTRUCTIONAL DETAILS:
Production <input type="checkbox"/>	Will be supplied upon request.
AVAILABLE FOR SALE:	FOR FURTHER INFORMATION CONTACT:
Yes <input type="checkbox"/> No <input checked="" type="checkbox"/>	Richard A. Foulds, Dir. Biomed. Eng.
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INTRODUCTION

The application of technology to the communication difficulties of people who are non-vocal due to physical dysfunction has been documented by this author, as well as numerous others. The interest in this population has grown considerably in the past few years and is now reaching a stage where many individuals are receiving services that were beyond expectation in past decades.

The result of this interest has been the unveiling of many subtle communication difficulties that had been formally masked by the high degree of physical disability present in members of the population. Engineering efforts to overcome physical limitations have provided sophisticated equipment that allows the severely involved individual to interact with his environment. Clinicians, however, are finding that the replacement or substitution of motoric function does not automatically lead to complete expression. Very few congenitally non-vocal individuals have been capable of immediately utilizing an electronic system to the full extent of their cognitive abilities.

The staff of this laboratory has been involved in the application of electronic devices with people who are non-vocal due to disease or accident after normal language learning has taken place. These individuals show the ability to use their previously acquired language skills and are capable of generating,<sup>(4)</sup> in the electronic medium, expressive output comparable to their chronological age.

This difference in expressive abilities has lead a number of investigators to seek alternative communication systems for those who did not acquire proficiency in English before the onset of the disability.

Possible Language Acquisition System

Several important observations can be made relating to the language acquisition skills of the non-vocal person. In general the careful observer can obtain an appreciation for the receptive ability of the non-vocal person by engaging in a conversation and attending to the facial and other clues given by that person as

indications of comprehension. This rough estimation can be supported by more quantitative testing methods<sup>(2)</sup> to indicate that in many cases the receptive abilities of the person are exceptionally good when compared to the minimal expressive capabilities. It seems that in spite of the lack of both normal physical and vocal skills, these people are able to listen to the world, and understand its language.

A second observation is that in many instances adaptive equipment offered to the person requires spelling ability. This requires the use of a written coding to represent concepts that the person recognizes auditorily. There is often little correspondence between the written and spoken appearances of a word. English is neither phonetic nor unphonetic, but rather disorderly phonetic<sup>(6)</sup>. There are numerous examples of one phoneme being represented by multiple symbols (e.g. -e, ee, ea, ie, y), and one symbol standing for multiple phonemes (S, C, Y).

Downing, conducted a study using 873 English school children who were taught a phonetic alphabet (The Initial Teaching Alphabet) and were taught to spell English phonetically. This group was compared with a similar 873 member control group. He showed that traditionally spelled English is a deterrent to the learning of spelling, since the children in the experimental group showed superiority in progressing through the standard elementary school reader program. He also showed that the experimental group exhibited better skills at the decoding of unfamiliar written words<sup>(3)</sup>. Roger Brown, supports this line of thinking when he hypothesizes that if our writing system were consistently phonetic, a teacher could teach a child the letters of the alphabet with their corresponding sounds. The child with little practice could convert his spoken vocabulary of 10,000+ words into written form<sup>(1)</sup>.

Shane, proposes that such a phonetic system should be applied to the congenitally non-vocal person in an attempt to make full use of his receptive abilities. A person with a moderate receptive vocabulary could conveniently encode them into an output form. Shane, used Downing's Initial Teaching Alphabet in a pilot study, and has demonstrated the potential of a phonetic system<sup>(7)</sup>.

#### Auditory Feedback

The key to the success of a phonetic writing system is the teaching of the correspondence between the auditory and visual symbols. In the work of Downing and Shane, the symbols were taught by a teacher representing the sounds vocally, and identifying the symbol. Since Downing's study involved physically able bodied students, they were also able to repeat the sounds themselves. In Shane's work, subjects were non-vocal.

If one were to consider the normal speaking process, there is a constant monitoring performed by the auditory system to correct both the quality and content of the utterance. Similar monitoring tells the beginning pianist which represents

which note.

The availability of electronic voice synthesizers has made the same type of system possible for use as an expressive language trainer. The user can select phonetic symbols by means of a communication aid and hear the auditory representation. It is this type of system that has been designed in this laboratory.

#### Auditory Feedback System

In the laboratory of the Biomedical Engineering Center, a model VS-6 Votrax voice synthesizer has been linked to a series of interfaces through a PDP II computer. The interfaces are representative of those commonly used in communication aids (i.e. scanning, encoding, and direct selection).

The user makes a selection of a phonetic character (based upon the Goldman-Lynch modification of the Initial Teaching Alphabet<sup>(5)</sup>) on his interface keyboard. The character is simultaneously printed on a video screen and spoken by means of the synthesizer. Characters are stored on the visual screen, as well as in the computer buffer. The user can command the system to speak all phonemes previously entered at any time, and can edit prior entries.

Special character generators have been developed to accommodate the phonetic symbols that are not ordinarily printed on video displays. In addition, certain deficiencies in the Votrax device have been overcome by software modification of phonemic entries. For instance, certain consonants when ending a word are difficult to hear. The system is programmed to recognize these problems, and make corrections that improve the quality of the output. These corrections are made without the involvement of the user.

A very important observation in this work has supported the claim that the simple stringing together of phonemes does not necessarily make an understandable word. Our initial tests have shown that many words require successive "tuning" by the programmer before they are acceptable. This fact has led many to avoid using a system of phoneme stringing with physically disabled individuals.

The one assumed fact in the above is that the use of the synthesized output is for communication with another person. In all cases in our work, the person who combined the phonemes was perfectly satisfied that his word was spoken nearly correctly. He knew the intended word and, therefore, expected it to sound correct. Others who listened to the words were often unable to make sense of the utterance until told the word.

The intended use of the system assembled in the laboratory is as a teaching system to be used in the feedback mode. The user is expected to know his message in advance, and to recognize the words when spoken correctly. He is not expected to be able to correctly spell the words. By "sounding" out the words by successive trials with the system, he can teach himself the phonetic

spelling by listening to the output, and accepting a close representation of the message. Since the phonetic symbols resemble the Roman Alphabet, and the system follows English grammar, the printed output can be used for communication. The printed output is not temporal, and is not influenced by pitch, inflection, or other auditory variables.

#### CONCLUSION

The development of the experimental system will be followed by experimentation by a population of non-vocal individuals who are tested to be deficient in written English. Further investigation will indicate the viability of such a technique. Parallel engineering studies will concentrate on the voice synthesizer quality and cost. Several low priced synthesizers are now marketed and will be compared with the VS-6.

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VIDEO THERAPY FOR THE PHYSICALLY HANDICAPPED  
WITH PERCEPTUAL DISABILITIES

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Experiments currently in progress suggest that a video camera-monitor system may provide alternative kinesthetic feedback pathways for individuals with perceptual disabilities caused by poor body-eye coordination, and thus offer a possible therapeutic technique for aiding certain physically handicapped individuals with perceptual disabilities.

CATEGORY:	INTENDED USER GROUP:
Device Development <input type="checkbox"/>	
Research Study <input checked="" type="checkbox"/>	AVAILABILITY OF DEVICE:
STATE OF DEVELOPMENT:	AVAILABILITY OF CONSTRUCTIONAL DETAILS:
Prototype <input type="checkbox"/>	
Clinical Testing <input checked="" type="checkbox"/>	
Production <input type="checkbox"/>	
AVAILABLE FOR SALE:	FOR FURTHER INFORMATION CONTACT:
Yes <input type="checkbox"/> No <input checked="" type="checkbox"/>	
Price:	

PAGE 2

### I Introduction

Certain physically handicapped individuals, especially those with congenital cerebral palsy or early spinal cord injury (involving severe motor neuron damage) exhibit not only motor-control problems, as one might expect, but also sometimes exhibit unusual and subtle perceptual problems that are difficult to describe and even harder to explain, particularly in cases where afferent pathways appear to be intact. At first sight, this may seem paradoxical; one naturally thinks of perceptual disabilities in terms of a breakdown at the input rather than the output, or motor-control, end of the system.

A possible explanation, based upon research by Richard Held and Alan Hein of the MIT Psychology Department(1,2,3), is that normal development of perception depends to some extent upon a good kinesthetic sense and adequate motor feedback pathways. It is often these motor-feedback pathways which are lacking in individuals with severe physical handicaps.

It is suggested here that a video system, a television camera and monitor, represents a possible alternative feedback pathway that may help establish the necessary conditions for normal perceptual development in individuals with severe motor-control disabilities. This technique is intended primarily for those whose visual system is intact but who have suffered some loss of motor coordination.

### II Background

For the past four years the Charles Stark Draper Laboratory has been experimenting with new approaches to the problem of designing aids for the physically handicapped(4). This effort has resulted in the design of a number of devices in the form of simple "do-it-yourself" kits that may be assembled, maintained, and even improved upon, by the handicapped individual himself. Part of this effort involves the development of materials and methods for training the handicapped to do some of their own engineering and design.

At present the goal is to develop a set of course materials for a secondary level class in practical engineering for the physically handicapped, in which the kits are used to illustrate solutions to various engineering problems presented in class. A pilot class for handicapped students was initiated to serve both as a "test bed" for curriculum development and as a basis for training films and video tapes for prospective teachers in special education.

### III Student Participation in Video

As the pilot class in practical engineering for the physically handicapped was being documented, some of the students in the class took an interest in the video equipment we were using. Without really expecting very much, we let a few of them shoot some of the scenes we had planned to incorporate in the tape which was to be used as a training vehicle for prospective high school teachers.

What was particularly interesting and exciting about this experience was that it seemed as though the act of focusing and framing scenes through a camera, with instant feedback on the monitor, began to change the way the students perceived the world around them. Many individuals became much more active and mobile in front of a camera when they could watch themselves "live" on a monitor. Some noticed things about their gait and posture that they had never noticed before. It is true, of course, that a similar effect is possible with film, but the full effect is lacking without the instant, real-time, playback made possible by video. For example, one could look at a film that was shot from the back to get a new perspective and learn something about the way one stands and walks, but to be able to see oneself from the back in the act of walking as it is happening makes it much more apparent which particular motor-commands are contributing to a posture or gait problem. One can see and correct problems almost instantly.

Having once observed that video could help make some changes in the way people saw themselves, gradually we began to wonder whether it could be applied to individuals with perceptual problems, to change the way they perceived the world around them. Some of our students were observed to have interesting but subtle perceptual problems. For example, one individual, a spastic with what appeared to be normal vision, exhibited an unusual reading problem; in particular, he had difficulty recognizing paragraph indentations even though he seemed to be able to read all the words, at least when presented singly.

We approached this problem in this way. It has long been observed by artists and photographers that looking at the world through a camera serves to call one's attention to particular features of a visual scene that one may not normally be aware of; for example, elements of foreground and background size contrast are more noticeable when viewed through a lens. Having reasoned, therefore, that framing scenes through a camera seems to change one's perceptual process somehow, we asked ourselves what would happen if we let our spastic point a camera at a book and try to read it off the video monitor. Viewing a scene through a hand-held camera in this way is interesting because it involves a feedback pathway that is somewhat different from a simple hand-held through-the-lens viewfinder; the video monitor on a table does not move as one moves the camera, while the viewfinder on the camera does. This uncoupling of the viewed scene from the hand movements produces some interesting insights in some individuals.

Although our conclusions here are extremely tentative, it appears that holding a camera and viewing the output from the monitor either makes his problem disappear, or else transforms it into a less obvious one. Our spastic was actually able to notice the paragraph indentations better.

Apparently commanding the camera to move vertically presents a visual stimulus on the monitor that makes it clearer that all the sentences line up evenly under one another except where paragraphs begin. Ocular motor-control problems seemed to have prevented a clear vertical scan of printed material.

This experience seemed to offer the prospect of a new and interesting therapeutic technique for individuals with perceptual problems that relate to motor-feedback deficiencies. At this point it is not clear whether it was the instant feedback on the monitor system or the fact that in framing a scene one looks at that scene differently that was the contributory factor in modifying perceptual behavior. In any case this effect warrants further investigation.

### IV THEORETICAL CONSIDERATIONS

Within the last decade, several research reports have appeared (1,2,3) suggesting that form perception is intimately linked with motor feedback functions. That is, perception is a function of the efferent as well as the afferent pathways of the nervous system. Constraints in motor activity were shown to inhibit the development of normal pattern recognition in cats and other higher vertebrates.

In a classic experiment by Held and Hein(1), two kittens from the same litter were reared in an enclosure with a number of shapes and forms printed on the walls. One kitten was allowed to move around the enclosure dragging the other strapped to a cart. The first engaged in normal active motor behavior, while the second was a passive participant "along for the ride." The first kitten developed normal form recognition, while the second did not. Although Held has indicated(5) that he and Hein did not feel the evidence here supported any specific claims about the inner workings in the nervous system, these experiments are certainly suggestive. If one were allowed to rhapsodize on the general theme, perhaps running ahead of the evidence, it might turn out something like this.

These experiments suggest that the nervous system encodes and transforms visual scenes in terms of motor feedback commands. For example, when one looks at a table that is described as "square," one rarely "sees" directly a square; in fact the image that is projected on the back of the retina is more likely to be a rectangle or at least a trapezoid. The ability to transform the given trapezoid into a standard square depends upon one's having learned at some point to lean forward, cock the head, etc., to bring the image "squarely" into view. That one visual scene is transformable into another is not solved as a problem of abstract spatial coordinate transformation such as matrix inversion in a digital computer; rather it is solved by "remembering" a series of internally felt motor commands that succeeds in performing the desired transformation. If one has a paralyzed back or neck, and cannot, therefore, move forward or cock one's neck reliably in the appropriate way, it is easy to see how such an individual might have subtle perceptual problems.

#### V Video system Configuration

If this picture is essentially correct, then a hand-held (or in some way personally controlled) video camera may represent an alternate way of transforming a visual scene in terms of motor feedback commands required by the central nervous system. For example, an individual with severe body-eye coordination problems which results in confusing rectangles and trapezoids, may learn to hold a camera over a picture of a square and move his hand around until the square looks "square." This experience allows him to internalize a set of motor commands that successfully transform visual scenes.

In thinking about what such a system might look like in the context of a person using it, one should resist the temptation to imagine a video camera strapped to the top of one's head. This is perhaps the least effective configuration. If motor deficiencies gave rise to perceptual problem because the body, head, and eye were poorly coordinated, then it would be better to remove the camera as far as possible from the head position. The camera should be held or controlled by whatever part of the body has the most controlled mobility.

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## AN INTERACTIVE MATCHING TRAINER FOR TEACHING DEVELOPMENTALLY DELAYED CHILDREN

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Abstract

The objective of our research program is to evaluate the thesis that developmentally delayed children, through the use of properly designed instructional devices, can acquire a variety of cognitive skills mediated via the task requirements of a discrimination learning set. In this connection, we have developed and evaluated an interactive teaching device. The teacher presents both an auditory and visual cue to the child indicating a color to be selected. If the child responds correctly by lifting the properly colored peg from a slot, feedback is automatically provided. A pilot classroom study showed that a discrimination learning set was acquired in approximately 500 trials using this device.

CATEGORY:	INTENDED USER GROUP:
Device Development <input checked="" type="checkbox"/>	Developmentally delayed children
Research Study <input type="checkbox"/>	AVAILABILITY OF DEVICE:
STATE OF DEVELOPMENT:	N/A
Prototype <input type="checkbox"/>	AVAILABILITY OF CONSTRUCTIONAL DETAILS:
Clinical Testing <input checked="" type="checkbox"/>	Yes
Production <input type="checkbox"/>	FOR FURTHER INFORMATION CONTACT:
AVAILABLE FOR SALE:	Albert M. Cook
Yes <input type="checkbox"/> No <input checked="" type="checkbox"/>	Price:

Introduction

One of the most basic skills underlying every form of learning is the ability to differentiate between two stimuli, and developmentally delayed children are capable of solving such simple discrimination problems [1, 2]. Having been exposed to a large number of discrimination problems, these children can also learn a strategy or rule with which to approach such problems, making the solutions increasingly easier to achieve [3]. In using a simple discrimination rule to solve problems bearing a family resemblance, the children would be said to have acquired a discrimination learning set.

Efficient acquisition of a discrimination learning set depends on systematic presentation of the material, consistent performance feedback to the child, and rapid trial-by-trial tabulation of the child's performance by the teacher [4]. Although a trained instructor can meet these requirements, the procedures are cumbersome and highly subject to human error (e.g. nonuniformity of stimulus presentation and feedback). It is, therefore,

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not surprising that learning can be facilitated by using properly designed instructional devices [5].

When devices have been constructed specifically for developmentally delayed children, limited success has been achieved in testing simple learning abilities. For example, Driscoll [6] evaluated four electromechanical devices in clinical and community settings and found them to have pedagogic and therapeutic value. Another useful device recently reported is an electronic spelling instrument offering minimal "reward" for a correct response [7].

Description of Matching Trainer

A prototypical device has been developed in our laboratory with the above needs specifically in mind. This device is shown in Figure 1. It is comprised of a peg board interface, a 35 mm slide display, and an electronic controller. When a certain preselected peg is lifted from its slot, a clown face and a pleasant noise are triggered. The face and noise composite serves as feedback to the child, indicative of a correct choice of pegs, and also serves as a reinforcer (i.e. it increases the probability of a correct response). The device also presents to the child a visual cue in the form of a 35 mm slide.

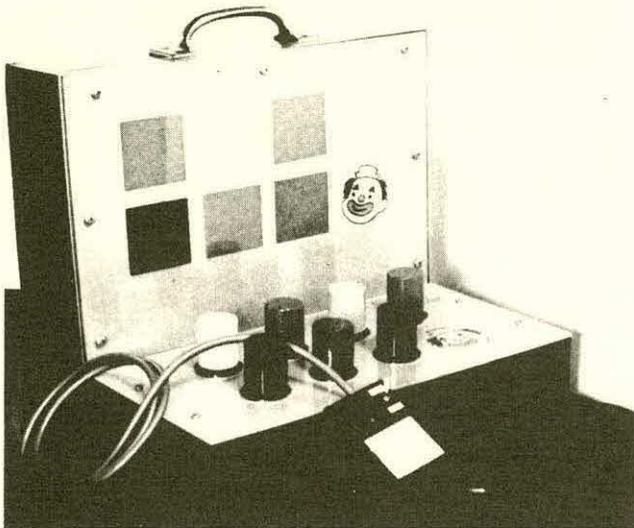


Fig. 1 Front View of Color Matching Trainer

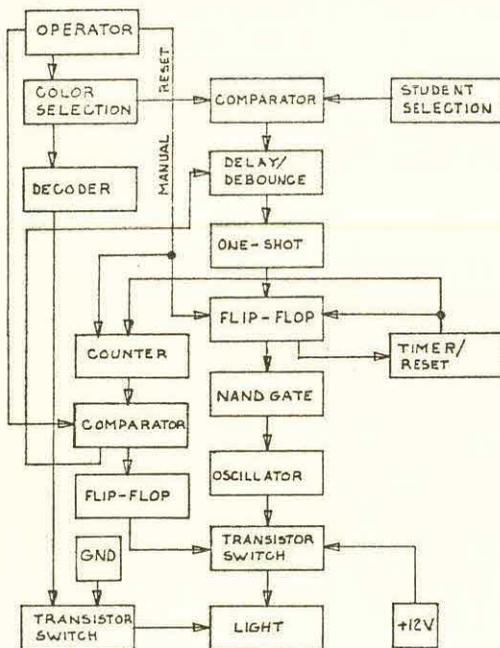


Fig. 2 Block Diagram of Matching Trainer

Figure 2 is a block diagram showing the signal flow in the matching trainer. The comparator circuitry is the decision-making element which evaluates the choices of the student and the instructor and feeds the result to the remaining circuitry. The operator also selects which light will come on if the student's selection agrees with that of the operator's. The color to be selected by the student is entered by the instructor and decoded. This drives the appropriate transistor switch, which illuminates the proper 35 mm slide. The signal from the comparator circuitry is processed in a circuit which delays the signal, effectively eliminating false turning on of the lights caused by noise introduced from the peg sockets. The one-shot, flip-flop, and NAND gate comprise a func-

nal AND circuit which responds identically to a signal introduced from anyone of eight different sources. This signal then drives an oscillator which controls the power to the reinforcer light, resulting in the clown face blinking.

A remote hand-held selector switch allows the operator to enter the chosen color, via a BCD code. The pegs have printed contacts on the bottom consisting of three concentric circles and a center dot. Ground is fed to the center dot on the pegs through a spring finger contact in the sockets. Depending on the code for the color, this ground signal is wired to the concentric circles on the back side of the printed contact. When the pegs are placed in the sockets, only the comparator which is fed from the socket housing the correct color is in the "compare true" state. A signal change from any comparator occurs only when a correct response is made by the child.

#### Classroom Evaluation

The matching trainer was evaluated in a pilot project at the Laurel Ruff Center, a school for developmentally disabled children in Sacramento. A child was presented with two pegs, one being randomly designated as "correct." Each trial consisted of different colored pegs from the total of seven possible. The slide showing the correct color was presented when the pegs were in place. Thirty five trials were run each day. Performance stayed at chance (50%) for the first 280 trials, increased to approximately 60% correct over the next 175 trials, and rapidly accelerated to 100% correct choices during the final 70 trials. Thus, after 525 trials, the child developed a discrimination learning set. Five other children did learn to associate peg removal with the reinforcement but did not develop a learning set within the time frame of the pilot study.

#### Significance

The development of the matching trainer and the associated pilot study have shown that developmentally delayed children can acquire a discrimination learning set through the use of an instructional device. A more extensive classroom evaluation based on a simple two-color discrimination is currently in progress. The approach and procedures outlined here enjoy a potential advantage over standard classroom techniques and over available instructional devices for developing learning skills. In these latter techniques, each time the child is taught a new concept, the child must also be taught a new response through which that concept can be expressed. The developmentally delayed child's job is thus made doubly difficult. In our approach, this double learning problem is bypassed. After the child learns to lift a peg in response to a cue, that behavior becomes a part of the response repertoire of the child and need not be learned again.

Once the child masters this simple task, the lesson to be learned could be made more abstract. In response to a picture of a puppy, for example, the child would choose a peg containing a picture of some other baby animal. In doing so, the child would develop the somewhat abstract concept of

"young animal." Additional advantages were shown by the pilot study. By providing a device in which the learning procedures are standardized and internally controlled and which at the same time is trivial to operate, there is little teacher-to-teacher variation in the presentation of the learning task to the student. The pilot study also showed an increase in attention span in children using the device, increased fine motor control due to manipulation of the pegs, and a demonstration of the effectiveness of the light and sound as reinforcers.

#### Acknowledgement

We thank Sr. Helen Hermreck and her staff at the Laurel Ruff Center for their help, and Judy Vaszary for preparing the manuscript.

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## GRAPHIC AND WORD COMMUNICATION FOR THE VISUALLY HANDICAPPED

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Results of current research, funded by the United States Geological Survey, now allow us to create graphic communication devices efficiently, flexibly and at lower cost than has been true heretofore. We are able to use manual or automated methods and to utilize most of the graphic materials and techniques currently in use. Graphics and braille are created in two-dimensional form and converted to three-dimensions photo-mechanically. Current work involves integrating the techniques, hardware and software of high speed word-processing systems to allow for rapid conversion of text materials into a braille equivalent. There seems good potential for an audio output as an alternate communication mode in the near future.

The thrust of our research and experimentation is to eventually be able to use one message input and a range of flexibility and economically achieved outputs representing several different types of communication modes.

CATEGORY:	INTENDED USER GROUP:
Device Development <input checked="" type="checkbox"/>	
Research Study <input checked="" type="checkbox"/>	
STATE OF DEVELOPMENT:	AVAILABILITY OF DEVICE:
Prototype <input checked="" type="checkbox"/>	
Clinical Testing <input type="checkbox"/>	AVAILABILITY OF CONSTRUCTIONAL DETAILS:
Production <input type="checkbox"/>	
AVAILABLE FOR SALE:	FOR FURTHER INFORMATION CONTACT:
Yes <input type="checkbox"/> No <input type="checkbox"/>	
Price:	

It is a pleasure for me to participate in and hopefully make some contribution to this Conference on Systems and Devices for the Disabled. While I am interested in and involved in various ways with some of the broad spectrum of subjects with which all of you are concerned I should like to confine my remarks to two special groups of users of a communication system. Those two groups include: 1) Persons who have very low levels of visual ability, sometimes referred to as partially seeing; and 2) Persons who are legally or totally blind including those who have had sight for part of their lives as well as congenitally blind individuals.

I do this for two reasons: 1) The functions of any communication system for these two groups is, in essence, exactly the same as for all human beings. These functions relate to the process of learning and understanding the static and dynamic characteristics of the world we live in and to do so with a maximum degree of independent selection of the communication modes used; and 2) The philosophy, methodology and technology of cartography (my special field), with some special modifications, is directly applicable to the creation of graphic and other communication modes to serve the needs of these two groups. Further, it is my belief that only the melding together of traditional methods with new ones made possible by

developing technology and applying the mix, in so far as possible, to multiple use or a variety of alternate purpose products will we be able to achieve the economies of scale I see as necessary in meeting the needs of the visually handicapped. Heretofore there has been too much compartmentalization in the approaches many have used in trying to serve these needs. Until about 1955 people who tried to develop mobility or general information type maps for the blind made little use of the methods and techniques of cartography. Very little progress had been made in almost a hundred years. Until recently those concerned with the improvement and application of the braille coding system were almost completely ignorant of rapid developments in "word-processing" methods and hardware which might have been applied. There are many other examples I am sure, but it is sufficient to point out that there should be more careful examination of methods and techniques that were and are being developed for sighted purposes to see if any can be applied directly or with some modification to the communication needs of the visually handicapped.

## Towards Improved Spatial Knowledge

Since 1954 I have been interested in the utility of maps for the visually handicapped and practical methods of creating such maps. During the

intervening years I have had contact with almost every major organization in the world which produces tactual communication aids for the blind. I have collected and analyzed tactual maps and other graphics, supervised the production of experimental products<sup>1</sup> and have undertaken and/or supervised some basic research<sup>2</sup> on tactual perception and design requirements for graphics to be read by the blind and the partially seeing. My colleagues, my students and I have really just begun for the research needs are extremely broad. We have, however, made some progress.<sup>3</sup>

Under a research contract funded by the United States Geological Survey we have been exploring the rationale for and methods of converting USGS map products into forms useable by the partially seeing and the blind. The range and variety of activities in which those who must adjust to severe visual malfunctions or blindness are participating is steadily increasing. Whether these activities involve sports, such as hiking, skiing, fishing and boating; are related to employment in industry or the professions; or involve the daily problems of learning to operate in and gain understanding about an unseen or dimly seen environment, maps could serve as useful communicative devices. The graphic mode of data presentation is not necessarily the most effective device for conveying information to all sighted individuals, neither can it be assumed to be best for those with severely restricted or no sight. Furthermore, the lack of a variety of easily available maps designed for different learning tasks has been so severe that many visually handicapped people have never seen a map designed for their use and thus have never acquired any training or experience in reading and interpreting them. Thus the increasing range of activities in which they participate has not generated an increase in demand for maps that could be useful tools in those new learning situations.

In this project we have had the objective of creating two experimental maps. The first is of Metropolitan Washington, D.C., all the area within the Beltway, at a scale of 1:24,000 or one inch to two thousand feet. Basically this involves conversion of all or portions of twelve quadrangle maps into a visual image designed for those with restricted vision as well as one which is tactually readable. This map for wall display will be published in two dual-use editions in molded plastic; one with the multi-color normal visual image with tactual symbols in relief and the other with a large type reverse image combined with tactual symbols also of molded plastic. The pre-printing on plastic and the vacuum forming of the final products is being carried out by the Defense Mapping Agency-Topographic Center which is cooperating on this project. The second map is of The Mall in Washington to function as a personal mobility map at a scale of one inch to three hundred feet. One dual-use edition will be produced combining a large print visual image and raised tactual symbols.

The Metropolitan Map is unique for I cannot identify a single map of a whole major city that has been produced anywhere in the world for use by the visually handicapped.<sup>4</sup> In fact the support and encouragement of the USGS is unique, the first case in the world in which a national mapping agency has ever attempted to produce maps for the

visually handicapped. The map scale eliminates its use as a mobility map, its function will be as a tool to learn about the gross morphology of the city and the major transportation linkages within it. The Mall map will be in the form of a twenty-four page booklet, portable with quite detailed maps for independent travel in The Mall.

It is not my purpose today to describe and analyze the many problems and solutions related to the function for and the design of these maps but rather to deal with the technical method of producing them that we have developed. This method and others which are speculative at the moment have very broad implications for and applications to the development of a communication system for the visually impaired which is multi-modal. While my special interest is and will continue to be in maps, basic techniques we are using are equally applicable to the creation of many other communicative tools.

#### Tactual Map Creation

For many years it has been obvious to me that we needed to find a photo-mechanical system with which we could create three-dimensional symbols which could be read tactually. Once developed we could utilize standard techniques and materials to create a two-dimensional image and then transform it to a three-dimensional. I will not detail all the techniques and products we have experimented with, in the end and for the moment we have found the Nyloprint printing plate system<sup>5</sup> most effective for our purposes. These polymer plates are exposed through a high contrast negative and when processed an image is formed whose height is .026 of an inch. This exceeds the internationally recommended height for braille dots which is .020 of an inch. Completed plates cost approximately twelve dollars per square foot, but are tough and durable such that they can be used directly as tactual graphics or as masters for vacuum-forming additional copies in plastic. Our experiments also indicate that a negative positive pair of plates can be used for blind embossing of paper copies at much lower unit prices. This photo-mechanical process makes possible pre-separated manuscript copy in hand drawn, scribed or plotter output form and use of conventional contact techniques for producing composite negatives from which plates can be made. Separation made feasible could allow several subject-specific maps to be produced on the same base at relatively low cost. For map symbols we now can create virtually any texture for area symbols, any shape for point symbols and a variety of structured linear symbols which are tactually discriminable. It is therefore obvious that the technique is suitable for creating braille, graphs, mathematical and musical symbols, electrical diagrams, special and general purpose signs, etc.

Although I know that a large proportion of the blind in the United States do not read braille, our maps do incorporate identifiers (names) in braille. Thus we have had to develop a practical way of creating braille symbols in a form adapted to our photo-mechanical conversion process. In the University Department of Printing we have produced a master braille sheet which meets international standards. Converted to a film negative I now compose braille by opaquing and thus removing

unnecessary dots from each cell to create the individual letters or contractions of grade II braille. The selectively opaqued negative is ready to be used to make a Nyloprint plate. The system is not useable for placement of braille on a map but the master negative can be used with the rather new 3M Corporation Image-N-Transfer material<sup>6</sup> to make transfer braille type which is easily placed on a map. In this way all braille is in black-dot two-dimensional form and is not converted to a raised dot until the plate is made.

As already indicated we are creating large type visual images of our maps designed for reading by those with very low levels of vision, the partially seeing. Based on our past research,<sup>7</sup> all image elements are in reverse, that is white symbols and letters on a dark surround. All lettering is in capitals and lower case, specially letter spaced and at a minimum of 18 point (18/72 inch) in size. This image will be printed on flat sheets of plastic before they are vacuum-formed against a Nyloprint plate to create the tactual image. The end product is then dual use.

#### Experimental Applications

To date we have applied this new system to a variety of types of communicative devices. A special map was a floor plan of the new National Air and Space Museum in Washington, D.C. designed to aid blind visitors to move in the building from one exhibit to another. A graphic diagram (vertical and side profiles) of the Bell X-1 aircraft intended to be used in conjunction with an audio-tape as an aid to the blind in learning what an exhibit contained. We have equipped some fifty-five elevators on the campus of the University of Washington with braille identifiers, some of which are both tactually and visually readable. We have designed a sign for our Metro system to mark bus stops, eventually there will probably be some seven thousand of these signs made from Nyloprint plates at a unit cost of approximately forty cents. I recently furnished fifteen signs for a "See, Touch and Smell Garden" for Lewis County Parks and Recreation Department. These signs have raised visual letters as well as braille and some contain outline graphics of plants in the garden. While we have not solved quite all of the problems, we have been successful in embossing a map in paper utilizing a negative and positive Nyloprint plate. Our experience to date provides strong indications that this photo-mechanical system is applicable to creation of a very large range of devices useful to the blind.

#### Planned Research and Service Activity

All of the work underway to date has demonstrated possible methods by which we can utilize new materials, new techniques and to adapt old ones to increase the efficiency and flexibility with which we can help to improve the communication system presently available for the visually impaired. It is also increasingly clear that we need to do this in terms of a multiple products multiple function set of objectives.

As a result of our experience to date it seems evident that we can now organize a system utilizing techniques and equipment already available on this campus to significantly enhance our ability to

serve communication needs of the visually handicapped. We now have a technique for creating virtually any type of graphic quickly and inexpensively even though we still do not have adequate psycho-physical knowledge to develop optimal design parameters for low vision and blind users.<sup>9</sup> The production of text in alternate formats is our next thrust and at the heart of this objective lie the methods and hardware of modern word processing systems. The University's Department of Printing is cooperating and making available, at least for test purposes, their Optical Character Recognition scanner, editing terminal and high speed photo typesetting equipment. The Computer Center will be providing programmer help and advice in putting our Grade II Braille Conversion Program into operation. We are acquiring an LED 120, a high speed braille embosser, made possible by a gift to the University from the Washington State Council of the Knights of Columbus which will be activated by the output of the conversion program. We hope that by late summer we will be able to take a text typed on an IBM Selectric II utilizing a modified Courier 12 (No. 173) type element, put it through the scanner and editor and obtain a "clean" tape. The tape then submitted to the photo-type setter allows us to produce a text designed for those with normal vision or in large characters for those with low vision. The same tape can then be input for the Braille conversion program and the text finally embossed in braille on the LED 120. After conversion, braille data could be transmitted to an LED 120 located anywhere in the state or could be converted to tape which could be deposited in a library or shipped to any potential user. If a coded tape is already available in the printing plant no typing of that text would be necessary. In a similar manner tapes created for automated typesetters could be acquired from a publisher and converted to braille or large type versions in the same way.

#### Possible Future Developments

Once we have this system operational there are several further possibilities we want to explore. The braille embosser would be most efficiently used for a limited number of copies, possibly four to ten, the most frequently needed number. In the rare special case where several hundred copies are needed we want to explore the possibility of creating black dot two-dimensional braille on our photo-type setter. This would allow us to utilize pairs of Nyloprint plates on the embossing press and to produce multiple copies in embossed paper at fairly low unit costs. Black dot capabilities would also allow us to set braille identifiers to be incorporated on maps or any other type of graphic.

If the input encoding required by the recently announced Kurzweil Reading Machine<sup>10</sup> is compatible with the scanner type output it should be possible to create a synthetic speech audio tape of the original typed text. This would also mean that publishers' tape libraries, where they exist, could also be converted to an audio-tape form.

Our system developed on our USGS contract allows us to use a computer driven plotter to create two-dimensional graphics. We can use a penhead, a scribehead or lighthouse type of plotter and the last two would create a photo negative with

which we could produce three-dimensional Nyloprint plates directly. Coupled with improved knowledge of tactual perception we eventually hope to be able to design more effective graphic communicative tools than have been available and at a lower cost.

#### Conclusion

I have briefly described some of the possibilities I see for expanding the communications for the visually handicapped. We are looking into the potential of using digitally controlled laser systems for creating three-dimensional graphics, for example. We are cooperating with Kenneth O. Beatty, a Chemical Engineer at North Carolina State, who has developed a photo-mechanical technique with which we can create up to four different controllable levels of relief for graphic symbols, a major break-through.

I am sure that at this symposium I will hear of other ideas which might expand all of our abilities to improve communications for the visually handicapped. I hope my remarks are of some value to a number of you.

#### Footnotes:

1. Tactual Maps developed:  
Map of the Seattle Civic Center, 1968.  
The University of Washington Campus Atlas, 1973.  
Metropolitan Washington, D.C., 1977.  
Map of The Mall, Washington, D.C., 1977.
2. Greenberg, Gerald L., "Map Design For Partially Seeing Students: An Investigation of White Versus Black Line Symbology", unpublished Ph.D. dissertation, University of Washington, 1968.  
Heath, Willis R., "Maps and Graphics for the Blind; Some Aspects of the Discriminability of Textural Surfaces for Use in Areal Differentiation", unpublished Ph.D. Dissertation, 1958.  
Ogrosky, Charles, "New Approaches to the Preparation and Reproduction of Tactual and Enhanced Image Graphics for the Visually Handicapped," unpublished Master's Thesis, 1973.
3. Sherman, John C., "The Challenge of Maps for the Visually Handicapped", Proceedings of the International Symposium on Computer Assisted Cartography, pp. 91-98, U.S. Department of Commerce Bureau of the Census and American Congress on Survey and Mapping, Cartography Division, 1975.
4. The only comparable map is "Raised Map of Central London" published by the Royal National Institute for the Blind, London, 1st Edition, 1961.
5. Manufactured as a letter-press and dry-offset plate by BSAF in Wyandotte, Michigan.
6. "Image 'n Transfer" a Graphic Transfer material manufactured by 3M Corporation.
7. Greenberg, Gerald L., and Sherman, John C., "Design of Maps for Partially Seeing Children", International Yearbook of Cartography, X, 1970, pp. 111-115.
8. Two dissertations are presently underway.  
Ogrosky, Charles, "Investigation of Ordinally Classified Tactual Symbols" (only a tentative title).  
Hiatt, Charlett K., "The Role of Color Coding of Linear Symbols on Maps of Partially Seeing Children " (only a tentative title).
9. The Kurzweil Reading Machine was announced by the National Federation for the Blind in January, 1977. Six pre-production models are to be tested.

## MOBILITY STUDIES WITH A TACTILE IMAGING DEVICE

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Department of Visual Sciences  
University of the Pacific, San Francisco, California

In the evaluation of a new sensory aid for blind mobility comprising a wearable tactile vision substitution system we have made a number of behavioral measures. We have examined the effects of some 40 consecutive practice trials on the safety and efficiency of indoor mobility performance of each of two blind subjects in a laboratory travel environment. After two hours mobility experience with only this device, blind subjects walked freely at about one foot per second on a 65 foot mobility course through a room cluttered with furniture, detecting and avoiding over 95% of the obstacles (100% in half the trials). Subjects decreased stop and search time from 61 to 14 seconds with a 120 second mean total travel time. Travel efficiency (percent time spent walking) increased from 63% to 86% during these trials.

These tests demonstrate the feasibility of the concept that optical information alone presented on the skin can contain sufficient information to permit the blind to avoid obstacles and steer a clear path for successful indoor mobility.

CATEGORY:	INTENDED USER GROUP: Scientists, engineers and clinicians performing mobility research and evaluation.
Device Development <input type="checkbox"/>	
Research Study <input checked="" type="checkbox"/>	
STATE OF DEVELOPMENT:	AVAILABILITY OF DEVICE: The one laboratory prototype is available for inspection and demonstration and may be used in collaborative studies.
Prototype <input type="checkbox"/>	
Clinical Testing <input checked="" type="checkbox"/>	AVAILABILITY OF CONSTRUCTIONAL DETAILS: Circuit diagrams, photographs, drawings, engineering and biophysical data, and descriptive articles available.
Production <input type="checkbox"/>	
AVAILABLE FOR SALE:	FOR FURTHER INFORMATION CONTACT: Dr. Carter Collins.
Yes <input type="checkbox"/> No <input checked="" type="checkbox"/>	
Price:	

## Introduction

Vision is probably our most important mobility sense, permitting us to walk rapidly, accurately and confidently wherever we wish to go. Since this source of mobility information is not available to the blind, there has long been the need for an effective sensory aid permitting safe and efficient travel by the blind pedestrian. The latest electronic guidance devices (1, 2) have not yet been generally accepted by the blind community (3), and today the long cane remains their best available mobility aid (4).

It has been the specific aim of this present preliminary investigation to determine the feasibility of utilizing wide field optical information impressed onto the skin as a mobility aid for the blind. In this study we have set up a synthetic mobility environment and have made a number of objective measurements of the mobility performance of blind subjects using a newly developed wide field of view sensory aid as their only guidance device.

This investigation was supported by the Department of Health, Education and Welfare, Public Health Service Grant Number 1 R01 EY00686 from the National Institutes of Health, National Eye Institute; Grant Number 501 RR-05566 from the Division of Research Resources; and Grant Number SKF1004 from the Smith-Kettlewell Eye Research Foundation.

## Methods

Sensory Aid. The wearable sensory aid utilized in these experiments (Fig. 1) has been developed over the past ten years (5, 6, 7). It utilizes a miniature, monolithic, wide angle television camera mounted on the frame of a pair of glasses which serves as the artificial eye of the sensory aid. Images from this camera (Fig. 2)

are electronically impressed point-for-point onto the skin of the abdomen by means of a 10-inch square array of 1024 coaxial stimulus electrodes mounted on a flexible, elastic supporting garment worn directly against the skin of the abdomen (7). The complete system weighs five pounds including two pounds of rechargeable nickel cadmium batteries for eight hours of operation.

A small and versatile optical system was designed by one of us (CCC) for blind mobility use with the sensory aid. The optics provide an adjustable field of view up to 180°, an infinite depth of field which permits operation with no focusing adjustments required by the subject, and a large aperture (f:0.5) for operation with available room light.

Preliminary trials indicate that a 90-degree field of view appears to be about the best compromise between sufficient resolution with the 32-line system to detect obstacles and the very wide peripheral field of view

necessary for mobility. The optical axis of the lens was directed  $45^\circ$  downward to include a field of view from just above the horizon down to the space directly in front of the subject's feet in order to permit him to detect low obstacles within a footstep of his path. This field of view and lens direction were used throughout these tests.

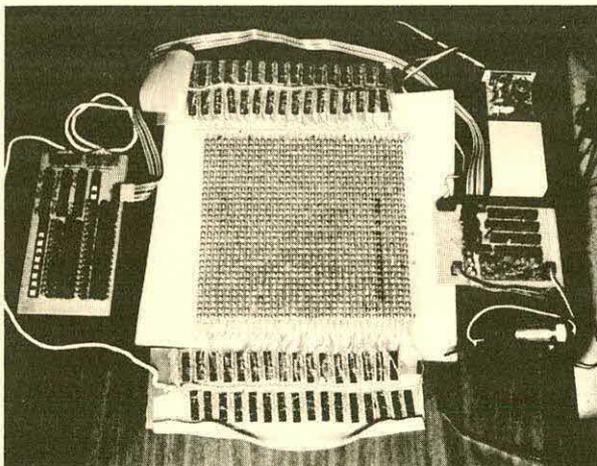


Fig. 1. The 1024 point electrocutaneous sensory aid system showing glasses mounted TV camera, video amplifier (middle right), logic electronics (left), hybrid electrode switches (top and bottom) and electrode matrix (center).

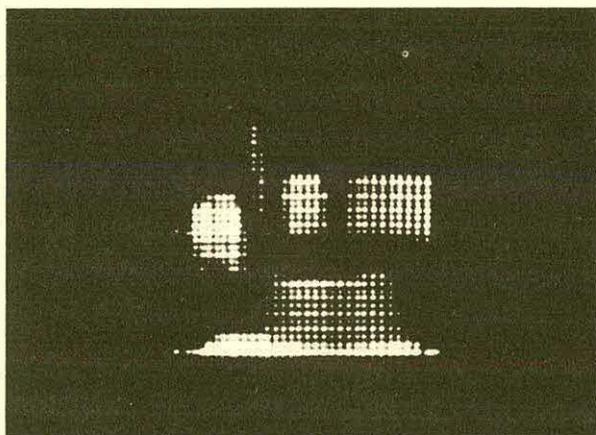


Fig. 2. 32-line resolution TV image projected onto skin by sensory aid in Fig. 3, clearly showing foreground chair and background chairs and table (right).

**Mobility Course.** The experiments performed in this study were carried out in a modular, quickly alterable and objectively definable synthetic indoor mobility environment contained in a 20 by 30 foot room. This mobility course was laid out in a Cartesian coordinate grid system with one foot square vinyl floor tiles (Fig. 3). The obstacles consisted of real walls, a door frame, pieces of real furniture, high and low tables, chairs, a podium, wastebaskets, boxes and wall curtains, as well as simulated columns and overhanging beams constructed of corrugated cardboard for subject safety (Fig. 4).

16 different courses were laid out on graph paper with obstacles located on numbered squares corresponding to those of the room. This facilitated quick relocation of obstacles and permitted a rapid and essentially random temporal sequence of different layouts to be presented to each subject. Illumination was 30 to 50 footcandles at floor level.

The mean total path length of a single mobility course was 65 feet (20 meters). Of the 30 total obstacles, it was expected that only 10 or 20 might be closely encountered by the blind subjects as they made slight variations in their travel paths. The mean number of closely approached obstacles requiring avoidance was 12 per course. The mean free travel path length between obstacles was 5 feet. There were 6 turns per route on average.

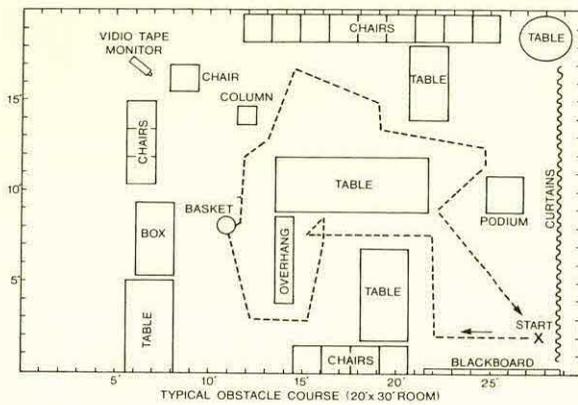
The mobility course and evaluation design philosophy has borrowed heavily from the precepts of Armstrong (8), Kay (1), and, in particular, Shingledecker (9), in Emerson Foulke's laboratory.

**Subjects.** Two blind male subjects, age 28 and 37, were utilized in these experiments. Neither subject possessed any degree of functional vision and each had been blind for over 25 years. Both subjects were excellent cane travelers with years of practice. They each had over 200 hours experience with other, fixed tactile imaging devices.

**Procedure.** Subjects were initially given about 15 minutes of pretrial mobility experience with the sensory aid. They were given a verbal description of the nature of the courses and were requested to walk at a normal pace avoiding collisions and that the course was designed to keep the "shoreline" left. The experiment consisted of the subjects walking completely through respectively 39 and 48 consecutive trial courses, each one selected from the 16 different courses, such that each course was different from the last. Successive trials were made about every five minutes. Experimental sessions lasted from about 15 minutes to one hour.

The entire series of tests was recorded on videotape and the experimental data were obtained by a number of replays of the tape. Two observers with stopwatches and a counter measured the distance and duration of each short path leg walked by the subject; number and duration of stops; number, location and type of collision, and number and size of head movements.

The detailed path of the subject was recorded in graphical form overlaying the plan of arrangement of obstacles for each course as in Figure 3. A separate plot resulted for each of the 87 total runs. Data were correlated with these graphical records.



Results

The travel safety of the blind subjects was scored in terms of collision avoidance, that is, the percent of the encountered obstacles with which they avoided colliding. The collision avoidance score showed a mean value of 91.77% for both subjects combined, with an initial value of 84.5% and final value of 95.04%; an increase of 12.5%. For subject B.G. the mean was 89.87%. The linear regression fit of the data for this subject indicates an initial score of 86.75%, increasing to a final score of 92.99% for a 7.19% increase over 39 trials. The mean collision avoidance score for subject L.S. was 93.31% with an initial score of 89.91% and a final score of 96.72%, an increase of 7.56% over 48 trials. This performance is shown in Figure 5 with the linear regression fit of the data.

Fig. 3. Plan of one of the mobility courses with obstacles laid out on X-Y coordinates and a typical path walked by a blind subject.

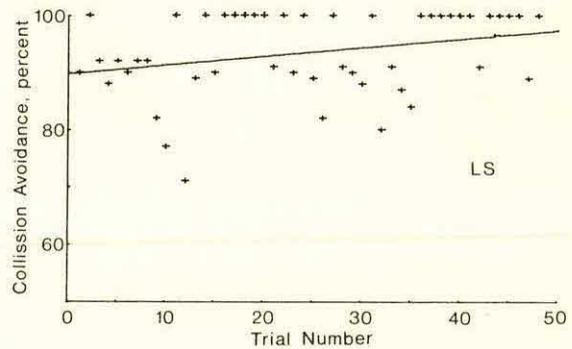


Fig. 5. Collision avoidance mobility data is one measure of blind pedestrian safety with a sensory aid. Performance improves over 48 trials.



Fig. 4. Sensory aid as worn in mobility course. Suspended overhang (right), chairs and table with videotape recorder and TV camera (left) for recording performance of subjects.

As suggested by Shingledecker (9), the change in travel time with practice was analyzed in terms of three components of travel efficiency: walking speed, number of stops, and duration of stops along the travel path. The mean total time to negotiate the mobility course was 120.3 seconds for both subjects. Subject B.G. took more time at the outset, 183.4 seconds vs. 108.9 seconds for subject L.S. But with two hours training both subjects took the same final time, about 98 seconds mean to complete the course. During this experiment subject B.G. decreased his total travel time 46% with a mean time of 141.1 seconds (Fig. 6). The faster walker, subject L.S., decreased his total time by 10% with a mean of 103.3 seconds total travel time to complete the mobility course.

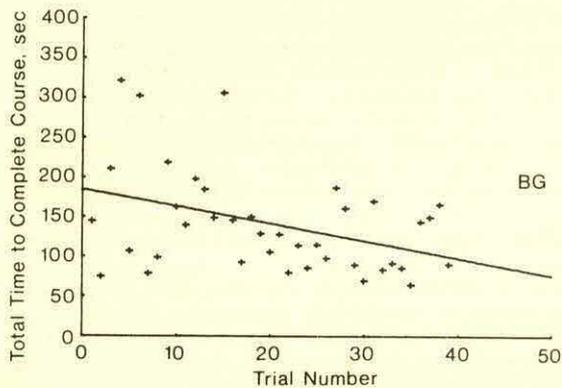


Fig. 6. Total time to complete each course is a measure of efficiency of blind mobility.

Walking speed indoors was fairly stable at 0.8 feet per second mean for both subjects. (We have observed indoor walking speed to be roughly half that of outdoor speed for both blind and sighted persons.) The mean walking speed for subject B.G. was .73 fps, showing a 5.6% increase (Fig. 7). The mean walking speed for subject L.S. was .84 fps over 48 trials. We could not measure a change in his walking speed.

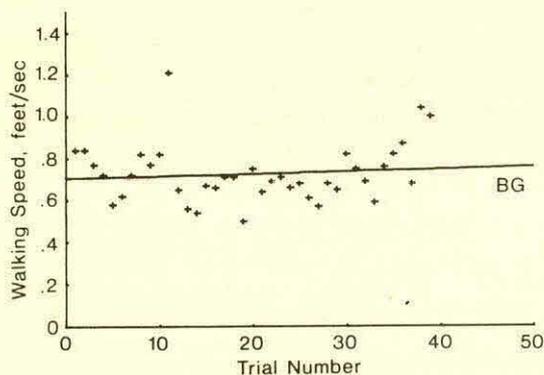


Fig. 7. Walking speed of one subject.

The mean number of pauses or stops along the travel route to search for a new clear travel path was 2.95 for both subjects combined. They initially made a mean of 5.11 stops decreasing by 80.3% to a mean of 0.92 stops by the end of the experiment. Subject B.G., with a mean number of stops of 3.36, showed a 72.8% decrease from an initial value of 5.5 stops to a final value of 1.2. The mean number of stops for subject L.S. was 2.62, with an initial value of 4.8 and a final value of 0.7, for a decrease of 85.4% during the course of the experiment. The mean number of stops for both subjects combined decreased from 5.11 initially to 0.92 stops at the end of the experiment, an 80.3% decrease.

The mean total stop and search time for both subjects combined was 37.5 seconds, varying from an initial value of 61.3 seconds to a final value of 13.7 seconds; a 78% decrease over the deviation of the experiment. Subject B.G. with a mean total stopped time of 55.2 seconds decreased 88.3%; from 98.8 seconds initially to 11.6 seconds final value (Fig. 8). Subject L.S. exhibited a mean total stopped time of 23.2 seconds, decreasing 49.8% from 30.9 seconds initially to a final value of 15.5 seconds.

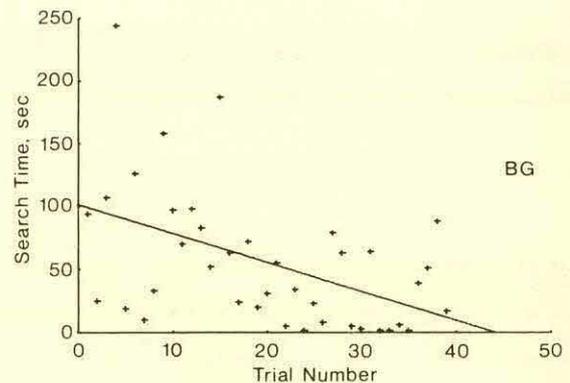


Fig. 8. Cumulative time subject stopped to search for new path during each trial.

The mean duration of each individual stop and search period was 12.93 seconds for both subjects combined; initially 12.0 seconds, it actually increased to 14.89 seconds final value (but subjects averaged only one stop at the end of the experiment).

The PWI, or Productive Walking Index, introduced by Armstrong (8), is a measure of the continuity of progress of the subject towards his goal. It is the percent total time spent actually walking. The mean PWI score for subject B.G. was 68.2% with an initial value of 48.7% and a final value of 87.7% for an increase of 80%, an impressive practice effect as shown in Figure 9. The mean PWI score for subject L.S. was 80.60% with an initial value of 74.12% and a final value of 87.12% for an increase of 17.48%. The mean PWI for both subjects was 75.04%. Initially 62.7%, with a final value of 87.3%; mean PWI for both subjects increased 39%.

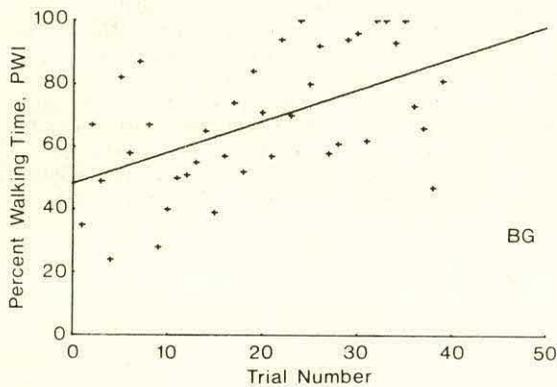


Fig. 9. Productive Walking Index (PWI) is the percent of the total time spent actually walking.

#### Discussion

The experimental results indicate that the optical information provided by the new tactile television sensory aid has permitted blind subjects to safely avoid most obstacles and to steer a clear path for successful and increasingly efficient indoor mobility.

Apparently the device immediately provided them anticipatory information about the travel route as evidenced by their initial 85% collision avoidance score. We are encouraged to believe that with considerably more practice subjects could learn to avoid essentially all obstacles, as suggested by their 95% collision avoidance score after only two hours of practice, and 100% in 10 out of the last 12 trials for subject L.S. (Fig. 5).

The blind subjects quickly learned to increase their travel efficiency with the sensory aid as shown by the 39% increase in their Productive Walking Index and 31% decrease in travel time during the same two hours practice. The most significant component contributing to the decreased time to complete the mobility course was the 80% decrease in the number of stops made by the subjects, resulting in a 78% decrease in stop and search time. By the end of the experiment subjects were averaging about one 15 second stop for the entire 65 foot mobility course. The relatively long scanning time taken by subjects at each stop may well be due to their attempts to recognize details of obstacles and escape routes with the low resolution ( $3^\circ$ ) due to the  $90^\circ$  wide angle of the display ( $90^\circ/32 \text{ lines} = 3^\circ$ ).

An avoidance device requires a wide field of view analogous to peripheral vision for orientation and locomotion. A recognition device requires a high resolution, narrow field of view analogous to foveal vision for discovering the salient details of obstacles in a complex travel path. To meet these dual and seemingly mutually exclusive requirements, one of us (CCC) has conceived an electronic zoom control to continuously vary the field of view of the camera over an 8 or 10 to 1 range from, say, 20 to 180 degrees, at the instantaneous command of the user. Rapid time sharing of such a versatile omni-resolution optical-to-tactile display would permit the user to focus his attention down onto the details of a landmark at one moment and at the next to embrace the panoramic flow pattern of his environment, "anchoring himself 'visually' to the terrain" (10).

Walking speed remained remarkably constant as the subjects learned other skills during the course of the investigation. Hence, walking speed did not contribute to the measured increase in mobility efficiency in these experiments. In the next set of experiments, we will attempt to enhance the subject's walking speed (after they have learned to reduce their stop and search time sufficiently). Walking speed is the most significant remaining parameter governing travel efficiency.

If the observed stable walking speed represents a saturation of mobility sensory capacity with the  $90^\circ$  field of view, we may see a significantly useful increase in walking speed with the availability of a rapidly variable 180 degree field of view. Such a field would more closely mimic the design of the human peripheral visual system which was apparently evolved specifically for the purpose of mobility.

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## TACTILE LEARNING DEVICES FOR THE BLIND-SENSORY QUILLS

D. R. Traylor, M. M. Jones, P. G. Hedgcoxe  
Socratic Education, Incorporated

During the past six years advances have occurred in the development of tactile learning devices for the blind. Prior to this time rather unsophisticated and unsatisfactory devices have been available to provide immediate raised line impressions of drawn or written subject matter. Now, in prototype form, and soon in production form are several devices, each of which gives rise to immediate raised line impressions of any drawings, mapping, or writing inscribed. New teaching and learning opportunities are presented and new research directions opened.

CATEGORY: Multi-purpose	INTENDED USER GROUP: Blind and Partially Sighted
Device Development <input checked="" type="checkbox"/>	
Research Study <input checked="" type="checkbox"/>	AVAILABILITY OF DEVICE: July 1, 1977
STATE OF DEVELOPMENT:	
Prototype <input checked="" type="checkbox"/>	AVAILABILITY OF CONSTRUCTIONAL DETAILS:
Clinical Testing <input checked="" type="checkbox"/>	
Production <input type="checkbox"/>	
AVAILABLE FOR SALE:	FOR FURTHER INFORMATION CONTACT: Authors
Yes <input checked="" type="checkbox"/> No <input type="checkbox"/>	
Price: Varies	

## Introduction

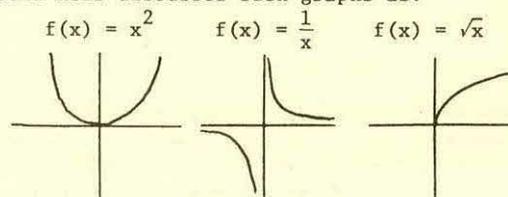
In 1970 two blind students were pursuing mathematics at the University of Houston. One, a freshman, was enrolled in analytic geometry in a class of over 300. She was congenitally blind and suffered from epilepsy. The other was a junior level student enrolled in point set theory, a course depending upon geometric impressions spontaneously drawn on the chalkboard by both student and teacher. This student was adventitiously blind. Each had progressed through the state school for the blind system though the junior student had enrolled in the state school for the blind after completing junior high school at home in competition with sighted students. On the university campus was officed a representative of the State Commission for the Blind. The function and responsibility of that office was to assist each blind student with any difficulty, provide whatever supporting equipment was necessary and to assist in vocational placement upon graduation.

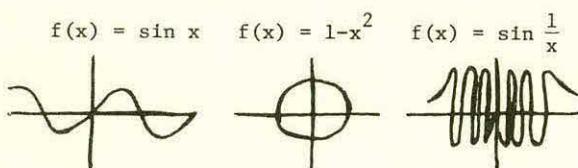
In the course of experience with these two students, the three investigators became acquainted with the technology available, at the time, to assist in the learning of certain concepts which are graphically represented to sighted students. The resources available to the two college students

and the three investigators were those of which the State Commission for the Blind was aware, those to which the students had been exposed in their training, and those which the investigators could ferret out for themselves. At the outset, the investigators were quite unaware of the absence of adequate technology to reduce the difficulties met by blind students. Of the three investigators, Jones was a Research Associate, Hedgcoxe a Professor of Mechanical Engineering, and Traylor a Professor of Mathematics.

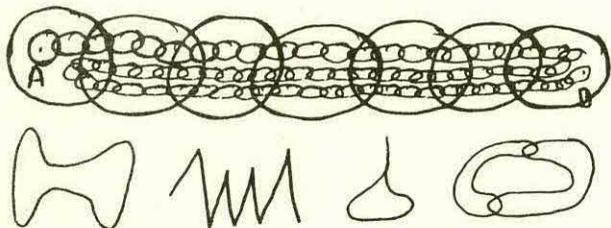
## Development of Prototype

At first, the initial effort was narrow, but was met with substantial difficulty. The simplest task seemed to be to find a realistic means to provide a student an immediate raised line impression of that which was drawn on the chalkboard. In analytic geometry for instance, the blind student would hear discussed such graphs as:





In the point set theory class, such graphs as the following would be drawn on the chalkboard spontaneously, to make a point, to present an argument, or to clarify a question:



It was of extreme importance that the blind student be able to tactually evaluate representations of such graphs or drawings. Verbal descriptions simply are not adequate. Of as much or even more importance was the need to develop a realistic device to allow the student the opportunity to give rise to his own drawing or graph, evaluate it tactually, and then offer comments or receive criticism of the concept pictured. Known devices, such as existing drawing kits, light tin impressed with a sharp point from the backside, balsa wood and string, and screen wire just were too time-consuming, too slow, or too inadequate and had been discarded as unrealistic opportunities.

With much effort (and as the investigators were later to learn was not uncommon, little real assistance from the agencies which serve the blind) a prototype device was constructed after about a year by Richmond Industries, meeting the needs as stated by the investigators. The first prototype instrument, called the "Quill," accommodates a piece of paper which is 16" x 23". The paper, via a clamping device, is stretched taut on a rectangular frame which is metal. Above the paper is a stylus which is held by the user. The bottom of the stylus, the foot which rests on the surface of the paper, has indented into it a narrow channel. The foot of the stylus revolves a full 360°. Directly below the foot, beneath the paper, is a motor driven reciprocating pin which, when the motor is started, hammers upward into the channel in the foot of the stylus. With each upward stroke the paper is forced up into the channel by the reciprocating pin and a raised dot occurs. As the stylus is moved about the paper, the raised dots become lines. The Quill is engineered in such a fashion that the reciprocating pin is always directly below the foot of the stylus, whenever the stylus is placed on the paper surface.

#### Applications of the Quill

Once the prototype was developed, many more uses have been determined for the capability represented. The Quill has been evaluated in a variety of settings, ranging from the college classroom to the Criss Cole Center for the Blind in Austin,

Texas, Arkansas Enterprises for the Blind in Little Rock, Arkansas, The Houston Lighthouse for the Blind, various national and sectional conferences, and in settings in Victoria, Texas which serve special education needs of the partially sighted and dyslexic. Several examples give flavor of applications available.

- A. A college blind student had difficulty with a geometric definition which involved horizontal and vertical lines. The cause of his difficulty was not known until he was able to give rise to his own concept using the Quill. His concept of horizontal lines was proper; that is, they possessed indefinite length. However, his concept of vertical lines was not correct; they were only a few inches long to him and surely did not possess indefinite length. Thus, an example of verbalization skills, confirmed by examination of objects, still generated a wrong concept that was not discovered until the student could offer a raised line impression of his own concept, evaluate it tactually, and say, "Here is what I mean."
- B. A partially sighted high school student suffered eye strain and severe headaches reading test papers prepared in large, bold, black print. By reinforcing the print with raised lines, the reading became easier.
- C. The example of B applies to those who suffer from dyslexia. Letters, print, numbers, and graphs can be reinforced tactually by the teacher or by the student afflicted.
- D. Map drawing is quick and simple. Maps of meeting areas, grocery stores, house plans, vocational areas, etc. can be offered in seconds to a blind or partially sighted user.
- E. As a mobility aid, a blind person has another learning tool. After gaining standard mobility skills, the client can be asked to draw the map of his proposed route; his failure to perform may be because he doesn't understand the route, not because he has not mastered his skills.
- F. Conceptual learning among the young is most potential and least explored. The Quill alters teaching of many spatial concepts from a method of "identification" to that of effective communication.
- G. Vocational applications are many, ranging from flow charting by a computer programmer, to understanding a graphic layout by a blind owner and manager of a printing shop.
- H. Handwriting skills may be differently learned than now or may be continued as a practice by those who lose their sight.

#### Future Developments

With each new hardware development, new areas open for software development.

With the prototype Sensory Quill, the raised line has certain dimension. What is the best height and width of that line and for which population is the question answered? Those who lose sight because of diabetes surely present problems of a sensory nature similar to those of a congenitally blind pre-school age child and even those are different from an adventitiously blind pre-



## A NEW APPROACH TO ORTHOTIC MANAGEMENT

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This orthotic system was developed for preschool children from approximately 18 months to 6 years of age who are myelodysplastic or have similar clinical symptoms. These devices are fabricated from ABS plastic in components which when assembled and fit will allow him to stand, ambulate with aid or sit unaided. The components are thoracic, pelvic and foot pod sections, all of which are made in 3 different sizes in order to fit a large percentage of the disabled. When the child is in a sitting position with this orthosis, he can be placed in a mobility device with wheels that he can control by hand for short distances. This wheeled device can be converted quickly into an upright wheeling position plus allowing a parent to transport the patient, allowing a far greater range of mobility for this type of patient with parent. The hope is to supply a system for this age group in a kit form which will be simple for an orthotist to apply, multifunctional and relatively non-complex.

CATEGORY:	INTENDED USER GROUP:
Device Development <input checked="" type="checkbox"/>	
Research Study <input checked="" type="checkbox"/>	AVAILABILITY OF DEVICE: Limited.
STATE OF DEVELOPMENT:	AVAILABILITY OF CONSTRUCTIONAL DETAILS: Readily.
Prototype <input type="checkbox"/>	
Clinical Testing <input checked="" type="checkbox"/>	
Production <input type="checkbox"/>	FOR FURTHER INFORMATION CONTACT: Author
AVAILABLE FOR SALE:	
Yes <input type="checkbox"/> No <input checked="" type="checkbox"/>	
Price:	

In essence this paper is to present an orthotic management system for the preschool age myelodysplastic and similarly disabled children. As in the past, the challenge has been to try and mold these children physically and mentally to function in society by developing to the utmost their remaining potential. Naturally it would seem reasonable then for these children to progress more quickly when interrelating with their peers as much as possible. However, their physical disability, in particular their inability to be mobile for short or long distances is a deterrent.

At this point, I don't think it is necessary to go over and over the physiological and psychological importance of the benefits of assisted mobility for these children. This orthotic system deals with children who have approached the sitting stage of development, approximate ages 8-12 months, or at least should be sitting and can't because of their neurological involvement. This system can be used throughout the preschool era ending at the approximate age of 6 years. At this time another form of orthotic management must be applied because of obvious limitations which will become apparent later in this paper.

At the Rehabilitation Engineering Program in Memphis which is jointly administered by the

Crippled Children's Hospital School and the University of Tennessee, we have undertaken a project involving preschool spina bifida and similarly disabled children and their parents. This project consists of a mobility system which is comprised of two main devices -- a plastic upright positioner (Fig. 1) and a base equipped with wheels (Fig. 2). Both are thermal formed from ABS plastic. The plastic upright positioner or PUP can be easily converted to a sitting position (Fig. 3) by changing the relationship of the thoracic and pelvic sections. The combined weight of these two devices is 7-1/4 kg; 2 of which is the standing device. The base is equipped with a fold-out handle permanently attached. For as you all know, anything that is removable from a device usually becomes permanently removed. The common parental response is usually "Gee, I just can't understand what could've happened to it." The handle can either be folded into the base during hand propulsion in sitting, or folded out in the upright wheeling position which affords a greater range for transportation.

The base is fabricated to accept the pelvic section of the PUP securely retaining it by a spring loaded pull pin and hook. Intermittent stopping is achieved in the upright wheeling position simply by tilting the base forward to rest on two posts permanently attached to the base. This total unit

allows four main modes of use; crutchless standing, independent sitting (Fig. 3), mobility during sitting (Fig. 4), and mobility during standing (Fig.5).

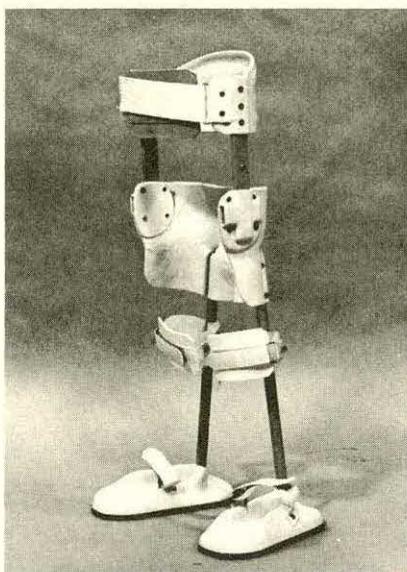


Figure 1



Figure 3



Figure 4

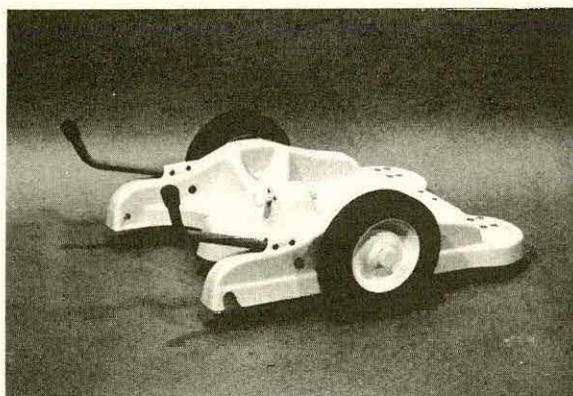


Figure 2



Figure 5

Crutchless standing frees the hands which of course will allow the child to participate in ADL activities at table level. The foot pods and the pelvic section in the sitting position produce three-point stabilization to give those who require it, more support. Mobility during sitting can be achieved by positioning the PUP on the wheeled base. By swiveling the wheels into the forward position, mobility is achieved during standing. Steps no longer present a problem as with most four-wheeled devices. When mother approaches her vehicle for departure she simply detaches the base from the already standing PUP by the use of the pull-pin, places the base in the back of the vehicle and positions her child beside her, seated, with a safety belt. Incorporating these modes of application through two simple devices affords much better acceptance by the child and parent and it no longer becomes a major operation to take the child on an outing.

The fabrication of these two devices involves vacuum forming 1/4" ABS plastic over hard plaster or epoxy molds. The standing device comes in 3 different sizes, to accommodate a large percentage of these children. The wheeled base will accept all 3 sizes of the pelvic component. Both standing device and base can be formed from 2 30" X 30" X 1/4" sheets of ABS. A "T" configuration on the hip section of the mold produces a receptacle during thermal forming which will accept the thoracic component in the two positions, sitting and standing. Similarly, tubular aluminum stock is placed on the mold to produce the foot pod receptacles. By pre-trimming and fabricating the main component parts, pelvic, thoracic, and foot pieces, the fitting procedure is quite simple, depending of course on the severity of each individual patient. A large deformity of the spine can be accommodated to a certain extent by localized heating and modification. During fitting the pelvic section is placed into position and measurements are taken from it to the thoracic section and to the feet. From these measurements the appliance is assembled.

A good comprehensive physical therapy program strengthening increasing coordination of the child's remaining functional muscles is necessary coupled with training him/her to become familiar with the device and its modes of use. Falling, swivel walking, swing to walking with a walker or crutches, removing and donning his standing device, just as much as the child is capable of achieving should be taught. This gives the child a good healthy attitude towards assistive devices which he or she will inevitably have in some form or another as the years pass by.

A disadvantage at this point is the inability to flex the knees in the sitting position. However, children at this age and small stature will not need to bend at the knees to sit in most places. This system then demonstrates the problem for the older school-aged children and of course something new is definitely needed. As in all rigid standing devices there is a problem with mobility -- its cumbersome. There is still a need for a walker, crutches or some other form of supportive aid.

The foot pods can be altered by the orthotist in many ways for each individual child. For instance, in the initial stages of standing, he may

want the foot pods to be totally flat on the floor, then later wedging them to reduce friction for the ambulating child. Slight abduction of the hips increases the stability of lax hip musculature. It is also a simple matter to accommodate for knee flexion contractures and leg length discrepancies. Children who need extra support are controlled during sitting. The device is quick and easy to put on. The thoracic section can be placed either anteriorly or posteriorly depending on the extent and level of the neurological involvement. Often a large deformity on the back will necessitate the placement of the thoracic section anteriorly. One of the main advantages is the ability to fit a large percentage of these children quickly with prefabricated component plastic parts. We all know the management of these children becomes more difficult as they get older and heavier.

The next phase of the project will be concerned with the development of concepts and devices that will permit the continuing management with children like Melvin as they become older and have wider ranging rehabilitation needs.

AUTOMATED EXTERNAL HEAD STABILIZATION AND RESISTANCE  
EXERCISE FOR CEREBRAL PALSIED CHILDREN

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University of Washington School of Medicine  
J. I. Nicholls, Department of Restorative Dentistry  
University of Washington School of Dentistry

Control system instrumentation has been developed to eliminate the "involuntary" uncontrolled head movements of pedodontic patients with cerebral palsy. The patient wears a helmet connected to a shoulder-pad reference, with attached pneumatic cylinders delivering compensatory forces to prevent the head from deviating in either pitch or roll from a preselected "setpoint". An air compressor delivering 140 psi is used for power. Hydraulic damping cylinders are adjusted individually to the return swing initiated whenever the head moves away from the desired position. Each patient's "free" independent head control is initially assessed. Recordings are then made of several cycles of active head movement without external force application. Next, external stabilizing force is applied and recordings made of head position under this influence. Finally, the patient performs a series of resistive exercises against the return force applied by the cylinders. Quantitative methods and cinematography are used to study the interaction between the patient and stabilizer.

CATEGORY:	INTENDED USER GROUP: Cerebral palsied children and adults
Device Development <input checked="" type="checkbox"/>	
Research Study <input type="checkbox"/>	AVAILABILITY OF DEVICE: Still in development.
STATE OF DEVELOPMENT:	
Prototype <input checked="" type="checkbox"/>	AVAILABILITY OF CONSTRUCTIONAL DETAILS: No.
Clinical Testing <input checked="" type="checkbox"/>	
Production <input type="checkbox"/>	
AVAILABLE FOR SALE:	FOR FURTHER INFORMATION CONTACT:
Yes <input type="checkbox"/> No <input checked="" type="checkbox"/>	Fredric A. Harris, Ph.D.
Price:	Dept. of Physiology & Biophysics SJ-40
	Univ. of Wash. School of Medicine

## Object

The goal of this project is to develop an apparatus to provide active, external stabilization of the head necessary for diagnostic, hygienic, and restorative dental care delivery to pedodontic patients with cerebral palsy. The concept involves countering the tendency for the handicapped child's head to move in an unpredictable fashion, through application of control systems technology. The apparatus functions as a feedback control system operating to hold the head in a preset position regardless of "involuntary" muscular contractions tending to move it away, by detecting incipient motion and applying opposing forces. A secondary gain which may be realized from application of such an apparatus is that it may be possible to train the child for improved voluntary head control. If the child repetitively moves his head through pitch and roll ranges of movement cycles while the apparatus resists the movement with a less than equal opposing force (i.e., provides the equivalent of resistive exercise), the child's muscular strength and balance should be improved and this may provide a basis for better independent neuromuscular control.

## Method

The strategy is to provide a somewhat elastic (i.e., non-rigid) "clamping" of the head within preset limits by an electromechanical feedback control system. It is possible to approximate such stabilization simply by clasping the child's head in one's hands and manually opposing any tendency for it to move from the desired position. Thus, the proposed device duplicates a manual operation which has already proved effective in eliminating head movements. However, developmental efforts must be focused on ensuring that it performs this function without either interfering with the dental care activities it is intended to facilitate or causing discomfort and distress to the patient wearing it. The device must be kept as cosmetic in appearance as possible, and also kept from being so ungainly and complex that the dentist cannot work around it in approaching the child's mouth. In the current prototype, head motions are referenced to a platform mounted on a set of shoulder pads worn by the patient. The patient also wears a fitted head support coupled to the platform by means of a two-axis gimbal system which resolves head motions in pitch and roll. The system incorporates transducers for measurement of these head motions, and also a set

of pneumatic actuators which provide controlled input or restraining torques, singly or in combination. It also includes a control system for manual or automatic operation of the actuators, using analog voltage selector controls, by means of which the operator can place the child's head in positions required for diagnostic or restorative dental work or actively resist the child's efforts to move his head in various directions so as to provide resistive exercise.

Production of desired motions: Since the axes for fore-and-aft rotation (a line parallel to the shoulders, through the atlanto-occipital joint) and for side-to-side rotation (a line passing through the base of the neck from front to back) do not intersect, it was necessary to utilize an "offset" gimbal configuration. The necessity for this axis offset created geometrical complexities in translating the action of two pistons into fore-and-aft and side-to-side rocking movements of the head, respectively. In the present form, side-to-side motion is produced by driving a sector gear attached to the head manipulator directly from a linear gear rack attached to one piston, while fore-and-aft motion is produced using a chain drive to transmit rotation of a sector gear attached to the head manipulator.

Power source: Primarily for cleanliness of operation, a pneumatic rather than hydraulic power source was chosen. An air compressor was fitted with a "buffer" tank and a pressure regulating valve adjusted to deliver a working pressure of 140 psi. The compressor and tank are installed in a sound-deadening, portable box and connected to the manipulator cylinders using flexible rubber tubing so that the compressor can be located at a distance from the actual working area. A secondary tap from the buffer tank is used to provide an air-cushion equivalent of a "counter-balance" for the weight of the head manipulator assembly, which would otherwise act as a dead weight constantly tending to tip the head backwards.

Electronics: The desired head position or "set-point" is represented by two voltages, one for pitch and one for roll, adjusted by means of potentiometers. These voltages are compared to voltages representing actual position at each instant; the latter are derived from transducers mounted on the force applicators. If at any instant the desired and actual head positions differ, the comparator activates relays which control delivery of gas to the cylinders for repositioning the head. The child is provided with a lever-operated over-ride control by means of which he can reduce the applied forces instantly if they produce discomfort, are frightening, or reach excessive levels.

Design criteria: Various dimensions (shoulder width, head circumference, vertical distance between the two axes of rotation, etc.) were measured for cerebral palsied subjects ranging in age from 5 to 15 years. The range of fore-and-aft and side-to-side motion was determined for each subject by passively moving the head. Also, the force which each subject could actively generate in each direction of tilt was measured to permit order-of-magnitude estimation of the restraining torques which would have to be generated by the head stabilizer. All of these

measurements were incorporated into design specifications for the apparatus.

Damping requirements: Bench testing with the empty apparatus indicated a strong tendency for overshoot to occur and oscillation to be initiated whenever a return swing of the head manipulator was triggered by moving the manipulator outside of the tolerance dead-band limits or centered on the setpoint. This tendency was confirmed in preliminary operational tests of the apparatus using normal subjects. The simple addition of a damping cylinder sufficed to eliminate overshoot and oscillation. (While the force-applicator cylinders are pneumatically operated, it was found necessary to use hydraulic damping cylinders.) Variable-flow regulators were provided at both ports of each cylinder, so that adjustment individualized to each subject was possible. Before each patient run, the damping was adjusted so that the empty helmet was returned to the setpoint by the manipulator without any overshoot after a maximal amplitude displacement. Final adjustments for critical damping were made with the subject in the apparatus.

Data collection: Cinematography, strip-chart recording (for display of raw data) and FM tape-recording (for A-D conversion and computer processing of two channels of head position data) were used to study the interaction between the subject and head stabilizer in both "stabilizing" and "resistance exercise" modes. In the former case, the pressure was maximized so that the head would be returned immediately to the setpoint in the event of any involuntary movements by the subject. In the latter, the pressure was reduced to the point where the subject could overcome the restorative force, and the subject was instructed to move his head back and forth between the extremes of the range of motion permitted by the device in both pitch and roll. He also practiced holding his head at each extreme position in turn against the constantly applied opposing force. This "move and hold" activity was repeated for as many cycles as the subject's endurance permitted.

Digital data representing head position in terms of angles of pitch and roll deviation from the neutral (or any other setpoint) are analyzed by computer programs which yield readout in the form of scattergram plots indicating the distribution of instantaneous positions of the head over the entire time period of each trial run (3 to 10 minutes in length). Sequential comparison of scattergrams representing daily performance provides the basis for establishing the duration of training necessary to achieve reasonable head stability for each child. Portions of each day's run written out on the strip-chart recorder are visually inspected to study the nature of transitions from one head position to another; elimination of oscillation and sudden, jerky movements are additional criteria by which progress is judged. Cinematography is used both to document progress and provide material for training films to be used with personnel who will ultimately employ the apparatus in the clinical setting.

## Results

Independent head control, control with the head in the apparatus with damping in effect but no restoring forces applied, and control with restoring forces applied have all been studied for each subject participating in the program. "Move and hold" cycles, a form of resistive exercise, also have been studied for indications of changes in the range of motion, smoothness and strength of voluntary movements. The interaction of subject and stabilizer has been studied while the subject performs target-directed voluntary movements of the upper extremities (i.e., a cerebellar function test), obviously leading to exaggeration of head control difficulties, to determine whether the stabilizer is effective even in extreme cases of involuntary head motion. Finally, dental procedures were first simulated and then actually carried out to determine whether the introduction of novel stimuli in and about the mouth might exaggerate involuntary movements, thus subjecting the apparatus to a worst-cast test rather than simply studying its effect on a relaxed subject.

The quantitative data (strip-chart records and computer-derived position "scattergrams"), films, and comments from the subjects (and/or their parents) indicate their interaction with the Head Stabilizer was beneficial to them. It was possible to perform actual dental diagnostic and hygienic procedures with reliable stabilization of the head by the control system. Also, improved kinesthesia relating to the head and neck and improved voluntary head control with the head free of the apparatus were sequelae of interaction with the apparatus in the resistance exercise mode. (Films of the Head Stabilizer in use with one of the subjects will be shown to illustrate this presentation.)

## Significance

Dental care for children with cerebral palsy is often omitted entirely or poor in quality because of the difficulty in gaining safe access to the oral cavity over reasonable periods of time for dental work.<sup>(1,2,3,4,6,7)</sup> Utilizing the Head Stabilizer, the dentist should be able to work with the CP child (as well as with children having other handicapping conditions affecting head stability) over as long a period as he needs to complete his work without concern about head movements interrupting the work or possibly injuring the child. The Stabilizer should save time and effort, and allow better care under safer conditions than is possible using manual restraint or general anesthesia.

If such an approach proves effective, the need for it is clear. There are over three-quarters of a million individuals with CP in the United States. In one dental clinic for handicapped children, 214 out of 1406 children seen had CP and there were extreme difficulties working with them.<sup>(8)</sup> Dentists who have published about these difficulties indicate that the use of general anesthesia is the only dependable way to achieve safe, prolonged access to the oral cavity.<sup>(5)</sup> Certainly, general anesthesia is to be avoided, if possible, both in terms of inherent danger and complexity of administration. A

device to hold the awake, unanesthetized child's head in any position required would be a highly desirable alternative.

Secondary gains which might also be realized include use of the device with normal adults and children during procedures such as the taking of x-rays where absolute head stability is essential, and training CP children for improved independent head control. The latter is extremely important for balance and stability in both posture and ambulation, and should also influence learning ability by virtue of improving attention to classroom and individual activities demanding a stable field of vision and good visual perceptual skills.

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## PONG GAME AS A REHABILITATION DEVICE

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The Pong game has been adapted for the rehabilitation setting and is being used by patients recovering from stroke. The game concept helps to maintain high level of interest, enhances motivation and adds enjoyment to the hard work of rehabilitation. Certain features considered necessary prerequisites for the adapted video game include variable ball speed, variable paddle size, 2-dimensional paddle movement, interchangeable interface devices and Player vs Player and Player vs Machine modes. The training procedure is discussed and one case is reported where a patient noted an increase in strength, accuracy and coordination of movement after three weeks of training on the Pong game.

CATEGORY:	INTENDED USER GROUP:
Device Development <input checked="" type="checkbox"/>	Rehabilitation centers for the physically handicapped.
Research Study <input type="checkbox"/>	
STATE OF DEVELOPMENT:	AVAILABILITY OF DEVICE:
Prototype <input checked="" type="checkbox"/>	Not Available
Clinical Testing <input type="checkbox"/>	AVAILABILITY OF CONSTRUCTIONAL DETAILS:
Production <input type="checkbox"/>	J. Madey or W. Kaufman
AVAILABLE FOR SALE:	FOR FURTHER INFORMATION CONTACT:
Yes <input type="checkbox"/> No <input checked="" type="checkbox"/>	J. Madey or W. Kaufman
Price:	

The San Francisco Rehabilitation Engineering Center has been engaged in the development of high technology tactile sensory substitution systems for a number of years (1,2). More recently we have also been developing systems and devices for individual handicapped persons, primarily vocational devices for blind workers (3). Our experience in both of these areas has emphasized the advantage of having an adequate research and development staff ("critical mass") to enable ideas to be translated into useful devices. This presentation will describe a simple device that was quickly developed because such a staff was available.

The electronic Pong game, commonly found in bars, and increasingly popular as recreation for the family at home, has been adapted for use in rehabilitation. We use it primarily with people recovering from stroke; but modifications allow its use by other disabled persons, such as those with cerebral palsy, spinal cord injuries, and head injuries. For stroke patients, the Pong game facilitates use of the impaired upper extremity, the game concept helps to maintain a high level of interest, enhances motivation, and adds enjoyment to the hard work of rehabilitation. In the right setting, playing Pong promotes patients' initiative in their own rehabilitation and encourages interaction with other patients, while

requiring a minimum of supervision and/or help from the professional staff. The overall goal in using the Pong game is to facilitate the recovery process, providing a purposeful use of the impaired extremity outside of the regular therapeutic exercise mode. During a Pong game, the patient has an immediate goal for every movement of the arm. The patient also receives immediate visual feedback as to the accuracy of the movement. The responsibility of the therapist is to set the relevant parameters of the game so that a measure of success can be achieved by the patient.

Some video games are more adaptable than others to the needs of the physical rehabilitation setting. The following features were considered necessary prerequisites as they allow for adjustments according to a patient's skill: variable ball speed, variable paddle size, 2-dimensional paddle movement and interchangeable interface devices. The Player vs Player and Player vs Machine modes give further flexibility to the game playing. Variable speed and interchangeable interfaces are not generally available in the games market and must be added to the basic device circuitry. In general, "analog" games (those which use timing elements as opposed to computer-type digital logic for generation of basic display parameters are easier to adapt). A ping-pong type game produced by VISULEX was selected as most nearly satisfying

the above criteria and capable of easy modification. The random ball speed feature of the Visulex game was substituted with a continuously variable control. A special mechanical linkage to the paddle position control was constructed allowing vertical paddle movement.

Three different hand pieces were machined to coincide with varying grips of the stroke patients for use with a modified exercise track interface (The Herring Adjustable Exercise Track). The interface allows for forward flexion and extension of the arm in a designed track. A patient must reach forward to 90 degrees of the shoulder flexion with full elbow extension in order to reach balls at the top of the screen. This movement can be either helped or resisted by changing the angle of the track slope. The Pong game, as it is adapted requires that the player have minimal shoulder and elbow movement to control the paddle or use the unimpaired arm to assist the movement. The immediate visual feedback provides patients with precise knowledge of their accuracy. Eye-hand coordination is enhanced as patients follow the moving ball visually while positioning the paddle with arm movement to anticipate the ball. Attention is necessary; patients quickly find themselves absorbed in playing the game. Some patients prefer playing against the built-in computer, or against their unaffected arm. Others enjoy the socialization which develops during a game with an aide or another patient. In one case, after 3 weeks of playing Pong three times a week in 10 to 30 minute sessions, both therapist and patient noted improvement in strength and coordination of the patient's movement, during regular exercise sessions. Both felt that the game was responsible for reinforcing use of the impaired extremity without focusing attention on actual movement of the extremity.

Generally, training with the Pong game must begin with a slow ball speed and large paddle size, with gradual stepping-up of either or both as the skill develops. At all stages, the values of ball speed and paddle size should be chosen to ensure a moderate success of performance.

Any tool that will keep the patient actively interested in restoring an impaired function, should be helpful during the extremely sophisticated process of re-shaping the neural and neuromuscular mechanisms which make purposeful activity effective again. Every therapist knows that absorbing, purposeful activity holds more promise in development of a function than a monotonous exercise does.

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We wish to thank games makers ATARI, Inc. and VISULEX, Inc. for supplying their Pong games; Beth Caldwell-Klein, O.T.R. for valuable suggestions; and the Garden-Sullivan Rehabilitation Center day-care staff for their generous cooperation. Appreciation for technical assistance in device fabrication is offered to the University of the Pacific Coop Program Students, James Hestbeck and Phillip Mizuno, and the Institutes of Medical Sciences Instrument Shop. Robert Bowen provided the photograph. This work was supported by the Rehabilitation Services Administration, HEW, and by the Smith-Kettlewell Eye Research Foundation.

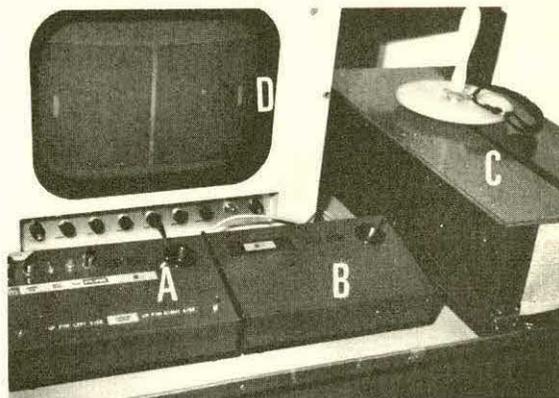


Figure 1:

- A. Modified VISULEX control box with variable ball speed, paddle size, game select, reset, volume, first player positioner, and computer controls.
- B. Second player positioner.
- C. Alternate second player positioner--modified Herring Track interface device.
- D. Video screen.

school age child.

What really is known of the thought processes of congenitally blind persons whose intuition development has never been influenced by sight and whose learning has been dominated by those with sight or those who have had sight? Few have been the opportunities to allow a blind person realistic opportunity to give rise to his concepts, tactually evaluate them to be satisfied as to their accuracy, and then offer them to another as a better means of communicating ideas.

Support workshops, development of new teaching approaches, and related exercises surely will be developed with each new useful advance of hardware. Additional hardware development, related to the Sensory Quill, is forthcoming. Soon there will be available Master-Slave units which will allow one device and then another to assume the "Master" role with other components similarly arranged. This promises much use in both the totally blind classroom setting and in the sighted setting with blind students. For instance, a teacher could simply record each chalkboard drawing on a desktop Sensory Quill, stimulating that of the blind student. The student's Sensory Quill could stimulate the teacher's unit for questioning purposes. This, of course, means new teaching methods.

As with many other devices, certain obstacles must be overcome. There is a natural reluctance of teachers to wish not to undertake new instruments of approaches to teaching which is disturbing to their routine. Some receive a new innovation in their classroom as a criticism of past performances. Federal funding agencies too often are non-responsive to new sources of development preferring instead to continuance of old established relations.

## A Key-Grip Orthosis for Quadriplegic Patients

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This is a description of a Bowden cable actuated key-grip orthosis. It uses a figure-of-eight harness with a Northwestern ring. The device was designed because of the high rejection rate of three-jaw chuck prehension orthoses. The devices allow two different methods of thumb adduction; voluntary opening with spring closing or voluntary opening with Nyloplex bar. A third version is a wrist driven device which utilizes voluntary closing. The basic material is molded Nyloplex.

CATEGORY:	INTENDED USER GROUP: C-4,5,6 quadriplegia
Device Development <input checked="" type="checkbox"/>	
Research Study <input type="checkbox"/>	AVAILABILITY OF DEVICE: On request
STATE OF DEVELOPMENT:	
Prototype <input type="checkbox"/>	AVAILABILITY OF CONSTRUCTIONAL DETAILS: Yes
Clinical Testing <input type="checkbox"/>	
Production <input type="checkbox"/>	
AVAILABLE FOR SALE:	FOR FURTHER INFORMATION CONTACT:
Yes <input type="checkbox"/> No <input checked="" type="checkbox"/>	Dept. of Orthotics & Prosthetics
Price:	The Burke Rehabilitation Center
	785 Mamaroneck Avenue
	White Plains, N.Y. 10605

## Key-Grip Positioning in Hand Orthoses

The following description explains the construction of a hand orthosis based on the mechanical principles of a below-elbow prosthesis, utilizing the body power of the patient by means of Bowden cable and a figure-of-eight ring type harness. The basic purpose of the design is to provide the patient with the ability to use his thumb and first digit in key-pinch position. In addition, this patient needs support for the forearm, and assistance to maintain the wrist in dorsiflexion.

There are two separate components which apply the forces for positioning and motion; the hand component and the thumb component. These are constructed from Nyloplex. The larger hand component encompasses the volar surface of the forearm (distal half), supports the palm of the hand (including enough of the metacarpal-phalangeal joints to prevent drop of the non-functioning digits), and spirals around the index finger. The first 180° turn of the spiral begins at the palmar surface, follows around the lateral and across the dorsal surface of the first digit, between the MP joint and the first IP joint. This semi-spiral begins the alignment of the digit. The spiral continues another 90° to follow the medial side of the finger, completing the finger alignment and posting it for opposition by the thumb. Fixation of the distal

phalanx is accomplished by widening the Nyloplex and curving the extra width of material to prevent the finger from extending.

The smaller thumb component is a movable unit. It is connected to the larger hand component by a custom made nylon joint at a level corresponding to the carpal-metacarpal joint of the thumb. This piece of Nyloplex is designed with a central shaft from which three functional projections emerge. The uppermost section has one of the most important functions of the orthosis. As it curves across the dorsal surface of the distal phalanx, it brings the pad of the thumb into pinch position and transmits the force necessary for holding objects. Because of the pressure involved, the use of padding under the Nyloplex adds to the patient's comfort. The second projection partially encircles the ventral surface of the thumb at the level of the proximal phalanx and exerts the force for abducting the thumb when the cable is operated. The third projection, opposite the second, was originally designed to be a surface against which the patient could manually apply force with his other hand. The patient was able to use this method when greater holding power was necessary. This projection was also useful with an alternate system for thumb closing.

The original design for thumb closing

uses a 4 1/2 lb. tension spring between the hand and thumb components. Ideally, the posts for spring attachment should be in as distal a location as possible. It was necessary to compromise in the placement of the spring so that it would not interfere with the ability to pick up objects. Therefore it is positioned between the level of the IP joint of the thumb and the 5th MP joint of the hand. The similarity between this involuntary spring closing and that of a prosthesis is readily apparent. The spring provides larger force for larger objects because the force varies directly as the length to which the spring is stretched.

Voluntary opening is accomplished by the cable and harness arrangement in the traditional manner, incorporating a triceps pad and straps to keep the cable taut. The point of attachment of the cable to the orthosis is a stud located on an extension of the Nyloplex thumb component. The length of this extension measured from nylon joint to stud attachment should be at least equal to the distance from the joint to the spring, so that the forces of opening and closing will be in balance and the patient need not exert undue force to operate the cable. The longer the extension, the less cable force will be necessary to overcome the force of the spring.



Fig 1 Orthosis Voluntarily Opened

The cable runs from the stud attachment diagonally across the volar surface of the forearm piece to insertion on the triceps pad. Above this insertion is the hanger for attachment of the Northwestern ring type figure-of-eight harness.

An alternate design for thumb closing uses a Nyloplex strip 7/8" wide spanning the

distance from the proximal end of the orthosis to the last mentioned projection of the thumb piece. The proximal end of the strip is permanently fixed by a small bolt and nut attachment to the forearm piece. The distal end slides freely outside the thumb extension, applying pressure for thumb adduction. At the approximate midpoint of the bar, a bolt and wing-nut attachment between the bar and the orthosis allows for adjustment of the amount of force the bar will produce. This system for closure produces greater holding force than does the tension spring. The spring produces 1 1/2 lbs. of force as measured by a pinch meter, while the bar can produce up to 3 1/2 lbs. of force. Greater force can be accomplished by curving the Nyloplex toward the thumb, but too much adduction force results in a smaller possible opening for grasping purposes.



Fig 2 Hand Closed in Key-Grip Position

The flexibility of this arrangement allows for the situation in which the patient is unable to tolerate any pressure between the thumb and finger for any length of time. In another clinical application, an identical orthosis was fabricated using the bar closure. The adjustment was made for a range of 0 to 1 1/2 lbs. of force. The zero force allowed for patient comfort when not actively using the orthosis, and the 1 1/2 lbs. force was sufficient for light tasks.

The application of the key-grip principle to a wrist driven orthosis also employs Bowden cable, but the unit is far more compact. Three Nyloplex pieces are required: the thumb piece with two projections to transmit abducting and adducting forces; the hand piece incorporating the index finger spiral, and a sepa-

rate wrist piece to partially encircle the wrist and provide a terminal for cable attachment. The hand and thumb pieces are attached with a nylon joint as described previously. The wrist piece attaches to the hand piece at the level of the radial styloid process by means of another nylon joint.

The opening of the thumb is involuntary, accomplished by a tension spring between the shaft of the thumb piece and the radial side of the hand piece. The patient has some control of this function, however, in that it is necessary for the wrist to drop in order for the spring to operate. Thumb closing is cable operated by the voluntary wrist extension of the patient. The cable runs from a stud at the compromise position of the thumb piece, through a swivel holder on the ulnar side of the handpiece to a stud on the ulnar side of the wrist piece. As the patient extends the wrist, the span from thumb to wrist lengthens along the route of the cable, and the cable necessarily tightens, providing a variable adduction force. At the present time in clinical use, the orthosis is generating up to 2 lbs. of force, but it is hoped that further refinements of design will permit more.

Once the basic patterns for the Nyloplex components were established, customized patterns were designed for each patient, based on length and circumference measurements of key points, especially the palm of the hand and distances between the involved joints. The final adjustment of patterns was done on the patient's hand before the patterns were cut from sheets of 3mm Nyloplex. A time breakdown for the entire operation is as follows:

Fabrication and adjustment of patterns	4 hrs
Machining Nyloplex pieces	3 hrs
Shaping Nyloplex to functional position	4 hrs
Attaching hardware	3 hrs
Final adjustment on patient	1 hr.
Follow-up w. Occupational Therapy	3 hrs
Total:	<u>18 hrs</u>

## SHAPE AND VOLUME MEASUREMENTS OF STUMP AND PROSTHETIC SOCKET OF LOWER EXTREMITY AMPUTEES USING A STEREOMETRIC FORM SENSOR (CONTOURGRAPH)

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There has been an insufficiency of accurate and quantitative information in relation to the success or lack of prosthetic fitting, especially in above-knee amputees. Methods such as radiographic techniques and the use of electronic pressure transducers have had very little acceptance by amputee clinics or prosthetists. Shape and volume measurements of unloaded stumps and the prosthetic sockets of lower extremity amputees have been done using a stereometric form sensor. The sensor consists of a fixed disk and a concentric rotating feeler which, by contact, obtains the contour of a cross section of an amputee's stump and prosthetic socket at any chosen level. Results have shown that the contourgraph has helped determine respective variations of stump and socket volumes, noting the changes that occur in the stump-socket interface during normal prosthetic wear.

CATEGORY:	INTENDED USER GROUP:
Device Development <input type="checkbox"/>	
Research Study <input checked="" type="checkbox"/>	
STATE OF DEVELOPMENT:	AVAILABILITY OF DEVICE:
Prototype <input type="checkbox"/>	
Clinical Testing <input checked="" type="checkbox"/>	AVAILABILITY OF CONSTRUCTIONAL DETAILS:
Production <input type="checkbox"/>	
AVAILABLE FOR SALE:	FOR FURTHER INFORMATION CONTACT:
Yes <input type="checkbox"/> No <input checked="" type="checkbox"/>	
Price:	

### Introduction

Available information reveals that over 86% of the total number of amputations performed are of the lower extremity (1). The shape and volume of the amputee's loaded and unloaded stump and of the prosthesis are physical parameters which must be considered in trying to solve current prosthetic fitting problems. There is a lack of accurate and quantitative information in relation to a fitting success or lack of success.

In a clinic-prosthetic survey of above-knee amputees, the medical records of 117 above-knee amputees (excluding bilateral amputees) seen in the Amputee-Prosthetic Clinic of the Texas Institute for Rehabilitation and Research during the years 1963 through 1974 were reviewed. Of the total number of amputees, 45.3% were found to have had stump problems, and 14.5% had not problems. Of the stump problems, shrinkage, weight variations and pain predominated. A minority (3.4%) had prosthetic problems.

Several methods have been tried to achieve a more precise assessment of the prosthetic fit. These

have included radiographic techniques (2) and electronic pressure transducers (3,4). None of these has achieved acceptance by amputee clinics or prosthetists.

Newman (5) observed that, in order to learn quickly of any changes in stump contour and size, there is an unequivocal need to determine its exact size and shape and at the same time have tracings of periodic reevaluations.

Improved accuracy and precision in measuring the continuing changes in stump shape and bone-tissue relationships will increase the ability to predict the requirements for an effective stump-socket interface (6,7). The presently developed prototype contourgraph makes it possible to know when shrinkage and shaping have been fully accomplished and when a properly fitting prosthesis has been fabricated.

The main objectives of this study were to measure the shape and volume of the unloaded stump and the prosthetic socket of lower extremity amputees to describe quantitatively the representative volumes; to analyze the nature and quantity of stump tissue deformation and the

associated pressures operating with the loaded socket; to record trends in shape and volume changes in the stump due to time, weight change and activity of the amputee; and to facilitate fitting procedures.

### Methodology

The majority of subjects in this study have been unilateral above-knee amputees selected from the amputee clinics in the Baylor College of Medicine Affiliated Hospital Program, and the large reservoir of amputees who have been fitted by the Muilenburg Prosthetics, Inc., Houston, Texas.

A prototype of the contourgraph in use consists of a fixed disk and a concentric rotating feeler which, by contact, determines the contour of a cross-section of the amputee stump and the prosthetic socket at a chosen level (Figure 1). The contour is then traced out by a plotting pen. The instrument is capable of carrying more than one feeler which can permit the drawing of more than one cross-section in a single turn. The pressure of the feeler against the stump is adjustable.

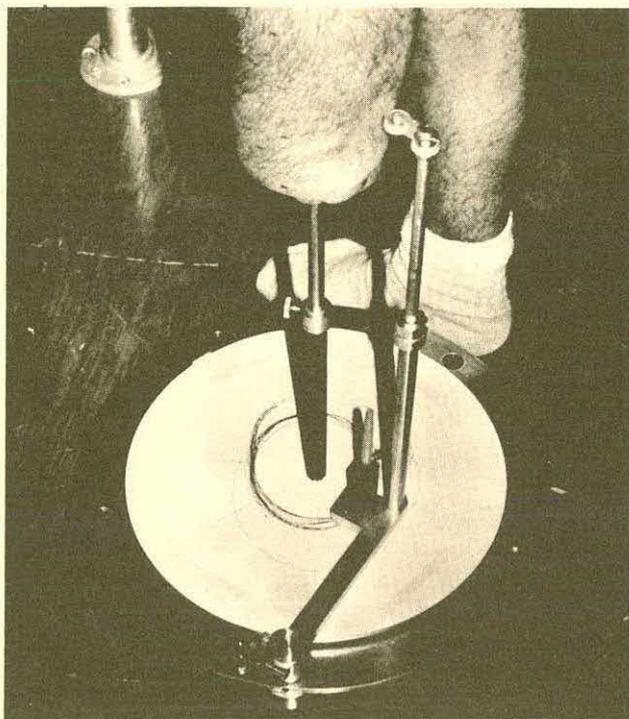


Figure 1

With the amputee seated or standing comfortably, circumferential measurements of the amputation stump are performed at designated and marked levels. To perform the contour tracing of the prosthetic socket, the prosthesis is mounted upside down on an adjustable support. Contour tracings of the inverted socket have been made, distal to proximal, at one inch levels corresponding to the stump contour tracings levels. The

topographics relationships (anterior, posterior, medial and lateral), circumference and cross-section levels of each stump and socket tracing are identified. The circumference and cross-section area levels of each stump and socket are then measured with a planimeter. A relatively good approximation of either the stump and socket volume can be obtained by using three cross-sectional areas and the linear distance between consecutive cross-sectional areas.

The computational method used in this study to determine the volume follows Simpson's rule<sup>(8,9)</sup>. The data are then represented graphically to show: (a) respective stump and socket volume distribution curves, (b) socket-stump volume differences, and (c) variations of stump or socket volumes at sequential intervals.

Contourgraphs of the unloaded stump and prosthetic socket have been obtained when the amputee has had his prosthesis issued initially. At sequential intervals, contourgraphs have been made of the stump to determine the amount of shrinkage and how much has occurred at given cross-sectional levels (Figure 2). This can be evaluated by determining the variances of the contourgraph tracings.

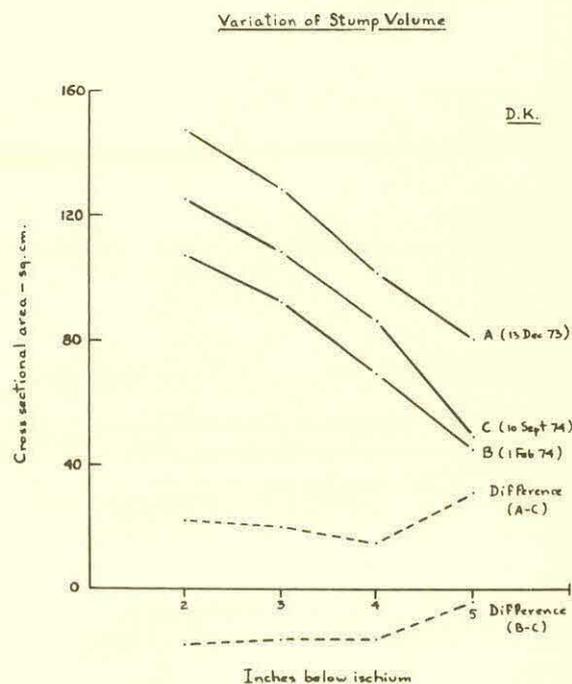
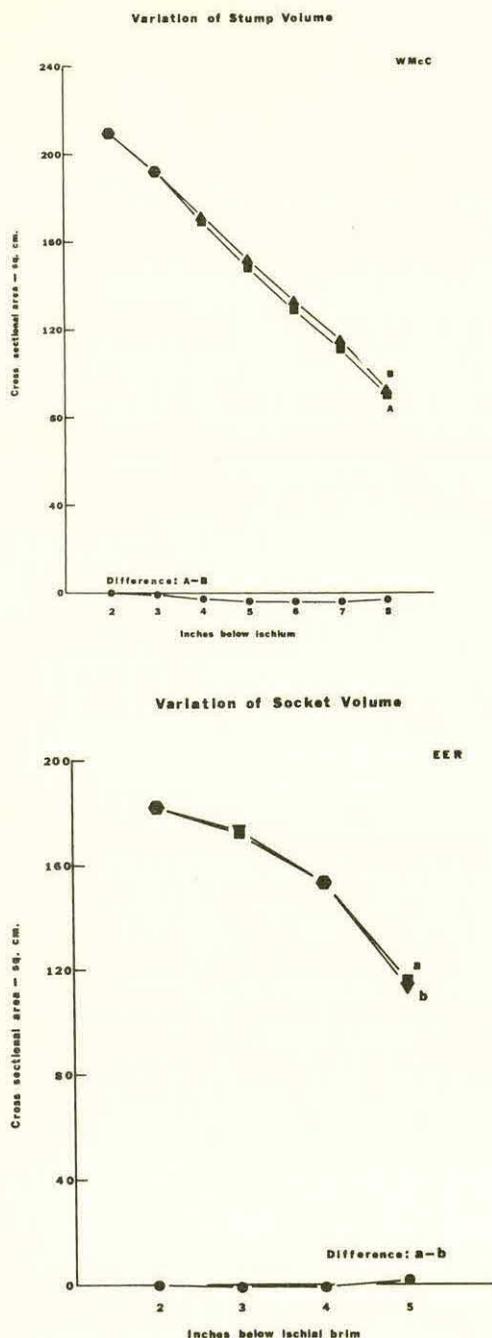


Figure 2

### Results

The contourgraph has undergone biomechanical evaluations and has performed very satisfactorily with prior calibrations for stumps and prosthetic sockets. Reproducibility within 1% was obtained. A 1.8% variation of stump volume difference from contourgraphs of amputee subjects seen in the prosthetic shop and in the clinic was obtained (Figure 3). A 0.25% to 1.0%



Figures 3 and 4

variation of socket volume difference was also obtained (Figure 4). Variation of stump volume difference was found to be 1.4% with an amputee seated and leaning forward as compared to an amputee seated upright. This data insured the reliability of utilizing the contourgraph in the prosthetic shop.

To date, the stump and prosthetic socket shape and volume of 80 amputee subjects have been

measured. Males comprised 87.5% of the total while 12.5% were females. All were between 18 and 80 years of age. Just over fifty-two per cent (52.5%) involved the left residual limb, 46.25% the right and 1.25% was bilateral. Among the reasons for amputation, disease ranked first with 50%, followed by trauma (40%) and tumors (10%). Most of those measured (57.5%) were fitted for the first time. Follow-up measurements on initial prosthesis wearers represented 74% of the population.

To anticipate the shape of a deformed stump in order to assure that the loads are carried at the proper points on the stump and thus minimize the effects of pressure on the stump-socket interface, a test socket was made from contourgraph unloaded and loaded stump data.

#### Significance of Results

The contourgraph has the following advantages: noncomplex design; ready reproducibility; low cost; practicability for routine clinical use; use by easily trained personnel; applicability to all types of stumps and sockets; and immediate availability of results.

The manual stereometric sensor has been evaluated in the clinical setting and by the prosthetist to measure the shape and volume of the unloaded stump and the prosthetic socket of lower extremity amputees. It has been possible to note the changes occurring in the stump pressure relationship in normal prosthetic wear.

The accurate measurement of volume and volume distribution of the residual limb and socket has already been recognized as being helpful in evaluating prosthetic fit by an experienced prosthetist.

Through the availability of the contourgraph and its established methodology, the products of this study could be very helpful for social and rehabilitation workers in the evaluation of unsuccessful prosthetically rehabilitated amputees. Thus, they could return the amputee to his community in a status where he or she could assume more normal activities in the day-to-day vocational rehabilitative program.

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#### Acknowledgements

The authors wish to acknowledge their appreciation to Kenneth Rouk, Youssef I. Abdel-Aziz and Kathy Hyland, part-participants, for their contributions; and last but not least, to the amputees without whose cooperation this study would not have been possible.

This study was supported by REC Grant 23-P-55823/6 (TIRR-TAMU-BCM).

This paper is dedicated to the memory of Dr. Lewis A. Leavitt, the originator of the idea for this study and widely recognized for his work in the prosthetics and rehabilitation of amputees.

THE MOTORIZED WHEELCHAIR SEAT  
A NEW CONCEPT IN RESTING SUPPORT

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Pressures were measured under the ischial tuberosities and thighs of normal subjects while sitting on a mechanical resting surface. Pressures under the tuberosities ranged from 0-150 mm Hg. depending on the position of the supporting roller devices; under the thighs, the pressures ranged from 0-60 mm Hg. Since complete relief of pressure for short periods of time is more effective in preventing skin breakdown than constant, low pressures (above capillary pressure) for prolonged periods, it is essential that the patient be provided with complete relief of pressure at regular intervals. A wheelchair sitting surface consisting of a series of rollers incorporated into a continuous belt-assembly has been designed to provide this intermittent relief of pressure. Pressure determinations and possible clinical applications of the mechanical unit as well as a comparison with pressure distributions of currently available resting surfaces will be presented.

CATEGORY:	INTENDED USER GROUP:
Device Development <input checked="" type="checkbox"/>	Wheelchair confined patients, especially cord-injured.
Research Study <input type="checkbox"/>	
STATE OF DEVELOPMENT:	AVAILABILITY OF DEVICE:
Prototype <input type="checkbox"/>	Available
Clinical Testing <input type="checkbox"/>	AVAILABILITY OF CONSTRUCTIONAL DETAILS:
Production <input checked="" type="checkbox"/>	Not available.
AVAILABLE FOR SALE:	FOR FURTHER INFORMATION CONTACT:
Yes <input checked="" type="checkbox"/> No <input type="checkbox"/>	Medrest Corporation
Price: \$1,150.00	3305 Skycroft Circle
	Minneapolis, Minnesota 55418

The management of ischemic ulcers encompasses a wide variety of conservative and radical procedures, is always costly and time-consuming and invariably results in increased patient morbidity and disability. The complete lack of a standardized, generally-accepted method of treatment of this perplexing problem has continued to plague the medical community.

Because treatment is complex, costly and sometimes controversial, effective preventive measures are imperative. Since disabled persons, especially the cord-injured, are usually non-ambulatory, these people spend much of their time in a sitting or recumbent position. To these people, the resting surface is a matter of prime importance.

In spite of a myriad of resting surfaces currently available, ischemic ulcers have continued to manifest themselves in even the most sophisticated cord-injured patient. Obviously, the ideal resting surface has not as yet been developed.

#### The problem

Man, while he resides on earth, is constantly being subjected to pressures of varying degrees depending on his functional state. Gravitational forces result in pressure being applied at all

times to various parts of the anatomy whether the person is walking, sitting or in a recumbent position. The amount of pressure to which the skin is subjected depends obviously on man's state of function.

The weight bearing area available to the patient is considerably less when sitting than when supine; it depends primarily on the sitting surface itself and to a lesser degree on the intertrochanteric distance and the sitting posture. If the intertrochanteric distance is assumed to be approximately 30 centimeters and the true anterior-posterior resting distance approximately 20 cms., the available sitting area is 600 square cms. Approximately 75% of the subjects total body weight when sitting is exerted over the limited area.

The sitting surface of a 72 kgm. person would be subjected to approximately 54 kgms. of pressure which if evenly distributed over the entire sitting surface would amount to 66.2 mm Hg., more than double that of capillary pressure. A lighter person, because of the general development of the hips and pelvis would probably have less actual sitting surface available and therefore the pressure distribution would be essentially the same. This fact has been substantiated by testing of various sitting surfaces with the result that no static resting surface can demonstrate a distri-

bution of pressure beneath the ischial tuberosities of less than 60 to 80 mm Hg.<sup>1-4</sup>

#### Method

Five normal adults, three men and two women whose weights ranged from 110 to 190 pounds were seated on a mechanical resting surface (Fig 1).



Fig 1--Mechanical resting surface.

The surface consisted of a series of rollers operating on a continuous belt assembly powered by a small direct current motor which was energized by four D-size batteries. The entire belt assembly moved from an anterior to a posterior direction with each individual roller moving approximately one centimeter per minute or each roller displacing the adjacent one every six minutes. The seating surface was contoured so as to provide relief of pressure beneath the ischial tuberosities. The surface was also fixed at an angle of 6 degrees from posterior to anterior. That is, the front of the seat was positioned one inch higher than the back.

Subjects were seated with the thighs parallel to the ground with the feet bearing as little weight as possible on the foot rests. The arms were in a position of rest with the hands in the lap. Pressure readings were obtained beneath both ischial tuberosities and at 9 and 15 centimeters distance from the anterior edge of the sitting surface. The two pressure sensing devices were positioned approximately 13 centimeters apart.

The pressure-sensing system consisted of two CT-200+ transducers manufactured by Scimedics, Inc. The signals from the transducers were fed through a signal conditioner and recorded with a Brush recorder. Calibration of the sensors was done by placing the sensors within an air-tight cannister in which the pressure could be varied. Pressure readings on a mercury monometer were then compared with those on the Brush recorder.

Six to ten readings were obtained at each position on each subject for a total of more than 200 separate pressure determinations. The pressures at each position were then averaged to obtain the mean pressure reading at that position.

#### Results

Pressures under the ischial tuberosities and thighs were measured during operation of the

mechanical resting surface (Fig 2).

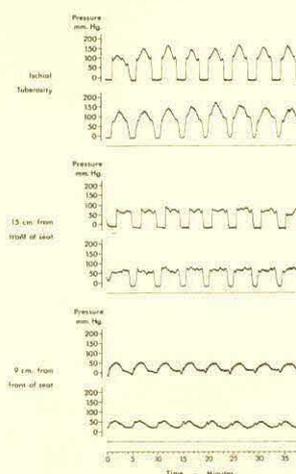


Fig 2--Pressure-time relationship under six areas of buttocks using mechanical resting surface.

Average pressures under the tuberosities ranged from 0 to 148.1 mm of Hg. depending on the position of the supporting roller devices. The pressure range under the thighs and anterior to the ischial tuberosities was considerably less but at all times, the minimal recorded pressures fell well within the range of capillary pressure and usually to zero pressure for short intervals of time. An alternating pressure distribution was effected by the movement of the roller surface.

At a distance 15 cms. from the anterior edge of the seat, pressures reached a maximum of 81.8 mm Hg. However, pressure routinely fell into and below the range of capillary pressure at regular, predictable intervals.

Pressures measured at point 9 cms. from the anterior edge of the seat achieved an average maximal reading of only 53 mm Hg. Again, regular repeated drops in pressure within and below the range of capillary pressure were noted during operation of the resting surface.

#### Discussion

Millions of dollars have been expended in attempts to develop resting surfaces which would be compatible with capillary pressure. These have ranged from various types of animal hides and polyurethane foams to gel pads and more recently to plastic or rubber envelopes filled with air, water or some viscous gel.

Extensive and accurate pressure measurements recorded on all these resting surfaces have failed to demonstrate any one surface which would reduce resting pressures beneath the ischial tuberosities within the range of capillary pressure. Though simple mathematical calculations have determined that this is an absolute impossibility as long as man is subjected to the gravitational pull of the earth, researchers and especially medical products manufacturers have persisted in developing cushions of various shapes, designs and materials.

Clinical and experimental studies have demonstrated that intermittent pressure relief is effective in delaying and even preventing the

destructive effects of pressure. It would then appear that a resting surface which provides complete relief of pressure for even short periods of time would be the surface of choice.<sup>5</sup> Only a mechanical surface is able to provide this type of pressure relief.<sup>6</sup>

The mechanical resting surface described in this study provides sitting patients with complete relief of pressure at regular, predictable, three-minute intervals. That is, one half of the sitting area at all times is completely free of pressure for up to three minutes. Since the supporting rollers are in constant motion, the body is subjected to maximum pressures for only short periods of time.

The pressure distribution curve produced by the resting surface resembles a sine wave, achieving a maximum pressure only momentarily before decreasing to near-zero pressure, then rising again as the next roller support moves into position. Though short periods of high pressure are not desirable, these pressures are not as destructive as low pressures (above capillary pressure) when applied for prolonged periods of time.

The fluctuations in pressure are due to the fact that the circular-shaped supports are rolling continuously beneath the patient. This rolling action not only minimizes trauma to the skin surface but also allows operation of the unit with a relatively compact power supply.

The roller surface weighs only 8 kg, is easily transferable and fits any standard adult wheelchair. Unique mechanical construction permits the unit to operate continuously on four D-size rechargeable batteries for up to 30 hours while supporting a weight of 75 kg. The power supply is easily removed, and the batteries are recharged as a unit.

The unit is covered only by a fitted flannel cloth that allows the desirable pressure extremes - especially the relief of pressure at regular intervals - to be transmitted to the sitting area. This effect cannot be achieved with plastic or naugehyde-type coverings. The flannel covering also limits heat build-up, a common problem experienced by patients sitting on plastic or rubber cushions. "Bucket seat" contouring of the roller resting surface tends to promote sitting stability, a characteristic frequently lacking in gel and foam pads.

#### Summary

This study demonstrates the potential effectiveness of a dynamic resting surface which at regular intervals, provides sitting patients complete relief of pressure for short periods of time. Resting pressure extremes ranged from 0 mm Hg to 160 mm Hg, depending on the position of the roller supports. At all positions, including the area beneath the ischial tuberosities, the pressures were well within the range of capillary pressure and usually dropped to zero pressure at regular intervals.

This mechanical surface may be the beginning of a new concept in resting surfaces. In addition to providing intermittent relief of pressure to the sitting area, the surface lends itself and the patient to a mobility that has not been heretofore possible.

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A PROPOSED EVALUATION METHOD FOR BIO-SUSPENSION DEVICES  
USING A DECUBITUS THRESHOLD PRESSURE CONCEPT

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ROHO Research and Development, Inc.

ABSTRACT

A method for the evaluation of bio-suspension structures using the suspension characteristics of fluids as a standard is presented. Included is a theoretical approach to ascertain how well a bio-suspension device meets a Decubitus Threshold Pressure criteria for an individual when exposed to continuously applied suspension loads.

<p>CATEGORY:</p> <p>Device Development <input type="checkbox"/></p> <p>Research Study <input checked="" type="checkbox"/></p> <p>STATE OF DEVELOPMENT:</p> <p>Prototype <input type="checkbox"/></p> <p>Clinical Testing <input type="checkbox"/></p> <p>Production <input type="checkbox"/></p> <p>AVAILABLE FOR SALE:</p> <p>Yes <input type="checkbox"/> No <input type="checkbox"/></p> <p>Price:</p>	<p>INTENDED USER GROUP:</p> <p>AVAILABILITY OF DEVICE:</p> <p>AVAILABILITY OF CONSTRUCTIONAL DETAILS:</p> <p>FOR FURTHER INFORMATION CONTACT:</p> <p>ROHO Research and Development, Inc. P. O. Box 658 Belleville, Illinois 62222</p>
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### Introduction

The ultimate purpose of a bio-suspension device, for the immobilized user, is to minimize mechanical interference with blood flow and therefore his metabolism at a pressure site.\* Even with continuous exposure to suspension loads, body tissue health should be maintained to their fullest potential. Cushion and mattresses must also provide many other features and functions. Only the pressure criteria for continuous suspension exposure are considered in this discussion.

Two basic design approaches for cushion and mattresses have evolved; alternating and static pressure devices. The alternating concept for a bio-suspension device depends on weight loading segmented soft tissue groups while a complementary group is unloaded. Loading is then alternated with the relieved group in a continuous cyclic manner. The major problem is that a

\*The etiology of Decubitus Ulcers is discussed by Kosiak (13) and Lindan (4).

power source must always be connected to or made part of the device. Weight shifting is also used to achieve pressure relief. The most popular bio-suspension device used for wheel chairs and prosthetic interfaces is static structures, i.e., foam, which produce fixed load patterns.

To give assistance to the selection of a suitable bio-suspension structure, many evaluations of various cushions have been performed. The methods used include the all mechanical test, Cochran (1), peak pressure test under the ischial tuberosity, Mooney (2), Reactive Hypermia evaluation by DeLateur (3), and the clinical evaluation.

None of these test methods has provided the industry with a comprehensive means of determining what suspension device applies to what person. The results of these test methods do not provide a means to normalize the information obtained, so it can be applied to a wide variety of needs and compared to a standard. Any evaluation must also be meaningful to the end user of the device,

he should be able to make some judgement and feel confident he has received the best possible value. For most immobilized users their decisions will usually be made for them by medical advisors, (including medical equipment dealers), friends and his insurance/welfare agency and they also should have the opportunity to make good judgements in the selection process.

Discussion

An important factor in selecting a cushion or mattress for an individual would be to determine his current and projected Decubitus Threshold Pressure suggested by Lindan (4).

A review of available literature shows that no method has been devised to ascertain an individual's Decubitus Threshold Pressure. A general criteria, of not having a localized area of pressure (peak pressure) exceed capillary pressure has been the accepted rule of thumb. No simple indirect test to measure capillary pressure is available.

An often quoted figure for capillary pressure is 32 mmHg. This was determined by Landis (5) using microcanulation of the capillary of the fingernail with the finger at heart level. When the arm position was changed to hip level (approximately 42 cm below the heart) capillary pressure rose to about 52 mmHg due to the pressure head. For the purposes of this discussion these values will be used. It should be noted that this data was obtained on normals. No studies of capillary pressure on the spinal cord injury persons have been located by the author.

A bio-suspension device in effect acts as an occlusion cuff placing an average load on the contacted tissue. This average loading for the purposes of this discussion will be considered equal to venous pressure.

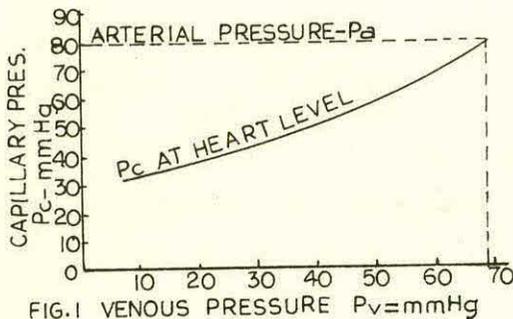


FIG.1 VENOUS PRESSURE  $P_v$  = mmHg  
The effect on capillary pressure with increases of venous pressure induced by a pressure plethysmograph.

Studies of capillary pressure and blood flow, when subjected to uniform hydrostatic loads by use of a pressure plethysmograph have been performed by McLennan, McLennan and Landis (6). From their studies it has been shown that increases in venous pressures causes an increase in capillary pressure as shown in Figure 1.

If a bio-suspension structure acts to increase venous pressures it then follows that it causes capillary pressure to increase.

In studies performed by Fish, Gilson and Taylor (7), they measured blood flow by use of a plethysmograph at congestion pressures of 30, 40 and 50 mmHg. Figure 2 extrapolates their data to zero flow at a value for a venous pressure of 69 mmHg determined by the capillary pressure intercept with arterial perfusion pressure ( $P_a$ ) which they determined to be 80 mmHg (see Fig. 1). This would appear to be the upper limit for increasing capillary pressures by increasing venous pressure under localized contact conditions.

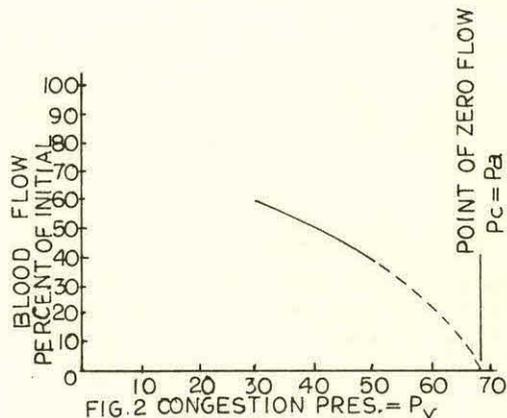


FIG.2 CONGESTION PRES. =  $P_v$   
Blood flow extrapolated to zero flow based on data measured by Fish, Gilson and Taylor (10) and a flow limit established by the intercept of arterial pressure  $P_a$  with capillary pressure  $P_c$ . See Fig. 1.

Lindan (4) showed that localized area of force, when the surrounding tissue was at atmospheric pressure, needed to be at 20 mmHg to produce no evidence of cellular damage. Assuming a capillary pressure of 32 mmHg for the ear of a rabbit (Lindan used rabbits as his test subjects), a pressure difference of 12 mmHg would exist. This pressure difference seemed great enough

to maintain sufficient blood flow and prevent mechanical collapse of the capillaries.

Figure 3 is the combination of capillary pressure shown in Figure 1 at heart level and with the pressure head added to estimate capillary pressures at the buttocks level.

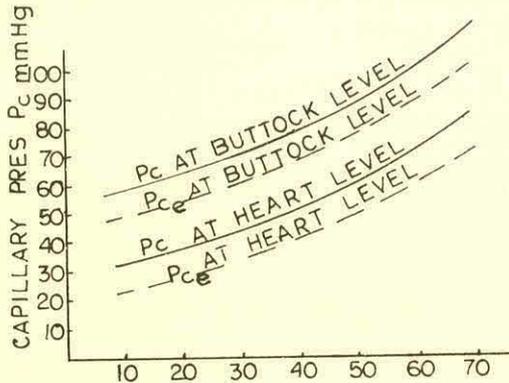


FIG. 3 VENOUS PRES.  $P_v$  = AVERAGE  
SUSPENSION PRES.  $P_A$  mmHg

Effective Capillary Pressure  $P_{ce}$  at heart level and Buttock level which when not exceeded is assumed to maintain adequate blood flow to maintain tissue health when continuous suspension loads are applied.

A capillary hydrostatic pressure of about 10 mmHg less than actual pressures is assumed. This pressure differential must be sufficient to resist mechanical collapse and therefore maintain sufficient flow. An effective (working) capillary pressure,  $P_{ce}$  (Decubitus Threshold Pressure), can be developed and is shown by the dotted lines. This establishes a pressure limit or threshold that when not exceeded is assumed, for the purposes of this discussion, to permit continuous exposure to suspension loads without cell necrosis.

When the pressure threshold is exceeded, cell necrosis is assumed to begin at a rate dependent on the degree of pressure applied as well as local metabolism requirements.

It has also been shown by Landis (5) that an increase in local skin temperature to 40°C. will raise capillary pressure to 60 mmHg. It is not clear what happens to arterial perfusion pressure with temperature change in individuals who have suffered a spinal cord injury.

It could be concluded that a warm cushion would raise capillary pressures and therefore the Decubitus Threshold Pressure, but more information is required to establish the effects of pressure, flow and increased metabolic demand.

Figure 4 is a plot of the  $\Delta P$  values for buttocks and heart levels which corresponds to the seated and prone/supine positions using the data from Figure 3.

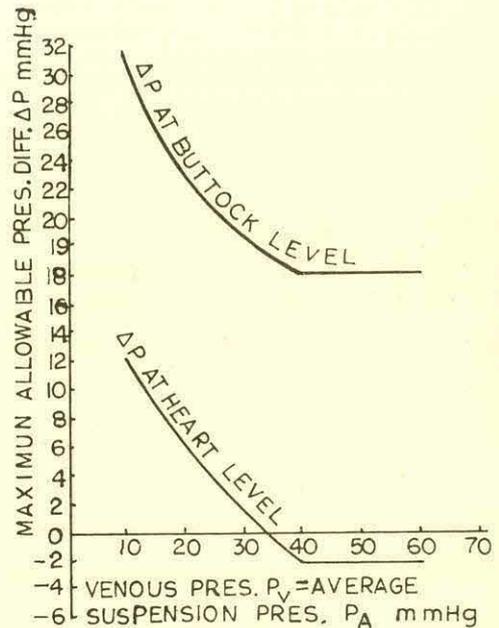


FIG. 4

Maximum allowable pressure difference  $\Delta P$  above venous pressure  $P_v$  equal to average suspension pressure  $P_A$ .

An object when immersed in an actual fluid will experience uniform hydrostatic forces. Therefore it can be stated that the average pressure,  $P_A$ , equals the peak pressure,  $P_p$ . Under these uniform pressure conditions decubitus ulcers appear not to develop regardless what the pressure level may be. To illustrate the point, consider that people can (through the techniques of saturation diving) live in undersea habitats (8,9,10) for weeks and not suffer from pressure sores (Decubitus Ulcers). The pressure loads which these people experience is in the thousands of mmHg, (every 10 meters of water depth equals one more atmosphere of pressure - 760 mmHg).

Peak pressure by itself does not present enough information to ascertain that a Decubitus Threshold Pressure level has been exceeded.

The relationship of average pressure to peak pressure appears to be a more accurate measure of a safe continuous pressure exposure level.

#### Proposed Standard

When a fluid is used as a standard for making comparisons of various bio-suspension structures then the ratio of  $P_A$  to  $P_p$  becomes of interest. In a fluid this ratio is one and is the efficiency that a fluid will provide in producing uniform hydrostatic suspension loads. When the  $P_A$  and  $P_p$  of a cushion or mattress is measured, then this efficiency of how well it approximated a fluid can be calculated by taking the ratio of  $P_A/P_p$ .

From Figure 3 an allowable efficiency rating can be calculated versus average pressures by taking the ratios of average pressure  $P_A$  to the effective capillary pressure  $P_{ce}$ .

Figure 5 is a plot of these estimated efficiencies based on the data presented in Figure 3. It can be seen from this data that the prone/supine position requires a more efficient bio-suspension structure than that required for the sitting position since expected average pressures,  $P_A$ , are much lower as well as the effective capillary pressures at heart level (11,12,13,14).

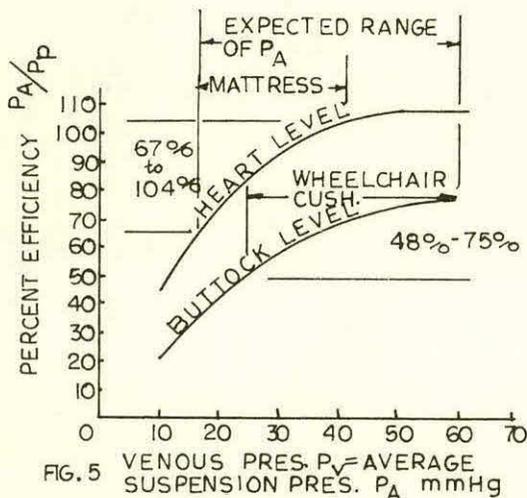


FIG. 5 VENOUS PRES.  $P_v$  = AVERAGE SUSPENSION PRES.  $P_A$  mmHg

Percent efficiency required (of a bio-suspension structure) not to exceed a selected Decubitus Threshold Pressure.

#### Proposed Measurement Procedure

When a person engages any type of suspension structure other than a fluid, he will develop a unique set of pressure readings and gradients.

The magnitude and location of these pressures will generate a pattern which is analogous to the fingerprint in that it is unique to that individual. It becomes very difficult and costly to measure and interpret such information, however, average pressure and peak pressure can be measured.

An inherent problem in making any pressure measurements between two soft surfaces is that the pressure sensor modifies the compliance of this, i.e., cushion and buttocks, interface.

As a bio-suspension structure more nearly approximates the floatation properties (low surface tension, constant buoyancy force independent of depth of immersion, molecular freedom and viscosity) of a fluid the more likely an error will be minimized if the sensor is very small, thin and very flexible.

#### Peak Pressure Measurement

Peak pressures must be measured by use of a pressure sensor inserted between the suspension surface and directly under a bony prominence usually the ischial tuberosity for the sitting subject.

For any one who has made pressure measurements on cushions, especially with a quadriplegic subject, they would agree it is a very laborious task for all. With a small sensor, such as the Scimedics 2 cm diameter and even the larger 10 x 10 cm sensor pad, as many as ten small positional changes may be required before the maximum (peak) pressure at the ischial tuberosity can be determined. To map enough pressure points to calculate the average pressure as well as the peak pressure so that sensor error can be minimized would involve a great deal of time.

Sensor error can be further allowed for in making cushion application judgments as long as everyone making similar measurements use the same sensor or a sensor having nearly the same size and flexibility.

#### Average Pressure Measurement

Average pressure can be calculated by dividing the total effective contact area by the sitting weight of the individual under test. For air inflated devices; internal air pressure is the average pressure.

Total skin area in contact with the cushion is not measured, only the plane of intersection with the supported position of the body is of interest since its intersection yields the effective area being supported.

A simplified layout of a contact plane is shown in Figure 6. Calculation of the effective support area is based on making four measurements as shown. Similar techniques can be developed for the prone/supine or amputated condition.

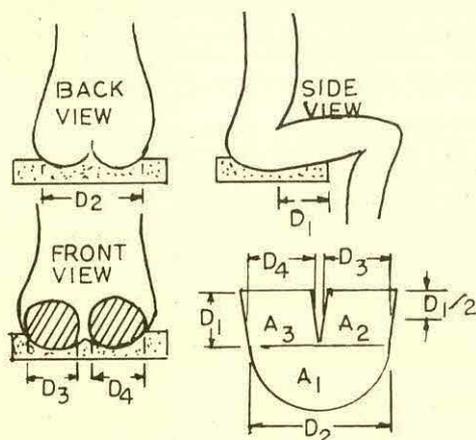


FIG 6 RECOMMENDED DIMENSIONS TO ESTIMATE EFFECTIVE SITTING AREA

#### Total (effective) Area

The curve made by the buttocks is assumed to be circular and to be a complete half circle to ease the burden of calculating its area  $A_1$ . The area of  $A_1 = \pi (D_2)^2 / 8$ . The approximate areas of  $A_2$  and  $A_3$  equal  $(D_4 \times D_1) + (D_3 \times D_1)$ . The total area of  $A_1 + A_2 + A_3$  can now be used to be divided into the weight being placed onto the cushion to obtain mmHg of loading. If cutout sections are used, or an amputation has occurred, their area must be subtracted from the  $A_1 + A_2 + A_3$  value.  $P_A = \text{Total Area} / \text{WT}$ .

To determine the sitting weight, a scale should be placed under the person while he is sitting in his wheel chair.

#### Conclusion

A need exists for a wide range of individuals to have a means of quantitatively comparing one type of bio-suspension device to another and further to ascertain that a proper bio-suspension device has been selected for the end user.

The suspension properties of fluids provide the ideal suspension characteristics which can be used as a standard to compare one static device to another. Additional standards are required for the many other functional characteristics required to make a cushion or mattress a practical structure, i.e., heat transfer, motion stability, portability, transfer

and etc., but were not considered at this writing.

When a bio-suspension device exhibits a high suspension ratio (average pressure to peak pressure), meaning that it is a good approximation to a fluid, it is less dependent on the suspension characteristics of the soft tissue between the skeleton and bio-suspension structure. When less perfect approximations are being evaluated by the ratio method, the same person should be used on each cushion under test. This leads to the recognition that a standard, mechanical, skeletal equivalent may be required.

The suspension characteristics of soft tissue on peak pressure measurements under the ischial tuberosity was inherently shown by V. Mooney (2) by comparing normals to spinal cord injured individuals. The percent difference calculated from their data between normals and patients ranged from the worst cushion at 75% difference to the best cushion at 50% difference.

When performing actual clinical evaluations, to determine that the person/wheel chair/suspension system does not exceed a Decubitus Threshold Pressure, soft tissue suspension characteristics are inherently included with the proposed method.

The accuracy of making measurements and selecting pressure thresholds which are dependent on capillary pressures (which can't be readily measured in the clinic) makes the proposed selection process still dependent on clinical follow-up for verification. It is felt that it does provide the basis of performing evaluations that are more meaningful than those presently being used. It further gives the medical and engineer/manufacture community a common basis for improving and understanding the bio-suspension problem.

#### Sample Calculations

$$D_1 = 6"; D_2 = 17"; D_3 = D_4 = 6\frac{1}{4}"$$

$$\text{Sitting Weight} = 145 \text{ lbs.}$$

$$A_1 = \frac{\pi (D_2)^2}{8} = \frac{3.14 \times 17 \times 17}{8} = 113.4 \text{ in}^2$$

$$A_2 + A_3 = (D_1 \times D_4) + (D_1 \times D_3) \\ = (6 \times 6.25) + (6 \times 6.25) = 75 \text{ in}^2$$

$$\text{Total (effective) Area} = 113.4 + 75 \\ = 188.4 \text{ in}^2$$

$$P_A = \frac{145 \text{ lbs}}{188.4 \text{ in}^2} = .77 \text{ psi}$$

$$.77 \text{ psi} \times 57.1 = 44 \text{ mmHg}$$

$$P_p \text{ (meas. by Scimedics Evaluator)} \\ = 60 \text{ mmHg}$$

From FIG. 3 Max. allowable  $\Delta P=18$   
 Calculated  $\Delta P=P_p-P_A=60-44=16$

16 mmHg would permit continuous exposure to suspension loads

From FIG. 5 The minimum eff. allowable when  $P_A$  is 44 mmHg is 71%.

Calculated eff. =  $\frac{44}{60} \times 100 = 73\%$   
 which is 2% above the min.

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## SESSION G SUPPLEMENTAL PAPER

G-1

THE DEVELOPMENT OF STANDARD CRITERIA FOR  
EVALUATION OF AUTOMOTIVE WHEELCHAIR LIFTS  
D.D. DUNCAN, McDERMOTT & PEIZER  
DEPT. OF IND. ENG. TEXAS A & M UNIVERSITY

P. 207

The Development of Standard Criteria for  
Evaluation of Automotive Wheelchair Lifts

D.D. Duncan and M. McDermott, Jr., Department of Industrial Engineering, Texas A&M University and E. Peizer, Veterans Administration Prosthetics Center, New York, NY

In recent years wheelchair lifts for installation in van-type vehicles have become a commercially available device for aiding in the transportation of wheelchair-bound persons. This paper reports on a research project at Texas A&M University sponsored by the Veterans Administration Prosthetics Center to evaluate a representative group of wheelchair lifts and to write a standard to which all lifts purchased by the VA must conform. The criteria used in the initial evaluations are given as well as a summary of the concepts in the resulting standard. Due to proprietary interests involved, the names of the lifts evaluated and specific results cannot be given.

CATEGORY:	INTENDED USER GROUP: Wheelchair-bound persons
Device Development <input type="checkbox"/>	
Research Study <input checked="" type="checkbox"/>	AVAILABILITY OF DEVICE:
STATE OF DEVELOPMENT:	AVAILABILITY OF CONSTRUCTIONAL DETAILS:
Prototype <input type="checkbox"/>	
Clinical Testing <input type="checkbox"/>	
Production <input checked="" type="checkbox"/>	
AVAILABLE FOR SALE:	FOR FURTHER INFORMATION CONTACT:
Yes <input checked="" type="checkbox"/> No <input type="checkbox"/>	
Price: Varies with manufacturer	

### Introduction

It is well recognized that most disabled persons have a strong desire to lead as normal a life as possible within their physical constraints. They desire to attain the same broad goals as do many, more fortunate people, e.g., education, occupation, recreation, family life, and to be productive members of society.

Progress has been remarkable over the last twenty to twenty-five years toward helping these individuals attain their full potential.<sup>1,2</sup> It is interesting to note a study conducted some twenty years ago in which investigators assessed "the correlation existing between the level of spinal cord lesion and the eventual functional potential" of persons with certain spinal cord injuries.<sup>3</sup> The study identified, on an average patient basis, which muscle groups remained functional following spinal cord severance at various vertebral levels, and discussed what daily activities and occupations the person might perform. For example, suggested occupations of patients with cervical lesions were subscriptions by telephone (the C-5 quadriplegics), light typing (the C-6 quads), or bookkeeping (the C-7s); all in the home, "since the patient cannot manage independently either his own car or public transportation."

Today, however, paraplegics and quadriplegics with high cervical lesions are managing indepen-

dently outside the home through the use of various assistive devices such as electric wheelchairs, orthotic appliances, automotive assistive devices, and others.

The ability to move about outside the home is a key factor in the independence of the paraplegic or quadriplegic. The wheelchair is the primary mode of mobility, and closely associated with the wheelchair's function of transporting the disabled person is the need for a means of transporting both wheelchair and occupant as a unit. This transportation need exists from the disabled person's home to any destination: school, shopping centers, job, or other location.

A perusal of the literature oriented toward the handicapped population, such as Accent on Living, Paraplegia News, and Paraplegia Life, shows that within the past four to six years there has been a virtual explosion of entrepreneurial activity to provide for movement of wheelchairs and their occupants.<sup>4,5,6</sup> This activity has resulted in an array of hoists, ramps, platform lifting devices, extensive van conversions, and minibuses. Also related to vehicular mobility for the handicapped are hand and servo controls necessary to enable disabled persons to drive, automatic door opener/closer mechanisms, wheelchair restraints, and associated equipment. This entrepreneurial ac-

tivity is obviously directed toward the estimated 100,000 disabled persons in the United States who are currently using or are capable of using specialized automotive transportation systems.<sup>7</sup>

Advertisements in the literature for the disabled show more than twenty companies that are involved in one or more aspects of designing, manufacturing, or selling wheelchair lifts for personal use. The illustrations and descriptions in the advertising literature indicate that many of these companies have been started by disabled persons who decided to build, or have built, some form of personal transportation system — usually a commercially available van-type vehicle with appropriate modifications, including lifts — suitable to that person's physical disability. These wheelchair lifts employ a variety of engineering principles and techniques in the use of chains, cables, hydraulic systems, linkages, electric motors, and other mechanisms. One problem is that there is no industry standard for lift device design, fabrication, reliability, or consumer safety. Further, it is almost impossible to compare these devices because of lack of dealerships and the relatively small number of lifts in use. Inspection of advertisements and the manufacturer brochures is of benefit only for gross comparisons.

Therefore, a prospective buyer may find it necessary to buy sight-unseen or choose a particular model solely because it is the only one he has seen or is available in his area, when in fact, a different model may be more satisfactory to him.

The experience of purchasing a wheelchair lift is unique in at least three ways: (1) a handicapped person may buy only two or three lifts in a lifetime because the lifts are (as suggested by the advertising) transferable from one vehicle to another, (2) the initial cost is high with current prices varying from approximately \$1,200 to \$2,000, and (3) to most people, a lift device is an unfamiliar piece of mechanical equipment.

#### Need for Improvement and Standardization

As with most new products there is a period of initial failures, design improvements and other changes. Due to the nature of their use, wheelchair lifts need to have a minimum of these early failures and changes. The design of lifts needs to be such as to ensure high reliability over a long period of time and with minimal maintenance. They must be safe for use by the paraplegic and quadriplegic population as well as for attendants and family of the disabled user. Finally, the lift must satisfy the physical characteristics and limitations of a broad cross-section of paraplegics and quadriplegics.

The Veterans Administration (VA), under the provisions of Title 38, U.S. Code, is the nation's largest purchaser of adaptive equipment for disabled persons. The VA Prosthetics Center, New York, NY, is responsible for a long term program to develop standards for hardware and prefabricated accessories.<sup>8</sup> In discharging the responsibility, the VAPC has contracted with the Texas A&M Research Foundation to test, evaluate, and write standards for a variety of assistive devices for handicapped drivers of automotive vehicles. Included in this program is (1) a study of the design and operational characteristics of a representative sample of currently available wheelchair lifts, (2) an evaluation under simulated normal

use conditions the acceptability of the lifts based on developed criteria, and (3) to develop a standard which the VA can use to assess the acceptability of lifts to be purchased for veterans.

The following sections briefly describe the evaluation work done and the salient points of the resulting standard for wheelchair lifts.

#### Evaluation

A representative cross-section of lifts of those available in mid-1975 to early-1976 was selected for evaluation. These lifts represented the output of the wheelchair lift "industry" at the time. There were others on the market, but this group displayed a variety of concepts for providing the van entry-exit function for wheelchair-bound persons. It was expected that from this representative group of lifts would come the basic data necessary for the development of a standard to which all lifts would be required to conform with respect to the "function, safety, and the quality of manufactured prefabricated components."<sup>8</sup>

In the development of the criteria for the evaluation of the lifts, it was immediately apparent that the usability of the lifts by handicapped persons was of utmost importance. The matter of usability by the handicapped was a difficult area to assess because of the wide range of capabilities among paraplegics and quadriplegics. Likewise, physical body dimensions are important from the standpoint of foot and leg interference, arm reach, and to a lesser extent, weight. Further, a simple task for an able-bodied person may be completely beyond the capability of some persons with spinal cord injuries. Therefore, it was decided that lifts would be evaluated assuming the user would be a C-4,5,6, or 7 quadriplegic of over six feet in height.

The second area of important consideration to an evaluation of mechanical hardware for the disabled was the matter of design and fabrication. There was no new technology seen in any of the lift designs or fabrication techniques; therefore, the evaluation needed to determine the extent to which the lift system adhered to currently accepted standards of industrial practice.

Related to the subject of design and fabrication is the installation, use, and maintenance of the wheelchair lifts. It was noted early in the research effort that some manufacturers had given proper thought to installation and operating procedures while other manufacturers had not. In some cases the manufacturer required factory installation and provision had not been made for a mail-order, install-it-yourself lift. It was recognized that there was no reason for requiring that a lift be customer-installed, but if the company did elect to make that provision, then adequate installation instructions must be provided. Furthermore, it was seen that the designer/manufacturer must take due consideration of the manner in which the lift was to be used and of the maintenance requirements to keep the equipment operating properly.

Safety features and the lack thereof was an extremely important area of concern when developing evaluational criteria. Initial inspection of the lifts revealed a number of potentially dangerous conditions and indications that the matter of safe design and operation had not been fully

considered by the designers.

There was a need to evaluate lifts to determine what is required of a person to operate the lift safely and properly, and to identify those execution errors that would result in injury to the person. Human factors aspects were important, not only from the standpoint of whether a handicapped person would operate the lift, but also relative to control movements, types of controls, platform dimensions, component locations, and similar factors.

The above comments can be distilled into short definitive statements of the evaluation criteria.

1. Adherence to accepted engineering design and shop fabrication practices.
2. Extent to which the lift can be installed and operated according to the manufacturer's instructions and claims.
3. System safety features and shortcomings.
4. Identification of potential user errors and possible results.
5. Ease and convenience of use by handicapped users having various capabilities.

Evaluations based on the above criteria were done on each lift in three steps.

1. Static Test Fixture Evaluations: (a) Engineering evaluation of design and fabrication practices, physical measurements (dimensions, operating times, electric current, sound levels, accelerations), and a system safety analysis. (b) Operational evaluation by able-bodied and disabled persons in wheelchairs.

2. Accelerated Life Tests: Evaluation during and after an equivalent of two year's use by an "average" user (component failures, required maintenance and overall performance).

3. In-van Evaluation: (a) Installation and operation. (b) Operation at various street-side-walk conditions.

A one-time destructive test was done on two lifts of different generic types of suspension systems to evaluate the effect of a catastrophic failure of the suspension system during lift use.

#### Concepts of the Standard

By using the information gained as a result of the evaluation and from a search of related industry standards and specifications the lift standard was drafted. After review by the VA, including a public dissemination and comment period, this document will become the VA standard to which lifts must comply in order to be purchased by the VA.

The following summarizes the concepts of the standard:

1. Engineering Design:
  - Lifting capacity of 400 lb minimum
  - Electrical compatibility with vehicle
  - Electrical current less than 100 amps
  - Minimum alteration of vehicle to install lift
  - Electrical, mechanical, and hydraulic component applications to conform to existing industrial standards
  - Availability of replaceable components
2. Fabrication:
  - Welding and alignment to conform to existing industrial standards
  - Standard fasteners
  - Coating (e.g., paint) of light color and

- to conform to existing industrial standards
- Wire, cable, or hose stowage
- 3. Human Factors:
  - Platform width at least 29 in.
  - Adequate platform length to allow foot clearance
  - Crossarm height at least 32 in. (if used)
  - Minimum of dirty or greasy surfaces
  - Ease of platform entry/exit
  - Control location, access and usability
- 4. Operation:
  - Operating instructions provided
  - Require minimum user actions
  - No unpleasant or dangerous accelerations
  - Long term reliability
  - Low noise level
  - Manual emergency operation mode available
- 5. System Safety:
  - No required wheelchair movement during operation
  - Electrical isolation except when operating
  - Automatic wheelchair roll preventing device
  - Automatic platform stop at required positions
  - All platform openings smaller than 3/4 in.
  - Slip resistant surfaces
  - No sharp edges or projections
  - No exposed mechanisms
  - Non-flammability of all components
- 6. Installation and Maintenance:
  - Instructions provided by manufacturer
  - Necessary hardware provided by manufacturer
  - Only standard tools required
  - Ease of access to parts requiring maintenance
  - Warranty, preferably at least one year

#### Summary and Conclusion

The wheelchair lift is an important link in the chain which leads to independence of a wheelchair-bound person. This paper has shown in general terms the steps used to develop a set of criteria by which wheelchair lifts can be evaluated.

The Veterans Administration, sponsor of the research described herein, has a vital interest in providing high quality assistive devices for veteran beneficiaries. It is expected that the application of these standards of quality, reliability, and safety will result in improved wheelchair lifts not only for veterans, but also for non-veteran wheelchair-bound persons.

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## AUTHOR INDEX

<u>NAME</u>	<u>PAGE</u>	<u>DATE</u>	<u>TIME</u>
ALDEN.....	170-174.....	6/3.....	1:00p
BACH-Y-RITA.....	187-188.....	6/3.....	9:30a
BOSTROM.....	75-77.....	6/1.....	3:30p
BROOKS.....	58-63.....	6/1.....	1:00p
CHARBONNEAU.....	153-156.....	6/3.....	8:30a
CHIARIZZIO.....	37-40.....	6/1.....	3:00p
.....	41-43.....	6/1.....	3:30p
CLAGNAZ.....	147-150.....	6/2.....	2:00p
CLARK.....	132-138.....	6/2.....	11:00a
COCKRELL.....	129-131.....	6/2.....	10:30a
COGAN.....	187-188.....	6/3.....	9:30a
COLLINS.....	170-174.....	6/3.....	1:00p
COOK, A.M.....	163-165.....	6/3.....	10:30a
COOK, D.E.....	78-80.....	6/1.....	4:00p
COSSALTER.....	153-156.....	6/3.....	8:30a
COTE.....	153-156.....	6/3.....	8:30a
CULLER.....	58-63.....	6/1.....	1:00p
CUZZI.....	192-195.....	6/3.....	11:00a
DAHER.....	44-47.....	6/1.....	4:00p
DENYS.....	96-98.....	6/2.....	10:30a
DIEGNAN.....	163-165.....	6/3.....	10:30a
DRIVER.....	181-183.....	6/3.....	8:30a
DUNCAN.....	207.....		
EULENBERG.....	109-114.....	6/2.....	2:00p
EVANCHEWSKI.....	31-36.....	6/1.....	2:00p
FLANAGAN.....	83-85.....	6/2.....	8:30a
FOLEY.....	51-54.....	6/1.....	10:30a
FOULDS.....	157-159.....	6/3.....	9:00a
FREAL.....	64-66.....	6/1.....	1:30p
GERSTMAN.....	157-159.....	6/3.....	9:00a
GRAEBE.....	199-204.....	6/3.....	1:30p
GRISWOLD.....	189-191.....	6/3.....	10:30a
HANKS.....	37-40.....	6/1.....	3:00p
.....	41-43.....	6/1.....	3:30p

## AUTHOR INDEX--continued

<u>NAME</u>	<u>PAGE</u>	<u>DATE</u>	<u>TIME</u>
HARRIS.....	184-186.....	6/3.....	9:00a
HAYES.....	78-80.....	6/1.....	4:00p
HEDGCOXE.....	175-177.....	6/3.....	1:30p
HENKEL.....	107-108.....	6/2.....	1:30p
HERRON.....	192-195.....	6/3.....	11:00a
HOBSON.....	37-40.....	6/1.....	3:00p
.....	41-43.....	6/1.....	3:30p
HOLMLUND.....	187-188.....	6/3.....	9:30a
HOLT.....	86-91.....	6/2.....	9:00a
HOLTE.....	31-36.....	6/1.....	2:00a
.....	44-47.....	6/1.....	4:00p
HUGGINS.....	37-40.....	6/1.....	3:00p
.....	41-43.....	6/1.....	3:30p
IMRE.....	117-120.....	6/2.....	8:30a
JONES.....	175-177.....	6/3.....	1:30p
KAUFMAN.....	187-188.....	6/3.....	9:30a
KELSO.....	86-91.....	6/2.....	9:00a
.....	99-102.....	6/2.....	11:00a
KINNE.....	67-70.....	6/1.....	2:00p
KO.....	117-120.....	6/2.....	8:30a
KOSIAK.....	196-198.....	6/3.....	1:00p
KRAFT.....	64-66.....	6/1.....	1:30p
KROUSKOP.....	192-195.....	6/3.....	11:00a
LEAVITT.....	192-195.....	6/3.....	11:00a
LE BLANC.....	11-13.....	6/1.....	10:30a
LEGAL.....	121-125.....	6/2.....	9:00a
LETTS.....	51-54.....	6/1.....	10:30a
LEVY.....	14-18.....	6/1.....	11:00a
LOUIE.....	147-150.....	6/2.....	2:00p
MADEY.....	187-188.....	6/3.....	9:30a
MALASSIGNE.....	75-77.....	6/1.....	3:30p
MALLIK.....	19-22.....	6/1.....	1:00p
MC DERMOTT.....	207.....		
MEYERS.....	163-165.....	6/3.....	10:30a
MOOGK-SOULIS.....	103-106.....	6/2.....	1:00p
MORTELMAS.....	96-98.....	6/2.....	10:30a

## AUTHOR INDEX--continued

<u>NAME</u>	<u>PAGE</u>	<u>DATE</u>	<u>TIME</u>
MUELLER.....	19-22.....	6/1.....	1:00p
MUILENBURG.....	192-195.....	6/3.....	11:00a
NELSON, P.J.....	153-156.....	6/3.....	8:30a
NELSON, W.J.....	129-131.....	6/2.....	10:30a
NEWMAN.....	71-74.....	6/1.....	3:00p
NICHOLLS.....	184-186.....	6/3.....	9:00a
ORPANA.....	153-156.....	6/3.....	8:30a
PAUL.....	31-36.....	6/1.....	2:00p
.....	44-47.....	6/1.....	4:00p
PEIZER.....	207.....		
PETELSKI.....	121-125.....	6/2.....	9:00a
PRICE.....	71-74.....	6/1.....	3:00p
QUANBURG.....	51-54.....	6/1.....	10:30a
RAHIMI.....	109-114.....	6/2.....	2:00p
RAITZER.....	86-91.....	6/2.....	9:00a
REID.....	109-114.....	6/2.....	2:00p
RINARD.....	139-142.....	6/2.....	1:00p
ROEMER.....	58-63.....	6/1.....	1:00p
.....	132-138.....	6/2.....	11:00a
ROSS.....	83-85.....	6/2.....	8:30a
ROUNDS.....	64-66.....	6/1.....	1:30p
RUGG.....	139-142.....	6/2.....	1:00p
SCADDEN.....	170-174.....	6/3.....	1:00p
SELL.....	143-146.....	6/2.....	1:30p
.....	147-150.....	6/2.....	2:00p
SHERMAN.....	166-169.....	6/3.....	11:00a
SHURTLEFF.....	55-57.....	6/1.....	11:00a
SILVERMAN.....	99-102.....	6/2.....	11:00a
SOUSA.....	55-57.....	6/1.....	11:00a
STEINKE.....	51-54.....	6/1.....	10:30a
STIEFEL.....	67-70.....	6/1.....	2:00p
STERN.....	189-191.....	6/3.....	10:30a
STOW.....	126-128.....	6/2.....	9:30a
STRATFORD.....	143-146.....	6/2.....	1:30p
TELZROW.....	55-57.....	6/1.....	11:00a

## AUTHOR INDEX--continued

<u>NAME</u>	<u>PAGE</u>	<u>DATE</u>	<u>TIME</u>
TRAYLOR.....	175-177.....	6/3.....	1:30p
TRAYNOR.....	92-95.....	6/2.....	9:30a
TREFLER.....	37-40.....	6/1.....	3:00p
.....	41-43.....	6/1.....	3:30p
VANDERHEIDEN.....	86-91.....	6/2.....	9:00a
VASA.....	23-30.....	6/1.....	1:30p
VON KAMPEN.....	31-36.....	6/1.....	2:00p
WAKSVIK .....	14-18.....	6/1.....	11:00a
WARREN, C.G.....	117-120.....	6/2.....	8:30a
WARREN, R.E.....	160-162.....	6/3.....	9:30a
WARRICK.....	153-156.....	6/3.....	8:30a
YODIN.....	147-150.....	6/2.....	2:00p
ZIMMERMAN.....	143-146.....	6/2.....	1:30p
ZUNIGA.....	192-195.....	6/3.....	11:00a