PROCEEDINGS

5th Annual
Conference on Systems and Devices for the Disabled

June 7, 8, 9, 1978
Houston, Texas

Baylor College of Medicine
Texas Institute for Rehabilitation and Research

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5th Annual
Conference on Systems and Devices for the Disabled

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Rehabilitation Research and Training Center No. 4
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ADDRESS INQUIRIES TO

Texas Institute for Rehabilitation and Research
Biomedical Engineering Department
1333 Moursund Avenue
Houston, Texas 77030
(713) 797-1440, Ext. 297

WELCOME ...

to conference No. 5 and to Houston. Your presence here verifies that there is an ever-growing concern for helping one another, and in particular our physically disabled.

This concern is expressed graphically in the CSDD symbol. The circle represents mankind's complete environment with the innermost figure representing the disabled person. Silhouetting this figure is a person who, complemented with "systems and devices", is able to extend himself and become more in touch with the complete environment.

This conference is the fifth of a series which evolved from the 1972 and 1973 Carnahan conferences. The First Conference on Systems and Devices was held in Boston in 1974, and subsequent conferences were held, respectively, in Philadelphia, Boston, and Seattle.

The major objectives of the annual meetings are to bring together consumers, therapists, clinicians, engineers, designers, technicians, educators, members of government, representatives of industry, and third party payers who are vitally interested in the application of technology toward aiding the handicapped population in becoming more independent and hence more productive citizens.

Thanks for your active participation in this conference, especially to those of you who are presenters and exhibitors.

ACKNOWLEDGEMENTS

I wish to express my sincere gratitude to the Baylor College of Medicine grants which provided the major source of sponsorship, namely, Rehabilitation Research and Training Center No. 4 and the Cooperative Rehabilitation Engineering Center of Houston.

A most gracious acknowledgement is given to those private industries and organizations who have made financial contributions. Special thanks to the review committee of the conference papers, the judges of the student engineering design competition, and to Gerald Warren and Rick Foulds, past conference chairmen.

Also, I wish to express my appreciation and gratitude to those members of the Program Committee who have put forth tremendous effort in making this conference a success - from the call for papers to the adjournment of this conference.

Many thanks are extended to my associates at TIRR and to TIRR Volunteers who have graciously given us their support.

Joe Canzoneri
Conference Chairman

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A CONSUMER VIEWS BIO-MEDICAL ENGINEERING

Harold S. Remmes

The author is critical of the Bio-Medical Engineering field because he feels it is not functioning at its optimal capacity. He proposes that there should be a closer relationship between the Bio-Medical Engineering and marketing and industry, to insure that products reach as many consumers as possible. He further feels that too little attention is given to aesthetics of design and that Bio-Medical Engineers fail to utilize consumers, and available marketing and technological resources which are available to them.

CATEGORY: Device Development ☐ Research Study ☐	INTENDED USER GROUP: AVAILABILITY OF DEVICE:
STATE OF DEVELOPMENT: Prototype ☐ Clinical Testing ☐ Production ☐	AVAILABILITY OF CONSTRUCTIONAL DETAILS:
AVAILABLE FOR SALE: Yes ☐ No ☐ Price:	FOR FURTHER INFORMATION CONTACT:

Introduction

Adapted housing for handicapped persons, especially those in wheelchairs, has literally opened the door to independence for countless individuals. Specially designed apartment units now offer the wheelchair user lower sinks and counters, wider doors, convenient stoves, and well situated grab bars; they provide maximum comfort, conservation of physical energy, and substantially reduce the accumulative fatigue on coping with non-adapted environments for many other mobility or functionally impaired individuals. Imagination and innovation in biomedical engineering have played a major role in making independent living one of the buzz words of modern rehabilitation.

As research into adaptive measures continues to expand, it is important to be aware of ways in which such adaptive housing can have adverse effects. Ironically, removal of physical barriers can create other invisible barriers to independence by creating an environment which fosters dependence on the adaptive measures, and affects the function of the handicapped individual in the "normal" world. The person who functions almost independently in an adapted unit may be unable to function maximally when removed to non-adapted settings. This can preclude travel and discourage participation in many daily activities which the able bodied world takes for granted.

A major challenge to biomedical engineering in the 1980s will be to design adaptive equipment which allows the person to function in a variety of settings with devices sufficiently portable and aesthetically acceptable to accompany the individual where he or she might go.

Different population: different needs

Looking at the overall handicapped population, one notes that needs are as individual in number as handicapped persons. For example, the quadriplegic in a wheelchair who has a personal care attendany may require more space but would certainly not require the lower adaptations for the wheelchair user since he, himself, would not be doing the homemaker chores. On the other hand, the quadriplegic who has had good rehabilitation and who functions without a personal care attendant would need about the same amenities as would the paraplegic living independently. Both groups would require lowered stoves, counters, and the usual amenities which are built into units designed for wheelchair living. The ambulatory person who may walk with difficulty using crutches or walker, or, who is unsteady on his feet for any reason, might find that the lower counters would adversely affect his functioning in the apartment. The same might apply to the cardiac who may have difficulty in reaching or bending but who can function relatively well if the cabinets are lowered or raised for his optimal convenience.

Location of adapted units

Most adapted units are either specifically designed for a particular population and included in low rent public housing facilities or in centers for independent living. While no one is trying to be disparaging about either of these programs it should be noted that those in low rent public housing are usually located in buildings which house elderly persons. The conflict in life style between the young handicapped individual and the geriatric population is tremendous and creates many, many problems of a social nature. The centers for independent living create a lifestyle wherein the special needs of the handicapped are available. This is not available in either the public or private sector for the population which requires them. Thus, the handicapped have gravitated toward specialized facilities of these two types.

In Houston, Texas, there is an excellent setting for independent living. In Boston, Massachusetts, there are many, many buildings which have specially adapted apartments. Throughout the State of Massachusetts there are several centers for independent living and in one location there is even a transitional housing facility designed as an interim living arrangement which gives the person training for independent life.

While many handicapped individuals whether in Berkely, California; Boston, Massachusetts; Minneapolis, Minnesota or Houston, Texas, report how much they appreciate their independence we would ask you are they independent? Can they move to another location, enjoy the same kind of freedom?

Economics of adapted units

It has been the experience of many landlords, be they public or private, that it is not practical to maintain a large number of adapted units. In some parts of the country the law requires that a certain percentage of units built in public housing be useable by the handicapped of any age. Since most housing authorities are not building family dwelling units, the apartments are built into complexes for the elderly and handicapped.

The landlords who are required to build this type of unit do not know (in many instances) how to market the units and, because they are adapted, often cannot find appropriate persons to fill the units. This rental loss is a disincentive to building more units for the handicapped.

If biomedical engineering could alter the personal environment of the individual there would be no need to create more specialized housing stock. Existing units in developments for the elderly could be utilized by elderly handicapped persons while the younger handicapped person would have the opportunity to elect where he might like to live.

Because architectural barriers are gradually being removed, more and more new construction will become accessible. Your challenge is to modify the individual's environment so that he can utilize accessibility and function maximally without the need of adapted units.

Transportation

In the area of transportation we see the government forcing local transit authorities to spend millions of dollars to make buses and trains accessible. Not only is this one of the least effective ways to go in terms of cost, it alienates the non-handicapped population because of the large amount of tax support required. Many handicapped cannot or will not use this system. There are too many other considerations such as the lack of curb cuts, fear of traffic, fear of crowds, or fear of being trapped in an elevated train high above the street.

Many consumers feel that there has not been enough attention given to driving and transfer adaptations so that the mobility impaired could use his own personal vehicle. Would this not be more cost-effective? Would this not be less restrictive? And would it not improve one's self-image?

Yet the devices which have been developed for driving are largely neolithic in terms of our space age developments. Almost everything is manual and requires a certain degree of strength and dexterity.

Bio-medical engineering must invade the areas of housing and transportation. In some cases modifying the environment will be indicated. In others. however, modifying the individual's wheelchair so that it is adjustable for height or so that it can easily become a part of one's vehicle without the need to transfer would be a more viable solution.

The self-image of the handicapped person

The adapted housing about which we have been talking is usually at least aesthetically good looking. Other devices for the handicapped, however, are usually less than attractive. In some cases they even look bizarre. Many of the devices used for the physically handicapped look like something from the space program or make the user appear as if he were a visitor from Mars or some other extra terrestrial location. What does this do to the self-image of the person? What does it do to the way in which people relate to the person? Besides frightening those who come in contact with the individual using these aides, the handicapped person himself feels strange and foreign. Very little attention is given to the aesthetics of devices for the handicapped and, it is my opinion, that every time one uses a device which is in any way grotesque, bizarre or unattractive, one alienates himself from the rest of society.

In the rehabilitation process many doctors, therapists and professionals tend to treat the handicapped person as a case. This contributes to his self-image adversely. When the person goes home, the family is often overprotective. This, too, has an adverse affect on the self-image of the individual.

Dr. Frederick A. Fay notes that:

> When a person breaks his neck or back and becomes permanently paralyzed, he is to a certain extent, at the mercy of the professionals and others around him, not only for his medical care and rehabilitation, but also for his psychological readjustment. He may regard himself in very negative terms if doctors and nurses continue to treat him as a 'sick patient.' His self-image will also suffer if family and friends persist in relating to him as a 'poor, helpless cripple.' However, he may learn to think of himself in very positive terms if medical and associated help staffs recognize and relate to him as a person with feelings, rather than as just 'another medical case.' Similarly his self-image will improve if people who are important to him relate to his abilities rather than just his disability. If others expect him to be a 'normal achieving person' who will soon return to 'normal community living' he is more likely to live up to their expectations.1

The design features of those of you who are in the engineering or design field do a great deal to help the individual but, are they, in fact, helping or hurting? Is it better to be able to do something when those who watch you do it are appalled and made nervous? I have no answer to this question, but I strongly suspect that there are many simple devices which could be designed which would answer a need by the handicapped population and which would be designed in such a way so as not to frighten off the rest of the population who are observing their use. If the public attitude of being "different" was not constantly reinforced then the self-image of the H/P would be improved. Bio-medical engineering could play a major role in this effort.

Consumers can offer suggestions

As you have probably guessed by now I am appalled by the devices which I see advertised in the magazines for the handicapped in the professional journals, and in the various broadsides I receive in the mail. Most of them are cumbersome, unattractive and, while they may function quite well, are extremely costly. If you would follow a little book which is published in Bloomington, Illinois, by Raymond C. Cheever, called Accent On Living Magazine, you would note that there is a column in there in which consumers say, "I wish there were." In this column handicapped consumers point out some of their needs. I would like to mention some of these needs to you now, just to see some of the things which handicapped people themselves envision as items which would make their life easier. One of the items which sounds very easy to design would be a counterbalanced arm to mount on the wheelchair arm. A Illinois handicapped person would like to see a folding and swiveling bracket similar to the one used on high intensity lamps which clamp to a table. He wants to clamp it to the arm of his wheelchair to hold his binoculars or camera. A female from New York would like to have a device that would enable her to go to the bathroom by herself instead of having to wait for her husband to help her. Another reader suggests something that could be attached to a wheelchair which would allow that person to push a shopping cart in a supermarket. And one man suggests that a wheelchair be designed where you would pull on the wheels rather than push them forward, where you would have a backward motion like rowing a boat because it is easier to pull than to push. These simple things could very easily be designed and manufactured but no one has bothered to tell the people who are in the area of design manufacturing what is needed.

Bio-medical engineering fails to utilize available resources

In recent years bio-medical engineers have gained recognition for designing and manufacturing devices for purposes of aiding in the rehabilitation of the handicapped individual. The relatively new field had to first gain the respect of both the medical and engineering professions. Well, this has now been accomplished. You are no longer considered the "junk reclaimers" of the engineering world. Many centers now receive respectable budgets and you have become an integral part of the medical and engineering world.

That is why many of us have not been critical of your activities. We have recognized the relative infancy of the new field. With your approaching adolescence, however, the time has come to point out some deficiencies in the system before they become too deeply embedded and require major surgery to excise them. Admittedly, you have done wonders with a few wires, some mini switches, transistors of assorted kinds, and the various engineering skills which you possess. But I see, at least, two major deficiencies which need attention.

The first criticism which, I feel, is valid is that you have not utilized maximally the available technology. The R&T Center with which I am associated has developed the TIC, a scanning device which scans horizontally and vertically an alphabet on a screen. The client, utilizing a switch stops the scan at the appropriate letter and, in so doing spells out words. Voila, communication for the non-verbal person! After developing the prototype, refinements were made to speed up the process and a limited number of units were manufactured and are now being utilized by many non-verbal persons.

Currently, the new video games were gaining in popularity. They are inexpensive, lightweight, extremely portable, and easily attachable to any TV set. It would seem to me that a marriage of bio-medical and commercial development would have been a natural and most worthwhile development. Essentially, almost any program can be produced for these machines; a small control unit with appropriate switch for individual needs could be plugged in, and all that the user would have to transport would be a small cartridge and a small control. One could use it almost anyplace one would go.

In addition to providing recreational activities, these devices could have an important educational benefit. For many patients in rehabilitation hospitals, much time is spent lying immobile with little mental stimulation; since vocational possibilities are for many of these persons now quite limited to thinking, or managerial positions, devices to strengthen and test abilities of concentration and reasoning would be most useful. Chess games, mathematical exercises, and other programs to develop concentration skills would contribute a great deal to the vocational futures of newly disabled persons who must contemplate building a life under conditions requiring patience, and tolerance. Biomedical engineering can do much to make hospital stays a productive time for mentally alert minds.

This is but one example of this entire thesis. We have tremendous bio-medical engineering skills. Industry has the knowledge of making an inexpensive, attractive, and portable package. Why hasn't anyone given thought to bringing together the best of both worlds?

Some suggested solutions

Why cannot the handicapped enjoy the same aesthetically acceptable, portable, inexpensive devices as the regular customer in the non-handicapped population? Bio-Medical engineering cannot function in a vacuum. It needs to look to the consumer who can identify the greatest needs. It must then join with industry and marketing experts to get the technology into the market place.

If you would concentrate on making adaptations which could be used in any environment we could eliminate many of the barriers to independent living. If you could become more sensitive to appearance, maximum utilization of other existing technology, if you could convince manufacturers to produce your developments at reasonable costs, then the need for adapting the environment would be significantly reduced. Sure, we will still need certain amenities for certain segments of the population but, we will have a potential for greater independence and freedom of choice so that the handicapped may have many more options as to where one may live and work and play. I suggest that this is the challenge you face.

The second criticism I have offers you another challenge. You may be extremely well qualified as engineers, you may even feel well sensitized to the needs and concerns of the handicapped, but I have yet to meet anyone who knows his own wants and needs as well as the person who has these desires and requirements. Thus, greater involvement of consumers could greatly benefit your efforts. It is, after all, the consumer who will utilize your products. It must be acceptable to him and it must be useable by him. It is he, too, who can see how others react to the device. It is his family who can give great insight into advantages and disadvantages.

Thus, my second challenge is to recognize the value of the user. For he is as valuable a tool as any testing device in your lab. The greatest difference is that he must be given greater respect than any "scope" or meter.

As one who has watched the development of the bio-medical engineering field, I offer these suggestions in the hope that you will recognize it as a constructive effort to improve a new system by bringing a different perspective to this meeting.

References

1. Frederick A. Fay, Housing Alternatives for individuals with Spinal Cord Injury, Medical Rehabilitation Research and Training Center No. 7, Tuft's University, October 1977, page 2.

CONSIDERATIONS IN SELECTION AND PLACEMENT OF A COMMUNICATION AID

Benjamin E. Brown and Gregg Vanderheiden

Trace Center-University of Wisconsin-Madison

Much progress has been made in developing communication aids for non-vocal severely physically handicapped individuals in the last few years. Starting out as adaptations to stationary typing systems, these communication aids have evolved to more mobile typewriting systems and more recently to fully portable communication aids.

The selection and placement of a communication aid with a non-vocal severely physically handicapped individual is dependent upon several factors. Some of the more important factors are the appropriateness of positioning in a wheelchair prior to placement of an aid, the affects that different environmental situations might have on the use of an aid and the criteria used in selecting one particular aid instead of another.

CATEGORY: Device Development ☒ Research Study ☐	INTENDED USER GROUP: Non-vocal severely physically handicapped. AVAILABILITY OF DEVICE: N/A
STATE OF DEVELOPMENT: Prototype ☐ Clinical Testing ☒ Production ☐	AVAILABILITY OF CONSTRUCTIONAL DETAILS: N/A
AVAILABLE FOR SALE: Yes ☐ No ☒ Price:	FOR FURTHER INFORMATION CONTACT: Ben Brown, Trace Center Univ. of Wisconsin-Madison, 1500 Highland Ave. Madison, Wisconsin 53706

Introduction

Communication aids for the non-vocal severely physically handicapped individual have grown out of earlier developments which were initially intended for vocal individuals who required some mechanism to write.* These aids typically were adaptations to electric typewriters which enabled them to be controlled with sip and puff or other similar control mechanisms. As the non-vocal severely physically handicapped individual's problems came under closer scrutiny, these earlier writing aids were adapted for their use as well. Where the sip and puff technique and some of the earlier interfacing techniques were not appropriate for individuals having cerebral palsy and similar conditions, other techniques were found which could take advantage of the residual control and provide them with means for controlling the typewriter mechanism. Expanded keyboards as well as special interfaces to facilitate encoding and scanning techniques were developed and adapted for these individuals. These aids, however, fell short of meeting the total communication needs of the non-vocal individual since what they really needed was a communication aid and not just a stationary writing aid. Although earlier researchers recognized this problem, the state of technology wasn't sufficiently advanced at that time for them to be able to do much about it in a practical way. Technology has advanced, however, and during the recent years, we have seen the advent of a number of portable independent communication aids. (An independent aid is here defined as an aid which has some print out or read out which allows an individual to pre-compose a message and then present it.) Aids have been developed which provide portability, printed output, special displays and the ability to print out entire words, phrases or messages with a single selection. As such, these aids have gone a long way toward providing the non-vocal individual with the "voice" that he needs for communication and interaction in his daily life.

Areas of concern in selection and placement

There are a number of areas, however which should be considered in the selection and placement of a communication aid with a severely physically handicapped individual. Through evaluation programs and interaction with parents, teachers,

*For a review of aids for the non-vocal severely handicapped individual, the reader is referred to Vanderheiden, Luster, 1975; Vanderheiden, Grilley, 1976.

clinicians, researchers and communication aid users themselves, a number of concerns have been identified. Some of the more significant areas are:

A. Appropriate wheelchair positioning of individual prior to fitting of a communication aid: This is a very important factor which will affect the individual's ability to effectively use any type of communication aid. As an example, the random athetoid movements of the trunk of a severely physically handicapped individual can adversely affect control of purposeful hand or head movement. Unless there is an adequate base of support from which to initiate the purposeful movement, extreme difficulty may be experienced by the individual in completing the movement task.

Appropriate body positioning, to allow for more purposeful movements, can be obtained by adapting the seating structure of the individual. This could be accomplished by adapting the individual's wheelchair through the construction of removable inserts or the design and construction of a complete modular seating system. In either situation, the basic objective would be to provide the individual with a solid base of support for initiating movements required for using an augmentative communication system. Points of concern are:

1. physical factors - range of motion, points of control (primarily hips, trunk and head), degree of correctability through use of wheelchair inserts

2. health factors - presence or absence of respiratory problems, levels of vision and hearing

3. social factors - desire to communicate with others, ability to make eye contact.

B. Consideration of differing environments in which a communication aid will be used: All communication aids are not appropriate in all environmental situations. Tailoring the aid to the different situations in which the user may find himself will greatly enhance his abilities to use the aid effectively. As an example, the following situation is cited:

A twelve year old non-vocal severely severely handicapped boy is one of six children, in a family in which both mother and father work. The maternal grandmother, who is hard of hearing, also lives with the family. There is a constant stream of visitors coming and going most nights of the week, especially on weekends.

The child has been fitted with a communication board which also serves as a wheelchair lap tray. The speech therapist and teacher at the special school he attends have developed a 200-word functional vocabulary which he is able to use for communicating his needs while at school.

Upon investigating the home situation, the teacher and therapist found that the board was not being used for communication. The reasons were many, but basically the problem was no one at home had time to wait for the boy to spell out his messages by pointing to words on his board. With six children, mother and father, a grandmother, who was hard of hearing, and a constant stream of visitors the competition for communication time and space was keen. As a result, communication between the child and family consisted of quick yes-no questions requiring only simple head nod responses. Thus it can be seen that designing an effective communication system for a child must include an evaluation of the environmental constraints and not just the child's ability to use an aid.

To facilitate proper use of communication aids in differing environmental situations the following should be considered:

1. an urban setting vs. a rural or suburban setting - Size and weight of the aid (degree of portability) would, perhaps, be more of a concern for the urban dweller who is possibly faced with multiple-story apartment living and reliance on public transportation.

2. apartment living vs. single dwelling living - Many apartments tend to be less spacious that houses, especially in older section of many cities.

3. living at home vs. institutionalization - Care of the aid would be a primary concern. The more people who have contact with a communication aid the greater the chances of misuse or abuse.

4. the home environment vs. the work environment - How easily an aid can be adapted to the work environment will directly affect an individual's effectiveness in the work setting. Interfacing the aid to that setting can greatly enhance an individual's self-worth and work productivity.

5. constraints of message receivers - Will the child be communicating with peers and siblings or others who cannot read or see the child's output.

6. time constraints of message receivers - What are time constraints and how can they be minimized?

7. communication needs - Different environments will put different communication constraints and requirements on the child.

C. Selection of an appropriate communication aid: Once the individual has been seated properly and environmental factors have been considered, the next important consideration in selection of a communication aid is appropriateness of the aid. An augmentative communication system, to be appropriate, should meet the intellectual and emotional needs of the non-vocal severely handicapped individual. An example of an inappropriate communication aid would be a language board filled with animals, colors and other non-interactive words. Points to be considered are:

1. vocabulary size - The number of words in an individual's vocabulary will have an affect on the size of the aid. The larger the vocabulary the more space required for word display. Arrangement or location of words would also be affected by vocabulary size.

2. vocabulary choices - How the individual chooses words or puts words together in phrases or sentences will affect where words and phrases are located on the aid. Also their frequency of use and the individual's technique for finding the words (alphabetically, part of speech, rote memory, etc.).

3. speed of selection - If only an alphabet board is used then the speed in communicating is very slow. Whereas, selection of words is faster, with selection of phrases faster yet. There is concern, however, that "canned" phrases: can create stereotypic responding rather that functional communication.

D. Additional concerns in the selection and placement of communication aids: The following are important concerns specific to electronic communication aids. They represent a sampling gleaned from input from teachers, parents, clinicians, and the handicapped themselves in the field who have had experience with some type of electronic communication aid:

1. Correctability - The non-vocal severely physically handicapped individual makes both physical and language mistakes in constructing his messages and needs to have the capability to correct them both for intelligibility and for language development.

2. Output form - In conjunction with correctability, it is important that the output from the communication aid be clearly visible to the handicapped user. In addition, since few displays can be made large enough to hold substantial messages without drawing excessive amounts of power, printed output of some sort is also desired on communication aids to allow the individuals to assemble their complete messages in advance.

3. Word or phrase capability - The ability to print out words, phrases or entire sentences with a single selection can greatly increase the speed of communication for communication aid users.

4. Flexibility - This refers to the ability of aids to operate in completely different modes of operation. This capability allows teachers, clinicians, parents, etc. to purchase an aid which approximately meets the needs of their children, and then to try it out in completely different modes of operation in order to find out which particular approaches best match the particular capabilities of their children. As the child's abilities change, this type of aid can be changed over time to continue to best match the child's changing abilities. Teachers and clinicians are looking toward the development of aids which are more adaptable and which can, therefore, be more easily custom fit to the various individual (physical, cognitive and language) abilities and handicaps of their users.

5. Developmental - The need exists for aids which can be quite simple for their initial application but which can grow with the child to take advantage of his increasing physical or cognitive skills to meet his expanding communication requirements.

6. The ability to control external displays, printers, and other devices - The aids must be able to interface with other displays or page printers to provide the handicapped individuals with the necessary tools for education and employment.

7. Durability - One area needing particular attention, especially in more advanced aids is the ruggedness and the durability of the aids.

8. Maintenance - A commonly cited problem area has been the maintenance of equipment when it does fail. At present, some clinicians are very hesitant to allow individuals to become dependent on communication aids which can be absent for a great length of time for repair when they are damaged.

9. Cost - Cost continues to be a very large consideration in the application of electronic communication aids. The actual cost of the aids, however, turns out to be largely a function of the information dissemination and the application/fitting costs. Although the cost is usually cited as one of the major barriers to securing an aid, it is usually ranked behind having an aid which is going to genuinely meet the needs of the individual and will be reliable.

Conclusion

Placement of an appropriate communication aid is dependent upon several important factors. Preliminary consideration of the need for an aid must address the problem of appropriate seating of the handicapped individual as well as how, when, and where the aid will be used. After all factors have been considered, however, the best evaluation of an aid is the amount and diversity of communication and interaction which the child engages in through the aid. Our goals should be allow the non-vocal child to communicate with the same spontaneity and diversity as the vocal child at the same age level. Only brief observations of the amount and diversity of vocal children's interactions are needed to point out the magnitude of our task.

Bibliography

This bibliography has been arranged in a categorized manner to aid in further research on particular topic areas.

Summary information

1. Copeland, K. Aids for the Severely Handicapped, Spector Publishing Co., Ltd., London, England, 1974.

2. Kafafian. H. A Study of Man-Machine Communication Systems for the Handicapped, 3 volumes (1970-73), Cybernetics Research Institute, Washington D.C.

3. Luster, M.J. Preliminary Selected Bibliography of Articles, Brochures and Books Related to Communication Techniques and Aids for the Severely Handicapped, Trace Center, 922 ERB, University of Wisconsin-Madison, Madison, WI 53706, 1974.

4. Luster, M.J. and G.C. Vanderheiden, Preliminary Annotated Bibliography of Communication Aids, Trace Center, 922 ERB, University of Wisconsin-Madison, Madison, WI 53706, 1974.

5. Vanderheiden, G.C. and M.J. Luster, "Non-Vocal Communication Techniques and Aids as Aids to the Education of the Severely Physically Handicapped," A State of the Art Review, Cerebral Palsy Communication Group, University of Wisconsin-Madison, Madison, WI 53706, 1975.

6. Vanderheiden, G.C. and D. Harris-Vanderheiden, "Communication Techniques and Aids for the Non-Vocal Severely Handicapped," in Lyle Lloyd (ed.) Communication Assessment and Intervention Strategies, University Park Press, Baltimore, Maryland, 1976.

7. Vanderheiden, G.C. and K. Grilley (ed.) Non-Vocal Communication Techniques and Aid for the Severely Physically Handicapped, University Park Press, Baltimore, Maryland, 1976.

8. Vicker, B. Nonoral Communication System Project 1964/73, Campus Stores Publishers, 17 West College, University of Iowa, Iowa City, Iowa,52242, 1974.

Facilitative body positioning

1. Bergen, A. Selected Equipment for Pediatric Rehabilitation. Valhalla, New York: Blythedale Children's Hospital, 1974.

2. Bergstrom, D. and C.H. Coles, Basic Positioning Procedures. Minneapolis: Kenny Rehabilitation Institute, 1971.

3. Bleck, E.E. and D.A. Nagel (eds.) Physically Handicapped Children. A Medical Atlas for Teachers. New York: Grune and Straton, 1975.

4. Finnie, N.R. Handling the Young Cerebral Palsied Child at Home. New York: E.P. Dutton and Co., 1970.

5. Gesell, A. and C. Amatruda, The First Five Years of Life. New York: Harper and Brothers Publishers, 1940.

6. Halpern, D., F.J. Kottke, C. Burrill, C. Fiterman, J. Popp, and S. Palmer, Training of Control of Head Posture in Children with Cerebral Palsy. Developmental Medicine and Child Neurology, 1970, 12, 290-305.

7. Hofman, R.B. How to Build Special Furniture and Equipment for Handicapped Children. Springfield, IL: Charles C. Thomas, 1970.

8. Macey, P.G. Mobilizing Multiply Handicapped Children. Lawrence, Kansas: University of Kansas, 1974.

9. Motloch, W.M. Seating and Positioning for the Physically Impared. Orthotics and Prosthetics, 1977, 31, 11-21.

10. Robinault, I.P. Functional Aids for the Multiply Handicapped. New York: U.C.P.A., Inc., Harper and Row, 1973.

11. Treffler, E., P. Huggins, D. Hobson, S. Hanks, and S. Chiarizzio, "A Modular Seating System for Physically Handicapped Children", Proceedings of the 4th Annual Conference on Systems and Devices for the Disabled, University of Washington School of Medicine, Seattle, Washington, June 1,2,3, 1977.

12. Willard, H.S. and C.S. Spackman, Occupational Therapy. Philadelphia: J.P. Lippincott Co., 1971.

13. Williams, C.E. Physical Therapy in Residential Facilities. In Pearson, P.H. and C.E. Williams, (eds.), Physical Therapy Services in the Developmental Disabilities. Springfield, IL: Charles C. Thomas, 1972.

REHABILITATION DEVICE EVALUATION - THE NEED AND AN APPROACH

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The need exists for detailed reports about the multitude of rehabilitation aids which are currently available commercially. Without such reports it is difficult to determine a device's appropriateness to a given situation. This paper describes an approach to providing the information needed in a standard form. Detailed descriptions are handled on both technical and functional levels. An evaluation of effectiveness contains both objective and subjective information. Some solutions to practical problems are offered so that application may be effected in difficult situations. Plans for distribution of information are presented along with the intent to expand the scope of reports to include a consumer evaluation of devices.

CATEGORY: Device Development ☒ Research Study ☐	INTENDED USER GROUP: Health care professionals, manufacturers and consumers of rehabilitation devices.
STATE OF DEVELOPMENT: Prototype ☒ Clinical Testing ☐ Production ☐	AVAILABILITY OF DEVICE: Immediately AVAILABILITY OF CONSTRUCTIONAL DETAILS: N/A
AVAILABLE FOR SALE: Yes ☒ No ☐ Price: approx. $1.00 + postage	FOR FURTHER INFORMATION CONTACT: Mr. T. Wallace Chedoke Hospitals Box 590 Hamilton, Ont. L8N 3L6

Introduction

The growing number of rehabilitation devices reaching the marketplace increases the problems of selecting and applying the most appropriate device for a given client in his particular situation. Knowledge, skills and mechanisms exist to evaluate a client's needs, functional capabilities and to some degree, his potential for future performance. Such evaluations have become day to day activities at rehabilitation centres around the globe.

If we regard the applied rehabilitation device as an extension of the user, we must also be able to evaluate the device in an appropriate fashion prior to application to ensure compatibility, acceptability and usefulness. For example, in the case of an electric wheelchair, we need to know its power, energy availability, and maintenance requirements. Functional capabilities of the device must be known in detail. While our client may only be able to operate the chair at slow speeds, today, with practice his performance will usually improve. If the chair does not have a high speed range, this restriction might soon become a burden to him. While the knowledge and skills exist to assess functional capability of devices, an integrated mechanism does not. What does exist are bits and pieces of information from various sources. For instance, cataloguing systems (such as ISAARE)[1] are available to locate devices. They allow access to the file through various entry points which converge to a device or class of devices. At this end-point we are left with a few words of description, perhaps a sketch and a manufacturer. What usually follows is contact with the manufacturer or his representative, who, for that particular device, gladly sends along his advertising pamphlet, which by its very nature is biased. If indeed we are fortunate enough to attend a rehabilitation devices conference, we may be able to acquire more information from an exhibit, but knowledge gained here tends to be largely subjective. At this point we try to acquire a device for our evaluation. If it is inappropriate we will try another and another and so on. This happens frequently with duplication of effort which is virtually as widespread as the number of centres dealing with rehabilitation problems. It is with this background in mind that a team from the departments of Biomedical Engineering and Occupational Therapy at the Chedoke Rehabilitation Centre undertook to design a standard protocol for the evaluation of rehabilitation devices.

The Protocol

The evaluation problem is most acute in the area of complex machines. Page-turners, environmental controllers, electric wheelchairs and the like fall into this category. The "Powered Technical Aid Evaluation Protocol" (see Appendix 1) is designed to deal with devices of this type.

The first page of the protocol contains the identification and description of the device under evaluation. Included here are such items as price, distributor(s), documentation available and warranty information. The technical description is arranged as follows:

1) Power requirements are identified.

2) Approvals from agencies such as Underwriter's Laboratories, Canadian Standards Association, Etc. are recorded.

3) The control input requirements for the main unit are identified. Included here are the type of connector and its mate with voltages and contact arrangements needed to initiate action.

4) The patient input device(s) are discussed giving details of pressure, range of motion required, power required, etc. for effective control of the machine.

5) A technical description is provided to relate how the main unit accomplishes its function(s). This may include such things as relay or semi-conductor switching of power, mechanical action of page turning, etc.

6) Procedures for getting service and repair work are indicated in answer to the following questions: How does one get service and repairs done? Who, where, if self, a description of routine service appears in this section.

7) The evaluators' observations relating to the technology used, reliability and ruggedness appear in this section. Any incidents of breakage or failure experienced would be described at this point. While the protocol has general applicability, there comes a point when experiments must be devised to reflect properties of specific devices. In the case of page-turners, an experiment to indicate reliability might be as follows. Various types of reading material (magazines, text-books, paper-back novels, etc.) would be applied to the machine. Numbers of pages turned without failure for each situation would be noted. Failure would be defined as a situation which could not be corrected using the patient input device in use.

8) Environmental and physical constraints are described. Such things as space requirements, weight of the device, positioning of the patient input device(s), and the position(s) in which the main unit can function are included along with any special constraints of temperature, humidity, special power, etc.

The protocol continues with a functional evaluation under three headings:

1) Patient Input Device(s)

The interfaces available from the manufacturer are identified and described. Details of type and duration of patient action required are included for each type.

2) Number of Functions Available with this System

In the case of an environmental controller, it may indicate that TV, telephone, dictating machine, etc. can be activated.

3) Detailed Control Available

Once a function has been selected, what controls remain available to the user? For instance, once the TV is activated, channel-changing capabilities might be available, whereas volume control and fine tuning may not.

The concluding section of the protocol deals with possible enhancements and adaptations of the device. For example, experience may indicate that a Cerebral Palsied child may benefit from the use of a device, but has great difficulty dealing with the switching arrangement as supplied by the manufacturer. This portion would suggest some strategies to cope with the problem, such as new input devices or simple modifications to the existing one or the main unit itself. Further recommendations appear in this section and may be directed to manufacturers, para-medical staff or the consumers. Lastly the report provides a summary of the evaluation of the device and it general applicability to various handicaps.

Plans for Distribution

The protocol is at present being applied to devices already available at the Chedoke Rehabilitation Centre. When we have completed evaluations on all these devices, we hope to arrange evaluations with manufacturers' samples of other makes of devices.

A considerable amount of energy is to be directed toward the dissemination of the data acquired. Publication in rehabilitation, paramedical and consumer journals is envisaged. General distribution to rehabilitation centres, manufacturers and distributors would be useful. Plans are underway for broadcasting the information via the Radio Reading Services in the form of a "consumer report" type of programming.

Future Endeavours

One of the most important facets of the evaluation is not yet realized. That is the report from consumers in the handicapped community. It is our aim to extend the protocol to include some form of consumer testing. Only in this way can we hope to gain insights into the overall worth of any such device.

An operation such as this runs on money of course, and reports would be made available on a cost recovery basis. It is estimated that one full-time position could handle the co-ordination of this endeavour. The co-ordinator would be responsible for procurement of devices, scheduling of tests and experiments, consumer testing, writing of the final report and publicizing of the information. The departments of Biomedical Engineering and Occupational Therapy would take the role of resource centres for the co-ordinator.

Conclusion

We have attempted to provide a solution to the problem introduced at the beginning of this paper. It is our sincere hope that the manufacturer can gain insights into the properties of his product, which may exclude it from a wider marketability. These insights could perhaps lead to further development of a device or the development of new devices which would meet the needs of a more significant portion of the handicapped community at large. Herein lies a substantial benefit for the handicapped consumer. For the occupational therapists or biomedical engineering members employed in rehabilitation medicine, the gain is simply this: Access to in-depth reports on rehabilitation devices, can only lead to more effective decision-making, problem-solving and optimization of the process of applying the appropriate device to the one who needs it - the consumer.

References

1 a. ISAARE. Information System for Adaptive and Rehabilitation Equipment (Adaptive Systems Corporation, 1650 So. Amphlett Blvd. Suite 317, San Mateo, California, U.S.A. 94402).

b. Accent on Information (P.O. Box 700, Bloomington, Illinois, U.S.A. 61701).

c. NIRE. The National Institute for Rehabilitation Engineering (Pompton Lakes, N.J., U.S.A. 07442).

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Appendix 1

Powered Technical Aid Evaluation

Technical Aid:

Evaluator(s): Date:

General Description (to include description of Technical Aid, Price, Distributor, Documentation Available, Warranty).

PART A TECHNICAL DESCRIPTION

PART B FUNCTIONAL DESCRIPTION

PART C RECOMMENDATIONS AND CONCLUSIONS

PART A Technical Description

1) Power Requirements:

a) Voltage________________

b) Current________________

c) Power Consumption_______

d) Other__________________

2) Approvals (✓):

Underwriters Labs. (U.S.A.) ☐

C.S.A. ☐

Ontario Hydro ☐

Other ☐ Specify

____

3) Input Requirements to Main Unit:

a) Type of Connector: Mfr. & Model #___

____

b) Sketch of "a" with connections labelled. (i.e. - N.O./N.C. contacts, voltages, etc.)

c) Mating connector for "a" (That which is on the Pt. input device) Mfr. & Model #__________________

4) Patient Input Device(s):
(List each type with a technical description including patient action to operate, power required, etc. - use extra sheet if necessary).

5) How does Main Unit Accomplish its Function(s)?
(i.e. - Relay or semiconductor switching of line voltage, mechanical action of page turning, etc.)

6) How does one get Service and Repairs Done?
(Who, Where, and if self, describe routine service).

7) Subjective Feelings about:-

a) Technology used:

b) Reliability:

c) Ruggedness:

8) Environmental Constraints

a) Space occupied by main unit, and weight of same

b) Position(s) in which main unit can function

c) Space required by patient input device(s)

d) How may interface be positioned at patient?

e) Other Physical Constraints (i.e. - special power, temp., humidity, etc.)

PART B

1) Patient Input Device(s)
a) Type(s) Available: (under each describe the action required to operate including details of range of forces, range of motion, pressure ranges, duration of patient action, etc.)

Microswitch ☐

Pneumatic ☐

Touch Switch ☐

Proximity Switches ☐

Light Actuated Switches ☐

Voice Actuated Switches ☐

Other ________________ ☐

2) Number of Functions Available:
(List types).

3) Detailed Control Available:
(Pros and Cons).

PART C Possible Enhancements and Adaptations

a) Suggestions for other input device(s) (simple)

b) Simple modifications to main unit

c) Simple modifications to input device(s)

Further Recommendations:

Conclusions:

AN EXPERIMENT IN "SOCIAL DESIGN" EDUCATION

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The objective of the paper is to describe an on-going educational experiment in the undergraduate Industrial Design Department at the Faculté de l'Aménagement, Université de Montréal (Faculty of Environmental Design). The paper details an option introduced almost two years ago to enable students to study socially-oriented industrial design for groups such as handicapped persons and low-income families. The paper traces the background context of the profession and the raison d'être for developing this option, describes the operational set-up and the current project activities in "social design" for disabled individuals, and outlines a new programme to expand this option to a research-oriented Master's degree.

CATEGORY:	INTENDED USER GROUP:
Device Development ☐ Research Study ☐	AVAILABILITY OF DEVICE:
STATE OF DEVELOPMENT:	
Prototype ☐ Clinical Testing ☐ Production ☐	AVAILABILITY OF CONSTRUCTIONAL DETAILS:
AVAILABLE FOR SALE: Yes ☐ No ☐ Price:	FOR FURTHER INFORMATION CONTACT: Ronald Levy, Ph.D., Clinique de Design Université de Montréal Case postale 6128, Succursale "A" Montréeal, P.Q., H3C 3J7, Canada

Introduction

Industrial design generally has tended to concentrate its efforts to serve lucrative consumer interests, and has largely ignored the needs of, and the potential services it could render to, disadvantaged marginal groups which unfortunately do not have the market force to attract corporate profit incentives. Nevertheless, within the past decade, a few isolated design professionals in the field have used various platforms to call for the awakening of social awareness and social responsibility on the part of product designers so that they may contribute their specialized knowledge to help fringe groups within society gain a stronger foothold within the mainstream of society.

This type of design intervention which we call "social design" is not entirely new. Considerable work has already been carried out in regards to environmental design for the elderly, design of "normalizing" environments for mentally retarded or psychiatric individuals, housing design for low and moderate income groups, design of learning environments for children and barrier-free environments for physically disabled persons. However, the above all tend to focus on improving the performance of the environment rather than the performance of the individual.

Our primary concern in this paper is to demonstrate the contribution which the design profession can also make in the realm of special equipment (product) design for physically disabled individuals to increase their potential for a fuller interaction within or upon the environment.

The industrial design profession itself has recently acknowledged a definite need to develop new viable alternatives of design intervention. Both in philosophical and practical terms, persons such as Papanek[1], Maldonado[2], Salovaara[3], and

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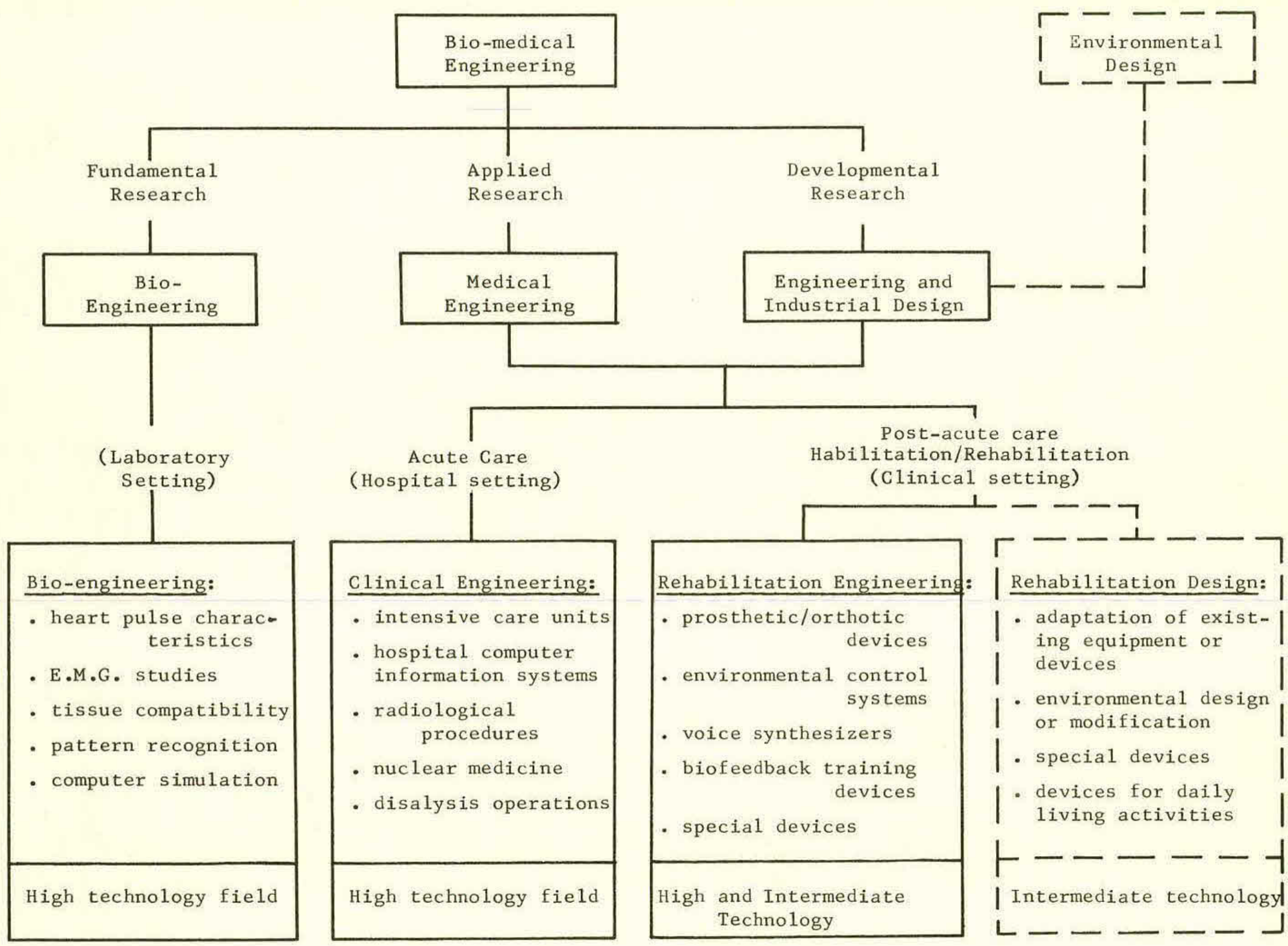
those within the Institut fur Sociales Design[4], have been identifying an important role for the designer in more socially-oriented areas. A gradual acceptance of this role is emerging among the design profession at the academic level, but has not yet filtered down to the profession as a whole.

A context for "rehabilitation design"

We want to clarify here and now that the intervention of the designer in special equipment for disabled individuals is not in the high technology fields of bio-, clinical or rehabilitation engineering, but is rather in the realm of intermediate technology dealing with relatively simple devices. Such equipment is perceived as separate from the orthotic and prosthetic devices traditionally handled by the rehabilitation engineer, and is rarely technical enough to be of sufficient interest to other engineering sectors. It is therefore believed that the design disciplines may offer the necessary complement to provide additional techniques to the rehabilitation team to help develop intermediate technology devices to enhance the independence of disabled individuals.

Model A below shows the context within which we believe "rehabilitation design" of simple devices can be situated in relation to the engineering disciplines. (Adapted from Reswick[5])

It is recognized that the physical and occupational therapy professions are the first in line to help disabled individuals cope with the physical environment. However, their technical support should come not only from the rehabilitation engineer, but also, we suggest, from the industrial and environmental designer. The concern of occupational therapists to devise adaptations for disabled individuals perhaps best describes the field of intervention called "special devices". There is a close relationship among the fields of therapy, engineering and design, and interdisciplinary relations need to be established for the ultimate



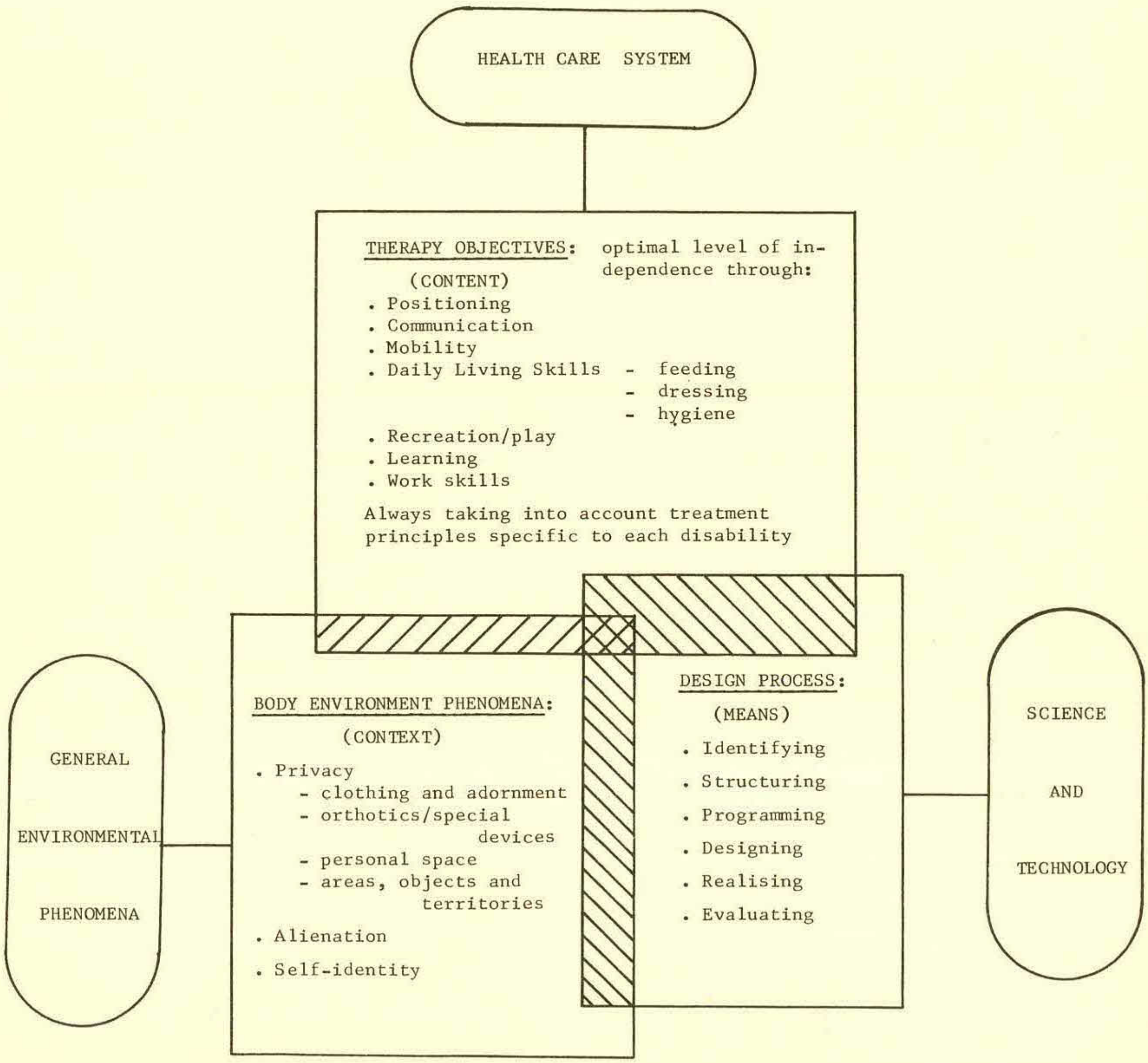
Model A - A Context for "Rehabilitation Design" in Relation to the Engineering Disciplines benefit of the user. The designer brings to the rehabilitation team a knowledge of ergonomics, design methods, materials, production techniques, environmental considerations and graphic communications. Furthermore, he has developed some concern and sensitivity in the area of man-environment phenomena, including such concepts as body image and personal space.

Model B below, from a recent paper by Levy and Waksvik[6], identifies the interacting components which we think are necessary for the successful implementation of "rehabilitation design".

Three major components have been identified:

The first, contained within the context of the health care system, is concerned with therapy objectives. Therapy objectives are related to the attainement of the highest possible level of functional independence in daily life and/or improved quality of care, and are always seen in terms of certain principles of intervention specific to each disability. This provides the content for "rehabilitation design".

The second, contained within a higher level context of environmental issues, is concerned with specific body-environment phenomena (i.e. those directly related to the physical and behavioural manifestations of the intimate environment of an individual). This forms the immediate micro-context



Model B - Interacting Components in "Rehabilitation Design" for "rehabilitation design", and is concerned with the concepts of privacy[7], alienation[8], and self-identity[9].

The third deals with the design process, or the means of achieving therapy objectives. This process, since it incorporates all the activities that are required in developing a device congruent with body environment phenomena and therapy objectives, is necessarily global (holistic) in nature. This assures a comprehensive identification of the problem area, realistic user participation, viable economic realization of the device, and an extensive evaluation procedure to maintain high standards of user protection and utility.

An educational experiment in "social design"

In the academin year 1976-77, a "clinique de design" (design clinic) was established within the Industrial Design programme at the Université de Montréal. It provides an operational base for a study option in the general field of "social design", with special equipment for disabled users as a major focus.

The "clinique" sets out to achieve three objectives:

First, to provide a viable means whereby students of industrial design can participate directly in real projects, which are of value to fringe groups within the community. It is thus a teaching clinic where students gain practical experience working with those sectors of society who would otherwise not be able to find or afford this type of expertise.

Second, to provide a limited service to the community at little or no cost. The clinic is a non-profit organization dealing only with other non-profit or social benefit groups.

Third, to provide an operational climate for research into special equipment needs of the disabled and other deprived sectors of society. Thus, the clinic is able to group individuals whose collective objective is to develop a strong knowledge base in "social design".

The clinic establishes working relations with organizations outside the University, and the design projects which are selected are each carried out by a team comprised of student(s), professor(s), consulting professional(s) from the participating institution, and the user(s). It is important to emphasize that the clinic takes responsibility for each project and follows it to a satisfactory conclusion. This may well extend beyond a student's pedagogically-accepted level of intervention. Thus the project does not terminate with a student's withdrawal, but is continued by others. The period may encompass 2-3 years, from the initial definition stage, through the design process, to the realization of functional prototype(s), to a thorough clinical evaluation and eventual production.

The clinic is oriented towards using intermediate technology means to develop simple equipment for activities for daily living, and as such does not concern itself with the traditional orthotic/prosthetic or other high technology devices.

The following projects are currently being developed in the clinic. They will be visually presented and explained during the presentation.

1 - Ergonomic chair for muscular dystrophy users
2 - Universal wheelchair tray
3 - Communication aid (adaptation for walker) for ambulatory non-verbal individual
4 - Hydraulic bath seat and transfer aid
5 - One-hand operated mechanical can-opener
6 - Insert/seat for cerebral palsy children
7 - Bolster seat for cerebral palsy children
8 - Functional clothing for disabled children
9 - Mobility aid for spina bifida children
10- Optical pointer for cerebral palsy user.

Recently, several courses were introduced in the 'clinique' programme to supplement the pedagogical aspect of the design projects.These deal with:

1 - Introduction to various disabilities and their characteristics;
2 - Barrier-free environmental design;
3 - Design methodology for research and development of special equipment.

A working relation has also been established with the School of Occupational Therapy at the Université de Montréal, and information and student transfer have significantly improved the overall design process within the 'clinique'.

Conclusion

The 18-month existence of the 'clinique' is insufficient time to assess fully the value and impact of the program, but results to-date are encouraging. A number of potentially viable devices are being developed, and a thorough process of clinical evaluation is evolving. An example of this evaluation approach is presented in the paper "The Design and Evaluation of an Optical Pointer" by Levy and Waksvik, at this conference.

There is a growing base of interest within the Faculty of Environmental Design, not only within the Industrial Design Department, but also within the man-environment studies of the School of Architecture and the Landscape Architecture Department. There are sufficient students involved in the option to warrant continuing the experiment. Special funding has been obtained for the clinic from the Université de Montréal and from government agencies. For example, Design Canada has made grants available for student employment through a summer apprenticeship programme.

Finally, in order to expand the area of "social design" research, the Industrial Design Department, with support from the School of Occupational Therapy, has developed a research-oriented option in the General Applied Science Master's programme in the field of special equipment for the disabled. The two-year programme, to begin in September 1978, would be based on therapy objectives, the principles of man-environment phenomena and the design process, concentrating more than three-quarters of the time on clinical research. It is hoped that the programme will attract a wide group of students from disciplines in the design, rehabilitation and engineering fields, so that the required trans-disciplinary activities can flourish.

References

1. Papanek, V., (1971), Design for the Real World: Human Ecology and Social Change, Pantheon, N.Y.

2. Maldonado, T., (1975), Le design et la politique d'état, 9th Congress of the International Council of Industrial Design Societies, Moscow.

3. Salovaara, J., (1975), Le design et le travail, 9th Congress of the International Council of Industrial Design Societies, Moscow.

4. __________, (1977), Summary of Activities of the I.S.D. in the Field of Problems Concerning Handicapped and Elderly People, Institus für Soziales Design, Vienna.

5. Reswick, J.B., (1976), "Some Thoughts Relative to the Rehabilitation Engineer", in (eds), Hobson, D., Forrester, J.H., Snyder, W.T., Report of the Workshop on Rehabilitation Engineering Education, University of Tennessee.

6. Levy, R., Waksvik, K., (1978), Design for the Disabled: Towards Enhancing Independence through Design for Special Devices, 9th Conference of Environmental Design Research Association, University of Arizona, Tuscon.

7. Altman, I., (1974), "Privacy: A Conceptual Analysis", in 5th Annual E.D.R.A. Conference, (ed) Carson, D.H., Part II, Wisconsin.

8. Manderscheid, R.W., Silbergeld, S., and Dager, E.Z., (1975), "Alienation: A Response to Stress", in Journal of Cybernetics, Vol. 5, No. 1

9. Sandahl, D.A., (1972), "Conceptions of Self as Individual Orientations to the Spatial Environment", in 3rd Annual E.D.R.A. Conference, Section2/3, Los Angeles.

A VOCATIONAL EXPERIMENT IN COMPUTER PROGRAMMING FOR QUADRIPLEGICS

A. K. Anderson, K. H. Miller (Both with The Mitre Corporation, 1820 Dolley Madison Blvd., McLean, Va. 22101), and R. C. Pilgrim

This paper describes an experimental vocational course for Richard (Rick) Pilgrim, a homebound quadriplegic. The goal of this program was to develop training techniques which might prepare Rick for a profession as a computer programmer. This paper relates how the training was performed using a voice-operated terminal, the successes and problems encountered, and how the course led to Rick's status as an entry-level computer programmer.

CATEGORY:	INTENDED USER GROUP:
Device Development ☒	Severely paralyzed; quadriplegics
Research Study ☐	AVAILABILITY OF DEVICE: 3 Months
STATE OF DEVELOPMENT:	
Prototype ☐	AVAILABILITY OF CONSTRUCTIONAL DETAILS: N/A
Clinical Testing ☐	
Production ☒	
AVAILABLE FOR SALE:	FOR FURTHER INFORMATION CONTACT:
Yes ☒ No ☐	The Mitre Corporation
Price: $15,000 - $25,000	1820 Dolley Madison Boulevard
	McLean, Virginia 22101

Introduction

This paper describes an experimental vocational course for Richard (Rick) Pilgrim, a homebound quadriplegic. The goal of this program was to develop training techniques which might prepare Rick for a profession as a computer programmer.

It is hoped that these training techniques will continue to be used by the trainee when he becomes employed. This paper relates how the training was performed, the successes and problems encountered, and how the course led to Rick's status as an entry-level computer programmer.

An accidental gunshot wound four years ago resulted in incomplete C-1, 2 quadriplegia, destroying Rick's motor ability from his head down, but not his sensation. He is 23 years old, and his health is generally good. Although he has some difficulty with breath control, he is able to breathe unassisted. This respiratory involvement affects his endurance and the strength of his voice, but he is able to work in sessions of one to two hours several times a day. He spends all his time in bed, lying on his back, to ease the effort of breathing. At the beginning of this training course, Rick had not completed high school, having dropped out prior to his disability.

The experimental vocational course was devised and carried out by The Mitre Corporation, the Virginia Department of Vocational Rehabilitation, the George Washington University Job Development Laboratory, and SCOPE Electronics for three purposes:

a. to develop a vocation for Rick in computer programming, since his disability precluded any non-intellectual endeavor,

b. to investigate the suitability of the speech-controlled computer terminal for the physically disabled,

c. to investigate the availability of jobs based on telecommunications and computers for homebound severely disabled persons.

Voice-Operated Terminal

Voice-operated computer terminals and typewriters were developed and tested in earlier programs[1] as tools for communication and control by the physically disabled. For Rick, the voice-operated terminal offers a unique means for operating a computer, since he has no use whatever of his limbs. His voice, while not strong, is controlled and clear.

The terminal utilized in this program is a SCOPE Electronics VDETS, shown in Figure 1.

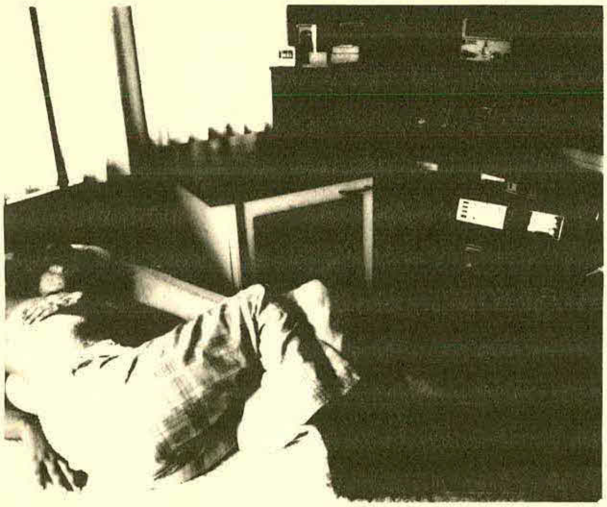


Figure 1. Rick Pilgrim Using Voice-Operated Terminal.

It is similar in concept to a standard teletype or CRT terminal except that the keyboard is replaced by a speech recognition system. The user, wearing a microphone, speaks the name of the typewriter character (letter, number, or symbol) which he wishes to activate. His voice signal is analyzed by a speech recognition device which he has trained to interpret the words he is speaking. Training refers here to the recording of the user's voice-prints in the machine for each word which will be recognized in later use. In use, the voice recognition device selects the character whose voice-print best matches the spoken word, and sends the corresponding letter, digit, or symbol to a remote computer. It simultaneously prints the character on the user's CRT. Rick repeats each character in the vocabulary five times to train the terminal to recognize his commands. The terminal stores the resulting voice-prints indefinitely.

Experience has shown the error rate in speech recognition to be acceptably low. Rick has noticed that his error rate increases with fatigue during the day. When an error does occur (i.e., the wrong character is recognized and transmitted) it may be corrected by issuing a "Rubout" command to erase it. Correction of text which has already been stored in computer files is accomplished using the computer's text editor utility.

Rick posed a challenge for the voice-controlled terminal application, since his physical ability is the absolute minimum which might be encountered in a person with a spinal cord injury.

Initial Vocational Training Course

The vocational training course was quite ambitious, and involved general education, computer training, and a search for suitable employment opportunity. The first steps involved orientation in computer communication, timesharing, operating system, and utilities. These are features which are generally unique to a particular computer installation and must be known by the programmer. To accomplish this orientation, a Teletype with an acoustic-coupled modem was placed in Rick's room. His instructor (Mr. Miller) visited him several times a month, describing the functions, then demonstrating them on the Teletype. (The Teletype was connected by telephone to a DEC PDP-10 timesharing computer at SCOPE Electronics in Reston, Virginia.) The typewriter printouts had to be torn off and held up for Rick to read them. Rick then operated the system by telling the instructor what to type for him. The instructor would read back responses and discuss any problems. Rick's mother assisted with his homework assignments by operating the typewriter for him at his direction. She also assisted him in using manuals, finding pages and holding them up for him to read.

When the system had been mastered, a course in elementary FORTRAN was completed in the same fashion. During this course, a reading stand was made and installed on Rick's bed to support manuals above his face to facilitate reading and study. Help was still required to turn pages, but the stand improved Rick's reading ability.

After Rick had demonstrated competence in FORTRAN fundamentals and extremely strong interest in continuing, the project was reviewed by all organizations which were involved, and several decisions were made. First, a voice-operated computer terminal was purchased and installed in Rick's room. The terminal had a CRT display with large characters so that he could read it from his bed. With voice control and a CRT, he could now work unassisted, reading, writing, controlling the computer and accessing data. Second, the programming language was changed from FORTRAN to COBOL, since COBOL is more widely used in business and government and seemed to offer more promise for a future job opportunity. Third, tutors were secured to further his general education.

General Education[2]

Rick's educational background would not have led him into computer programming under ordinary circumstances. In fact, he had quit school in the tenth grade, about two years prior to his accident. His early work with computers clearly pointed up the need for a stronger general mathematics and English educational background.

Rick began a concentrated program of study leading to his high school equivalency degree in June 1977, with the help of the Fairfax County (Virginia) Volunteer Learning Program. This program serves people in the country who have not completed high school or who are seeking a job but lack the necessary basic educational skills. Two volunteer tutors visited Rick twice a week for four months, for 90 minutes per session. Studies included algebra, grammar, spelling, and literature. Through the help of his tutor Rick has developed a strong interest in reading. They also taught him to play chess, which he feels helps him with the logic needed for computer work.

In retrospect, Rick feels that he has learned more from his tutors than he did in school.

COBOL Training

The last phase of Rick's vocational training was designed and conducted by Mr. Anderson.

The sequence of training was (1) learn the COBOL instructions, (2) practice with designing and running programs, and (3) document the program.

At the beginning of training, basic COBOL concepts and instructions were explained. Reading assignments were given. The instructor visited weekly to review Rick's progress and to give him new work. After several weeks of COBOL instruction, Rick began the design of an inventory management program for Mitre's electronics lab. Up to this point, it was necessary that the instructor visit Rick weekly for about two hours at a time. This time was required because of the newness and quantity of the material being covered.

After Rick started programming, the instructor worked with him over the phone. When Rick had a problem with his program, the instructor would access the same computer which Rick used (by telephone) to print out the program at a terminal in the instructor's office. He would then call Rick to discuss the problem. This approach was very successful and eliminated the need for the instructor to travel to Rick's house while the programming effort was underway. The successful use of telephone and computer files for remote communication is a very important result, since it suggests extension of training programs and job opportunities for other homebound individuals. Similar good results were achieved in an earlier effort.[1]

Computer Program Design

Because of Rick's disability, several new techniques had to be developed to allow Rick to design and document computer programs. These techniques included a word-only (rather than symbolic) flowchart, and the use of a tape-recorder for doing documentation.

It is standard technique for computer programmers to design their programs using flowcharts. Flowcharts use a series of graphically-drawn box-like symbols to represent the series of functions that a program performs. The symbols are connected with arrows to indicate the flow or order of the steps that the program performs.

Rick is not able to draw flowcharts, nor is he able to handle paper. Instructors in programming courses at the Virginia vocational rehabilitation center have felt that this could rule out programming as a career option for individuals such as Rick. However, much of the modern software community is moving away from flow-charting as a design tool in favor of structured programming methods such as Process Design Language,[3] a textual language well adapted to use with a computer's text editor which can be operated through the voice terminal.

Our experience with Rick indicates that such textual methods do provide good design tools as well as documentation for programming in higher level languages.

Frederick P. Brooks, Jr., known as the "father of the IBM System/360," was project manager for development of the System/360 and was later manager of the Operating System/360 software project during its design phase. In Reference 4, Brooks discusses computer program documentation extensively, and in Chapter 15 he discusses the role of flow charts. Several points are made there which are relevant to our conclusions in this project. Brooks says that "many programs don't need flow charts at all; few programs need more than a one-page flow chart." He refers to the detailed flow chart, especially for higher level languages, as "an obsolete nuisance, suitable only for initiating beginners into algorithmic thinking."

Since in this case graphic flow charts were not a viable choice, a technique was developed to represent the functions, organization and flow of his programs using brief phrases rather than symbols and arrows. Since the phrases consist of letters, numbers, and special characters, it is possible for Rick to use his voice terminal to develop the program logic and to recall it from a computer file for viewing and editing on his CRT display.

Table 1 shows an example of the program design technique developed for Rick. The statements are easily converted into COBOL instructions and are also easily readable and editable.

```
 90 Read category from CRT

    Does category = numbers?
    Yes - go to 100.
    No - Output:  'error in category'

100 Read subcategory from CRT

    Does subcategory = numbers?
    Yes - go to 100.
    No - Output:  'error in subcategory'

110 Read code from CRT

    Does code = numbers?
    Yes - go to 120.
    No - Output:  'error in code'
    Retrieve record from file.
    Error - go to 200.
    Output record to CRT
    -
    -
    -

200 Output:  'Lookup error'

    go to 90.
```

Table 1. Example of Statements in the Design Language Used to Replace Flow Charts.

Once an individual becomes adept at programming, he is often inclined to neglect the design step and to code immediately into COBOL. This happened with Rick during this phase of training. However, this is not good practice and was discouraged. The quality and development time of resulting programs both suffer if inadequate attention is given to structure and design.

Computer Program Documentation

Once a computer program has been written, the programmer then documents the program so others can understand and use it. We considered it too tedious for Rick to generate documentation using his speech terminal (although it is reasonable to do this in some cases) since his breathing was somewhat limited and since typing requires entering one spoken letter at a time. Rather, Rick records his documentation orally on an audio recorder using voiced commands to direct a typist. After a draft has been prepared, he edits it, again using the tape recorder. The tape and draft are exchanged between Rick and the typist until the document is completed.

The tape recorder approach to documentation was only a partial success. We had four different secretaries type from the tape and there were significant problems with the transcriptions. For an undetermined reason there were words that the typists could not understand.

There are several possible causes for this unintelligible information:

- Rick's speech is not clear enough.
  - We did not find this a problem when we listened to the tape. However, we were used to Rick's voice and we understood the information he was relating. We are also used to his manner of taking breaths while he is talking.
- The typists are not used to dictation.
  - None of the typists involved takes dictation regularly.
- The typists did not recognize the terminology.
  - This is possible. However, they type similar information each day from written copy.

We feel that this problem does not represent a serious limitation of the method, and can be solved by developing a working relationship between programmer and typist.

We recommend the tape recording approach and find it a good way to document a program with minimum intervention from an in-between person. This increases the independence of the handicapped programmer by significantly broadening his abilities to communicate.

Status and Plans

At this point, Rick has successfully completed his high school equivalency degree, training in the use of voice-operated terminals and the PDP-10 Operating System, introductory FORTRAN, and advanced COBOL. He owns his voice-operated terminal, CRT* and printer. He has developed an active intellectual life style.

As a main part of his COBOL training, Rick wrote a computer program to automate the parts inventory for The Mitre Corporation's electronics laboratory. The program was coded entirely by Rick with guidance from his instructor and is currently being used by Mitre personnel. The document describing the operation of the program was also written by Rick. He has now developed a program from the initial design to completion of the documentation.

Rick has prepared a resume of his background for distribution to prospective employers. We feel that Rick is prepared for an entry-level COBOL programmer position, having demonstrated his ability to learn rapidly and to work independently.

We recommend that Rick be employed with an organization which uses a computer with an interactive, dial-up capability. This will allow him to work with company data bases and software from his home voice terminal. Meanwhile, his supervisor can monitor his work via company terminals and discuss changes and problems with Rick over the phone.

We also recommend that Rick work in a non-pressure environment for the first year to enable him to further develop his work habits and communication ability and to get to know the company's procedures and requirements. All of these important needs are made more difficult by Rick's inability to work directly in the office. The most important career problem remaining before us is making the transition to a real work environment in spite of being homebound.

Currently, the state DVR and the George Washington University Job Development Laboratory are actively seeking an employment situation matched to Rick's abilities.

Conclusions

It is unlikely that Rick would ever have become a programmer if he had not become handicapped. In fact, he did poorly on early programmer aptitude tests and it was only because of the lack of other possibilities that he was trained in programming. It appears that these obstacles have been successfully overcome. We would hope that our experience with this non-conventional training program might lead other handicapped individuals to training and careers in the information industry, conventional or otherwise. We feel that computers and communications offer unique opportunities for extending the horizons of homebound, physically disabled individuals.

The major impediment for Rick, and for many homebound individuals in the future, is the fact that jobs and ways of getting work done are traditionally office-centered. Modern technology makes it possible to communicate rapidly at long distances and to access large data bases remotely. It is our hope that the Rehabilitation Community will take the lead in designing new ways of organizing jobs to find career opportunities for the homebound in the information industry.

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*The CRT display with keyboard is a Teleray 3311 terminal, which was generously donated to Rick by its manufacturer, Research Incorporated of Minneapolis, Minnesota, and its distributor, J.E. Cuesta Company of Valley Forge, Pennsylvania.

References

1. K. Miller, "Talking to Computers - Powerful New Tools for the Physically Disabled," Tufts-New England Medical Center, 1976 Conference on Systems for the Disabled, Boston, June 1976.

2. Stephen J. Cohen, "Paralyzed Man Runs Computer," Fairfax Journal, Fairfax, Virginia, March 22, 1978.

3. R. C. Linger and H. D. Mills, "Structured Programming and Software Engineering," International Business Machines Corporation, Federal Systems Division, 18100 Frederick Pike, Gaithersburg, Maryland 20760, November 30, 1975.

4. Frederick P. Brooks, Jr., The Mythical Man-Month, Essays on Software Engineering, Addison-Wesley Publishing Company, Reading, Massachusetts, 1975.

COMMERCIAL VIDEO GAMES AND ENTERTAINMENT FOR QUADRIPLEGIC PATIENTS

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Hamilton, Ontario, Canada

An inexpensive interface has been constructed and tested which will allow handicapped patients, such as functional tetraplegics, amputees and spinal cord injury patients, to play commercially available video games.

CATEGORY: Device Development ☒ Research Study ☐	INTENDED USER GROUP: Functional Tetraplegics, spinal cord injury patients.
STATE OF DEVELOPMENT: Prototype ☒ Clinical Testing ☒ Production ☐	AVAILABILITY OF DEVICE: AVAILABILITY OF CONSTRUCTIONAL DETAILS: from source given below.
AVAILABLE FOR SALE: Yes ☐ No ☒ Price: N/A yet	FOR FURTHER INFORMATION CONTACT: Mr. Ted Bojanowski Biomedical Engineering Dept. Chedoke Hospitals, P.O. Box 590 Hamilton, Ontario, Can. L8N 3L6

Introduction

Until the present, very little time and energy has been devoted to the development of devices for the handicapped for the purposes of entertainment. Conventionally the systems produced, have aimed at being environmental controllers or communications devices. In the former category are machines for turning on and off of various appliances such as the radio, television, lights and fan, as well as controlling the functions of a tape recorder. In the latter category are the typing machines and the book pageturners. In some cases both types of machines have been integrated into one mainframe, usually in a hardwired configuration, not very conducive to change. This has resulted in a system that is very inflexible and inherently expensive entirely due to the small quantity produced for a very limited market (1,4). A new generation of environmental controllers using commercially available microprocessors has eliminated most of the above pitfalls (2).

Controllers As Entertainment Devices

In the category of hardwired controllers, the extent that entertainment is mentioned is usually limited to controlling entertainment devices such as a television set or radio. The controller itself is not used for entertainment purposes. In the case of microprocessor controllers, the device, when programmed for games such as pong, tennis, or Star Trek, becomes a very useful entertainment device. These programmes, however, are not usually even attempted until the machine is programmed for turning appliances on and off or a routine for typing has proven successful. Games and entertainment appear to be low on the list of priorities. Perhaps games seem to be a frivolous activity or that the expense of the controller is better justified in more useful endeavours, such as typing. The interest in games was first noted when quadriplegic patients were brought into the laboratory to gain expertise and evaluate a newly designed microprocessor environmental controller. In addition to the typing and the activating of utilities, a great deal of time was spent playing Lunar Lander, as well as Star Trek on a PDP 11/10, with the aid of a normal subject in the latter case, to make selections. It is felt that both types of activities, the typing of letters for communication and the playing of games for entertainment are equally important. The microprocessor controller has the potential to meet both requirements more than adequately, but there are a great many patients and institutions who possess the older hardwired controllers with no provisions for games. The advent of the commercial video game more than fills the resulting void. Because these games are commercially mass produced using Large Scale Integration in the electronics, their cost is very low. At present, two types of systems for games exist (3). The first is a simpler package with a limited number of games. These may include variations of pong, tennis, hockey and shooting gallery. Depending on the version, either up to two, or up to four players can participate. In some of the games, such as handball, a single individual can play with the machine. The display is a standard television set, and because the games contain built-in video R.F. modulators, the machines can be connected directly to the antenna terminals of the T.V. set. A colour or black and white display depends on the sophistication of the game. Games in this category retail at the present time for approximately fifteen dollars.

The second type of game is much more versatile. Because the more simple machines use a single programmed integrated circuit for the game selection, the variety is usually restricted to six or eight games. The second generation of devices use software programmable microprocessors as the controlling elements.

Now the number of games and variations available are limitless. In addition to the basic game, which may contain the same six to eight games as the older hardwired version, cartridges, or plug-in modules may be purchased commercially, to augment the library of games. Features common to both types however include: a variable bat size, the smaller one for the more experienced, or high/low speed select, variable angle select, scoring which appears on the screen and the appropriate sound effects indicating ball contact, rebound, and score.

Interfacing

In the particular game that was acquired by our laboratory, a simple 6 game version, the interface controlling the bat position consisted of a 500 KΩ potentiomer. To move the bat over the width of the screen, 180^{o} of rotation of the potentiometer was required. In order for a handicapped person (e.g. quadriplegic or stroke patient) to utilize this interface, the amount of rotation needed to be reduced. Because the paddle position of the game is a function of an R.C. (Resistor, Capacitor) time constant, an increase of the size of capacitor resulted in an angle of approximately 5^{o} rotation needed for complete paddle control. With an extension in the form of a lever, glued to the knob of the potentiometer, the mouth could be used to control the paddle while playing the game. Two pneumatic switches were also connected, one in each of a sip/puff combination. The first was used to activate a reset to begin the game over, and the second for a manual service of the ball. Both features are also accessible on the panel of the game, but the switches allow a quadriplegic, if playing alone, to reset the game himself and, if desired, to play in the manual mode (automatic serve is also available by selection of a switch on the front panel). It was found, that when the configuration of a modified interface was used as a mouthpiece, neck fatigue resulted due to the necessary movement of the joystick. This simple potentiometer was replaced with an isometric joystick employing a conventional pipestem and a plastic rod with semiconductor strain gauges and two pneumatic switches. The above isometric joystick is the one used in conjunction with a microprocessor environmental controller, also developed in our laboratory (2). Only one degree of movement, of the two available on the isometric joystick, was used. Since the output from this interface is a voltage, a field effect transistor in a variable resistor mode was put in place of the potentiometer supplied with the game (figure 1). Thus the isometric joystick allows the patient to play against the machine or against an opponent, whether normal or handicapped, without fatigue.

It may also be directly interfaced without modification to the patients' environmental controller. This allows the patient to practice and obtain expertise with his mouthpiece while enjoying the competition provided by the game.

It should be noted that amputees or patients who do have even limited use of one hand, need use only the modified control supplied with the game.

Subsequent tests were carried out with both normal and handicapped individuals using the standard controls, the modified potentiometers, and the isometric joystick.

A quadriplegic patient (C3) using the isometric joystick and the interface could very easily compete with normals in the playing of the various games. With increased practice the skills at manipulating the game controls improved for both the normal and the handicapped individuals. A gamut of specialized interfaces could be constructed or existing controls modified to fit the needs of the individual patient.

As a follow-up to this initial experiment, the recreation department at Chedoke Rehabilitation Centre has purchased a microprocessor version of the video games for installation in the recreation area of the wards. With the appropriate interfaces, it will act as a very inexpensive entertainment centre for stroke, amputee, head and spinal cord injury patients as well as patients with various forms of paralysis.

Because the machine is microprocessor based, it may be possible, with the addition of reprogammed memory, to expand the video game into an environmental controller. Presently, microprocessor based environmental controllers are being programmed for games, but due to the extremely large number of commercial microcomputer games being produced for the consumer market, these games may one day be programmed as environmental controllers.

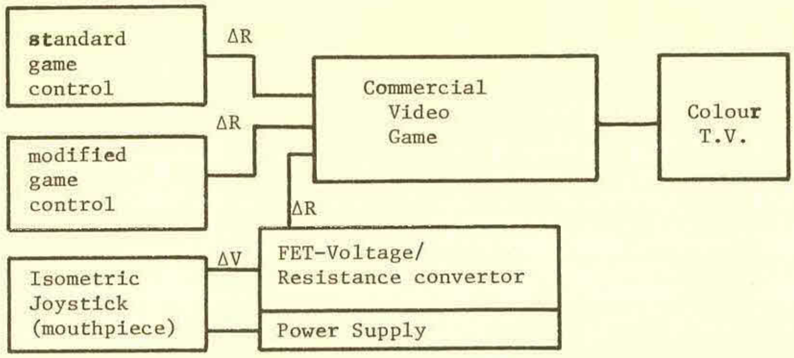

Fig. 1. Block Diagram of the System

In conclusion, a commercial video game has been interfaced to various input devices, allowing the handicapped patient access to this new form of entertainment. Because of the economics involved in the mass production of these games this can be done so inexpensively that it makes it affordable to many handicapped individuals. Time, previously spent by these people in boredom, may now be spent in an entertaining competitive manner.

Fig. 2 Video Game and Interfaces

References

(1) Bloch, R.: "Design Considerations for An Environmental Controller System for the Severely Handicapped" Proceedings of the Seminar on Electronic Controls for the Severely Handicapped. Vancouver, B.C. Canada 1974.

(2) Bojanowski, T.: "Microprocessor Environmental Controller for Functional Tetraplegics" M.Eng. Thesis in preparation - 1978. McMaster University, Hamilton, Ontario, Canada.

(3) General Instrument Corporation: "Gimini TV Games" June, 1977, Section 4B. Micro Electronics.

(4) Vanderheiden, G.C. et al.: "A Portable Non-Vocal Communications Prosthesis for the Severely Physically Handicapped" Proceedings fo the Seminar on Electronic Controls for the Severely Handicapped. Vancouver, B.C. Canada, 1974.

My thanks go to Tony Wallace of Chedoke Hospitals, for the helpful discussions.

DEVELOPMENT OF A SYNTHETIC VOICE RESPONSE COMMUNICATION AID FOR THE NON-VERBAL/NON-VOCAL

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The development of a phoneme-based, voice output communication aid for non-verbal/non-vocal individuals is discussed. Interviews with non-oral persons, educators, and rehabilitation professionals resulted in progressive improvements and enhancements in working models of a voice output communication aid. Field experiences are described. These experiences lead to the design of the two current models, called the Phonic Mirror Handi Voice. These units are portable, battery operated, and have the capabilities for a virtually limitless vocabulary through the use of phonemes. The devices have been used by cerebral palsied, mentally impaired, spinal cord injured, neuromuscularly diseased, and head and neck injured persons. Applications and future research implications are discussed.

CATEGORY: Device Development ☒ Research Study ☐	INTENDED USER GROUP: Cerebral Palsied, neuromuscularly diseased, mentally impaired, spinal cord injured, stoke, and head and neck injured persons.
STATE OF DEVELOPMENT: Prototype ☐ Clinical Testing ☐ Production ☒	AVAILABILITY OF DEVICE: 60-90 days after received order. AVAILABILITY OF CONSTRUCTIONAL DETAILS: Not at present.
AVAILABLE FOR SALE: Yes ☒ No ☐ Price: $1,995.00	FOR FURTHER INFORMATION CONTACT: H. C. Electronics, Inc. 250 Camino Alto Mill Valley, Calif. 94941

Introduction

Individuals with disorders which deny them the ability to develop speaking, and often writing, skills, experience one of the severest of all handicaps: the absence of an effective communication system. Speech is the norm, the expected, the accepted mode for personal communication. To compensate for the deficiency in this vitally important system, one must learn to communicate by some non-standard process or mode which often takes many more years to learn than speech, and carries no guarantees of workability, efficiency or effectiveness. For all the research being compiled in the area of nonverbal communication, two problems have presented the greatest challenge: 1) the design of an effective communication mode, and 2) the development of a prescriptive (individual) approach to communication habilitation-rehabilitation.[1]

Technological contributions have been made by a number of interdisciplinary groups in order to solve these basic communicative problems. The most recent electronic advancements have allowed voice synthesis to become a real and usable communication tool for nonverbal individuals.

The following pages will describe the development of a hand-held voice response system in terms of its physical evolution and expansion in the area of nonverbal communication. The paper will continue to explore the refinements of the instrumentation to accommodate individualized communication needs, measuring motivation and language (expressive and receptive), input via visual channels.

Background

As the concept of voice response spread, its potential as a viable communication tool for the nonverbal individual increased. Researchers in computer and speech science, in engineering, in education, and in linguistics were the first to experiment with synthetic voice devices as a computer peripheral for a communication system.[2]

Initially VOTRAX, a phoneme based electronic voice synthesizer, was used as the voice output for such a system to aid those with severe

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sight and motor impairments. Prior to looking at the handicapped application, voice response systems were being developed to meet the communication needs within industry: i. e. for computer/telephone communications systems, computer inventory checks, personnel training approaches and computer output alternatives. The design and development of tools for interfacing other technology with the handicapped was already in progress. Combining the data received from both areas provided a glimpse at the possibility of synthetic voice being the tool to substitute for human voice in the person communication system.

The individuals in the research group which developed the hand-held voice response system were qualified to pursue unique developments in the area of electronics and voice synthesis. Their shift to the development of voice devices for the handicapped was initially influenced by previous research efforts. These groups continually expressed the need for interdisciplinary cooperation which, when achieved, by this group was responsible for the introduction of the hand-held voice response system to the nonverbal community.

The researchers' personal involvement with handicapped individuals and public's positive response to the need for devices continued to motivate the development, but it was painfully evident that intense and extensive research in many areas needed to parallel the electronic development. The engineers were presented with a new set of users whose needs and orientation were foreign to them. Their investigation was then organized to reflect the problems, habits, and objectives of the handicapped in order to analyze the communication process presently used, and to define the one that they intended to develop. This called for gathering information about the nonverbal in terms of the physical, neurophysiological, psychological and education phenomenon occurring. The framework for such an investigation was then created to accommodate the paralleling of activities: mechanical development, information exchange (interdisciplinary) and field testing/exposure.

Investigation

To establish developmental boundries, the following questions needed answering:

WHO needed the device?
WHERE would the device be used?
HOW could the device best function for an individual.
WHEN would the device be used?

Therapists, special educators, linguists, doctors, engineers and handicapped individuals contributed to defining the needs which voice response devices would fulfill. Through questionnaires, interviews, observations and field experience, a level of understanding was reached regarding requirements.

WHO? Cerebral Palsied, Stroke, Multiple Sclerotic, Mentally Retarded, Head and Neck Injuries
WHERE: In school, at home, at work, multiple settings
HOW? Interface voice response and handicapped with existing mechanical systems, educational methods, and personal language.
WHAT? Small, easy to use, portable, safe, versatile, durable, human factors design for minimal physical effort.
WHEN: Operable 24 hours a day, seven days a week, for the fulfillment of communication needs.

The most astonishing information was about the non-verbal population statistics.[3] It documented that speech impairment was present in at least the five handicapped areas listed above. Differences in the levels of physical and mental function, within and between the various disorders, were very individualistic. It was apparent that just one, or even two, devices would not service this potential population. The most significant information showed the oral communication was preferred by the majority over symbols, lights, movements, signs, etc. With this information the WHAT? boundary was expanded from a single device to a system to include several interfacing devices. The two standard components of the system were known: speech generator (Votrax) and its output speaker. The other components were first generated as a series of laboratory devices, each a progressive improvement over its predecessor, before the prototype became a formal effort. Handi-Voice emerged from this effort.

The first device developed was designed for a stroke victim whose only controlled movements were lifting an eyebrow and producing a faint guttural sound. To communicate, the listener used an alphabet board to spell words for the patient. A "yes" response for each correct letter selection was given by lifting the eyebrow. A non-audible system was requested first, thus two types of activator switches were designed for an electronic alphabet board. These switches were: a throat pick-up (voice sensitive switch) and a brow plate (movement sensitive switch). Either one could be used to trigger a light scanning device. The patient would grunt once to start the scanner and, again, to stop it when the appropriate letter was indicated. Although the devices were useable, problems were noted. The patient couldn't spell very well. To increase mechanical efficiency and reduce the patient's frustration, it was suggested that phrases, words, or pictures replace the alphabet on the light scanner board and that some feedback mechanism be provided. Voice response was added next. The important factor here was that it was learned people could be interfaced to mechanical devices no matter how severe their disabling problems were.

The first voice response system was a milestone. Specifically designed at the request of a local school system, this system interfaced Votrax and a light scanner in a single unit. A minimal vocabulary was submitted by the school and it was placed in memory for later speech output by Votrax. The vocabulary was visually represented on the scanner by Blissymbols, the method of language training being used by the school. The voice sensitive throat pick-up switch was worn by the student and used to activate the scanner. The scanner, in turn, activated Votrax. The system was used as a language development tool by teacher and student. As a result of field trials, a number of physical and mechanical adjustments were required to allow the teacher some controls, but the system, overall, earned merit as a communcation and training device. Three very important observations were made during the field trials with this Device --the student learned to use the device with greater speed than ever anticipated, motivation to use a language tool appeared to increase, and the student appeared to master the prescribed vocabulary rapidly, requiring an expanded vocabulary sooner than anticipated. These points stimulated formal development in the form of a field design for a portable voice response device.

This system included a Votrax, an output speaker, and five different activating devices. The Votrax memory was expanded to 400 words, considered by some to be a maximum amount for basic communicating needs (more when spelling capabilities are considered). The output could be words, phrases or sentences prescribed by the user. The voice activating devices were hand held or easily portable designs each requiring a different type of physical function for vocabulary selection. These functions ranged from depressing numeric keys to making contact with a touch-sensitive board. Scanning capabilities were designed as an option for most devices, thus the auxiliary switches could be attached if desired. The visual display of the vocabulary was the picture, word, or number system already being used in the educational program and interfaced nicely to teacher-made flash cards and transparencies. Field trials suggested certain improvements in the calculator keyboard design, such as making the numeric keys larger and farther apart, making the number inscriptions larger, and placing a guard over the keys in order to prevent accidental input (selection) or activation. It was suggested that the vocabulary board device have a larger display area. The most desirable feature expressed by the handicapped was battery operation.

HandiVoice, as the hand-held voice response system was now being called, emerged in another form to include all the improvements for the nonverbal user with the medium to maximum motor capabilities and with a higher level of mental ability. Vocabulary selection became a four-step process. A three digit code corresponding to a word, phase, or sentence was typed on the keyboard. Votrax stores the selection. A fourth key was depressed to activate speech output. As many as 40 codes could be typed and stored before output was necessary. The selections were then repeated in sequence upon command of the user. Visual feedback of the numeric selections was available. Each digit of the code appeared in a window directly above the numeric keys. There was an echo back mode available for additional audible feedback. When desired, this mode allowed that each selection be spoken when chosen as well as spoken later in sequence. For minimal motor capabilities, the auxiliary activator devices could be attached. Key activation would then be automatically inhibited and number scrolling becomes the mode of entry.

The interchangeability of activating devices allowed the vocabulary board to be interfaced to the same speech generator as described above. The touch-sensitive board was divided into 128 blocks, four selections per block. Each block had four color codes to allow the user to select one of the four words or phrases in a box. Transparent overlays to display the vocabulary gave versatility to the teacher and the user. With this, one or more of the levels of vocabulary could be used at one time. Audio/visual feedback during a typical vocabulary board entry was accomplished with a tone and a flash of light. Echo-back mode was also available. The devices were still missing a basic feature: battery operation. With recent technological breakthroughs, it was now possible to create a battery operated device. Keep in mind that as each step of development is taken, additional field trial information is included and information continues to be exchanged between interdisciplinary groups.

Field Experience

With the advances in microprocessor technology, the HandiVoice was now capable of becoming a truly portable, hand-held device operating on rechargable batteries. The decision was made to place these portable HandiVoices in the field. One hundred prototypes were produced. Fifty of the prototypes were with touch-sensitive key pads and a basic self-contained vocabulary of nearly 500 selections. Fifty were the calculator-type with a basic self-contained vocabulary of 1,000 selections. Each had the capacity for a limitless vocabulary because of the inclusion of all English phonemes and letters of the alphabet. These prototypes were placed in key centers throughout the United States. They were used in educational, rehabiliation and hospital settings.

Interest in this new communication aid was high. Numerous inquiries concerning its operation and application were received from professionals, non-oral individuals, and family members. It seemed as though everyone who saw it knew someone who could benefit from this technology.

As a result of the placement of these prototypes in key centers, an abundance of critical feedback became available. As anticipated, further issues to be addressed included offering the unit with touch-sensitive key pad in horizontal as well as vertical position. This was needed because children are taught to track from left to right as a pre-reading skill. A key guard was needed on this unit for those individuals with limited pointing skills and limited receptive vocabularies. Larger visual stimuli were needed for persons utilizing symbol systems for communication. There was also a need for all four vocabulary overlays to appear on one overlay. The calculator model needed a higher key guard as well as no key guard at all. Users of the prototypes requested handles on the carrying cases and shoulder strap for further portability. Mounting brackets were requested for wheel chair and bed-bound users.

Continuing investigation

Even with this critical input on hardware, enthusiasm remained the first response to the units. One key center reported that of all their communication aids, this one was preferred by the majority of non-oral individuals because of the speech-output.

As a result, the Phonic Mirror HandiVoice that is pictured here was introduced to the non-oral field in May, 1978. A majority of the suggestions and recommendations from key centers had been incorporated into this final model.

The hand-held voice synthesizer for many non-oral persons was no longer a dream into the future, but a reality... a real tangible device. However, this evolution, although remarkable, has elicited more questions than answers.

Technology remains at the threshold of the development of a speech-output communicator for all non-oral persons. Individuals with both profound physical and mental limitations continue to have extreme difficulties in developing functional communication systems. With the expansion of coordinated interdisciplinary efforts all non-oral persons will benefit from these advances.

Future implications

Future research continues to be necessary. Areas of investigation include what is the ideal organization of a limited vocabulary, what words should be selected. What impact will such a product have on testing, both diagnostic and progressive. Will psychological evaluation batteries incorporate such a device into their testing on non-oral persons. What will be the result of testing low-cognitive persons now that variable rate and pitch are available for this speech device? How will this technology interface with current language therapies, reading programs, and symbol systems? What will the ramifications of this product be in terms of personal motivation, socialization and rehabilitation. Supportive capabilities, such as visual and auditory memory, and pointing skills will be monitored to determine the impact of voice-output. How can better auxiliary switches be designed for severely physically impaired persons? Can aphasics (immediately post onset) be conditioned to respond to synthetic speech. If so, what will be the implication of providing "speech" during the spontaneous recovery period. Those persons with progressive neuromuscular disease such as amyotrophic lateral sclerosis and multiple sclerosis will have the potential for expressing their thoughts and needs. What will these non-oral persons tell us?

Conclusion

This sounds almost melodramatic, but this is the overall reaction that we have been observing in all of our investigation. The resounding response to this technology has been that voice is a powerful tool to someone who has had it and lost it or to someone who has never had it.

These portable speech units are becoming powerful, viable devices for reducing some non-oral communication problems. They have been used in educational programs by non-oral students. One student's first spontaneous utterance was "I like Saturday because..."[4] and he proceeded to list all of the television programs he watches. For many children the most popular phrase was "please leave me alone" spoken at selected intervals to emphasize their fatigue, frustration, etc., something they had not been able to tell anyone before. At one program, chronic absenteeism has decreased remarkably and the clinicians attribute this in part to[5] their work with Phonic Mirror HandiVoice.

Phonic Mirror HandiVoice has been used with adult cerebral palsied individuals to aid them in their vocational and education endeavors. It has been presented to spinal cord injured individuals who have been on respirators for three months post trauma. It has been used by adults with multiple sclerosis, amyotrophic lateral sclerosis, and Steele-Richardson's Syndrome. Individuals with deafness, blindness, or both, have used the devices.

Phonic Mirror HandiVoice was designed primarily as a communication aid for persons to use 24 hours a day. However, because of its visual and auditory feedback, educators have found it to be a valuable tool in developing language skills. Diagnosticians have viewed it as a complement to intelligence testing for non-oral persons. The applications for a device that can give a non-oral person speech are seemingly unlimited. The versatility and flexibility of the Phonic Mirror HandiVoice have paved the way for it to impact the non-oral person's entire life, education, social and vocational.

Educationally, as a language tool, a teacher may utilize Phonic Mirror HandiVoice for any training level that is desired. Socially, handicapped individual will be able to communicate with their peers as well as with people outside their immediate living environment. The personal impact of voice response for the handicapped is that they will no longer have to be content or satisfied with someone else's guess as to their needs, thoughts, etc. There may still be a waiting period while the users select

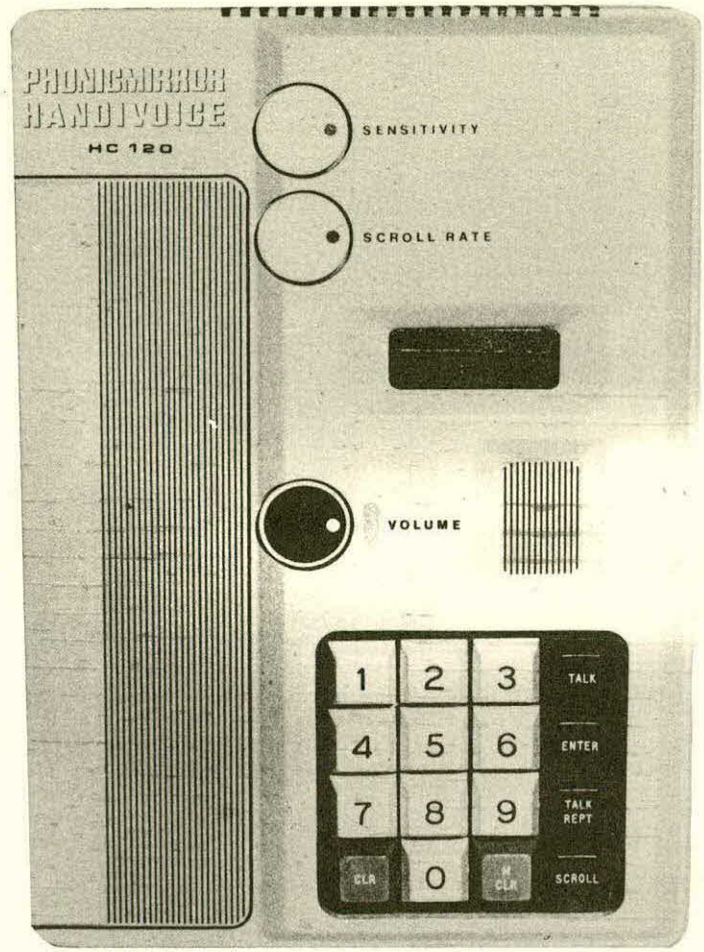

Figure 1

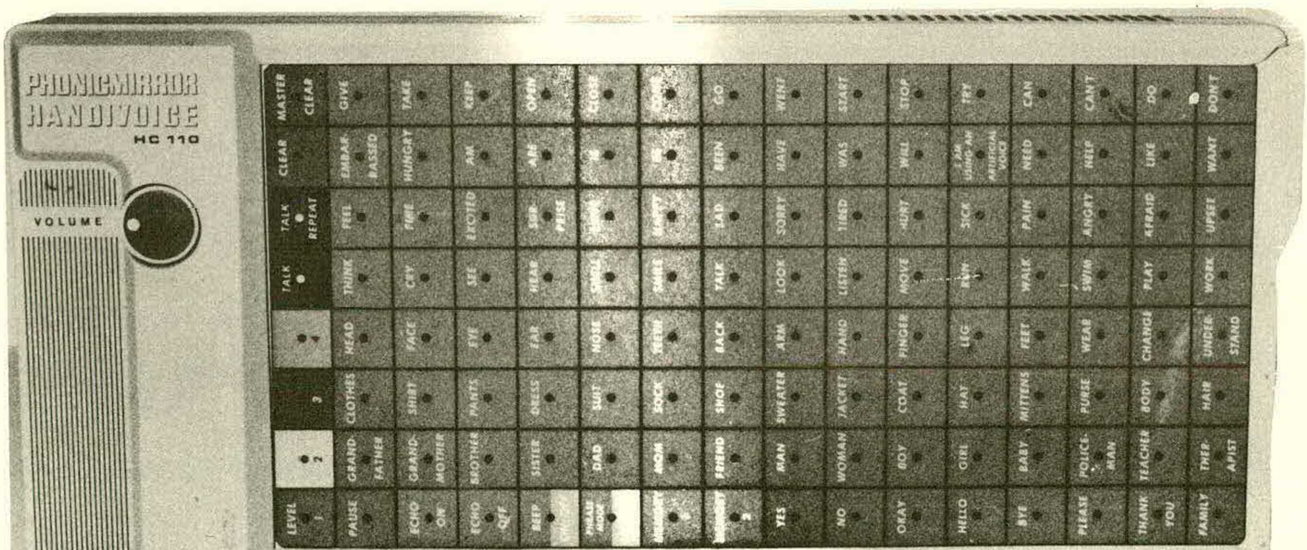

Figure 2

a response, but it will be their own response and communicated with greater dignity than ever before allowed. Occupationally, handicapped persons will be able to pursue higher education and occupational training not before available. The potential of these applications may still not be realized.

Footnotes

1. Oyer, Herbert J., ed., Communication for the Hearing Handicapped, Baltimore: University Park Press, 1976.

2. Rahimi, Morteza Amir, and Eulenberg, John, "A Computer Environment for the Blind", Proceedings National Computer Conference, 1975.

3. Fons, Kathryn, "The Development of Communication Devices for Non-Verbal Individuals Utilizing Synthetic Voice Response", Paper presented at Communication Enhancement Institute, Michigan State University, East Lansing, Michigan, August 26, 1975.

4. Interview, Anonymus, October 21, 1977.

5. Interview, Anonymus, October 28, 1977.

A PORTABLE DELAYED AUDITORY FEEDBACK DEVICE FOR THE SUPPRESSION OF STUTTER

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This paper describes an initial prototype study of a delayed-auditory-feedback (DAF) device for the suppression of stutter. The study involved a single male client with a chronic stutter problem, and who was considered to be unemployable in his chosen field of teaching. A prototype DAF device, using bucket-brigade technology, was built and has been in use for 18 months. The client has received a great deal of benefit from the device, and now has a job as a faculty member in a West Coast university.

CATEGORY: Device Development ■ Research Study ■	INTENDED USER GROUP: Chronic stutterers. AVAILABILITY OF DEVICE: Not currently available.
STATE OF DEVELOPMENT: Prototype ■ Clinical Testing ■ Production □	AVAILABILITY OF CONSTRUCTIONAL DETAILS: Not available.
AVAILABLE FOR SALE: Yes □ No ■ Price:	FOR FURTHER INFORMATION CONTACT: Prof. Derek Rowell Mech. Eng. Dept. M.I.T., Building 1-112 Cambridge, MA. 02139

Introduction

This report describes a project to produce a miniature delayed auditory feedback (DAF) assistive aid for stutterers through the use of modern solid-state technology. A single prototype device has been constructed and used by a single client with a chronic stutter problem and has been shown to have significant impact upon his vocational and daily living activities.

The client was a male doctoral student at M.I.T. in his middle twenties. He was considered by his department to be one of their better students and had published widely while completing his thesis research. However, he suffered from a severe stutter problem that prevented him from making oral presentations, and from taking job interviews. His therapists and research advisors considered him to be be unemployable in any academic setting, or in any position approaching his full potential.

He had been in speech therapy since early childhood, and was continuing his therapy in weekly sessions at the Massachusetts General Hospital. It has been found that he responded well to the delayed auditory feedback (DAF) therapy technique, in which his own speech was delayed by 100-200 msecs. and then fed back to his own ears through headphones. The concern of the therapists was that he was only able to practice for 1/2 hour each week, and they felt that if a new type of device could be developed which could be carried in a pocket and used during his work this would greatly benefit this particular client, as well as others. The DAF equipment available to his therapists used magnetic tape recorders with physically separated record and playback heads. This equipment was heavy, bulky and required a.c. power, and was suitable for use only in a clinical setting.

At the time of the initial involvement, a semiconductor company had just announced an entirely new type of analog delay unit that uses the "bucket-brigade" principle to pass an analog signal along 1024 delay elements on a single integrated circuit. It appeared that this new technology might offer a simple and effective method of designing a low-power, miniature DAF unit that could be carried with the stutterer and integrated into his activities of daily living.

The development and nature of stuttering

There is a very wide body of literature de-

defining and suggesting the basis for stutter. The modern literature tends to ascribe no single cause for the development of the symptom[1], but accepts that there may be a variety of reasons.

Perhaps the simplest definition of stutter is that given by Van Riper[2]. "Stuttering occurs when the forward flow of speech is interrupted abnormally by repetitions or prolongations of a sound, or syllable or articulatory posture, or by avoid or struggle reactions". Thus stuttering (or stammering) is a temporal discontinuity of speech involving interruptions and broken sounds, syllables or words. The interruption is usually temporary, with an average frequency and duration that depends upon the severity of the affliction.

Stutter involves some obvious physiological manifestations, as well as others that are not so obvious. Several studies have shown that the onset of a stuttering attack can be accompanied by a temporary - or in severe cases permanent - abnormality in heart and pulse rate, breathing, blood composition and distribution, tremor, dilation of the pupils, and abnormal EEG activity[2]. Whether or not most of these abnormalities are a direct result of the stutter, or whether they represent the physiological manifestations of the emotional stress caused by the stutter has still to be determined.

The modern literature tends to divide the origin of stutter in an individual into three broad categories: the neurotic theories, the learned response theories, and the physiological theories. While there is evidence for the existence of all three, the most widely accepted would appear to be the learning theories.

(a) Stutter as a symptom of neurosis: According to this theory the stutter is an outward symptom of basic inner conflict, such as a repressed desire to satisfy inner needs[3,4]. Although such theories are not generally accepted as applicable to the majority of stutterers, it is accepted that there is a small minority of stutterers for whom the symptoms must be considered as a primary neurosis[2].

(b) Stuttering as a learned response: Many therapists view stutter as a learned behavior which begins in the early verbal fumblings, hesitancies, and interruptions that are a normal phase of the speech learning process. Parental influences and unconscious reinforcements may establish standards for speech that a young child cannot reach, with the result being interrupted, hesitant speech. The degree of communicative stress induced by the early parent-child vocal encounters is assumed to determine the intensity of the interruptions: with mild stress whole sentences or phrases will be repeated; with more stress a single word will be repeated. Finally, as the stress level becomes very high, oscillation on a single syllable, or even the first audible sound (for example, mmmmmmmmommy) will occur. It has been suggested that when a breakdown of this type occurs, the child will regress to an earlier stage in its development, such as babbling like an infant.

Other extensions to the learning theories include frustration responses, reinforcement of basic conflicts such as the competitive urges to speak or not to speak, and on-going operant conditioning attributed to listener reinforcement of the stutter condition.

(c) Physiological or organic causes of stutter: There has been a recent resurgence in the viewpoint that organic malfunctions may be underlying the stutter condition[5]. Numerous possible causes have been suggested, including motor and sensory problems.

Jones[6] reported that neurosurgery on the dominant hemisphere of epileptic stutterers relieved both seizures and the stutter. He surmised that the procedure had reduced inter-hemispheric competition in the production of speech, and that stutterers might be presumed to have not one, but two conflicting dominant hemispheres for speech.

A second proposal, not now widely accepted, was that the symptom could be attributed to dysphemia, which results in temporal abnormalities in the nerve impulses arriving at the paired musculature on two sides of the jaw.

There does appear to be some etiological evidence supporting a physiological cause of stutter. Stutterers tend to run in families, supporting a hereditary theory; there are more male stutterers than female, and stutterers are frequently seen to have abnormal EEGs and coordination difficulties. Karlin[7] attributes such observations to a possible delay in the myelination process of the nerve fibers devoted to speech production. He points to the fact that the myelination process is always more advanced in girls than in boys of the same age, especially between the critical ages of two to four, when most stuttering begins.

There is evidence for perceptual causes of stutter. Certainly, the normal development of speech requires an intact sensory-motor feedback loop. It would be argued from an engineering viewpoint that stutter resembles, at least superficially, an instability in a feedback mechanism, similar to that when a pure time delay is incorporated in the feedback loop. It is very easy to demonstrate that most stutterers will become fluent when speaking under masking noise of sufficient intensity to prevent perception of their own voice. The observation that many stutterers will become fluent under delayed auditory feedback (the basis for this work) is further evidence of involvement of both sensory and motor processes. The exact interaction and the true function of artificial stimuli in enhancing fluency has not yet been determined, and will need to be further studied before the organic theories find wide acceptance among therapists.

Artificial aids in the suppression of stutter

As described above, it has been amply demonstrated that artificial or external auditory stimuli can relieve the stutter symptoms. However, these techniques have not found wide acceptance among therapists, especially when it is suggested that electronic aids be made and integrated into the lifestyle of the stutterer. Part of the difficulty has been the lack of portable units for rigorous field evaluation, but more fundamental is the current wide acceptance of the learning theories of stutter development, with the consequent conclusion that true solutions to the problem will be found in psychological techniques, such as behavior modification methods.

Many therapists believe that any artificial stimuli from an electronic device will become a "crutch" and will detract from the application of therapeutical techniques that have a greater long-term potential. It is also frequently stated that electronic techniques serve only as a distraction from the learned response with the result that although the symptoms may be relieved temporarily, with continued use the distractive nature of the auditory stimuli will be reduced, and the stutter symptoms will return.

We are aware of such arguments, although we do not fully support them. Until the true nature of stutter is elucidated, we must accept the many plausible explanations. If a perceptual-motor malfunction is present it is entirely possible, or even probable, that an external auditory stimulus may interfere with that mulfunction on a long-term basis.

There are many adult stutterers who have not responded to the accepted therapies. We argue that if we can improve their vocational potential and quality of life through the provision of a simple electronic device, then it is not wrong to do so, and such a device does not provide the user with a "crutch" any more than the mildly hearing-impaired person uses a hearing aid as a "crutch".

We have not observed any great dependence, or any loss of effectiveness with the patient who has used the prototype device for more than five months. On the contrary, we have seen a carry-over from its use into unaided speech, and the relegation of the device use to those times when it is of particular benefit to the user, such as public speaking. This one person appears to have made a successful integration of the new device into his lifestyle.

The prototype DAF device

The structure of the prototype unit is shown in Figure 1. It uses a single operational amplifier as a microphone preamplifier, followed by four cascaded analog delay elements. The delay is adjusted by altering the frequency of a two-phase clock that is used to control the transfer of charge through the bucket-brigade stages. The nickel cadmium rechargeable battery allows approximately 5 hours of operating between charging cycles.

A single prototype was designed and built for field evaluation. It was built into a 5" x 3" x 3/4" box and provided an adjustable delay range from 50-200 msecs. The device has been used by the client for more than one year on a daily basis for independent speech practice, for talking on the telephone, and for making presentations to an audience. He has used it for job interviews, and solely upon the increased fluence gained through the device has been awarded a faculty position at a university on the West Coast.

His speech therapists and close associates have reported a very significant improvement in his speech since using the unit. There has been a great deal of carry-over into his normal conversation without the device. It is surmised that constant practice using the DAF unit has taught him new speech patterns and rhythms that overcome his tendency to block.

We are fully aware that the DAF technique is not applicable to all stutterers. However, because of this initial success, we propose to redesign the prototype device to take advantage of new developments and to complete a preliminary evaluation of the concept in collaboration with the same group of speech therapists.

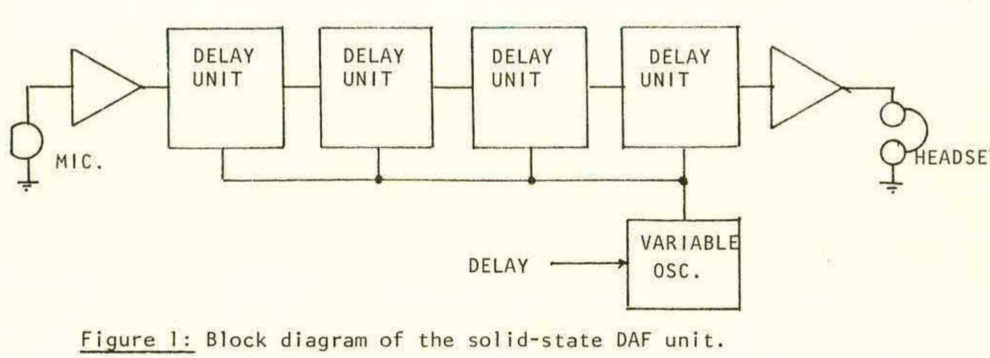

Figure 1: Block diagram of the solid-state DAF unit.

References

1. Wingate, D.E., "A standard definition of stuttering", Journal of Speech and Hearing Disorders, XXIX:484-489, (1964).

2. Van Riper, C., The Nature of Stuttering, Prentice-Hall, Englewood Cliffs, N.J., (1971).

3. Glauber, P., "The psychoanalysis of stuttering", in Jon Eisenson (ed.), Stuttering: A Symposium. Harper and Row, New York, (1958).

4. Dunlap, K., "Stammering: its nature, etiology and therapy", Journal of Comparative Psychology, 37:187-202, (1944).

5. Van Riper, C., Speech Correction. Prentice-Hall, Englewood Cliffs, N.J., (1972).

6. Jones, R.K., "Observations on stammering after localized cerebral injury", Journal of Neurology, Neurosurgery, and Psychiatry, 29:192-195, (1966).

7. Karlin, I.W., "Stuttering: basically an organic disorder", Logos II, pp. 61-63, (1959).

ARCHITECTURAL BARRIERS: DEPENDENCY VS. INDEPENDENCY

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The increasing involvement of disabled consumers in their own care has focused attention on quality of life in institutional and non-institutional settings. In the quest for improved quality of life and better vocational outcomes, architectural barriers continue to pose great obstacles in public and private settings. This paper addresses the issue of modifications of architectural barriers by documenting functional improvement as a result of structural modifications. This study has implications for the education and training of disabled consumers, health care professionals and third party payors, about the advantages and benefits of a well organized home modification program.

CATEGORY: Device Development ☐ Research Study ☒	INTENDED USER GROUP: Disabled Consumer.
STATE OF DEVELOPMENT:	AVAILABILITY OF DEVICE:
Prototype ☐ Clinical Testing ☐ Production ☐	AVAILABILITY OF CONSTRUCTIONAL DETAILS:
AVAILABLE FOR SALE: Yes ☐ No ☐ Price:	FOR FURTHER INFORMATION CONTACT: (617)956-5036 Jonathan C. Bretz, O.T.R. Tufts-New England Medical Center 171 Harrison Avenue - Box 1014 Boston, MA 02111

Introduction

For five years, since becoming wheelchair dependent, A.G., a 30 year-old woman with Multiple Sclerosis had been unable to wheel her chair into the bathroom of her private home. Since the doorway was too narrow to allow her wheelchair to pass, she crawled on her stomach to enter and use the facilities. This was exhausting and humiliating. One evening, she became so exhausted from the effort that she was unable to make it back to the wheelchair, and collapsed on the bathroom floor where she remained until police broke into the apartment the next morning to rescue her. Fed up, she contacted a state agency which dispatched an architect to find a solution. The architect's proposal was to remodel the entire bathroom at an estimated cost of $5,000.00. When a carpenter familiar with rehabilitation modification looked at the problem, he reversed the hinges on the door, making ample room for passage of the wheelchair. Total cost: $25.00.

This is just one illustration of the unwieldy barriers faced by physically disabled persons in their everyday lives. These barriers not only make the disabled more dependent on others (families, friends, Home Health Aides), they can also greatly hamper the ability of the disabled individual to secure gainful employment and independence in activities of daily living. If a disabled individual can not enter or leave his/her home independently or with minimum aid from another person, employment and activities of daily living become difficult to accomplish. Removal of architectural barriers from residential structures has been demonstrated to render physically disabled persons more independent, and consequently more employable as productive members of society. The maxim that has evolved out of this study of home modifications is "small solutions to small problems."

Background information

"The Effect of Home Modification on the Functional Performance of the Physically Handicapped" is a research project being conducted at the Regional Medical Rehabilitation Research and Training Center (#7) at Tufts-New England Medical Center in Boston, to determine the level of functional improvement of the physically disabled in relation to improvement in their residential environment.

Much rehabilitation and occupational therapy literature dramatizes the problems of architecturally unsuitable homes, or describes model layouts.

Lacking, but sorely needed, are examinations of practical programs to modify homes and evaluate benefits to the individual and the health system.

The biggest gap in the literature lies in the relationship of accessibility to functional performance. The primary objective of this study is to clarify this relationship by applying objective measures of functional ability (and hence independence) before and after structural modifications. The long range goal is to present this documented evidence to third-party payors and other health insurance agencies to encourage them to add this service to their programs on the basis of cost/benefit analysis.

Over the past several years, new building codes and laws pertaining to architectural barriers have come into existence. The new ANSI (American National Standards Specifications for Making Buildings and Facilities Accessible to and Useable by Physically Handicapped People, A117.1-1977.) standards are an example of such codes. Included in these standards is a section on residential homes. Another product of our study will be to propose amendments to this section in lay terms and to include other pertinent information in a manual so that the consumer can be well informed when deciding to modify his home.

Project description

For purposes of this research project, candidates for home modifications were screened on three criteria:

1. ability to perform activities of daily living is limited due to a physical disability (i.e., persons who are paralyzed, require ambulation aids, have neurological diseases, etc.);
2. live within a forty mile radius of T-NEMC;
3. are willing to have functional assessment evaluations administered before and after modifications are made (for purposes of this research project, requirements were more stringent than standards that might be developed by independent or state agencies).

Early in the project, an attractive brochure was designed and sent to professionals with clients who might meet the requirements. Referrals could be made to the project coordinator by telephone for consideration as a study participant.

The modifications undertaken by this study were limited to $500.00 per client, partly due to budget constraints, but mainly to extend the revenue to as many people as possible. To date, the most impressive outcome of this project has been the number of low-cost modifications: at the end of the first project year (October 30, 1977), the average cost per client (total 23 clients) was $397.93. This includes ramps, bathroom and kitchen modifications, threshold removal, and door widening.

Once referred, the next step involved a carpenter and an O.T.R. to determine, by home assessment, exactly what was needed by the individual. Again, if the estimate was within the $500.00 limit, the modification was applicable to this study.

Before the modification was started, an adapted version (developed especially for this study) of the Granger Long Range Functional Assessment (RT-7 Annual Report, 1975) form was administered to determine the present functional level of the individual. Once the work was completed and an appropriate time was allowed for the person to become accustomed to the change (i.e., 6 weeks), the same form was administered again. Any changes in functional independence would show in the analysis of these forms. Further statistics will be obtained through comparison of study forms to those of non-study forms.

Current activities

To date, a total of 68 persons have been referred to this project, with 31 jobs (modifications) completed. Analysis of the data obtained from those jobs is just beginning and is to be completed by October 31, 1978. The results will be published in several rehabilitation and disabled consumer journals.

Discussion of goals and relevance to rehabilitation

When a person becomes physically disabled, he is usually put through a rehabilitation program that attempts to restore function by working with his residual abilities. Another aspect of the patient's rehabilitation program is the adaptation of his environment to compensate for unregainable function. The overall program is usually the concern of the entire rehabilitation team, consisting of the physician, rehabilitation nurse, physical, occupational and speech therapists, vocational counselors and social workers. The occupational therapist has usually been called on to deal with the adaptive-equipment needs of the physically disabled. Through the use of such equipment (i.e., self-help devices), an attempt to achieve independent living is built into the treatment plan.

Since physical disability often means the loss of some or all ability to control the environment, most hospital-based rehabilitation is oriented to re-learning certain skills. All too often, however, a person who uses a wheelchair returns home to find doorways too narrow, shelves too high, second floors inaccessible, outlets beyond reach. Occupational therapists, therefore, are concerned with the patient's environment and how it will affect the individual's ability to function independently.

The inability to remove architectural barriers from private homes has made it very difficult, if not impossible, for some physically disabled persons to live independently after discharge from a rehabilitation program. Some of the physically disabled elderly or young have to go to nursing homes or chronic care facilities because for them there is no system set up to adapt to their environment.

Although the occupational therapist is trained to assess and plan modifications to the home environment, someone is needed to do the actual adaptations. Many times the disabled person will have a friend, relative or a carpenter do the modifications. As a result, much of the work proves to be unsatisfactory and sometimes unusable. There are at least two solutions to this problem which this project examines.

Educating both the disabled consumer and the carpenter in the area of architectural barriers is one approach to alleviating this problem. Preparing a manual with the ANSI standards, appropriate drawings and examples of equipment (i.e., stoves, ovens, sinks, etc., and advising where to obtain them) will serve as a guide for those people needing modifications to their homes.

Educating the carpenter can be done two ways-by developing a workshop on architectural barriers, and by working with vocational educational schools to educate their students studying carpentry. The goal of these workshops is to build skills for those carpenters who might become involved in home modifications, and to improve the quality of their work. Also, as new building codes are adopted, practicing carpenters will need to incorporate these changes into new construction.

An educational seminar in architectural barriers is currently being developed at the Research and Training Center. Its final form should consist of a two to three-day workshop with lectures, guest speakers and audio-visual materials. The curriculum will deal with physical disabilities and barriers in private homes, to familiarize the participants with some of the diseases and environmental stumbling blocks they could encounter.

The workshops would be open to vocational rehabilitation counselors (i.e., Massachusetts Rehabilitation Commission counselors), carpenters, general contractors, occupational and physical therapists, and any other interested persons who might have to deal with architectural barriers.

In addition to preparing training modules to educate health care professionals, carpenters and contractors about various aspects of home modifications, the project staff has been exploring ways to assure that the service delivery aspects are continued after completion of the demonstration research project. The Biomedical Engineering Center (BMEC) of the Tufts-New England Medical Center and the Regional Rehabilitation Research and Training Center, has developed a client service program for consultation to hospitals, vocational rehabilitation commissions, clinics, and other agencies dealing in the adaptation and customizing of durable medical equipment. Present plans call for continued scrutiny of all program aspects of the home modification project in a context of cooperation with the Massachusetts Rehabilitation Commission's adaptive housing program while striving to initiate the same type of cooperation with other state agencies.

The procedural set-up of this study (e.g. referral process) coincides with the procedural set-up of the client service program, and when completed will be incorporated into this existing system. This will insure a closer tie to the engineers of the BMEC. In cases where special design modifications were needed (such as changing controls of a wheelchair to allow independent use of a ramp), referrals were made to the client service program. This type of engineering back-up proved to be an important part of the program.

Conclusion

A goal defined in the original grant proposal was to determine the feasibility of incorporating a new member into the Rehabilitation Team - the Rehabilitation Adaptation Specialist (R.A.S.). The current thinking of this investigator is that to create a new discipline would be a duplication of services. The occupational therapist is trained in the areas of physical disabilities, activities of daily living, and the modification of environments, including the home. The occupational therapist, at least in a rehabilitation setting, should coordinate knowledgeable carpenters (i.e., carpenters who have attended the proposed workshops) and other needed services (such as engineers) to make the home environment truly barrier free.

When compiled, the statistics of this study will be presented to third-party payors and insurance companies to encourage them to add this type of coverage to their programs. To date, indications are that such home modifications programs will lead to significant savings by making it possible to maintain or improve functional ability and overall outcome. The more independent a disabled person becomes, the less dependent they are on friends, relatives or home health aides (H.H.A.). This allows their friends and relatives to be more productive workers and reduces or eliminates the need for services of a H.H.A. Increased independence for disabled persons also increases their chances of being productive members of society.

Acknowledgements

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Special thanks to Carolyn O. Cantu, original author of this grant.

MICROPROCESSOR CONTROLLED FUNCTIONAL STIMULATOR UTILIZING MYOELECTRIC INPUTS

P. S. Stutman

M. I. T. ISP and C. S. Draper Lab.
Center for Advanced Rehabilitation Engineering

A self-contained, user-worn, electrical stimulator, incorporating a C/MOS micro-processor as the controller is described. The prototype is aimed at restoring function in upper extremities such as elbow and digit flexors, to those with upper motor neuron lesions. EMGs from user controllable muscles are input to control the micro-processor and effect stimulation. Device characteristics are a function of the internal program which may be changed to accomodate different clinical situations. The processor has also been used to attempt to minimize the effect of change at the electrode tissue interface. Emphasis has been placed on designing a producible, reasonably priced system. Tests with normal subjects are reported. Additional uses are discussed.

CATEGORY:	INTENDED USER GROUP: Upper motor neuron lesions.
Device Development ☒ Research Study ☐	AVAILABILITY OF DEVICE: Not at present
STATE OF DEVELOPMENT:	
Prototype ☒ Clinical Testing ☐ Production ☐	AVAILABILITY OF CONSTRUCTIONAL DETAILS: Engineering sketches
AVAILABLE FOR SALE:	FOR FURTHER INFORMATION CONTACT:
Yes ☐ No ☒ Price:	P. S. Stutman P.O.B. 300 M.I.T. Cambridge, MA. 02139

Introduction

Functional electrical stimulation (FES) involves the application of appropriate electrical waveforms to paralyzed muscles which are still contractible in order to produce useful bodily movement.

In the case of upper motor neuron damage, skeleton, muscles, and connective tissue remain intact and usable except that muscular contraction cannot be voluntarily initiated in affected areas. If involved muscles could be volitionally controlled in proper temporal sequence, function could be regained. This would eliminate the need for a high energy-density power sources which are a limiting factor in externally powered orthoses since power gain in a FES system is high. Biological tissue is inherently well designed, hence it seems more efficient and easier to utilize as much as possible in any restorative solution.

Also, the psychological benefit to the user must not be discounted. The incorporation of the user's body as an integral part of the solution would seem to create a more natural and accepted situation. The less alloy, plastic, and silicon, the better.

The micro-processor affords a much greater degree of freedom than can be found in a hard-wired logic or analog system. The operation of the system may be altered as necessary by making software changes and reloading memory. This enables the system to accomodate a very wide variety of possible input/output combinations. The processor approach also creates a device which is able to respond and adapt to various conditions while operating.

In order to produce voluntary movement, the user must somehow control the functional stimulator. In the population for which this device is intended, manual control is either undesirable or impossible. An alternative is the use of volitional bioelectric potentials such as EEG (1) or EMG (2). The former will perhaps be of future use when more is known, while the latter is well known for prosthetic and orthotic control. The EMG may be obtained on the skin surface and can be used as either a bang-on, bang-off or variable control signal. Skin surface electrodes were used in this work since they are the only non-invasive technique easily available. Subcutaneous carbon-button or intra-muscular helical wire electrodes (3) might well prove superior, but resources at hand precluded their use. Perhaps, too, the psychological aspects of a non-surgical solution should not be overlooked.

Design Philosophy

Many devices depend on skilled technical personnel for support, both during operation and in the event that repair becomes necessary. This can result in a hesitancy on the part of the user who is concerned about damaging some "expensive equipment" or for various reasons unwilling or unable to learn complex adjustment or maintenance procedures. Not surprisingly the system should be reliable and easily maintained. Use should involve little or no calibration; adjustment of gain or range. Size is a consideration so that a 75 kg. user doesn't require 100 kg. of equipment to regain a few functions. A system intended for daily use must be rugged enough to continue working after being dropped on a few concrete floors. Above all economic realities must be firmly addressed. A $25K actual cost system will not have many users. In a device such as this, the electrical shock hazard must be minimized in event of a catastrophic failure.

Why Digital ?

Digital electronics tend to require less adjustment than analog counterparts. Analog adjustments may be performed under automatic digital control. The digital system facilitates implementation of logical structures. The C/MOS logic employed in the prototype results in very low power consumption and high noise immunity; two distinct advantages for portable equipment. As an added benefit this logic family exhibits relatively slow, low-current waveforms which radiate little electromagnetic to the outside world, such as radio and television receivers or measuring instruments.

System Description

The device can be viewed as a group of interconnected subsystems. These are:

1. Inout/Pickup electrodes and cables:

Two types of input electrodes were tried. The first was a common disposable EKG electrode (3M Red Dot) using Ag/AgCl electrolyte. The second was constructed of 1" Velcro and #24 garment snaps installed at appropriate points acting as the electrode. This type of electrode was moistened with HP Redux Creme. Shielded or twisted pair cables were used.

2. Input amplifiers:

These were LM 4250 with rolloff giving a passband of 80-400 Hz. First stage gain was X100. CMRR ~ 75 dB. AC input coupling was used to effectively eliminate electrode currents. Inputs of the differential configuration could be shorted to ground under program control to rezero.

3. Analog/Digital converter, microprocessor, Digital/Analog converter.

These subunits are described by Figure 1. Read only memory (ROM) was implemented with C/MOS random access memory (RAM) which had write lines inhibited and battery standby.

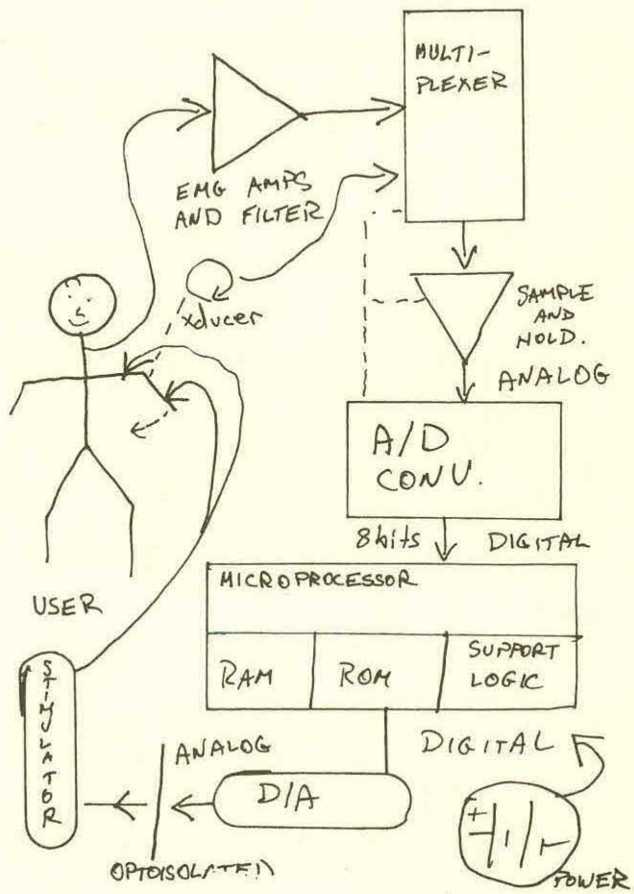


Figure 1: Block diagram of A/D, processor, and D/A.

4. Stimulating voltage generator and switching transistor array.

The output of the Digital/Analog (D/A) converter modulates the output of the voltage generator. This generator is a push-push DC/DC converter utilizing a pot core inductor to save weight and volume. 4.8 volts input gives 65 volts output (max.) at 70% efficiency. The switching transistors route the modulated stimulating voltage to the appropriate point under processor control. Optoisolated, floating.

5. Output electrodes and cabling:

Soft brass plates approximately 25 cm^2 were used as the basis of stimulating electrodes. These were covered with saline soaked felt pads. Twisted pair ribbon cable was used.

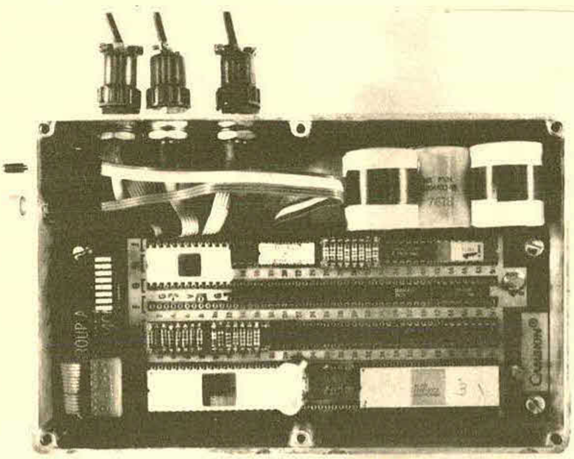
6. Position transducer:

When used, this was a potentiometer coupled to two radial arms which in turn were coupled to the elbow joint. A regulated voltage applied across the element gave a ratiometric output.

7. Power supply:

A nickel-cadmium rechargeable battery of 1250 mAH. capacity.

Physical size of the control package is 7 3/8 " L X 4 11/16"W X 2 1/4" H excluding small external switches and cabling. Weight is approx. 1.7 kg.



Control Package.

Modes of Operation

Three modes have been tried with the present device. The first is the "direct mode". In this type of operation there is proportional correspondence between the activity of EMG at the pickup point or "control site" and the stimulating pulse amplitude applied to the muscle at the overlying "motor point". There are two input channels in the prototype, hence only two motor points may be controlled and the control EMG input must exist continually. The basic design is expandable to 12 channels.

An example of the usefulness of the processor is the scaling of the input EMGs. After the device is turned on, the user pushes the RESET button; (For those unable to do so various other arrangements such as a dedicated control site are possible) in the next 5 seconds the processor looks at all control site outputs. The maximum at each site is measured and its value stored in processor memory. This value is used as a scale to interpret successive EMG. In a proportional case the expected range is between zero and this calibration. In the on-off case the on threshold is arbitrarily set at one half the observed maximum. In this fashion varying signal (EMG) amplitudes caused by electrode problems or user fatigue (in the long term) may be combatted. During this scaling operation the program inhibits stimulation. This sequence could be further automated by using an audio or visual signal, just prior to entering this mode on a cyclical basis.

If there are N EMG control sites available to the user there are 2^N possible combinations in the case where a site is either on (EMG output) or off (no output), and all sites are viewed simultaneously.* In almost all cases it is desirable to have the null combination, all sites off, cause no output. Thus there are at least 2^N-1 possible unique representations available for interpretation by the processor. In the present case, where N=2 there are 3 such states.

In certain cases, due to spasticity or difficulty in training unusual control sites such as facial or neck muscles, it may be necessary to use control sites in a binary on-off fashion and code for a specific final result. Two variants have been tried.

The first is "programmed position". Each unique combination of control inputs represents a particular limb position or state. For example, 45^o elbow flexion; digit flexion and 90^o elbow flexion; no digit flexion. These movements might be used in eating or perhaps turning pages. A potentiometer mechanically linked to the joint is used as a position transducer to provide feedback to the stimulator. The processor modulates the voltage output of the stimulator which is driven at 45 Hz. with 320 usec. pulse width. This mode would seem to provide the the most control with the least amount of training.

In certain extreme cases there may be only one control site or several sites which can be activated only one at a time. This is addressed by the last mode which

*The processor examines one channel at a time. The sampling is sufficiently fast with some filtering so that simultaneity is approximated.

is termed "programmed sequence". In this mode each control site is operated on-off. Each "on" signal triggers a preprogrammed sequence of movements which are deemed useful. For example: digit flexion (grasp), one second delay, elbow flexion. At present these modes are selected by three rocker switches inside the box; the switch could easily be made external. By expanding the number of input channels (which is done by adding one EMG amp. per channel needed) more than one mode could be made available to the user, if control sites were of varying quality.

Results

The three modes described were tried with normal subjects. Vodovnik (2) discusses the similarity between such subjects and injured individuals whose muscles have been maintained.

In the direct mode, trapezius and pectoralis major were used to control biceps and, with the use of a simple hand splint, digit flexors. This resulted in elbow flexion in the range 0-90° and a grasp with at least three distinct levels.

In the programmed modes facial and neck muscles were also tried. In these cases the cuff electrodes were not used. Movement in the programmed modes tended to be rough and ballistic. This is due to lack of a proper closed loop positioning algorithm as described by Stanic et al (4). The movements did conform to the intended temporal sequence. Some success was realized in picking up a ball from a table.

Future Uses

In order to obtain smooth natural movements further work is required to implement true servo processing in this device. This is possible with additional software and memory.

Other interesting applications of this device might be:

1. To stabilize gait using the processor to adjust critical timing intervals as a function of speed.
2. As an aid in reducing spasticity of movements in those with cerebral palsy. The initiation of a movement could trigger the output of a preprogrammed sequence which would reduce the ballistic component of movements through control of antagonist.
3. As a means of hazard avoidance. A sensor, for example a thermistor, could signal presence of hazard and initiate a movement in a safe direction.
4. Using a matrix type of electrode the motor point, which moves as a function of position, could be tracked, thus optimizing the stimulation.
5. As more becomes known about the content of the EMG signal, the EMG could be analyzed in real time yielding more control information per control site.

Conclusion

The feasibility of a user-worn, self-contained functional stimulator has been demonstrated. Useful movements can be effected by the utilization of a small number of usable EMG signals. Additional work is required to enable smoother movement.

Acknowledgment

The author wishes to thank R. E. Warren and others at Draper Lab. for their cheerful assistance.

Bibliography

0. Kralj, "Optimal Coordination and Selection of Muscles for Functional Electrical Stimulation.", in Proc. of 8th Int. Conf. on Medicine and Biomedical Engineering, Session 7-7.

1. Nirenberg, "Brain Waves for Control of Externally Powered Prosthetic Devices", I.E.E.E. Trans. on Biomed. Engr., Nov. 1971, p. 389
2. Vodovnik et al., "Myoelectric Control of Paralyzed Muscles", I.E.E.E. Trans. on Biomed. Engr. BME-12, July/Oct. '65, p.169.

3. T. Mortimer and E.H. Peckham, EDC report Case Western Reserve Univ.

4. Stanic and Trnkoczy, "Closed Loop Positioning of Patient's Ankle Joint by Means of FES of Antagonists", I.E.E.E. Trans. on Biomed. Engr., BME-21, No.5 Sept. 1974.

FUNCTIONAL ELECTRICAL STIMULATION FOR AMBULATORY SPINAL CORD INJURED PATIENTS

B. L. Galloway, M.S., J. Canzoneri, P.E, D.Sc.

Texas Institute for Rehabilitation and Research

Three ambulatory spinal cord injured patients were evaluated and fitted with the functional electrical peroneal activator. Each showed very positive effects on their gait pattern. This type of stimulation is not painful or difficult to utilize in the correct candidate; therefore an evaluation period is indicated in those who exhibit signs similar to the subjects discussed in this paper.

CATEGORY:	INTENDED USER GROUP:
Device Development ☐	Ambulatory spinal cord injured
Research Study ☒	
STATE OF DEVELOPMENT:	AVAILABILITY OF DEVICE: commercial
Prototype ☐	
Clinical Testing ☒	AVAILABILITY OF CONSTRUCTIONAL DETAILS: N/A
Production ☐	
AVAILABLE FOR SALE:	FOR FURTHER INFORMATION CONTACT: Lee Galloway, L.P.T.
Yes ☒ No ☐	T.I.R.R., P.O. Box 20095
Price:	Houston, Texas 77025 (713) 797-1440

Functional electrical stimulation of the peroneal nerve has been utilized in the past 17 years for dorsi-flexion assistance of the involved foot during the swing-through phase of ambulation in people with upper motor neuron lesions, primarily post cerebral vascular accidents (1,2). Since foot-drop in hemiplegia is a result of a central lesion, the lower motor neuron arcs remain intact. Therefore, peripheral nerves can be depolarized by an external electrical stimulus with a resultant functional muscular response. Ambulatory spinal cord injured people may exhibit many of the same problems in movement as those seen in hemiplegia. Their lesion can be asymetrical, leaving a one-sided spastic paresis which can mimic the typical cerebro-vascular hemiplegic gait.

Careful selection of patients for the program is crucial. They must have good hip and knee control, full passive range of motion of the involved ankle and genu recurvatum should be minimal. Since this system is active during the swing phase of gait only, selected patients must have adequate residual neuromuscular control and ligamentous support for the stance phase.

The system consists of a rechargeable stimulator with variable amplitude, frequency and pulse width (Figure 1). These are determined by a physical therapist following the initial period of evaluation and training, which lasts about two weeks. The stimulus delivery is controlled by a switch located in an innersole at the heel of the shoe. Percutaneous stimulating electrodes are positioned in the popliteal fossa just medial to the tendon of the biceps femoris and below and slightly posterior to the head of the fibula (Figure 2). When the patient starts the swing phase of gait the pressure comes off the heel switch. This initiates a train of stimuli with a pulse width which starts at about 20 microseconds and increases up to the maximum preset value (of less than 1200 microseconds) in 200 milliseconds. The train of stimuli ceases when the heel strike phase occurs. The pulse width train system allows a more natural

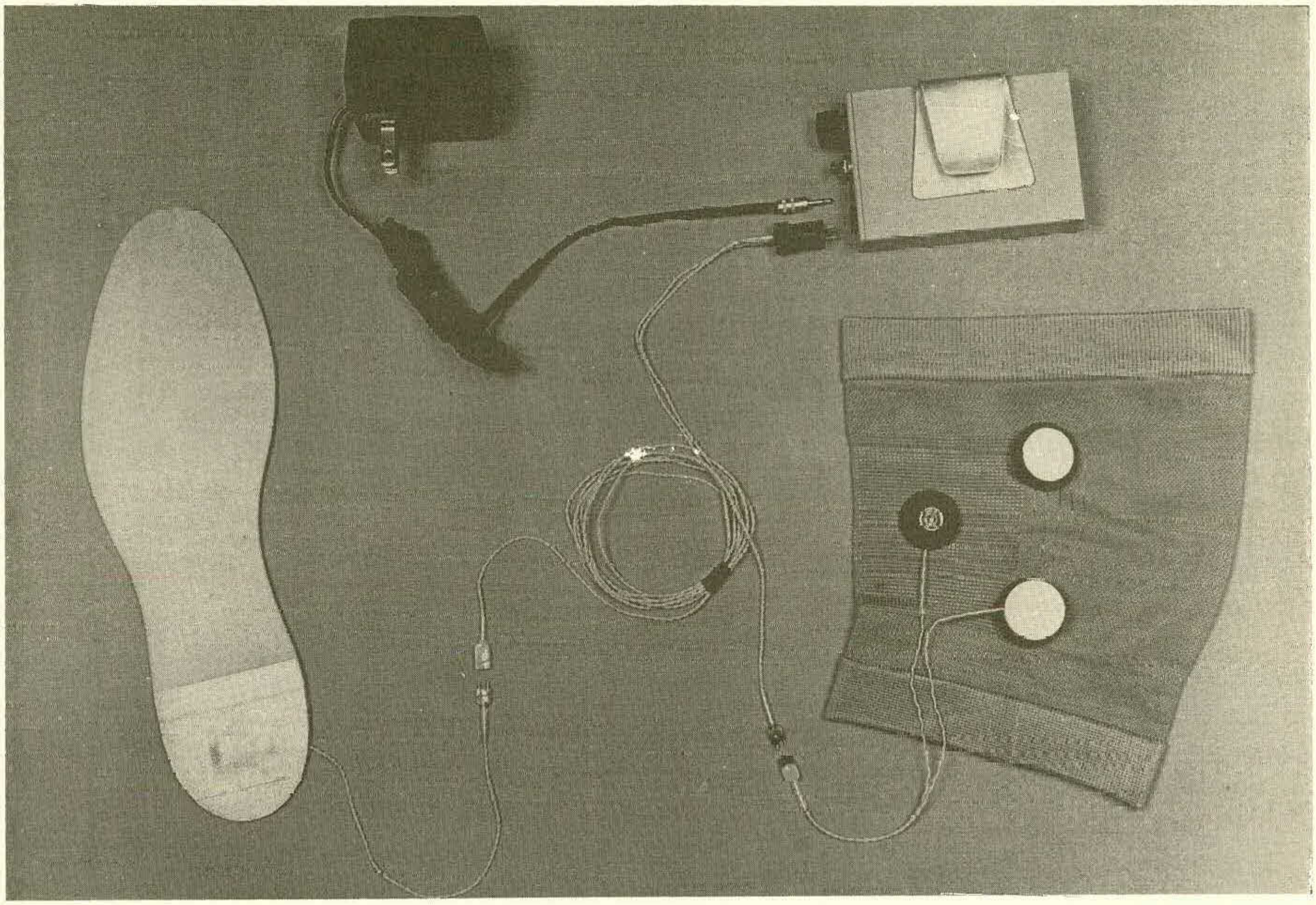


Figure 1. Complete components of the patient system: unit, cable assembly, battery charger and innersole.

recruitment of the muscle response rather than an on-off response.

In this study three ambulatory spinal cord injured males have been evaluated for use of the functional electrical peroneal stimulator. Mr. R.W. is a 31 year old male who was injured in an automobile accident August 29, 1971, sustaining a fracture of T-11 vertebrae with immediate onset of paraplegia. At this time, R.W. ambulates with the aid of crutches only. His gait exhibits bilateral extensor thrust patterns holding his lower extremities rigid. This causes great difficulty in producing hip and knee flexion for the swing through phase. He compensates for this by circumducting each limb to place them forward, which is very energy consuming. He now utilizes a bilateral system with crutches. Using this system, he is able to walk throughout the day without fatigue and even negotiate stairs.

Mr. H. F. is a 55 year old male, who was injured in an automobile accident on May 13, 1971, sustaining a fracture dislocation of the C-6 vertebrae resulting in an incomplete quadriparesis. Due to the nature of his lesion, his clinical involvement is of the left side only with minimal muscular weakness and spasticity on the right. He ambulates with a crutch and a polypropylene orthosis for foot drop on the left side. He came to us after 5 years with a complaint of left-sided low back pain. As his gait was examined, it was found that he was compensating for his weak left lower extremity by hip hiking and literally throwing his limb forward. He had developed a right thoraco-lumbar scoliosis with accompanying pain. This developed due to the abnormal biomechanical stress placed on his lumbar spine by his gait pattern by having to hip hike and throw his leg forward using his lateral abdominals and paraspinals. He now utilizes the system on his left side along with a crutch. His low back pain has stopped and he can ambulate throughout his working day without fatigue.

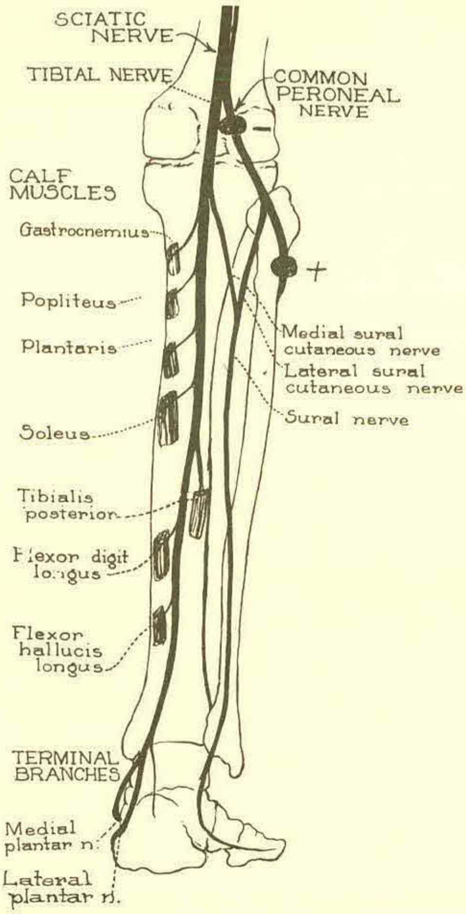


Figure 2. Anatomical depiction of the electrode placement.

Mr. T.R. is a 33 year old male who was injured in an automobile accident in 1975 sustaining a subluxation of C-4 and C-5 vertebrae resulting in incomplete quadriparesis. Due to the nature of his lesion his clinical involvement is of the right side only with minimal involvement of the left. He ambulates with a walker. His gait pattern exhibits a pattern of extreme extensor thrust in his right lower extremity. He brings this limb through very slowly due to the time it takes to break out of the extensor pattern. He can ambulate approximately 50 feet before he fatigues. Mr. T.R. utilizes the system on his right side along with a walker. He is now able to ambulate 5 times as far before he fatigues, although the primary useage is for exercise.

In each subject the results were positive. In two of the subjects an overriding extensor thrust pattern during ambulation was the main problem. The breaking of this pattern can be attributed to the flexor withdrawal of a hyperexcitable limb to an electrical stimulus. If applied at a certain threshold level to the peroneal nerve, this withdrawal can be made functional during ambulation (3).

This system aids the gait pattern in approaching normality biomechanically. It restores equlibrium of stresses on the skeletal system, helping to prevent abnormal stresses on other joint structures which can cause secondary problems such as scoliosis. By arranging so that each limb carries approximately equal body loading, a more functional and cosmetic gait pattern is produced.

Functional electrical stimulation of paretic extremities has other benefits. It has been used therapeutically as an anti-clonus model, reducing the excitability of the triceps surae muscle group (4,5). Also, patients report better proprioceptive input from the involved extremity during stimulation.

References

1. Liberson, W. T, Holmquest, H.J, Scot, D, and Dow, M., "Functional Electrotherapy: Stimulation of the Peroneal Nerve Synchronized with the Swing Phase of the Gait of Hemiplegic Patients," Arch. Phys. Med. Rehab., 42: 101-105, 1961.

2. Gracanin, F. and Dimitrijevic, M.R., "Application of Functional Electrical Stimulation in Rehabilitation," The Use of Reflex Mechanisms in Re-education of Mobility, 91-96 Balnea, Praha, 1969.

3. Dimitrijevic, M.R., "Use of Physiological Mechanisms in the Electrical Control of Paralyzed Extremities," External Control of Human Extremities, Proceedings of the Dubrovnic Conference, Yugoslav Committee for Electronics and Automation, 27-41, Belgrade, 1967.

4. Levine, M.G. and Kabat, H., "Co-contraction and Reciprocal Innervation in Voluntary Movement in Man," Science, 116: 115-118, 1952.

5. Dimitrijevic, M.R., Gracanin, F., Prevec, T., and Trontelj, J., "Electronic Control of Paralyzed Extremities," Bio-Med. Engineering 3:8-14, 1968.

A PROPOSED WORKSHOP FOR PRACTITIONERS ON CONSTRUCTION OF PRACTICAL REHABILITATION DEVICES

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Mechanical Engineering Department
Massachusetts Institute of Technology

The authors are considering the preparation of a practical short-course for rehabilitation practitioners. The course would provide participants with background, resource information and detailed instructions necessary for assembly of specific therapeutic and assistive devices. It is intended that practitioners could then construct these devices as they are needed by their handicapped clients. At this conference, questionnaires will be distributed to obtain comments and suggestions, in particular to assist the authors in compiling a list of frequently-occurring device needs. It is hoped that a pilot presentation of the course may be given at a future meeting of this conference.

CATEGORY: Device Development ☐ Research Study ■	INTENDED USER GROUP: Rehabilitation practitioners
STATE OF DEVELOPMENT: Prototype ☐ Clinical Testing ☐ Production ☐	AVAILABILITY OF COURSE: Anticipate pilot presentations in about a year at conferences such as this. AVAILABILITY OF CONSTRUCTIONAL DETAILS:
AVAILABLE FOR SALE: Yes ☐ No ■ Price:	FOR FURTHER INFORMATION CONTACT: Michael J. Rosen Building 31-063 M.I.T., 77 Mass. Ave. Cambridge, MA. 02139

This brief paper is intended to introduce an idea and to invite responses to it. In particular, we need suggestions from rehabilitation practitioners, defined here to include anyone charged by profession or circumstance with daily responsibility for meeting the needs of individuals having motor and/or communicative handicaps. Occupational and physical therapists, nurses, physiatrists, and special education teachers are among the more obvious members of this group. Although it is intended that the comments we are soliciting be made verbally or via the questionnaire provided for that purpose at this conference, anyone reading this at any time subsequent to the meeting is encouraged to contribute in the same manner.

The idea is a course, a practical workshop, intended to teach rehabilitation practitioners to assemble therapeutic and assistive devices, independently, as the need for such devices arises in the course of their professional activity. (This concept shares some features with curricula developed by R. Foulds at Tufts[1] and R. Warren of C.S. Draper Labs[2].) It would assume no technical background or specialized skills, and would not require access to any but the most common hand tools. A detailed instruction manual providing step-by-step recipes for the construction of specific devices will be an integral part of this course. It will, in addition, include extensive resource information listing alternative sources of inexpensive, readily available materials and components. The course is intended as much to impart confidence as it is to convey information and provide instruction. To this end, designs will be chosen to be simple to build and maintain, and electrically safe. Devices will utilize only low-voltage D.C. power; the most disasterous consequence of faulty assembly would be the premature demise of an inexpensive battery.

The rationale for this project arises from the observation that rehabilitation practitioners who are constantly in a position to recognize the need for specific devices may nevertheless find such technological solutions to their clients' problems inaccessible. The mechanisms which maintain this gap between the therapist and the rehabilitation engineer are many and familiar. Listings of commercially available systems are often unavailable or inadequately disseminated. When existing technology is for sale <u>and</u> well publicized, the price of a device is often an insurmountable barrier. Devices which are unavailable commercially but well within the fabrication capability of a competent clinical engineer may be effectively unavailable to the therapist due to isolation from such an engineer. Even when institutional and/or personal ties to engineers do exist, the practitioner's patient-by-patient device needs may nevertheless go begging because of overwhelming pre-existing demands on the engineer's time.

What we propose, then, is an experiment in inter-professional education. To begin, we must compile a "needs list", a list of therapeutic or assistive problems faced by practitioners which they perceive as having technological solutions presently unavailable to them. We hypothesize that some of the problems in this list will have the following characteristics: (1) they are assigned high priority by many practitioners; (2) they can, in fact, be solved by means of devices utilizing techniques of well established value; and (3) such devices may be implemented using inexpensive, readily available low technology appropriate for assembly by people without technical backgrounds. Presently we need the input of rehabilitation practitioners in order to compile a list of problems which is more than just an educated guess on our part. We ask that descriptions of problems be as specific as possible ("I need a way of assisting an athetoid cerebral palsied 8-year-old to steady his arm when writing so that he can produce better formed characters.") but respondents are urged not to be inhibited by preconceived notions of technological feasibility. We consider practitioners attending this conference (or reading its proceedings) particularly well suited to providing us with the information we need since, by their attendance, they have demonstrated a pre-existing orientation toward devices as solutions to problems of the handicapped. All comments and suggestions should be sent to the authors at the institutional address shown above. Should we succeed in advancing this project past the planning stage, reports of progress will appear in the proceedings of later meetings of this conference.

What follows is a copy of the questionnaires distributed to rehabilitation practitioners at the present conference:

A Questionnaire for Rehabilitation Practitioners on Perceived Needs for Therapeutic and Assistive Devices*

1. Name and professional address.

2. "Professional" role in rehabilitation (therapist, nurse, teacher, parent, physiatrist, etc.).

3. Describe briefly the types of handicapped individuals with whom you work.

4. Please imagine that you are a student in a practical course/workshop intended to provide you with the background, resource information and detailed instructions necessary for assembly of a number of specific devices as you need them in your professional activity. Keeping in mind the problems you most frequently encounter in your involvement with handicapped individuals, please describe the devices you would most like to see covered by such a course. (While the nature of the problems to be solved should be stated as specifically as possible, you are encouraged not to be inhibited by preconceived notions of technological feasibility or present commercial device availability.)

5. Give a brief summary of your attitude toward, and experience with, technological solutions to rehabilitation problems. What obstacles have you encountered in identifying or obtaining devices which meet the needs of your clients?

6. List the manual skills and tools with which you presently feel confident as a result of professional or hobbyist/crafts activity (for example - simple wood working, electronic kit assembly, hand power tools).

* Submit responses to Michael J. Rosen, Building 31-063, Mech. Engin. Dept., M.I.T., 77 Massachusetts Avenue, Cambridge, MA. 02139.

References

1. Foulds, R., "Creative Engineering in Rehabilitation", taught at Tufts-Boston School of Occupational Therapy by Foulds and colleagues (personal communication).

2. Warren, R.E., "A Research Program for the Physically Handicapped to Develop Independence via "Build-It-Yourself" Kits and Practical Instruction in Engineering Technology", Charles Stark Draper Laboratory Progress Report R-1074, Cambridge, MA., 1977.

ENGINEERING FOR REHABILITATION*

by H. L. Taylor
Department of Electrical Engineering
University of Texas at Austin
Austin, Texas 78712

Developing devices, apparatus, or systems for satisfactory use by handicapped persons provides an unusual challenge to engineering faculty. The uniqueness of the problems and the subjectivity of the evaluations poses serious communication problems. Thorough and extensive discussions, planning, and cyclic fabrication and test among the client, the counselor, and the engineer can produce reasonable and workable solutions to many needs.

CATEGORY: Device Development [X] Research Study [ ]	INTENDED USER GROUP: Specific clients of the Texas Rehabilitation Commission AVAILABILITY OF DEVICE: Undetermined
STATE OF DEVELOPMENT: Prototype [X] Clinical Testing [ ] Production [ ]	AVAILABILITY OF CONSTRUCTIONAL DETAILS: Undetermined
AVAILABLE FOR SALE: Yes [ ] No [X] Price:	FOR FURTHER INFORMATION CONTACT: H. L. Taylor 3419 Mt. Barker Drive Austin, Texas 78731

Introduction

As means of combining engineering training with practical problems, certain faculty members sought ways by which we could be helpful to the Rehabilitation Commission. Faculty members held visions of large programs in electro-mechanical systems, artificial limbs, and other extensive projects. The adminstrators in the Rehabilitation Commission viewed the possibilities in terms of that which benefits directly and immediately the individual client.[1,2] The need for faculty to become capable of communicating satisfactorily with rehabilitation administrators, counselors, and clients soon became clear.

Many of the particular tasks suggested for development study seemed small to faculty members. The rehabilitation staff looked at the particular client and his needs, with little inclination to extrapolate into more complicated considerations. Thus the faculty found it essential to demonstrate a capability to do those things viewed as important to the rehabilitation staff as a means to developing an opportunity and means for further interactions.

Operations

Consulting toward suggestions concerning alternatives or special purchasing possibilities constituted the positive technical portion of the first few meetings between faculty and rehabilitation staff. The real benefit came from the mutual education of each group to the considerable improvement in learning how to talk to each other in a meaningful way.

One particularly imaginative counselor working with the Homebound Employment Program discovered the availability of the engineering faculty and machine shop.[3] He provided us with several interesting projects. The most successful project concerned preparing jigs to assist with tying leaders to fish hooks. A contract to the Rehabilitation workshop could provide wages to a number of persons if they could hand-tie leaders fast enough to earn at a rate greater than the minimum wage. After much discussion and several versions of cut-and-try, we produced some rather simple, inexpensive work stations to assist the task of tying leaders to fish hooks as illustrated in Figure 1. After the initial definition

* This work has been partially supported by the Texas Rehabilitation Commission and the Bureau of Engineering Research.

provided by the TRC staff, approximately 75% of the effort came from the machine shop and 25% from the faculty.

With practice, a wide variety of kinds of handcapped persons could earn between $3 and $4 per hour tying leaders. Competition from foreign labor markets and automated equipment has kept that project to a modest size.

The Rehabilitation Commission print shop employs a deaf printing press operator. The noise of the printing equipment doesn't bother him much. Unfortunately, the common way for an operator to recognize a malfunction of the paper transport mechanism is through the sound it makes. An uncorrected paper jam will soon wreck the printing press. Could an engineer suggest a useful solution?

Examination of the press indicated that the paper accumulated in a certain place for a brief period before the accumulation would cause a destructive jam. A sensitive electrical switch, tripped by the weight of a few sheets of paper, could turn on a lamp above the press (note Figure 2) in easy view of the deaf operator. The device, as installed by the faculty member, reportedly worked quite well but the operator did not want to be "different" from the other operators and learned to do his job without having to use the indicating device.

Another task concerned assisting a paraplegic restaurant artist with appropriate lighting for portraits in a dimly lit restuarant. Supporting tripods, as used for lights by photographers, and a battery pack system and a 110 volt line system with intensity adjustments in each adequately provided for her illumination needs as outlined in Figure 3. The equipment was light and small so that it was still easily portable for a person in a wheel chair. Purchased apparatus consisted of about one-third of the finished apparatus. Designs and shop construction each provided another third of the effort required.

From a junior college dormitory for paraplegics and quadriplegics, we received a request for a device to help these students remove pull tabs from beverage cans without having to call for assistance. After several attempts we achieved a folding structure about 8 inches long folded and about like a 4x8 inch L when open (See Figure 4) which would nicely pull tabs from beverage cans, if the person could hold both the can and the lever device. For a person with only one hand with adequate grip and strength, a separate holder for the can is required. The faculty supervisor provided problem definition and the other 80% of the effort came from the machinists.

A common inconvenience to the deaf concerns doorbells, telephones, and such devices which normally signal by sound. Some deaf persons felt the small indicator lights commonly used with telephones to be inadequate to attract their attention when engaged in an occupying task.

A flash lamp similar to an electronic photographic strobe light has been arranged as in Figure 5 to give a brief, very bright flash of light as an annunciator system. Multiple means of triggering this circuit can be used. One of the simpler means is an inductive pick up coil placed under a telephone to pick up the signal from the ringing currents without the necessity of being wired directly into the telephone lines. From faculty definition and parts acquisition efforts, students provided the other two-thirds of the activity.

One project initiated by a student in a laboratory course concerns telemetry of the signal from an implanted heart pacer over telephone lines. Several patients find it rather inconvenient to make periodic trips to the physicians office merely to find out that battery supply for the pacer is still adequate. A relatively simple and inexpensive system by which a phone call could transmit the information would have utility.

Students provided about 90% of the effort on this problem to develop a circuit and test it so that transmitter and receiver ends could perform well over a minimum quality telephone line as illustrated in Figure 6.

Another sizeable student effort concerns developing a braille output device for the Texas Instruments scientific calculators which couple[4] to a remote printer as indicated in Figure 7. The voice synthesis calculators currently available have limited calculator functions and are still moderately expensive. A simple means to use commercially available calculators appeared to be a cost effective way to provide greater electronic calculator capability to blind persons.

Providing a vehicle suitable to aid the mobility of a dwarf proved to be an interesting challenge. An elaboration of the modified infant stroller he had used for years was desired. Motor drive could be added to increase significantly his range. The vehicle produced shows in Figure 8. The activity was about 50% faculty and 50% machine shop.

The cost benefit evaluation of the output cannot be properly done by the engineer alone. Thus far we have had no formal evaluation sessions in which the client counselor could provide a broad-based cost benefit evaluation.

Comments

The greatest short coming to developments in Rehabilitation Engineering we have encountered concerns the library function. Finding out what studies have been done or what products are manufactured for the special problems of handicapped persons has been unusually time consuming and unrewarding. The next largest problem concerns vocabulary between university graduate faculty and rehabilitation counselors. The backgrounds and frames of reference for these people differ enough that both they and the clients need to become involved in the problem definition and proposed solution evaluation until they really can speak meaningful to each other.

The next greatest problem concerns materials and supply. The wide variety of things needed to do these uncommon things requires peristence and patience in locating and obtaining delivery on the parts or material required.

The greatest assests we have at a College of Engineering for working on these atypical problems are the faculty with a very wide variety of training and experience and our machine shops with staff capable of building almost any thing we can describe to them. Sometimes the very elementary approach works well the first time. More often we require something not usually associated or used in that particular way.

Apparently no good mechanism exists for helping any developed tool or system become commercially available. Too often a good development remains hidden in a local report without anyone making the effort to study the business case to determine if any chance exists for commerical success. Perhaps the university setting can provide that service also.

Conclusions

We have gained a greater respect for the difficulties in actually fabricating a finished device or system to the satisfaction of the customer. Open cooperation between the counselor, the client, and the engineer has always yielded good approaches to the problems. For selected problems with reasonable time requirements and costs, we feel we have made useful, but small, contribution to a number of clients.

References

1. Mr. Doyle Wheeler, Deputy Commissioner, Texas Rehabilitation Commission, Austin, TX 78704.
2. Ms. Lisa Maxwell, Research Utilization Office, Texas Rehabilitation Commissions. 118 East Riverside Dr. Austin, Texas 78704.
3. Mr. Roland McArthur, H.O.P.E. Inc., Cooperative 410 West Avenue B, San Angelo, Texas 76901.
4. Texas Instruments Calculators SR-52, 56, 58, and 59 provide signals to a connector to drive an external printer.

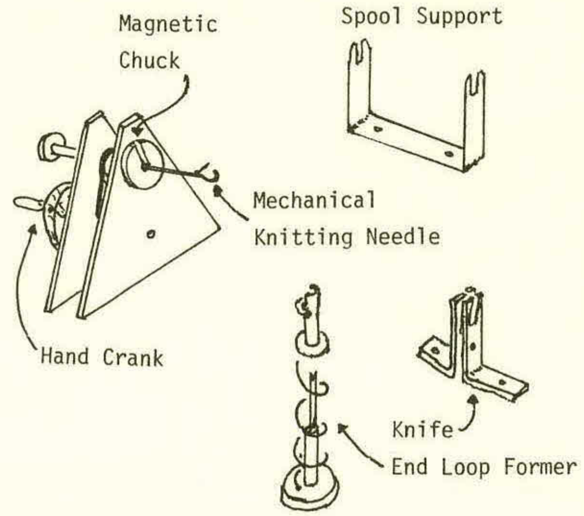

FIGURE 1. LEADER TYING FIXTURES

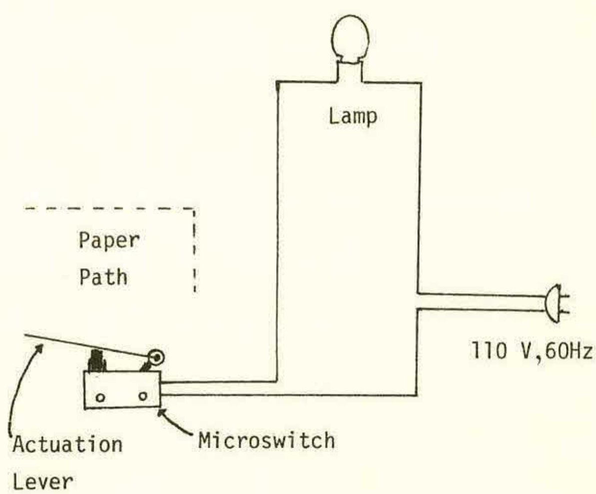

FIGURE 2. PAPER ACCUMULATION INDICTOR

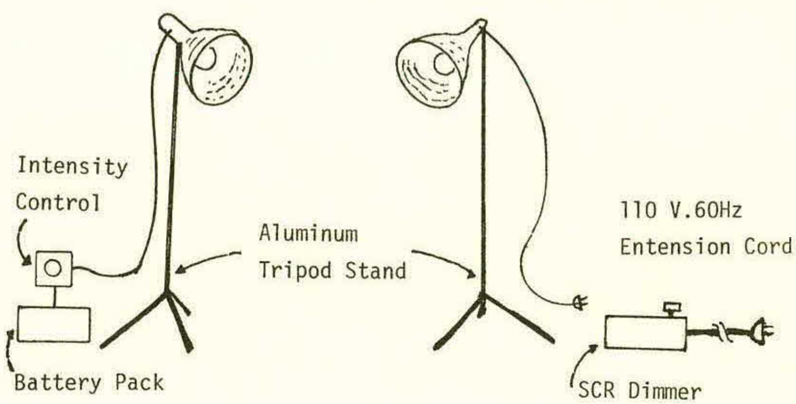

FIGURE 3. PORTABLE LIGHTING

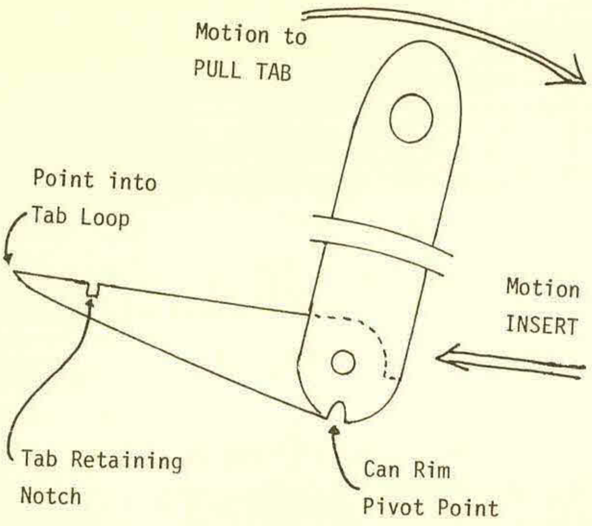

FIGURE 4. BEVERAGE CAN TAB PULLER

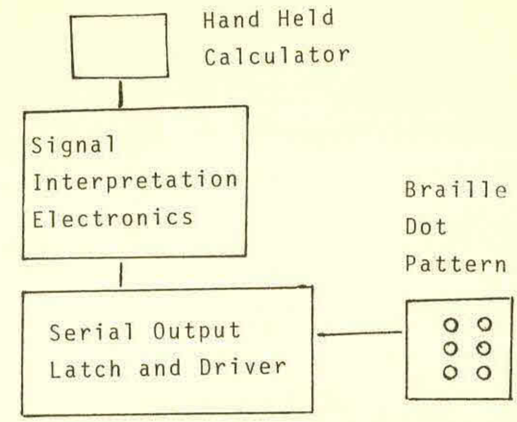

FIGURE 7. BRAILLE OUTPUT FROM CERTAIN CALCULATORS

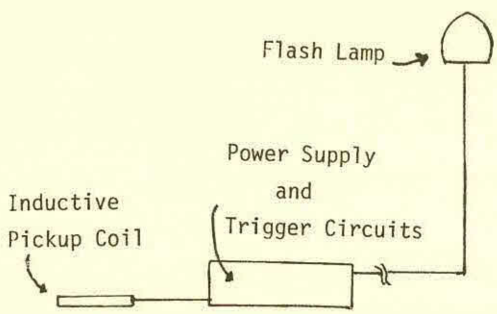

FIGURE 5. FLASH ANNUNCIATOR

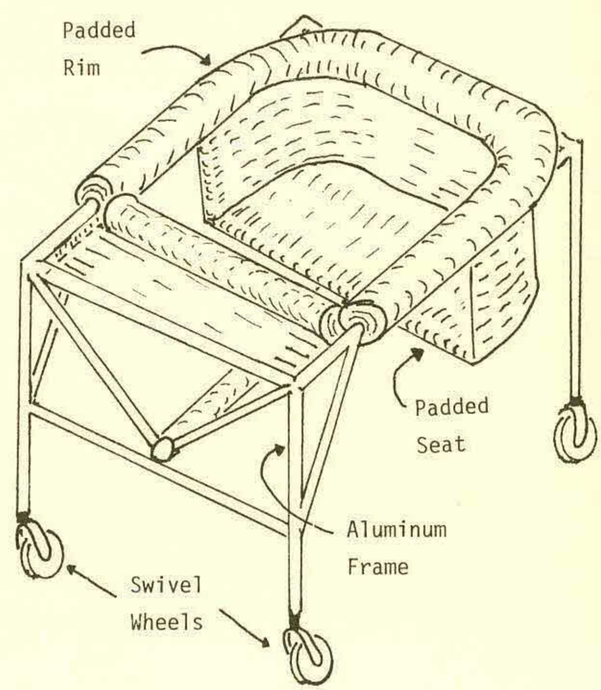

FIGURE 8. SPECIAL STROLLER VEHICLE

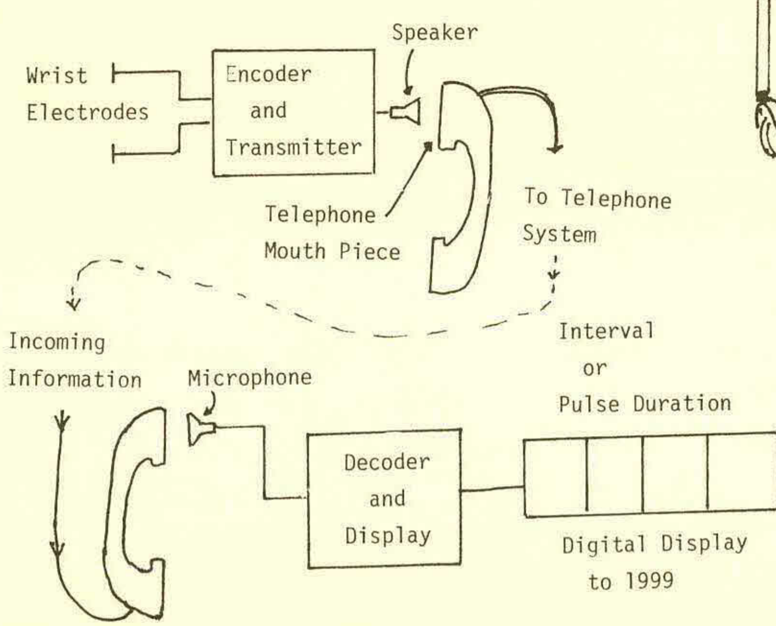

FIGURE 6. PACEMAKER TEST TRANSMISSION

A REHABILITATION RESEARCH UTILIZATION PROGRAM

F. O. Bohls, Ph.D., Project Coordinator-IMPART, Texas Rehabilitation Commission
Charles J. Laenger, Sr., Rehabilitation Engineer, Southwest Research Institute

The Texas Rehabilitation Commission has acquired a grant from the Research Utilization Office of the Rehabilitation Services Administration for Establishment and performance of a program which we call IMPART. The purpose of the program is to make the prescriber-segment and the user-segment of the rehabilitation community aware of available equipment and devices and technical information related to rehabilitation and better everyday living. IMPART is a public service and is available to anyone who has a work-related rehabilitation problem. However, we regard the rehabilitation counselor in the field as the focal point of this program. Problem solutions come from personal knowledge of rehabilitation engineering area, catalog searches, data bank searches, and direct contact with rehabilitation engineering and devices design personnel.

CATEGORY: Utilization Laboratory Device Development ☐ Research Study ☐	INTENDED USER GROUP: Anyone with a work-related rehabilitation problem.
STATE OF DEVELOPMENT: Prototype ☐ Clinical Testing ☐ Production ☐	AVAILABILITY OF DEVICE: AVAILABILITY OF CONSTRUCTIONAL DETAILS:
AVAILABLE FOR SALE: Yes ☐ No ☐ Price:	FOR FURTHER INFORMATION CONTACT:

Introduction

A young woman told our project officer that a kiss over the telephone was safe but not very effective. This mode of expressing affections is reminiscent of an issue facing researchers and users of research findings today. "How do researchers maintain the distance that objectivity demands and still maintain their effectiveness? How do users tolerate research efforts without becoming frustrated by the inability to obtain immediate answers to pressing problems? How do researchers and users effectively relate to each other?" These specific questions were asked by Mr. George Engstrom, who is Chief of the Division of Program Support, Rehabilitation Services Administration. He raised these questions in an article entitled "Research and Research Utilization - A Many-Faceted Approach" which appeared in the Rehabilitation Counseling Bulletin.*

The rehabilitation services-delivery community is deeply concerned and frustrated because they know that the best of technology is not being provided to the clients they serve. This community has insufficient knowledge of the equipment and devices that are commercially available. They have limited knowledge of technical information that is available and it is highly unlikely that they are aware of the work that you are doing.

A good researcher is concerned when months and even years elapse before a device that he has conceived and effectively demonstrated is available to the consumer. A good researcher is frustrated when the device that he nurtured costs too much for the handicapped consumer to afford. And the good researcher should be angry when the consumer, and his counselor, do not even know that the device exists. But before we indulge in righteous wrath, let us remember that ignorance of the counselor and the consumer are complemented by the equal ignorance of the developer and researcher of the rehabilitation devices. Like it or not, the technical researcher, particularly in the area of rehabilitation, has an obligation to participate in the technology dissemination process. This is an obligation which we, as rehabilitation engineers and designers of rehabilitation devices, do not adequately fulfill.

Utilization

Texas Rehabilitation Commission has taken the initiative to mediate this situation. We have acquired a grant from the Research Utilization Office of the Rehabilitation Services Administration for establishment and performance of a program which we call IMPART. IMPART is an acronym for Innovative Matching of Problems to Available Rehabilitation Technology. Simply stated, the purpose of the program is to make the prescriber-segment and the user-segment of the rehabilitation community aware of available equipment and devices and technical information related to rehabilitation and better everyday living.

We are taking a direct and pragmatic approach. First, we regard the rehabilitation counselor in the field as the focal point of this program. Let us objectively consider the qualifications of the average counselor and the constraints of the system in which he functions. Ordinarily, the counselor is trained in the area of sociology, psychology and special education. Very few of these people have any technical training and, therefore, as a group, they may have low mechanical aptitude. Their background, therefore, tends to make them exclude or to give low priority to technical approaches to problems. But the available time factor poses the most important constraint. Almost all counselors maintain a very heavy caseload and they must respond to many acute human needs every day. This leaves little time for them to seek technical solutions or to determine what devices are available.

Most of the people in this audience know that technology and technical devices offer effective and cost-effective solutions to many vocational rehabilitation and everyday living problems of handicapped people. We know, also, that rehabilitation personnel who provide direct services and handicapped consumers need technical access now.

With this in mind, I would like to discuss the mechanics of the IMPART program and to solicit your suggestons and your cooperation.

The first major step in the program is to acquire problem submissions and to establish an avenue of continuing dialogue with those who need rehabilitation devices and technical rehabilitation information. An attempt to acquire problem submissions from counselors via mailouts, even with a letter from the Commissioner of TRC, has been less than successful. We are finding that personal encounters with counselors are much more effective even though this approach is time consuming. We believe that the flow of problem submissions will be continuous once rapport has been well established and value and effectiveness of the program has been demonstrated.

The following figures illustrate the IMPART Project:

IMPART

INNOVATIVE MATCHING OF PROBLEMS TO AVAILABLE REHABILITATION TECHNOLOGY

PROBLEM STATEMENT

STRICT CONFIDENTIALITY WILL BE OBSERVED AT ALL TIMES.

Title: ______ Date: ______

Originator: Name ______ Position: ______

Firm or Agency ______

Address ______

City, State ______

What is Needed: ______

______

Also check three (3) descriptive words on the back of this page which best describe this need.

Disability: ______

Specific Physical Limitations: ______

Is Condition Progressive? ______

Other Information/Constraints, Specifications, Etc: ______

______

______

______

______

Please mail completed form to address shown below.

Frederick O. Bohls, Ph.D.	Charles J. Laenger, Sr.
Project Coordinator	Rehabilitation Engineer
Texas Rehabilitation Commission	Southwest Research Institute
118 East Riverside Drive	6220 Culebra Road
Austin, Texas 78704	San Antonio, Texas 78284
512 - 447-0100	512 - 684-5111

Figure 1

TEXAS REHABILITATION COMMISSION

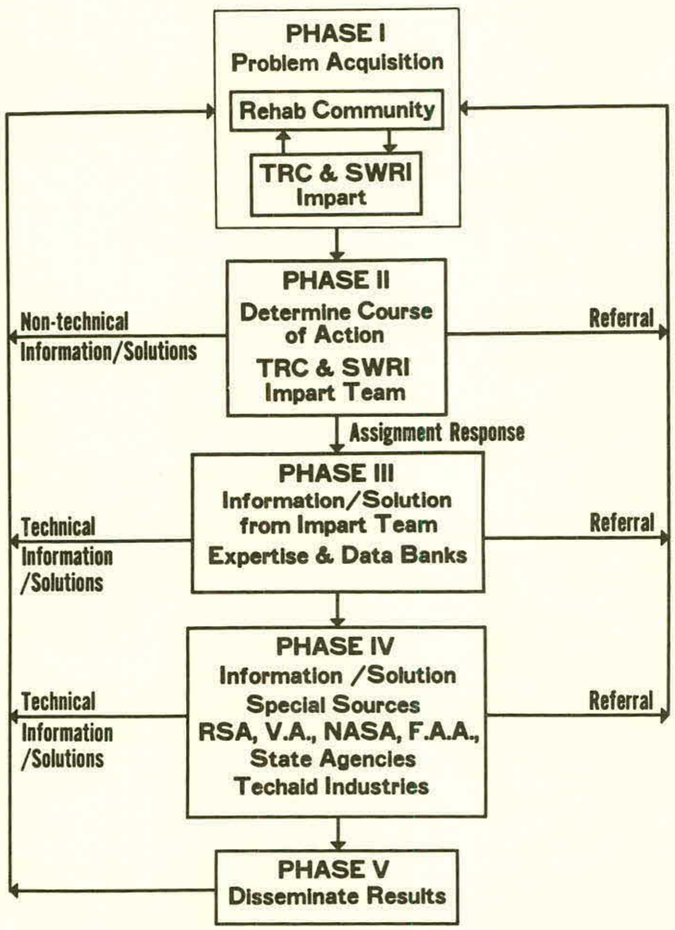

Figure 2

PROBLEM AREA - CHECKLIST

Please check three (3) descriptive words which best describe your need:

COMMUNICATION
___ Amplification Devices
___ Speech Producing Devices
___ Telephoning
___ Braille/Braille Writing
___ Writing
___ Typewriting
___ Reading
___ Communication Boards/Electron
___ Special Signaling Devices
___ Sensory Conversion Devices
___ Command/Control
___

MOBILITY AIDS
___ Wheelchair
___ Wheelchair Accessories
___ Walkers
___ Canes, Crutches
___ Orthotics
___ Prosthetics
___ Lifts, Transfers, Elevators
___ Other Stabilization or Positioning Aids
___ Electronic, Ultrasonic, Laser, etc.
___ Personal Vehicle, Specialized, Unlicensed
___

TRANSPORTATION
___ Automobile/Automotive Hand Controls
___ Adapted Van
___ Transfers/Lifts
___ Personal Vehicle, Specialized, Licensed
___ Wheelchair Restraints
___ Automotive Power Assists
___ Emergency, Safety Equipment/Automotive
___ Buses, Minibuses, Ambucabs
___

DAILY LIVING
___ Eating/Drinking/Feeding
___ Bathing
___ Toilet
___ Dressing/Clothing
___ Grooming
___ Sleeping
___ Safety/Security
___

HOME MANAGEMENT AND ADAPTION
___ Food Preparation and Serving
___ Child Care
___ Cleaning/Laundry
___ Other Home Maintenance
___

FURNITURE (Home/Office)
___ Chair
___ Table/Desk
___ Bed
___ Couch
___

MEDICAL THERAPY
___ Surgical
___ Diagnostic and Testing
___ Exercise
___ Therapy Devices
___ Muscle/Nerve Stimulation
___

RECREATION
___ Crafts
___ Sports
___ Games
___ Devices
___

For Project Personnel Use Only

Date: Received Closed

IMPART Personnel: TRC SwRI

UTA Other

Descriptors: Disability Area

Figure 3

To date we have acquired more than 100 problem submissions; most of these have been submitted by rehabilitation counselors. Titles of some of these problems are as follows:

- Alert for Deaf Restaurant Worker
- Communication System for Athetoid Cerebral Palsied Client
- Telephone Capability for Deaf
- Deaf Alert - Telephone, Baby Cry, Smoke, Emergency Vehicle
- Margin Alarm for Deaf (Typewriter)
- Extend Usefulness of Hearing Aid
- Large Field, Low Power Lens
- Lamp Identifier for Blind
- Sewing Fixture for Blind
- Bottom Margin Alarm for Blind (Typewriter)
- Recording Cuing for Blind Disc Jockey
- Heliarc Machine Control for Quadriplegic
- Writing Aids for Paralyzed Clients
- Carrier for Electric Wheelchair
- Stability Assist for Bus Egress
- Proportional Control "Trainer" for Electric Wheelchair
- One Hand Typewriter
- Elevating Wheelchair for Cerebral Palsied Office Worker
- Female External Urinary Collection Device
- Mobility Aid for Osteogenesis Imperfecta
- Housework Aid for Paraplegic
- Tire Cutter for Sheltered Workshop
- Protected Environment for Woodworker
- Portable Suction/Support Bars

Sources of Information

Our primary sources of information for solutions to these and similar problems are (1) personal knowledge and familiarity with the rehabilitation engineering area, (2) catalog searches, (3) data bank searches, and (4) direct contact with rehabilitation engineering and devices design personnel. One of the most valuable resources is people such as yourself and the facilities with which you are associated. We know many of you and have sought your help and advice in the past. For this we are sincerely grateful. We will be pleased to share information acquired on the IMPART program with all of you - particularly that information which will give rehabilitation engineers ideas and indications of the technical needs of handicapped people.

References

* Volume 19, No. 2, December 1975.

THE WHEELCHAIR ODOMETER: AN AID TO EVALUATION IN REHABILITATION

James L. Alexander, M.A., Edwin P. Willems, Ph.D., and Lauro S. Halstead, M.D.
Texas Institute for Rehabilitation and Research
1333 Moursund Avenue
Houston, Texas 77030

Arguing from the perspective that the purpose of many engineering innovations in mobility aids is to affect subjects' rates and patterns of mobility, it follows that measurements of subjects' actual rates of mobility are important criteria for evaluative purposes. A simple mechanical counter, the wheelchair odometer, is presented as a tool for measuring actual mobility rates and patterns. Two sets of odometer data are presented as illustrations of evaluative procedures.

CATEGORY: RESEARCH Device Development ☐ Research Study ☒	INTENDED USER GROUP: Evaluators, Researchers, Clinical Personnel
STATE OF DEVELOPMENT: Prototype ☐ Clinical Testing ☒ Production ☐	AVAILABILITY OF DEVICE: Custom orders accepted AVAILABILITY OF CONSTRUCTIONAL DETAILS: See Halstead, 1973 (reference #1)
AVAILABLE FOR SALE: Yes ☒ No ☐ Price:	FOR FURTHER INFORMATION CONTACT: Lauro S. Halstead, M.D. 1333 Moursund Avenue Houston, Texas 77030

Introduction

Most design improvements, modifications, or individual tailoring applied to wheelchairs or similar mobility aids are added in order to enhance the user's functional mobility. Sometimes, this goal is only implicit, but it is usually the goal or assumed criterion. It follows, then, that projects which are thought to enhance mobility should seek data which address the impact on the actual functional mobility of users. There are some dimensions of innovation and improvement that are clearly desirable, but cannot reasonably be expected to affect actual functional mobility (e.g., aesthetics and appearances, lower cost, enhanced durability, or reduced maintenance, etc.). However, most design changes or modifications for wheelchairs are proposed in order to enhance user's functional mobility.

While the argument for collecting data on actual rates and patterns of use as a means of evaluating engineering projects is clear and straightforward, actual reports of such data are sparse. The purpose of this paper is to present one instrument, the wheelchair odometer, as a means for collecting data an actual wheelchair use as an evaluation criterion. Data collected from odometers attached to the wheels of subjects' wheelchairs are presented to illustrate the use of the odometer in evaluation.

Instrument design

The wheelchair odometer is a small (2½" X 3/4" X 1½") lightweight (3.8 oz.) pendulum-arm actuated mechanical counter.(1) Movement of the pendulum arm is limited by stops in the polyurethane casing to a 36° arc which is sufficient to increment the counter (Veeder Root #746135) by one unit. One end of the odometer casing forms a fastener with a screw-down clamp which attaches the instrument to the spokes of the wheel. When clamped in place near the hub of the wheel of a wheelchair, the force of gravity and rotation of the wheel through one complete revolution produce a complete back and forth cycle of the pendulum arm through the 36° arc. Thus, one revolution of the wheel increments the counter by one unit. The odometer is virtually noiseless in operation and functions continuously. Its small size and weight and mounting point near the hub of the wheel make it very unobtrusive to both the casual eye and to the user. Figure 1 shows an odometer mounted on an electric-powered wheelchair.

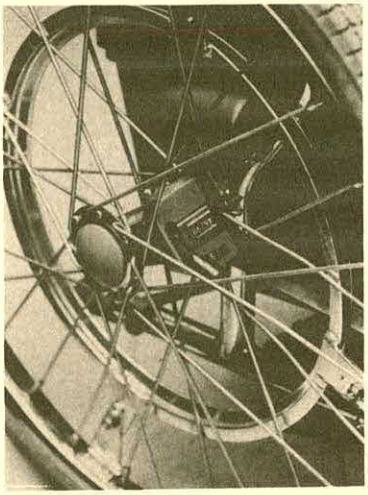

FIGURE 1. Wheelchair odometer, installed on an electric-powered wheelchair.

First example

As a clinical evaluation device, the odometer may be employed in at least two basic experimental strategies. The first strategy can be used with one patient at a time. While not absolutely rigorous experimentally, it can be employed with ease in a wide range of practical circumstances. This approach is termed a time series design (2) and employs the patient as his own control. The strategy is to attach the odometer to the subject's wheelchair and commence regular, periodic readings of the odometer's cumulative counter. Daily readings of the odometer will provide a measure of the distance the subject traveled in his wheelchair each day. This design requires continuous monitoring over long periods of time. A clearer picture over time is obtained by averaging out daily fluctuations. Thus, the data consist of average daily rates for each week. After a suitable baseline period of monitoring, the intervention is performed. The intervention may be a new wheelchair, some modification or innovation applied to the user's wheelchair, a new or different therapy program, a change in residence, or almost anything of interest to the researchers. The primary requirement is that the intervention being evaluated should have some impact on the subject's rate of simple mobility. Following the intervention, the monitoring of the odometer and daily rates of simple mobility continues. After a suitable period of time, the monitoring may be discontinued and the mobility rates (daily average for the weeks) before and after the intervention compared. The control data in this design are the subject's baseline rate of mobility before the intervention. If the intervention had some impact on the subject's actual functional mobility, then the rate of mobility following the intervention will be different than the rate before. Generally speaking, this design is quite powerful when used over long periods of time (months to years) and repeated with many subjects.

An example of this evaluation approach is presented in Figure 2. The data points are daily rates of distances traversed, averaged for a week. In every case, the weekly data points are averages of at least three daily figures. Also, in this case and for other purposes, each daily figure is the average of two odometers, one on each wheel. The data depict the simple mobility rate over a 47 week period from the life of a 23-year-old C 5-6 quadriplegic. The subject was hospitalized at the Texas Institute for Rehabilitation and Research (TIRR) three days following injury in August, 1974. Following a 17 week period of hospitalization for TIRR's comprehensive rehabilitation program, the patient was discharged in December, 1974. The patient recorded the daily odometer readings beginning in January, 1975. For the period of time until the last week of July, 1975, the subject lived with his sister in a typical suburban single family dwelling (house). During this period he resumed his pre-trauma occupation, computer technologist on a part-time basis. Late in July, 1975, he moved into a specially designed and constructed, barrier-free, multiple occupancy facility (apartment) across town. Primarily because of his newly acquired access to transportation arrangements, he resumed near full-time employment. The subject continued to record daily odometer readings until just before Christmas, 1975.

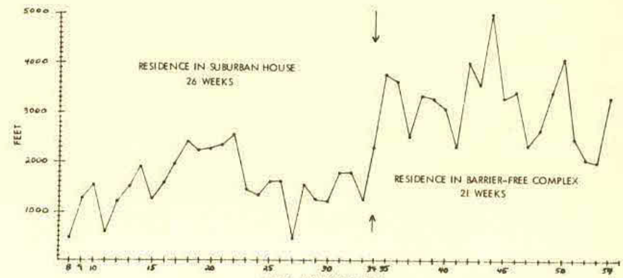

FIGURE 2. One patient's weekly rates of simple mobility for a year post-discharge.

As is clearly evident in the data, the subject's simple mobility rate increased by nearly 100% following the move (from a daily average of 1562 ft. to 3117 ft.). The variability or fluctuations from week to week in his mobility rate increased by approximately 50%. Without addressing the issue of causality for the moment, it is clear that the change in residence was associated with a dramatic change in this subject's rate of simple mobility. The specially arranged, barrier-free living environment allowed the subject greater mobility in the sense that he gained access to transportation arrangements, thus increasing his territorial range or environmental diversity. Concomitantly, his rate of simple mobility doubled. The increase in variability accompanying the change in residence can be interpreted as an increase in personal discretion exercised over functional mobility.

As a demonstration of the odometer's potential for providing evaluative data, the results need no further interpretation. Clearly, the odometer provides a powerful tool for evaluation when employed in the time series design. The precise interpretation of this specific set of data is much less clear. Single subject studies are not conclusive, only indicative. Although my own interpretation of these data is that this specially designed barrier-free living environment enhanced the rates of residents' simple mobility, the precise causal chains are not conclusively established. Since this particular subject is in many ways a research collaborator, I recently presented and discussed the data with him. His view of the barrier-free living arrangement is that it is an environment that demands high rates of simple mobility. He sees the environment as doing more than simply allowing greater freedom and personal discretion in mobility, it requires it. Whether or not the architects and designers of this facility had this demand feature in mind is an open question. Further, whether or not this effect is "good" from a clinical perspective is also an open question. In summary, however, it is clear that routinely employing the odometer on nonhospitalized subjects can provide an important and valuable aid to addressing specific evaluative issues as well as uncovering important research questions.

Second example

The second example of the use of odometer data as an aid to evaluation is more difficult to define precisely as an experimental design. In fact, the data were collected for other purposes and are not ideally suited for answering formal experimental or evaluative questions (3). However, the data captured what can be viewed as a natural experiment (4-7) and will be presented for illustrative purposes rather than as the result of an explicit evaluative design.

Table 1 summarizes demographic data for six patients hospitalized at TIRR for spinal cord injury. The patients were admitted over a 14 month period from May, 1974 to July, 1975.

TABLE 1

Patients' Demographic Data

Patient #	Age	Occupation	Level Injury	Date Injury	Date Admit	Date Discharge
30	17	Student	C-5	20 Apr 74	14 May 74	16 Aug 74
31	23	Railroad Engineer	C-4	13 May 74	28 May 74	7 Aug 74
33	23	Computer Tech.	C-5/6	11 Aug 74	14 Aug 74	4 Dec 74
34	16	Student	C-5	12 Feb 75	18 Feb 75	9 Jul 75
35	18	Truck Driver	C-4	4 May 75	30 Jun 75	17 Oct 75
36	19	None	C-5	28 Jun 75	10 July 75	10 Nov 75

All were males and all received the complete program of comprehensive rehabilitation offered by TIRR's regional spinal injury center. The patients had only an eight year range in age and were very similar in terms of level of injury (C-4 to C-5/6). The socio-economic status of the patients is not shown, but is also limited in range from upper lower class to solidly middle class. Only one was married and none had children. All had what could be considered a "good" structure of family and financial support. In summary, this group of six patients were all very similar along many of the dimensions thought to be relevant to SCI patients.

TABLE 2

Patients' Data Weeks

Patient #	# Wks Hospital	# Wks Odometer	Seq. Wk # Odometer
30	14	6	#8 - 13
31	11	5	#6 - 10
33	16	6	#9 - 14
34	20	9	#12 - 20
35	16	11	#6 - 16
36	18	8	#10 - 17
Total	95	45	

All of the patients had odometers attached to the wheelchairs they used during their periods of hospitalization. As soon as the patients commenced wheelchair activity, collection of odometer data began. Since the patients were generally bed-bound during the initial period of hospitalization, odometer data were obtained for roughly the last halves of the periods of hospitalization. Table 2 shows the weeks for which odometer data was collected for each patient. The data depicted in Figure 3 are weekly plot points. The odometer readings were recorded five times per week, Monday through Friday. The daily readings were used to calculate four individual weekday distances (Monday through Thursday) and a single three-day weekend figure. The four weekday distances were averaged to produce a figure that represented the average distance traveled per day for the four-day week. The three-day weekend distance was averaged to produce a figure that represented the average distance traveled per day for the three-day weekend. Thus, as seen in Figure 3, for each week of the patients' hospitalization, two average daily distance figures are presented, one for week days and one for weekends. In Figure 3 the weekend values are plotted between the corresponding weekday periods.

Viewing the weekly rates of simple mobility for this group of patients reveals that Patient #34 clearly had much more variability than the other patients; his data establish the maximum and minimum for the group, and his overall daily rate averaged across all weeks is over 1000 feet greater than the corresponding average of the other five patients. That is, Patient #34's daily rate of simple wheelchair mobility, averaged across his period of hospitalization was over 36% greater than the comparable average of the other five patients. Of the whole group of patients, only Patient #33 was ever capable of pushing his own wheelchair. All the rest of the patients had to have some other person push them around in their wheelchair as they moved from place to place in the hospital. All, that is, except Patient #34. During most of his period of wheelchair use, Patient #34 had access to and used an electric-powered wheelchair borrowed from another patient. Since Patient #34's use of an electric-powered wheelchair during hospitalization occurred serendipitously (that is, by chance one was available for him to borrow), this set of data reflects a natural experiment.

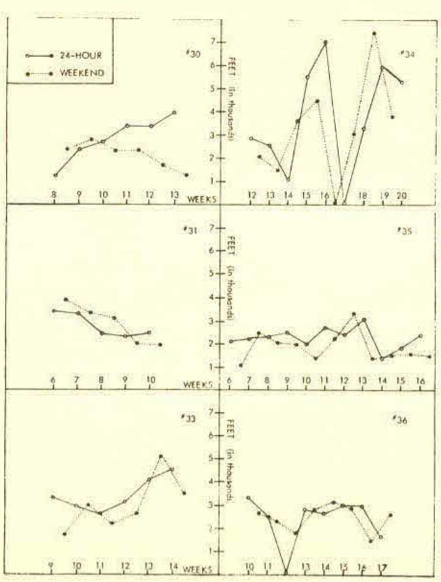

FIGURE 3. Inhospital odometer distances.

Viewing graphically the mobility rates during hospitalization for a group of patients similar in many respects supplies a figure and group perspective. The one patient most unlike the others in terms of mobility rates turned out to be the one who had access to and actually used an electric powered wheelchair. While it seems obvious that the use of an electric-powered wheelchair would have a dramatic effect on mobility rates, actual data of the sort presented in Figure 3 raise a series of important questions. For example, the noticeable dip at week 17 of Patient #34's graph corresponds to a urinary tract infection. This medical complication or setback occurred immediately after Patient #34 had achieved a remarkably high rate of mobility. During the week preceding the infection, (week 16), Patient #34 averaged over 7000 feet (over 1 1/3 miles) of transporting about the hospital per day. None of the other patients ever approached this rate. Whether or not there is some causal relationship between remarkably high activity levels and later medical complications is an important clinical issue. It is also interesting to note that the weekend values for Patient #34 seem to anticipate or lead the following weekday rate. While this phenomenon is not as clear in the plots for the other five patients, it does suggest that weekend activity may signal the activity for the coming week, another important research issue.

In summary, the purpose of presenting the data from these six patients was to demonstrate a second approach to using the wheelchair odometer as a clinical evaluation device. Had the introduction of electric-powered wheelchairs for use by quadriplegic in-patients been an explicit experiment by the clinical staff, it is clear that comparing mobility rates measured by the odometer would have provided important evaluative data. For experimental or evaluation purposes of this nature, the present set of data is less than ideal. However, the data do demonstrate the potential for evaluation purposes and raise some important research issues.

Summary

Arguing from the perspective that the purpose of many engineering innovations in mobility aids is to affect subjects' rates and patterns of mobility, it follows that measurements of subjects' actual rates of mobility are important criteria for evaluative purposes. Measurements of simple mobility provide data which illustrate the potential of the odometer as an aid to evaluation in rehabilitation.

References

1. Halstead, L.S. Wheelchair odometer: Method for quantitating patients mobility in wheelchairs. Archives of Physical Medicine and Rehabilitation, 1973, 54, 39-42.

2. Campbell, D.T. & Stanley, J.C. Experimental and quasi-experimental designs for research. Chicago: Rand McNally, 1963.

3. Alexander, J.L. The wheelchair odometer as a continuous, unobtrusive measure of human behavior. Masters Thesis, The University of Houston, 1977.

4. Campbell, D.T. Reforms as experiments. American Psychologist, 1969, 24, 409-429.

5. Cook, T.D. & Campbell, D.T. The design and conduct of quasi-experiments and true experiments in field settings. M.D. Dunnette (Ed.) Handbook of industrial and organizational psychology. Chicago: Rand McNally, 1976. Pp. 223-326.

6. Willems, E.P. Behavioral ecology and experimental analysis: Courtship is not enough. In J.R. Nesselroade and H.W. Reese (Eds.), Life-span developmental psychology: Methodological issues. New York: Academic Press, 1973. Pp. 195-217.

7. Willems, E.P. Behavioral Ecology, In D. Stokols (Ed.), Perspectives on Environment and Behavior. New York: Plenum Publishing Co., 1977. Pp. 39-68.

WHEELCHAIR ASSIST DEVICES FOR HANDICAPPED PATIENTS

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This paper describes two different prototype wheelchair assist devices for wheelchair bound persons. The first chair is designed for individuals who normally use a motorized chair even though they have good proximal muscle function in the arms. The device permits the person to utilize this residual strength to propel the chair mechanically, transforming linear arm movements into rotary motion with a special clutch and chain-drive mechanism. The second chair provides an alternative approach to standard and custom motorized chairs and features rechargeable batteries built into removable armrests and small electric motors attached to the brake levers which directly power the back wheels in tandem or individually. The chair can be readily collapsed and transported and weighs approximately 100 lbs. Both devices can be adapted in modular fashion to conventional wheelchairs. Physical, psychological and financial advantages of these two devices are described.

CATEGORY: Device Development [X] Research Study [ ]	INTENDED USER GROUP: Patients recovering from severe disabilities.
STATE OF DEVELOPMENT: Prototype [ ] Clinical Testing [X] Production [ ]	AVAILABILITY OF DEVICE: 12 months AVAILABILITY OF CONSTRUCTIONAL DETAILS: 12 months
AVAILABLE FOR SALE: Yes [ ] No [X] Price:	FOR FURTHER INFORMATION CONTACT: Lauro S. Halstead, M.D. T.I.R.R. 1333 Moursund Avenue Houston, Texas 77030

Introduction

Patients with compromised function of the lower and upper extremities from whatever cause are usually dependent on a wheelchair for their mobility. For such patients to be able to propel themselves, the design characteristics of most commercial wheelchairs require a combination of fair to good strength in the upper arms and sufficient dexterity and control in the wrists and hands to grasp the wheel or hand rim. As a consequence, independence in wheelchair mobility (self-propulsion) often remains an unrealized goal for many patients, especially persons with CNS injuries like quadriplegics with C 5-6 lesions or higher who have severely restricted use of their hands and wrists but good strength and function in their shoulders and upper arms. Although there are a number of adaptive devices currently in use, such as special rims and projections to enhance friction or provide better leverage, these are unsatisfactory for many patients and fail to make best use both functionally and mechanically of the residual motor power in the proximal muscle groups. As a result, many patients become more dependent upon motorized chairs than they would like and there is a consequent loss of the strength, endurance and general well-being which comes from increased activity and personal independence.

For those patients unable to propel themselves at all, currently available commercial motorized chairs are heavy, costly and cumbersome which for the active individual often impedes mobility rather than enhances it. Such chairs are difficult or impossible to load in a standard car, require two or more persons to lift, and cannot be stowed on airplanes because of potential battery explosions. The purpose of this paper is to describe two new wheelchair assist devices for handicapped persons which avoid some of these limitations. The first is a mechanical adaptive device which allows high quadriplegics and other patients unable to propel conventional chairs to become partially or totally independent in wheelchair mobility. The second is a conversion unit

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which transforms a standard commercial chair into a lightweight collapsible motorized chair safe for air travel.

Methods

The first device fits on the frame of a conventional chair and is protected from injury by the large back wheels. (Figure 1 and 2) The mechanism centers on an over-running roller clutch to transform the linear motion of the user's arms into rotary motion. A bicycle chain drive is used to provide the mechanical advantage necessary for a person to use the chair. By changing the sprocket ratios the mechanical advantage can be modified to fit the changing needs of the patient. The present version provides forward and reverse with a constant mechanical advantage. In the next generation, it is envisioned that a multiple speed transmission will be incorporated and provide the rider with the ability to change the mechanical advantage as the need for speed versus force changes during transit.

Figure 1.

The second device is a conversion unit that transforms a conventional manual chair into a motorized chair. (Figure 3 and 4) The conversion kit consists of two electric motors that are attached to modified brake levers, two battery packs that replace the conventional removable armrests and two battery rechargers. The converted chair uses a tractor-type steering system, each wheel is controlled by a lever and by energizing the wheels in various combinations, it is possible to steer the unit. By removing the battery packs, as one would remove the armrests (each weighs approximately 24 lbs.). The chair can be collapsed and stored like any standard chair. Total weight for this chair is less than 100 lbs. versus 150 lbs. or more for the regular motorized chair.

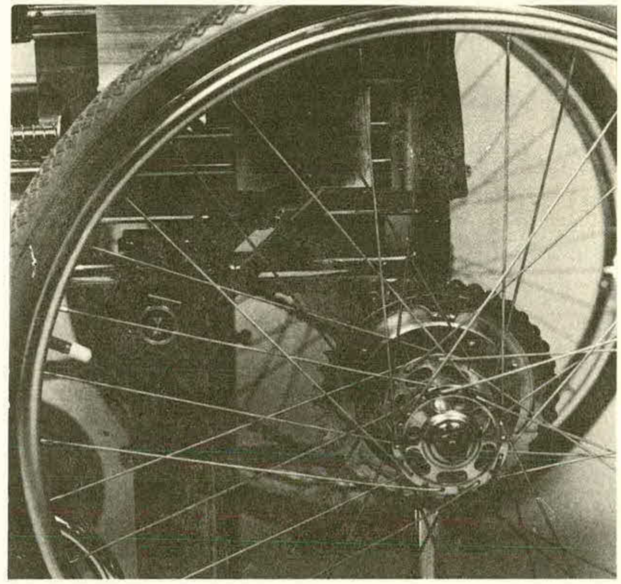

Figure 2.

Results

The first device has been designed, built and evaluated in a clinical setting. Preliminary results indicate that the principle employed is feasible mechanically and acceptable to patients who have tested it for one to two weeks at a time. Additional results will include a fuller description of a systematic clinical evaluation. For five subjects, a comparison will be made with patients using the mechanical wheelchair and the best alternate commercial model presently available. Comparisons will be made using the following parameters: (1) total distance the patient is able to propel himself on both smooth (linoleum) and rough (pile rug) surfaces; and (2) distance traveled in 30 seconds, 60 seconds and five minutes on each surface; and (3) energy expenditures as determined by oxygen consumption rates during (1) and (2) above.

Figure 3.

A conversion unit that transforms a conventional manual chair into a motorized chair has been built and extensively tested by one patient who prefers it to his regular motorized chair, especially when traveling. Critiques of this chair include loud motor noise and heavy armchair batteries which have led to several design changes that will be incorporated in the next prototype.

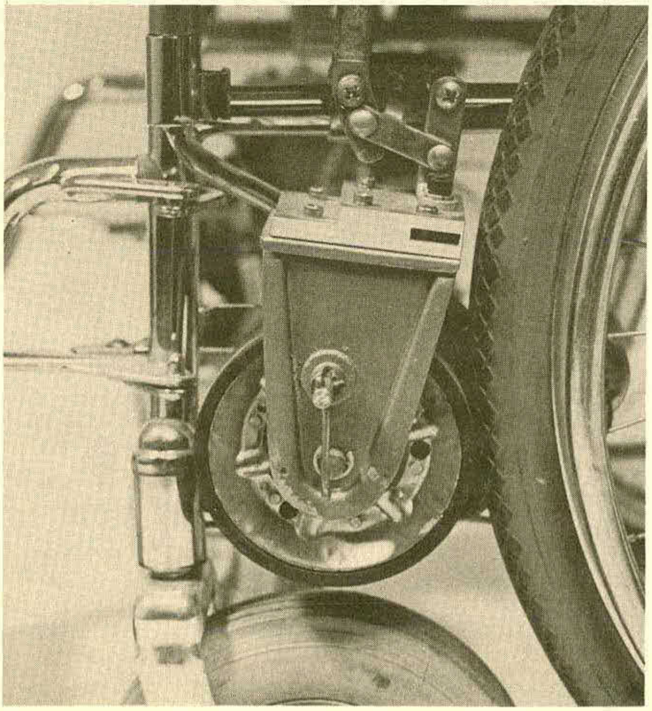

Figure 4.

Discussion

The development of assistive devices which can be attached to standard wheelchairs addresses itself to one of the most important areas in the rehabilitation of the severely disabled, namely the problem of mobility. Preliminary results described here suggest that these two devices directly enhance the wheelchair-dependent individual's functional capability by allowing him more independent wheelchair mobility. The extent to which a client is able to increase his own capacity to propel himself whether at home, school, or work is directly related to both a physical and psychological sense of self-sufficiency and decreased dependency on others. In view of this, it is not unrealistic to expect that such devices will enhance a person's employability and in the case of the manual assist device, help patients increase and maintain general strength in the upper extremities improving overall conditioning and well-being which could then lead to the ability to operate safely automotive adaptive equipment and minimize development of medical complications. In the area of cost containment, these devices would allow some patients to become completely independent of expensive motorized wheelchairs or simply reduce the amount of time they are used.

Both devices described in this paper provide consumers with operating characteristics currently not available on the commercial market. Preliminary experience with both types of chairs suggest there is a fairly large group of consumers who will find them more suitable than the standard chairs for their mobility needs and capabilities. A major problem in having these devices utilized lies in finding appropriate manufacturing and retailing resources.

FUNCTIONAL INDEPENDENCE FOR HIGH-LEVEL QUADS WITH A "TALKING MOUTHSTICK AND "PERIPHERAL" EQUIPMENT

Arthur Heyer*
Rancho Los Amigos Rehabilitation Engineering Center

The author describes the development and use of five pieces of equipment that has enabled him to function 100% independently in an office situation, in spite of his C-4,5 quadriplegia. He will show how properly designed equipment can liberate a highly disabled individual from his/her handicap for work and to make him/her functional and productive.

CATEGORY:	INTENDED USER GROUP: Quad
Device Development ☒ Research Study ☐	AVAILABILITY OF DEVICE:
STATE OF DEVELOPMENT:	
Prototype ☐ Clinical Testing ☐ Production ☒	AVAILABILITY OF CONSTRUCTIONAL DETAILS:
AVAILABLE FOR SALE:	FOR FURTHER INFORMATION CONTACT:
Yes ☒ No ☐ Price:	Extensions for Independence 12501 Old River School Rd., #9 Downey, California 90242

Introduction

The author has designed and has had built many devices used in his work surroundings. The following are but a few which will be described: (1) "talking" mouthstick, (2) mouthstick attachments, (3) twin-turntable desk, (4) portable desk, and (5) drafting machine for mouthstick users.

The "Talking" Mouthstick

This mouthstick is designed to be held firmly with the back teeth while allowing the user to work, talk, and swallow with no difficulty. It is constructed out of a single length of aluminum angle making it lightweight and sturdy. A mouthpiece has been designed that can be gripped with the molars on both sides, yet leave room in the middle for free movement of the tongue and a free path in between the front teeth for air flow. It consists of two, flat prongs arranged in a V-shape which are tapered in thickness to the end, following the natural bite angle. This eliminates a concentration of biting pressure at the tip of the prongs when clenching the mouthstick between the maxillary and mandibular molars.

The angle construction of the mouthstick provides an ideal receptacle for a base tool, such as a pen or mechanical pencil, that can be attached to the tip of the mouthstick with use of a small hose clamp. For independent interchange of additional tools, a system of attachments has been designed.

Mouthstick Attachments

The attachments are made of thin-walled aluminum cylinders into which the pen or mechanical pencil fits snugly. Into the other end of these attachments, different tools can be inserted. The attachments can be pulled off or pushed onto the pen by means of a two-step docking procedure. The docking procedure consists of inserting (through the lateral movement) the attachment into a fixed clamp and pulling out the

* Final editing by 5th CSDD. The author works as a rehabilitation consultant, design engineer and as an administrator of his own company.

pen. Needless to say, any number of tools can be made easily and independently accessible to the mouthstick user with this system. A rack (Figure 1) with several clamps will provide a multiple receptacle unit for an equal number of tools.

Figure 1. Interchanging Tools

Twin-Turntable Desk

Turntable desks have become essential aids for independent function at work and home. It is ideal for persons with limited reach since it provides easy access to a number of things by just rotating it. They are supported by ball-bearings, making them easy to turn even under a heavy load. In extreme cases of weakness, they can be driven with an electric motor operated by a microswitch.

A twin-turntable (Figure 2) has been designed offering the advantage of simultaneous access to two things. There is a fixed surface between the two turntables which is excellent for writing notes.

Figure 2. Twin-Turntable Desk

This type of desk, now commercially available, has been designed modular to fit most needs. The legs are detachable and extendable for height adjustment. Extension tables, for extra working surface, can be attached to either side of the desk. On one of the extension tables, a special telephone adapter for quadriplegics can be placed.

The "universal" telephone adapter (Figure 3) is designed to operate with practically any type of telephone or speaker phone. It consists of a gooseneck holder for the receiver and an operating mechanism for disconnecting or connecting the telephone. The telephone and the adapter form a self-contained unit that can be moved where it is needed.

Figure 3. Telephone Adapter

Portable Desk

At the office, the twin-turntable desk is useful for handling large volumes of work efficiently and with no assistance. To do some of the work when away from the office, a portable desk has been constructed that easily latches onto a lapboard. The portable desk is designed so that it can be taken or left behind independently. To facilitate this, the lapboard is equipped with tracks and the main desk (twin-turntable) with a docking fork. With the use of automatic latches, the portable desk is retrieved or parked just by driving into the docking fork (Figure 4).

Figure 4. Docking with Portable Desk

The portable desk is basically a box whose top slides to either side. A built-in ramp is used to bring things out onto the desk's top (Figure 5). Attachments on top of the desk are used for several items. For example, a folding ramp allowing the transfer of things from the top of the portable desk to the main desk. Another is for a drafting aid for drawing straight lines (Figure 6) that also serves in transferring books from the portable desk to a book shelf (Figure 7).

Figure 5. Using Built-In Ramp

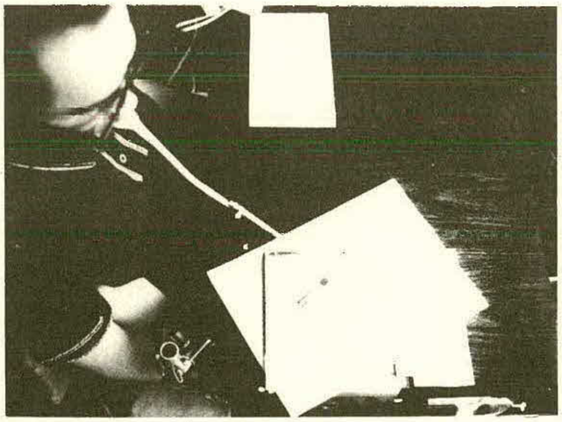

Figure 6. Straight-Line Drafting Aid

Figure 7. Transferring Books with the Dual Straight-Line Drafting Aid

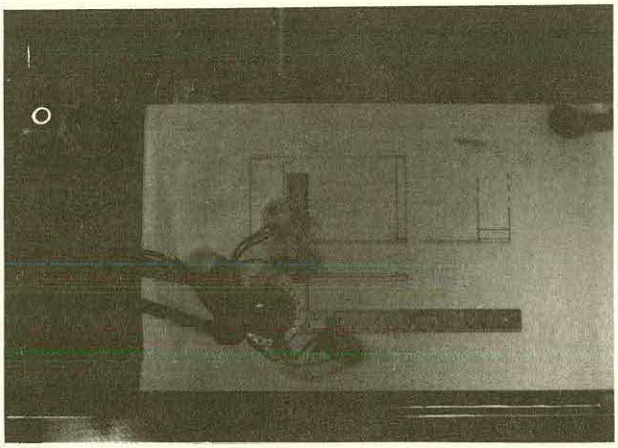

Figure 8. Heyer-Abadie Drafting Machine

Heyer-Abadie Drafting Machine

The Heyer-Abadie drafting machine was developed to enable a quadriplegic working with a mouthstick to make mechanical drawings. The mouthstick is the only means needed to sketch in free style or make a mechanical drawing with the Heyer-Abadie drafting machine. Necessarily, the machine can be used by a handicapped individual capable of manipulating a pencil. All functions on the machine can be performed with less than sixteen ounces of force.

The machine consists of a small board with conventional drafting arms, scales and protractor (Figure 8). By means of incorporating three electromagnets, three conventional switches, one dual function switch and a steel plate, the normal functions of a conventional drafting machine can be performed by the aforementioned quadriplegic using his mouthstick. The board is intended for use in a slanting position. In addition, there are provisions for moving a fresh sheet of paper into place when needed.

Electromagnets are used to hold the scales against the paper when drawing a line. To move the scales to a desired position, the operator inserts the end of his pencil into a special lever which operates a switch for de-activating the electromagnets. With this mechanism, the user can disconnect the electromagnets and at the same time slide the scales across the paper. The machine is also provided with a mechanism for independent changing of the angle of the rulers and for moving a fresh sheet of paper into place when needed.

Concluding Remarks

Satisfying the many needs of a severely handicapped individual presents countless challenges to engineers and other scientists of our society.

Acknowledgements

I owe much to my father who invented the basic tools for me to start my way back to an independent, productive function; to members of the staff at Rancho Los Amigos Hospital Rehabilitation Engineering Center who built a work station and other aids for me to work independently; and to Henry Abadie, a volunteer whose talent and determination have been the key to the development of very meaningful devices for the disabled.

References

1. Responaut (English Rehabilitation Journal): Quad Engineer Puts Talent to Work, September 1972.

2. Rehabilitation Gazette (American Reh. Journal): Engineering, Volume XIV, pages 32-33, 1971.

3. Rehabilitation Gazette: Liaison Engineer, Volume XVIII, page 17, 1975.

4. Rehabilitation Gazette: Preparing Quads for Independent Living, Volume XIX, page 31, 1976.

ENVIRONMENTAL AND TYPEWRITER CONTROL SYSTEMS FOR USE BY HIGH LEVEL QUADS: THE SUITABILITY OF VARIOUS ASPECTS AS DETERMINED THROUGH EVALUATION

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Some preliminary functional requirements for environmental and typewriter control systems have been identified as one result of a completed 3-year clinical evaluation. The requirements reflect what a consistent group of 39 high level quadriplegics find to be the essential characteristics of such devices. The compiled requirements should assist with design of devices which will meet population needs rather than individual needs. In addition, the requirements should facilitate design of devices which meet actual needs rather than needs projected by designers, manufacturers, and other non-consumers.

CATEGORY:	INTENDED USER GROUP: High level quadriplegics
Device Development ☒ Research Study ☐	AVAILABILITY OF DEVICE: Not applicable
STATE OF DEVELOPMENT: Prototype ☐ Clinical Testing ☒ Production ☐	AVAILABILITY OF CONSTRUCTIONAL DETAILS: Not applicable
AVAILABLE FOR SALE: Yes ☐ No ☒ Price:	FOR FURTHER INFORMATION CONTACT: Above authors

Introduction

The commercial market for devices for the severely disabled always has been, and always will be, numerically limited. However, an extra artificial limitation exists in that, often, device design appears to have been directed to the solutions of the problems of one or two patients rather than to that of a large diagnostic group. Among factors which perpetuate this reality is the lack of established functional requirements which reflect the needs and desires of specific populations. As one result of a recently completed 3-year evaluation project, we have had an opportunity to identify some functional requirements for certain types of devices for use by our test population, the high level quadriplegic.

Although evaluated equipment included environmental, vocational, and mobility devices, this report is limited to a brief discussion of findings which reflect what the high level quad considers to be functional requirements for environmental and typewriter control systems. More extensive findings for these and other commercial and prototype devices tested will be published in a monograph in the near future.

Advantage of Method

Although all patients (39) did not test all devices, most patients did test the majority. This resulted in patients becoming "informed consumers" who could comparatively "shop." In this case the typical consumer was a male of college age with a C-4 level of lesion. Our setting for comparative testing by a consistent population was very possibly the first time that many of the commercial units were ever compared to any other device by the same patients.

Results

Findings have proven to be a volume of positive and negative findings which have emphasized the strengths and weaknesses of the specific units. Findings were categorized into common groups and three major divisions identified: operation, performance, and construction. Subdivisions determined within each group

Table 1. FUNCTIONAL REQUIREMENTS with Comparative Evaluation Findings

CATAGORY	ENVIRONMENTAL									TYPEWRITERS			
MODEL	PSU-1	NuLife	F.C.C.S.	Robot	ECU-1	ECU-2	Genie	TOSC-2	ADT-5A	HiSpeed	Scanner	Printer	Minimum
OPERATION													
Easily learned	+	+	+	+	+	+	+	+	+	-	+	-	+
Easily operated	+	+	+	-	+	+	+	+	+	-	+	-	+
Accurately operated	+/-	+	-/+	-	+	+	+	+	+	-	+	-	+
Non-time consuming	-	+/-	+	-	+	+	+/-	+/-	+/-	-	-	-	+
Non-interferring with other activities	+	+	-	-	+	+	+	+	+	+	+	+	+
Appliances operable by family,others *	-	+	+	-	+/-	+/-	-	+	+/-	+	+	-	-
PERFORMANCE													
Provides desired functions	+	+	+/-	-	+	+	+/-	+	+	-	-	-	-
Reliable	+/-	+	-	+	+	+	+/-	+	+	-	-/+	-	-
Safe **	+	+	+	+	+	+	+	+	+	+	+	+	+
CONSTRUCTION													
Easily positioned, stored	-	-	+	-	+/-	-/+	+/-	+	+	-	-	-	-
Easily electrically installed	-	-	+	+	+	+	+	+	+	+	+	+	+
Unobtrusive presence	+/-	+/-	+/-	+/-	+/-	-	-	+	+/-	+	-	-	+
Easily transported	-	-	+	+	+	+	+	+	+	-	-	-	-
Easily maintained	-	.	-	+	+	+	+/-	+	+	-	-	-	-
Easily modified	+	-/+	+	+	+	+	+	+	+	.	.	.	.

* Non-patient interface ** Clinical results--not electrical compliance testing . N.A.

have permitted construction of a framework of functional requirements (Table 1) which reflects what patients find desirable in environmental and typewriter control systems. The comparative ratings of the commercial devices are presented to illustrate the diversity of findings.

Operation requirements

Patients consider that the "ideal" device would be one which could be easily, accurately, and rapidly operated and would require a minimum of practice to become almost "habit."

No one mode of operation was considered to be essentially superior or suitable for all applications. Direct selection (PMV Minimum Typewriter) was considered especially preferable when a large number of possible selections were available. Stepping modes were considered preferable when the number of possible selections was not greater than 15 and repeated use of a specific channel (page turning, channel changing) was a functional expectation. They were therefore more acceptable for environmental units than for typewriters. The automatic sequencing modes (Genie, PMV Printer) were not preferred as accuracy required increased concentration and the method was perceived as time-consuming. Sequencing which can be interrupted and held on a specific function (Nu-Life) was considered more acceptable, although somewhat greater in requirement for concentration than the stepping mode and, again, somewhat time-consuming. Automatic recycling to a starting point after a one-time activation (PSU-1, Scanner) was considered time-consuming and especially undesirable for operation of frequently repeated functions. Most unpopular of those tested were the encoded modes (Robot, Possum Hi-Speed Typewriter). Accuracy of operation was unsatisfactory and they were considered especially undesirable when a high number of possible selections were required thus increasing the complexity of the code.

Patients usually preferred interfaces which were easy to operate, utilized a remaining function of the lowest intact cervical level, and required inputs that the individual could produce in a sufficiently consistent manner to result in a satisfactory operation.

Patients generally liked the availability of various types of feedback of the operational processes of all devices in order that the functions be more easily, accurately, and quickly accomplished. Visual displays were desired for use during periods that viewing the display was convenient, such as out-of-bed. Auditory feedback was considered essential to provide an opportunity for total non-visual operation during periods when viewing a display was inconvenient or to provide the opportunity for concealed storage of the device for aesthetic purposes. Auditory feedback was also considered to be a useful supplement to observation of visual displays as it permitted faster scanning rates with neither a decrease in accuracy nor an increase in required concentration.

Performance requirements

Patients consider it essential that devices perform desired functions and do so in a reliable and safe manner.

Typewriter systems should provide full control of the keyboard and all functions, paper feed and withdrawal capabilities, and provide the opportunity for independent production of error-free typing copy.

Telephone capabilities which have been desired for home use have been call answering, total digit dialing and both confidential or speakerphone listening/speaking. Desired for vocational applications was the additional capability for multi-line operation.

A general overview of the desired non-telephone functions of the environmental systems indicates that the specific interests of each patient dictates what he does or does not wish to control. There is a desire for an assortment of on/off line power and low voltage control channels in a presently undetermined distribution. Currently most patients are desiring line power plug-in channels for control of a bedside lamp, desk lamp, radio, tape-recorder, and non-remote control television. Low voltage circuits are most often desired for operation of an assistance call, electric bed, remote control television, intercom, door lock, and page turner.

The electrical and mechanical performance desired by the population was that of total dependability. Patients became acutely aware that those devices which provide increased opportunities for privacy, such as telephones and intercoms, are especially critical when reliability is considered. Failure of control of these communication links results in isolation which is not only frightening but is also a safety hazard.

Construction requirements

Patients feel that a device should be constructed so that it is unobtrusive, easily maintained, and readily usable within any environment.

Small, compact packaging which permits easy positioning is preferred. Modularization which permits visual displays to remain in view and control components stored out-of-view is preferred over consolidated packaging. Attractive packaging which blends harmoniously with both home and work environments is desired.

There is a need for units to require no greater installation than that which can be easily supplied by family members or attendants. Easily transported units are preferred over fixed installation style designs.

Patients find flexibility important in order to provide inexpensive opportunities for modification and/or expansion of the unit. They found it difficult to project what they would definitely want to be able to control immediately post-discharge and did not want to be "locked into" a fixed scheme. Patients especially preferred units which permitted the connection of various types of interfaces and preferred that more than one interface could remain always connected. This was to provide an opportunity to use one type of interface out-of-bed and a second type in-bed. Patients felt it would be optimum if the interface from one company's device would be of suitable design to immediately connect to another company's device.

While patients did not expect that a piece of equipment might never break down, they did expect that service would be available, preferably on a warranty basis, and would be provided in a prompt, courteous, and reliable manner. Patients and staff agree that the most desirable alternative to a "never-fail" device would be immediate on-site repair. As this is an unrealistic solution, a satisfactory alternative would be a provision for prompt loan of substitute equipment for use during any required manufacturer repair period.

Conclusion

Our 3-year investigation has provided information suitable for a variety of applications, including device prescriptions[1] and device improvements. However, it is anticipated that the most enduring will be as an input into the formal establishment of functional requirements for electronic devices. Such work is currently underway in our recently established Rehabilitation Engineering Center. It is reasonable to expect that devices which are designed to meet such requirements will fulfill the needs of a typical group of quads better than any current devices. This should result in the reduction of unnecessary customization for "standard" needs. And concurrently, expand the commercial market with the potential for lower prices for more reliable and functional devices

References

[1]Sell GH, Stratford CD, Zimmerman ME, Youdin M, Milner D: Electronic Equipment for High Level Quadriplegics: Evaluation and Prescription. American Academy of Physical Medicine and Rehabilitation, 39th Annual Assembly, Miami, Nov. 2, 1977 (in press).

Acknowledgements

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.

WHEELCHAIR DYNAMOMETER DEVELOPMENT AND UTILIZATION

J. R. O'Reagan and J. G. Thacker
University of Virginia

A wheelchair dynamometer was designed and built for use at the University of Virginia Rehabilitation Engineering Center. This instrument can be used to evaluate wheelchair patient physical workload during wheelchair propulsion. When used in conjunction with metabolism measuring instruments the dynamometer becomes an ergometer useful in analyzing a wide variety of parameters involved with wheelchair ambulation. The apparatus is designed to be used by handicapped patients propelling a variety of wheelchairs. Measurements of wheelchair patient activity can be easily taken during travel over simulated terrain.

CATEGORY: Device Development ☐ Research Study ☒	INTENDED USER GROUP: Wheelchair-bound Population
STATE OF DEVELOPMENT: Prototype ☐ Clinical Testing ☒ Production ☐	AVAILABILITY OF DEVICE: Instrument is completed and located in Charlottesville, Virginia 22903 AVAILABILITY OF CONSTRUCTIONAL DETAILS: Immediately
AVAILABLE FOR SALE: Yes ☐ No ☒ Price:	FOR FURTHER INFORMATION CONTACT: Rehabilitation Engineering Center, P. O. Box 3368, University Station

Introduction

A number of federal programs have been established to apply the advances in technology to the needs of the physically handicapped population. One such program has led to the establishment of rehabilitation engineering centers throughout the country. These centers combine the disciplines of medicine, engineering, and related sciences in order to achieve a multidisciplinary approach to solving problems for the handicapped.

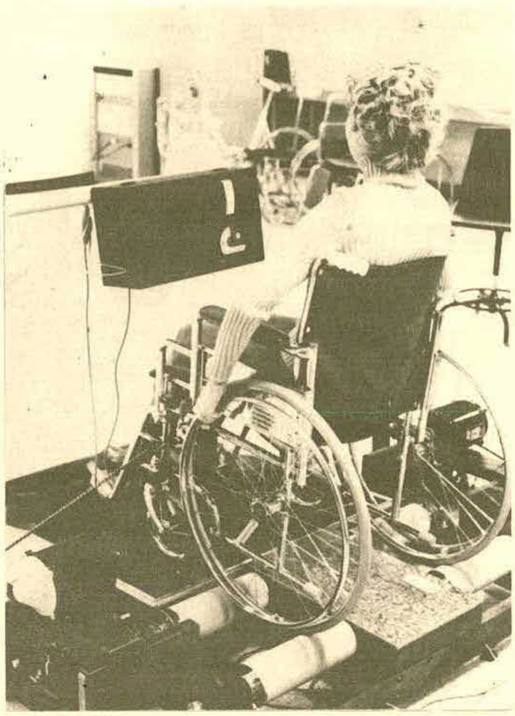
Development

Each center has been charged with a core area of research. The University of Virginia Rehabilitation Engineering Center concentrates on the general subject area of wheelchair mobility. To this end, a wheelchair propulsion laboratory has been established to study the mechanics of wheelchair propulsion. Therefore, an instrument was needed to accurately measure and record torque and power produced by a patient while he propels a manual wheelchair against controlled loads. The design objectives for this instrument are that it can accurately measure patient power (0-200 watts) and provide reliable measurement of input torques for wheelchair speeds of 0.20 KPH and above. It must be able to test different types of wheelchairs with varying drive wheel diameters and wheel base width and it should maintain a constant torque load during speed fluctuations. Other objectives are that the instrument simulate the acceleration characteristics of different wheelchairs and monitor the right and left-hand wheelchair drive separately. It should be sufficiently stable to support the wheelchair and the occupant and permit adjustment of the wheelchair support angle to simulate different grades. It is desirable to allow the left and right side wheels to turn either separately or together and it must measure the simulated distance traversed. The instrument should permit loading and unloading of both the patient and chair easily and safely and be able to maintain a constant work load as an optional, operational mode. Finally, it should display patient speed and direction of travel and be semi-portable.

An instrument that meets all of the previous criteria was designed for the University of Virginia, Rehabilitation Engineering Center and is called a wheelchair dynamometer.

Construction

The actual performance of a wheelchair patient is observed by placing the patient on the dynamometer with the rear wheels of his wheelchair riding on a pair of aluminum rollers (fig. 1).



.Fig. 1-Subject Evaluation on Dynamometer

These rollers are connected to two automobile alternators that serve as a means to apply a resistive torque load to the patient. The dynamic feedback that maintains a constant torque load to the test subject is produced by first mounting the housing of the alternator in such a way that it is free to turn in trunion bearings. A cantilever beam is attached to the housing and strain gages are fixed on the beam. A signal is produced by these strain gages when the rotor, which is connected to the rollers, is electro-magnetically coupled to its field windings. Since the windings are part of the alternator housing, this coupling generates a torque that bends the cantilever beam. This in turn gives a signal from the strain gages that is proportional to the torque produced. The output torque indicated by the strain gages is electronically compared to a desired torque, and circuitry then adjusts the field current to the alternator to achieve the desired torque. Adjustable dashpots are also connected to the alternator housing to avoid control instabilities.

The inertia inherent in the system was kept at a minimum so that a child in a wheelchair could be evaluated on the dynamometer. The equivalent inertia of a patient-chair combination can be accommodated for patient weight from 70 to 250 pounds simply by adding various size steel disks to each pair of rollers.

Each size wheel on a wheelchair as well as each type of actual tire will produce a different kind of rolling resistance. Therefore, constant-torque motors were added to the dynamometer to zero out the variations. By adjusting the torque motors so that the wheels of the wheelchair (with the patient in the chair) are just on the verge of turning, one can set a base line so that each patient's performance can be correlated. This procedure also gives an indicaticn of the variations in rolling friction due to tire size, type of tire and patient weight which will be useful in the evaluation of various wheelchair systems.

Furthermore, by adjusting the screw jacks on the loading platform one can spatially orient the test subject to represent the shift in the center of the gravity of the patient-chair system due to ambulation up an incline.

Speed, distance and direction of travel are all in a display visible to the test subject. The speed and direction of travel are taken from tachometer generators connected to the rollers. The equivalent distance travelled is obtained by means of a slotted disk interruping a photo-diode module which in turn generates a pulse that is counted and digitally displayed in meters.

In addition, for a test situation, a constant-power mode is available by interfacing the alternator output with the tachometer generator output in the feedback circuit.

Utilization

The wheelchair dynamometer serves as the instrumental core of a wheelchair propulsion laboratory at the University of Virginia Rehabilitation Engineering Center. Here the stated objects are to determine the parameters of optimal manual wheelchair performance as a function of patient need, patient capacities and wheelchair design. A primary interest will be propulsion efficiency which can be determined from the ratio of work output to energy cost for propelling a wheelchair. The energy cost will be assessed by a metabolic measurement system that makes use of a Bechman ® Metabolic System Cart while the dynamometer will measure the work performed. Manual wheelchair performance, as indicated by the propulsion efficiency, can then be evaluated for the effect of user conditioning, arm and trunk motion, differing mechanical drive systems, and a variety of exercise routines. A video computer system will be used to gather positional data of the upper limbs during propulsion. The results of testing at this laboratory should lead to an evaluation of the human and mechanical factors that contribute to the efficiency of the man-machine system.

The dynamometer is particulary suited for testing the energy cost of maneuvering on various terrains. Since the dynamometer can provide a constant retarding torque to the wheelchair user, different torque settings on the dynamometer correspond to various terrain conditions. Once resistive torque values have been obtained for real-life environments, test subject's ability to propel over a variety of terrains can then be evaluated without the subject ever moving from the laboratory.

In the future, a particular setting on the dynamometer controls might represent either 1.) a 3° slope of smooth concrete, 2.) a 1.5° slope of loose gravel 3.) a 2° slope of asphalt, or 4.) a flat floor covered with a thick carpet. Since each wheel resistance can be varied independently the dynamometer can effectly simulate a slope in two directions such as a slanted sidewalk on a hill. The odometer can indicate the distance travelled over an simulated terrain. Therefore, a patient could be tested against a duty cycle that involved a variety of surface conditions, each for a specified distance. Test of this nature could provide a therapist with a quick method of determining how a newly wheelchair-bound person is progressing towards desired goals. These desired goals would probably be based on a distance and type of terrain a person would expect to experience in his day-to-day life. Similar duty cycles could be employed to test the characteristics of different electric-powered wheelchairs.

The dynamometer will also be useful for the development of more efficient wheelchair designs, the more effective prescription of existing wheelchairs, and contingency feedback for increased patient motivation.

Acknowledgement

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References

1. Brattgard, S.O., Grimby, G. and Hook, O. Energy expenditure and heart rate in driving a wheelchair ergometer. Scand. J. Med., 1970, 2, 143-148

2. Engel, P. and Hildebrandt, G. Long term spiroergometric studies of paraplegics during the clinical period of rehabilitation. Paraplegia, 1973, 11, 105-110.

3. Engel, P. and Hildebrandt, G. Wheelchair design - technological and physiological aspects. Proc. Roy. Soc. Med., 1974, 67, 409-413.

4. Hildebrandt, G., Voight, E., Bahn, D., Berender, D. and Kroger, J. Energy cost of propelling wheelchairs of various speeds: cardiac response and steering accuracy. Arch. Phys. Med. Rehabil., 1970, 51, 131-136.

5. Lehamn, J., Warren, C., Halar, E., Stonebridge, J. and Delateur, B. Wheelchair propulsion in the quadriplegic patient. Arch. Phys. Med. Rehabil., 1974, 55, 183-186.

6. Peizer, E., Wright, D., and Frieburger H. Bioengineering methods of wheel chair evaluation. Bull. Pros. Res., 1964, 77-100.

7. Stoboy, H., Rich, B.W., and Lee, M. Workload and Energy Expenditure During Wheelchair Propelling. Paraplegia, 1971, 8, 223-230.

8. Voight, E.D., and Bahn, D. Metabolism and pulse rate in physically handicapped when propelling a wheelchair up an incline. Scand. J. Rehabil. Med., 1969, 1 (3), 101-106.

9. Zwiren, L. and Bar-Or, O. Responses to exercise of paraplegics who differ in conditioning level. Med. Sci. Sport, 1975, 7, 94-98

KINEMATIC ANALYSIS OF QUADRIPLEGIC PERSONS USING POWERED RECLINING WHEELCHAIRS

C. Gerald Warren, Michael Ko & Edward Delahanty

Persons who are severely paralyzed often use reclining wheelchairs to allow them to rest and relieve areas of pressure concentration during their daily activities. Repeated cycling of currently-available wheelchairs, however, causes shifting of body segments in the chair and wrinkling of clothing, as well as producing areas of pressure concentration and skin irritation. This study evaluated the use of sliding seat and sliding back mechanisms to determine their effectiveness in reducing displacement of the body during recline and to determine the effective axis of body rotation. The data shows the sliding seat mechanism to be relatively ineffective at reducing these problems. The sliding back was more effective, while the combined use of the sliding seat and sliding back produced the greatest reduction in thigh displacement. Research was continued to determine the location of the apparent center of rotation of the body. Once this is determined, a hinging mechanism will be developed to alleviate the problem without interfering with transfer activities.

CATEGORY:

Device Development ☐
Research Study ☒

STATE OF DEVELOPMENT:

Prototype ☐
Clinical Testing ☐
Production ☐

AVAILABLE FOR SALE:

Yes ☐ No ☒
Price:

INTENDED USER GROUP:

Severely Paralyzed Individuals

AVAILABILITY OF DEVICE:

Not Currently Available

AVAILABILITY OF CONSTRUCTIONAL DETAILS:

Not Yet Available

FOR FURTHER INFORMATION CONTACT:

C. Gerald Warren, BB-805 H.S.B., RJ-30
University of Washington, Seattle, Wn.
98195

INTRODUCTION:

People who are quadriplegic or otherwise severely paralyzed often require reclining wheelchairs to be able to function independently for significant periods of time. Many of them have complained about problems encountered with repeated cycling of their reclining mechanisms. Frequently these recliners cause shifts in the user's sitting posture, putting them in uncomfortable or unstable positions, as well as wrinkling clothing, causing areas of pressure concentration, and sometimes triggering severe muscle spasms. A previous study [1] found significant substantiation to these complaints, showing that considerable shear forces and displacements resulted from repeated cycling of conventional recline mechanisms. The study determined that relocating the axis of rotation of the chair could significantly reduce both these shear forces and the resulting displacements. However, because the human body does not rotate about a single point when pivoting at the hip, it is not a simple matter to determine the effective axis of rotation of the body. Thus this was pursued as a subject for further research.

Subsequently, a manufacturer designed a powered sliding seat mechanism to resolve some of these problem areas. This system, which is now commercially available, was also evaluated to determine its effectiveness at resolving these problems. The method for evaluating the effective center of rotation of the body required the use of a newly-designed sliding back mechanism, which was also evaluated to determine its effectiveness at reducing body motion in the chair during recline.

METHODOLOGY:

An Everest & Jennings powered reclining wheelchair (the Independence Recliner) was used in the study. This chair had a powered sliding seat mechanism installed by Falcon Research Corp, which moved the seating surface 3 cm to the rear during the full recline of the chair. In addition, the chair back was modified to incorporate a low-friction, counterbalanced sliding back mechanism. The chair was instrumented to measure the angle of recline of the back, the position of the sliding seat, the position of the sliding back, and the position of the thigh of the user with respect to the seat. The sliding back and seat were constructed and adapted so that either or both could be fixed during the evaluation. This resulted in a reclining wheelchair which could be used in any of the following configurations:

1. Fixed back and fixed seat.
2. Fixed back and sliding seat.
3. Sliding back and fixed seat.
4. Sliding back and sliding seat.

Positions and angles were measured by rotary and linear potentiometers. The output signals were amplified, multiplexed, converted to digital form, and were recorded by an on-line digital computer. The computer was then used to process the data, to plot curves of displacement vs back angle, and to calculate the centers of rotation of the body.

The subject used for the experiment was a C-5 quadriplegic person who has minimal spacticity. Before each run he was placed in the wheelchair on a ROHO cushion and was moved as far to the rear of the seat as possible to establish a typical and repeatable sitting position for him in the chair. The ROHO cushion was selected as the most likely cushion for such a person to use. The chair was then cycled up and down in each of the configurations mentioned above at least seven times, while taking data on the chair and on the position of his thigh with respect to the seat. When the sliding seat moved, its displacement was recorded; and when the sliding back moved, its displacement was measured. In all cases the angle of the back was recorded. In each of the configurations, if the subject was permanently displaced in the wheelchair at any time between cycles, he was repositioned prior to continuing the run. Additional runs were made to determine the effect of the position of the person in the chair on the apparent center of rotation of the body. In this case he was first tested when placed as far to the rear in the seat as possible for a series of cycles. He was then tested again when placed 4, 8 & 10 cm foreward in the chair from this rearmost position. Finally, four persons of varying stature were placed in the chair and were cycled with the sliding back mechanism operational to determine the effect of anthropometry on the variation of the apparent center of rotation of the body.

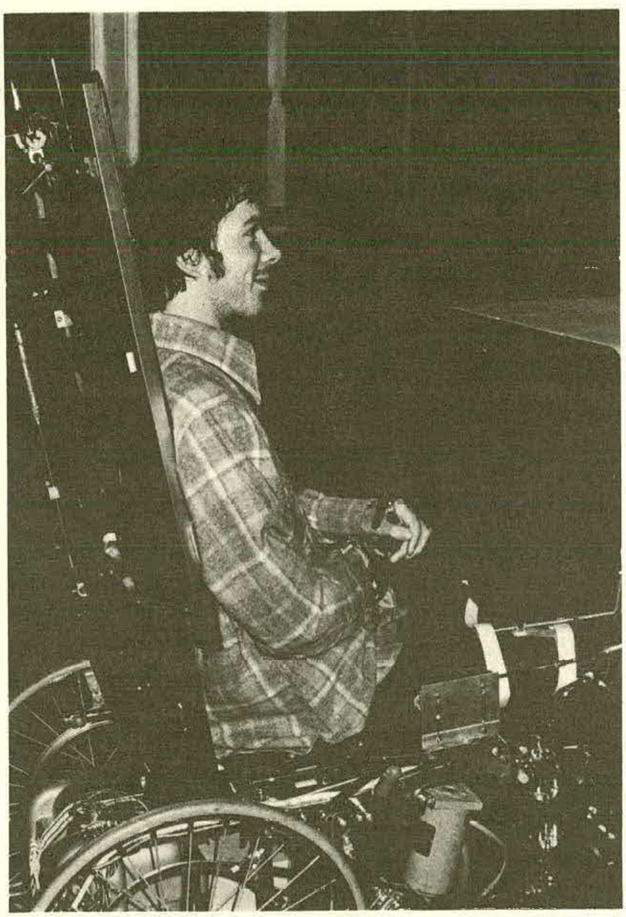

Figure 1. Subject seated in modified wheelchair.

RESULTS:

In order to determine a baseline for evaluation of results, the wheelchair was first set with both seat and back fixed. This configuration simulates the typical situation in most reclining wheelchairs. The subject was placed in the chair as previously indicated and was cycled with the thigh transducer measuring displacement in the chair. Figure 2 shows the average thigh displacement plotted against the angle of recline of the chair. The average range of thigh displacement was found to be 5.2 cm.

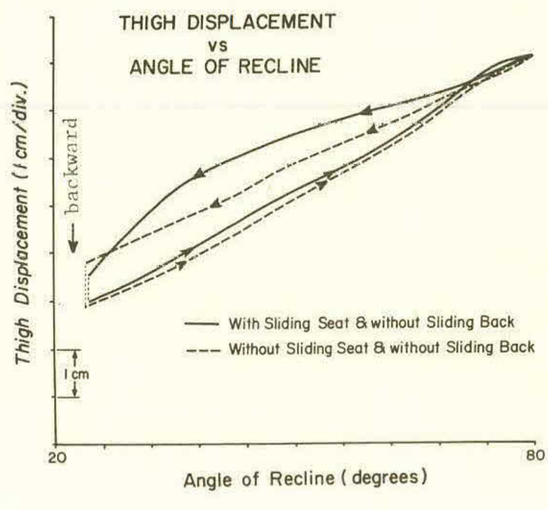

Figure 2.

The powered sliding seat was then connected, while the back of the chair remained fixed. Figure 2 also shows the average thigh displacements measured in this configuration. It must be emphasized that these displacements were measured with respect to the seat of the chair, and not with respect to the frame of the wheelchair. The average range of thigh displacement in this case is 5.0 cm, which is a slight decrease from the 5.2 cm measured with the seat fixed. This small difference raises the question of whether the backward motion of the seat during recline influences the displacement of the person's back.

The wheelchair was next tested with the back free to slide, with and without the powered sliding

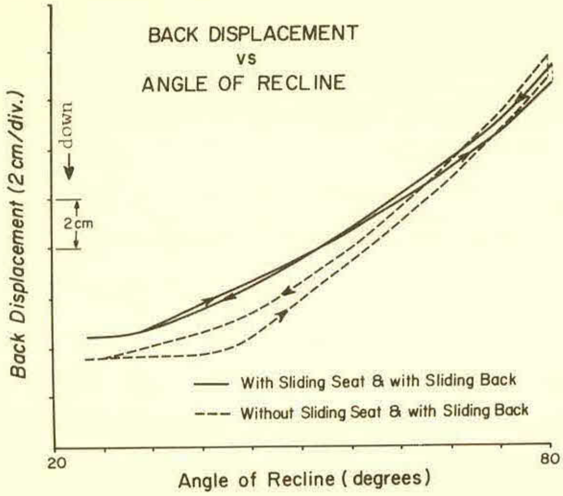

Figure 3.

seat. Figure 3 shows back displacement vs angle of recline for a series of seven cycles in each of these configurations. The data shows that the use of the powered sliding seat reduces back displacement only 10 per cent. The reason that thigh displacement is only marginally reduced is then related to the need of the back to move about the same distance during recline. The friction between the back of the chair and the subject's back pulls the thigh to almost the same excursion in either case.

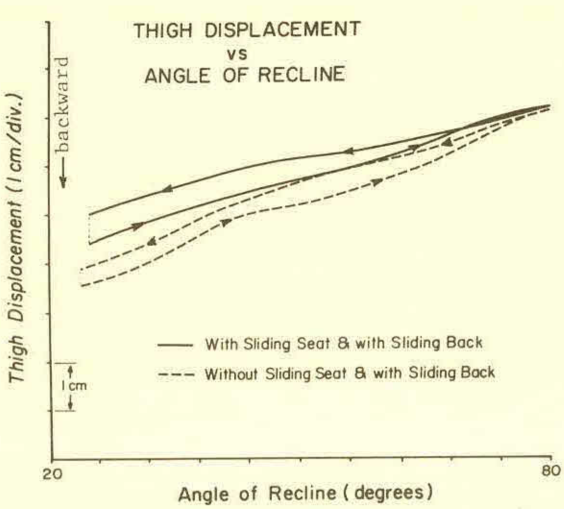

Figure 4.

It became apparent during the development of methodology for the experiment that a sliding back might also be considered to be a solution to the displacement problem in the wheelchair. Figure 4 shows thigh displacement plotted against angle of recline with the back free to slide with and without the powered sliding seat. Without the sliding seat, thigh displacement averaged 3.6 cm, considerably less than with the sliding seat alone. And when both seat and back were allowed to move, the thigh displacement averaged only 2.7 cm.

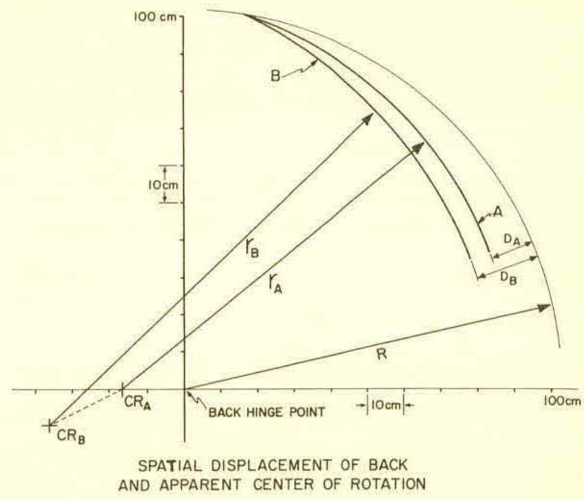

Figure 5.

Figure 5 shows the spatial displacement of a point on the moving back with respect to the fixed hinging point of the chair. From this displacement, the apparent center of rotation can be determined for the body since the back of the chair and the body are moving coincidentally. The data plotted in Figure 5 represent the range of spatial displacement for a person of small stature (5'6") seated as far to the rear in the seat as possible, Curve A. Curve B shows the same plot for a person of large stature (6'4") seated 10 cm from the most rearward position. Curve A represents the least displacement (D_A) while Curve B represents the maximum excursion (D_B). The apparent center of rotation was calculated from the extremes of these displacement curves, and these points are also shown in Figure 5 as CR_A and CR_B. The line connecting these points describes the possible positions of the axis of rotation which would place the curve of angular displacement within the envelope of Curves A and B.

OBSERVATIONS AND CONCLUSIONS:

The greatest thigh displacements were found to occur when the fixed seat/fixed back configuration was tested. In addition, the subjects were the least stable in their sitting positions when cycled in this configuration and had to be repositioned frequently. Patients with spacticity tended to experience more muscle spasms in this configuration, possibly due to friction and stretching forces placed on the body while cycling. The use of a powered sliding seat appeared to have little effect on the amount of thigh displacement produced during cycling. This was probably because seat actuation produced only a minor reduction in back displacement.

The use of the sliding back mechanism was more effective at reducing thigh displacement than the use of the sliding seat mechanism alone. And when both the seat and the back were allowed to move, the least thigh displacement and the lowest back displacement were recorded, however this solution may not be practical because of the mechanical complexity of such a combined system.

The most encouraging prospect for resolving these problems seems to be relocating the center of rotation of the chair to a location closer to the center of rotation of the body during recline. Since there was a relatively small difference between the displacement curves for short and tall subjects, the axis of rotation of the chair could be placed at a mid-point between the apparent centers of rotation of the body for these extremes. This would produce a lower back displacement for a wide range of body sizes since back displacement was found to have low sensitivity to relatively large differences in the location of the center of rotation.

REFERENCES:

1. Evaluation and Design Considerations for Powered Reclining Wheelchairs, C.G. Warren, M.J. Ko & J.V. Imre, Proceedings of the Fourth Annual Conference on Systems & Devices for the Disabled, Seattle, 1977.

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A COMPUTER TERMINAL FOR A QUADRIPLEGIC

David Hagelbarger, Robert Anderson, Peter Kubik
Bell Laboratories, Murray Hill, N. J.

Edward Rosenwasser
Texas Institute for Rehabilitation and Research, Houston, Texas

A computer terminal has been modified for use by a quadriplegic with no limb control; all operations are done with a mouth stick. A new keyboard was built and logic circuits were added to permit using the "shift" and "control" functions with only one "finger".

CATEGORY:	INTENDED USER GROUP: Quadriplegics
Device Development ☒ Research Study ☐	AVAILABILITY OF DEVICE:
STATE OF DEVELOPMENT:	
Prototype ☒ Clinical Testing ☐ Production ☐	AVAILABILITY OF CONSTRUCTIONAL DETAILS: see below
AVAILABLE FOR SALE:	FOR FURTHER INFORMATION CONTACT:
Yes ☐ No ☒ Price:	David Hagelbarger Bell Laboratories Murray Hill, NJ 07974

We have modified a computer terminal for use by a quadriplegic. It is clear that a quad who must use a mouth stick will have great difficulty using the conventional terminal. For instance the keyboard and display are frequently at right angles so that if the terminal is propped up so he can reach the keyboard with the stick, it is very awkward to read the display.

Figure 1 shows the modified computer terminal. There are four parts, the telephone, the modem, the display and the special keyboard. When being used by a quad the telephone is mounted next to the keyboard. It is tipped up and equipped with a special switch hook for use with a mouth stick. The modem(1), shown in front of the phone, is the kind that can be coupled to the line either acoustically or directly. It must be registered with the F.C.C. It can be mounted in any out-of-the-way place since the user does not need access to it. The display is a Lear Siegler ADM-3 terminal(2) which must be placed where the user can read it. The ADM keyboard is wired in parallel with the new one and still can be used if desired.

Figure 2 shows a close up view of the special keyboard. It was made by modifying the type of keyboard that is normally furnished with the ADM-3. We sawed the moulded base of the keyboard into strips and remounted them as shown without the usual stagger between rows. There is a bend down the center of the keyboard which makes the two halves tangent to a 16 inch radius circle. This makes the extreme edges easier to reach with the mouth stick. The wire at the bottom can be adjusted in height so it supports the stick in line with the bottom row of keys. It serves not only as a rest for the stick, but also makes it easier to type space, return, shift, and other bottom row keys. The switch at the top center was removed from the modem and extended to the keyboard. It is used to select the telephone or terminal when setting up a call to the computer. The lamp (CTS), in the upper right corner, lights when carrier is present.

One other modification was needed. The mouth stick user has only one "finger"; therefore we added two flip-flops for shift and control. If one

Figure 1 Computer terminal

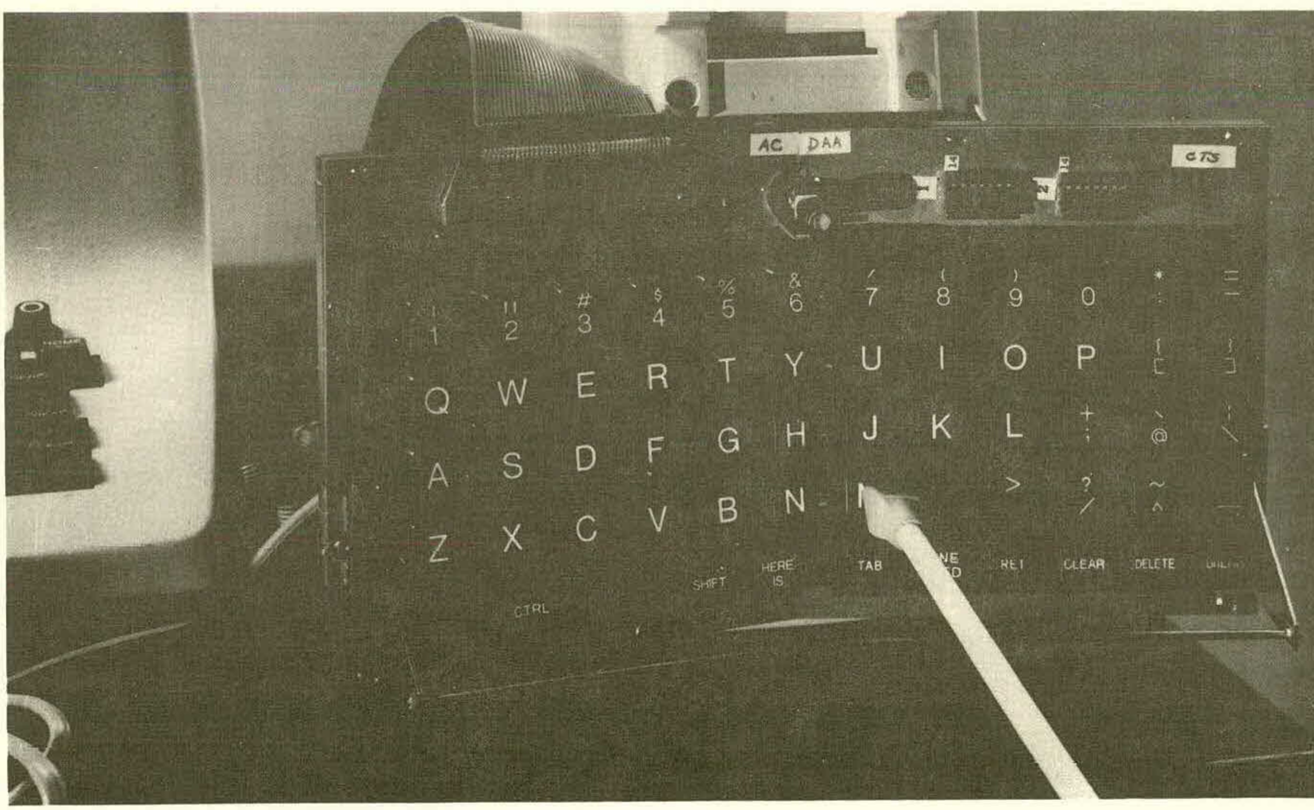

Figure 2 Keyboard

pushes the shift key, it sets the shift flip-flop. A light emitting diode on the key lights, indicating that the shift flip-flop is set. The next key is then "shifted" and the flip-flop is reset and the LED goes out. The control key works the same way.

(red end)

	Gnd	Gnd
	Col 0	Row 0
	Col 1	Row 1
w	Col 2	Row 2
i	Col 3	Row 3
r	Col 4	Row 4
i	Col 5	Row 5
n	Col 6	Row 6
g	Col 7	Row 7
	Brk	Row 8
s	Clr	Row 9
i	Here is	Row A
d	Ctrl	Row B
e	Shift	Row C
	Lo	Row D
	Xload	Row E
	(nc)	Row F
	(nc)	(nc)
	(nc)	(nc)
	+5 v	+5 v

Figure 3
Connector from ADM to new keyboard

Figures 3 and 4 are drawings showing the connectors added to the ADM-3 and the modem. Figure 5 shows the shift and control circuits on the new keyboard. The labels on the ADM-3 connector refer to drawing number 129461 on page 6-44 of the ADM-3 service manual.

The terminal will be demonstrated.

		o	o	WH/OR	6
16	WH/BL	O	O	OR/WH	5
9	BL/WH	O	O	BL/RED	4
8	WH/GR	O	O	RED/BL	3
7	GR/WH	O	O	WH/BR	2
		o	o	BR/WH	1

11 GREY/WH o LED o WH/GREY 12

Figure 4
Top view of terminals of AC/DAA switch and CTS LED showing wire color codes and cannon connector pin numbers

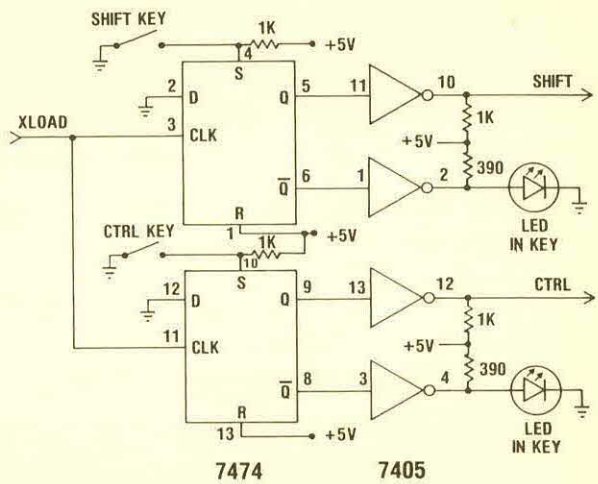

Figure 5 Circuit diagram

References

(1) Model TC 3002
vardon & associates,inc.
930 North Beltline
Irving, Texas 75061

(2) Lear Siegler,Inc.
Data Products
714 North Brookhurst Street
Anaheim, California 92803

INTERDISCIPLINARY UTILIZATION OF COMPUTERIZED CONFERENCING IN THE AREA OF TECHNOLOGY APPLICATIONS FOR THE HANDICAPPED *

Jane H. McCarroll

Innovative Systems Research, Inc.

The application of a new communication medium - computerized conferencing - is being assessed for its value in providing greater accessibility of information, timely feedback, and more effective communication in the area of technology applications for the handicapped. Participants in the exploratory research project include representatives of basic and applied research, marketing, production, distribution, consumption, federal and state agencies, and legislative bodies. Remote interaction is accomplished via a terminal device connected to a telephone. Severely disabled persons are able to use the system through the addition of special interface devices. Participants define their own objectives, and leadership and technical assistance are provided for trial applications.

CATEGORY:	INTENDED USER GROUP:
Device Development ☐ Research Study ☒	AVAILABILITY OF DEVICE:
STATE OF DEVELOPMENT:	
Prototype ☐ Clinical Testing ☐ Production ☐	AVAILABILITY OF CONSTRUCTIONAL DETAILS:
AVAILABLE FOR SALE:	FOR FURTHER INFORMATION CONTACT:
Yes ☐ No ☐ Price:	Innovative Systems Research, Inc. #1811, 1801 East 12th Street Cleveland, Ohio 44114

Introduction

The need for greater accessibility of information, timely feedback on ideas and results, and more effective and efficient means of communication among those involved in the application of technology for the handicapped, has been well documented. The nature of the problem calls for a long range plan for linking information, organizations, and individuals in a manner that will contribute to the provision of more cost/effective devices.

Innovative Systems Research (ISR) is currently working under a grant from the National Science Foundation to assess the application of a new communication medium - computerized conferencing - within the rehabilitation field. This project is oriented toward ISR's goal of contributing to the establishment of a communication/information network which will facilitate the process of device R&D and the utilization of results.

While still in the developmental stages, computerized conferencing has demonstrated its potential value as a medium to support such a network. Although it would be premature to report results of ISR's project at this time, those concerned with technology for the handicapped should be made aware of the efforts underway since their attention and input can influence the development of the medium to be responsive to their particular needs.

It is, therefore, the intent of this paper to briefly describe the system employed in ISR's project and its current trial application. It is hoped that this presentation will elicit responses from potential future users of the system to stimulate ideas for continued exploratory efforts.

* The project discussed is supported by the Access Improvement Program, Division of Science Information, National Science Foundation. Jane McCarroll is the Principal Investigator.

Computerized Conferencing

Computerized conferencing can be broadly defined as the integral use of computers to structure and facilitate communication. Interaction can occur among individuals, groups of individuals, and, with the more sophisticated systems, other computers. The addition of automated data processing capabilities to the human communication process extends that process beyond the limits of any other existing medium, and provides greater convenience by spanning time and geographic barriers.

ISR's current project is one of several recent efforts to explore the potential applications of computerized conferencing. The system in use is the Electronic Information Exchange System (EIES) developed by the New Jersey Institute of Technology (NJIT).

EIES is maintained on a dedicated minicomputer at NJIT. Each member of the system sends and receives information remotely via a computer terminal with an acoustic coupler. Access to EIES is gained by simply connecting the terminal to a telephone, dialing the local number of Telenet (a commercial telecommunication network), and then entering a personal access code.

The system is easy to use and explanations of all functions are provided on-line. The average user can learn the basic features within two hours.

Computerized conferencing is especially well suited for use by handicapped persons. Various terminal interface devices are available to enable severely disabled individuals to interact as any other member.

EIES provides four basic types of communication capabilities, all of which users can participate in asynchronously:

. Messaging - Sending private communications to individuals or groups of individuals. Messages can be sent directly to anyone with access to the system. Recipients are alerted to waiting messages when they sign on to the system, and senders receive confirmations when their messages have been received.

. Conferencing - Use of common (group) communication space for topic-oriented discussions over any period of time. The system maintains a permanent transcript of comments which is available to conferees at any time. Any combination of EIES members can be designated as participants or observers of a conference.

. Notebooks - Personal storage space for text composition and editing. Notebooks can be shared with other members for joint authorship of papers.

. Bulletins - Public communication space for use as an on-line newsletter or electronic journal.

All messages, conference items and notebook pages are stored with the name of the author (or a pen name to preserve anonymity) and the date and time of their entry. An associated item can be referenced and key words assigned for later searches and reorganization of entries.

Extensive text and document editing features are available for use in composing messages and other textual items, and for revising and refining stored information. The use of a typewriter quality printer enables a user to prepare publication ready documents via EIES.

Personal and descriptive data is maintained on each EIES member in a membership directory. Directory searches and non-confidential information about members are available to all users. A grouping structure is superimposed to affiliate members with common interests, concerns, etc. This facilitates such activities as sending group messages and referring to subsets of members.

Special procedures can also be used to expand the basic capabilities of EIES. Currently available ones are:

. Recording of sequential user operations for initiation by a single command.

. PILOT Computer Assisted Instruction programming language procedures.

. Collection of information via user-generated forms.

. Masking of specific user interfaces to control access to system features.

Plans are also underway to incorporate the BASIC programming language into the procedures available to users.

One of the most significant developments in progress is the capability of direct linkage with other computer systems. A microprocessor (a Zilog Development Unit) with its own automatic telephone dialer has been programmed to participate in EIES as a regular member of the system. This unit will have the same interaction powers as any other member, and the capability of accessing and relaying information from other on-line computer systems.

Direct linkage with other systems will significantly increase the value of EIES by making possible a communications network with advanced information processing capabilities and access to automated data bases.

The current costs involved in using EIES are relatively low, especially when taking into consideration the amount of time and expense saved by reducing the need to travel for meetings and information collection.

ISR/EIES Project

ISR's interest in the application of computerized conferencing to the rehabilitation field stems primarily from the company's experience in two areas: 1) the development of models for the study of the innovation process at the level of specific technologies, and 2) the provision of ongoing planning consultation to state and local agencies serving the handicapped. In the coordination of the trial EIES community, ISR is coupling this experience with a systems orientation in an assessment of the potential value of the use of EIES by multi-disciplinary communities in the area of device R&D.

The EIES project was initiated in December 1977 and will continue until the spring of 1979. Participants will have access to the system for a twelve month period.

The project community is a cross-section of approximately forty organizations and individuals representing the device R&D spectrum interpreted to include basic and applied research, marketing, production, distribution and consumption (i.e., consumer-oriented organizations and handicapped persons). Federal and state agencies and legislative bodies are also represented. Membership occasionally varies as temporary members are allowed access for short term, defined activities, and new members are added to replace previous participants.

Members use their own terminal devices to access the system via Telenet. NJIT supports the EIES system and provides on-line user consultation to assist members in learning to use it effectively.

The current project is conceived as an evolving "natural experiment," in that the community's use of EIES is not subject to the artificial imposition of controls or limitations, except as required by the grant provisions. As a major objective of the project is to determine the best network organization of the community, participants are enabled to develop their own lines of communication and conference groups. They are encouraged to employ EIES' special capabilities in support of their current work, to share ideas and information with each other, and to explore different methods and techniques for making use of the system.

ISR provides oversight and leadership to motivate the participants to interact as a community. In the role of group moderator, the ISR Principal Investigator must operate both within and outside of the group process to stimulate activity, structure communications, broaden participants' expectations and applications of the system, and recommend techniques for using the system effectively.

To get the project off to an active start, ISR conducted a two-day 'in-person' conference in early February. The purpose was for members to become acquainted with one another and to begin defining their objectives for the application of EIES. The project activities proposed at the conference fell into four categories:

1) A community newsletter containing information on project participants, community activities, upcoming events of interest to members, requests for information, information sources, and suggestions for more effective use of EIES.

2) A community notebook for dissemination of information on topics of general interest.

3) Community interest conferences - i.e., group conferences on topics of interest to the entire group. Proposed topics include issues of law and public policy, device delivery systems, public information programs and strategies, interdisciplinary course development, and potential improvements in EIES performance and use.

4) Special interest projects - private notebooks and conferences established by subgroups for specific purposes such as:

   - Exchanging data on a device undergoing clinical evaluation at various sites
   - Joint development of a standardized commercial device evaluation form
   - R&D planning conferences

- Special interest newsletters
- Communication among remotely located developers and users of specific devices
- Developing linkage to an existing data base
- Preparing journal articles for publication

Due to the limited scope of the current project, not all of the proposed activities can be pursued at this time, and the more complex and long term ones, such as compiling a data base, can only be preliminarily defined and demonstrated. Also, as participants gain experience with the use of the system, additional applications will be hypothesized and attempted. One member organization is already working on the definition of a software linkage between the EIES system and an automated data base of devices, which would essentially establish the data base as a member of the community so that it could be queried on-line by other members.

It is also expected that increased understanding of computerized conferencing and experimentation will stimulate users to conceive of increasingly sophisticated applications, moving away from the natural tendency to merely replace or supplement other forms of communication.

Based upon the original objectives, progress to date, and feedback received from current and prospective members, the following major outcomes of the project are anticipated:

- Demonstrated interdisciplinary involvement in activities aimed at improved cost/effectiveness of devices.
- Increased understanding of barriers to device R&D and their potential removal.
- Demonstration of effective participation of handicapped users in the R&D process.
- Practical EIES experience by a representative sample of device R&D participants.
- Deeper insight into the relationship between communication processes and the progress of science and technology in the rehabilitation field.
- Development of new hypotheses about potential applications of computerized conferencing.
- Demonstrated linkage of EIES with a data base system.
- Definition of a data base on developing devices to be compiled via computerized conferencing.
- Demonstration of the potential usefulness of computerized conferencing in moving between stages of the innovation process toward commercialization of devices.
- Increased public awareness of the needs for improved communication and access to information within the device R&D field.
- Contribution toward the definition of an ideal automated communication/information system for a network of individuals and organizations involved in device R&D.

The organization of the project community, the applications attempted, and the performance of the system are being assessed throughout the duration of the project. The interim evaluation results are fed back into the planning and operational process so that the community structure and techniques for applying the system can be continually revised and refined. At the end of the EIES utilization period, a summative assessment will be conducted.

The approach to assessment focuses primarily on EIES' effect upon the organizational characteristics, productivity, and information flow within the community. Based upon the use of repeated measures over time, the effect of computerized conferencing will be evaluated through the use of assessment techniques popular in the management sciences as well as standard information flow analysis techniques.

Conclusion

The concept of computerized conferencing has been well received by many persons involved in the application of technology for the handicapped. ISR believes that current evidence supports the hypothesis that this new medium can contribute to the provision of more cost/effective devices, and intends to further pursue the goal of an integrated communication/information network to serve the device R&D community.

The current EIES project is providing a preliminary test of some of the potential applications of computerized conferencing, and an opportunity to develop techniques for its effective use. Involvement in such initial applications affords the opportunity to provide input into the development of the medium.

There is a need, however, to go beyond the scope of the current effort in order to determine its full potential impact.

The nature of computerized conferencing allows a modular approach to the development of an integrated system. Small group applications can be linked at any time to create higher levels of organization and alternative communication channels. ISR anticipates that the current EIES project will provide a successful 'jumping off' point for broader applications, and plans to stimulate growth in the form of offshoots and extensions to the present effort.

References

Baltrush, Michael A., and Julian M. Scher. "The Microcomputer as a Conferee in the Computerized Conferencing Implementation of Interpretive Structural Modeling." New Jersey Institute of Technology, Newark, New Jersey.

"Computerized Conferencing: A New Medium," Mosaic, 1976, 7 (1).

Crane, Diana. "Invisible Colleges: Diffusion of Knowledge in Scientific Communities." Univ. of Chicago Press, 1972.

Hiltz, Starr Roxanne. "Altering the Informal Communication Structure Within Scientific Specialties: A Field Experiment Utilizing Computerized Conferencing," April, 1977.

Hiltz, Starr Roxanne. "Assessing the Future Impact of a New Technology: Computer Conferencing," October, 1975, Public Lecture at Upsala College.

Hiltz, Starr Roxanne, and Murray Turoff. "Computer-Mediated Communications and the Disadvantaged," New Jersey Institute of Technology, 1976.

Hiltz, Starr Roxanne, and Murray Turoff. "Potential Impacts of Computer Conferencing Upon Managerial and Organizational Styles," New Jersey Institute of Technology, 1976.

Kupperman, R.H., R.H. Wilcox, and H.A. Smith. "Crisis Management: Some Opportunities," Science, Feb. 7, 1975, 187, 404-410.

Nelson and Pollack, Eds. Communication Among Scientists and Engineers. D.C. Heath, 1970.

Price, Charleton. "Conferencing Via Computer," in Harold Linstone and Murray Turoff (Eds.), The Delphi Method: Techniques and Applications Addison Wesley, 1975.

"Report of the Panel on Research Programs to Aid the Handicapped," presented to the Committee on Science and Technology, U.S. House of Representatives, 95th Congress, First Session, April 1977.

Turoff, Murray. "Computerized Conferencing: Present and Future," Intellect Magazine, Sept. - Oct., 1975.

Turoff, Murray. The Delphi Method; Techniques and Applications, Addison Wesley Publishers, 1975.

Turoff, Murray. "The Future of Computer Conferencing," The Futurist, 1975, 9(4).

Turoff, Murray. "The State of the Art: Computerized Conferencing," in N. Macon (Ed.), Views from ICCC 1974, Washington, D.C.: International Council for Computer Communication.

Turoff, Murray and Starr Roxanne Hiltz. "Computerized Conferencing: A Review and Statement of Issues," Presented at NATO Telecommunications Symposium, Bergamo, Italy; September 1977.

DEVELOPMENT AND UTILIZATION OF COMPUTER BASED REHABILITATION INFORMATION SYSTEMS IN COMPREHENSIVE MEDICAL REHABILITATION

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Jane A. Nosbisch and Pamela L. Stahl
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Readily accessible, timely, and accurate data are critical to effective clinical management and decision making in comprehensive medical rehabilitation. The computer-based rehabilitation information system (REHABIS), developed at the Rehabilitation Institute of Chicago, was designed to monitor and synthesize critical patient assessment information derived from clinical and administrative departments. The system monitors over 300 patient progress variables from time of entry into the hospital to post discharge follow-up. The data base is used in a variety of tasks: generation of patient stay and service cost statistics, assessment of rehabilitation program effects to facilitate clinical planning, and cost/effectiveness analyses of clinical services. Discussed are system development, utilization and future system structuring.

CATEGORY: Device Development ☐ Research Study ☒	INTENDED USER GROUP: Clinicians, researchers, administrators AVAILABILITY OF DEVICE:
STATE OF DEVELOPMENT: Prototype ☐ Clinical Testing ☒ Production ☐	AVAILABILITY OF CONSTRUCTIONAL DETAILS:
AVAILABLE FOR SALE: Yes ☐ No ☒ Price:	FOR FURTHER INFORMATION CONTACT: Dr. Stefan J. Harasymiw Northwestern Univ.-Dept. of Rehab. Med. 345 East Superior St. Chicago, Illinois 60611

Introduction

Individuals involved in health care are becoming increasingly aware of, and interested in, advanced information systems such as those used in business, industry, and government. As the health care field grows in complexity, ever increasing demands are made on the mechanisms which evaluate service effectiveness and provide self-regulation feedback in the service management process. For example, one estimate indicates that over 25 percent of general hospital costs are related to communications and data processing (Flagle, 1966). Another study indicates that manual information processing costs often average $20 per patient day (Deland and Waxman, 1972). Thus, cost and time efficient information management is extremely important to health care systems and the need is becoming even more prominent because of the ever increasing concern about the rising costs of health care delivery.

The expanding field of Rehabilitation Medicine similarly has considerable need for computer based information systems. Several rehabilitation centers in the country during the last several years have introduced various automated information processing systems into their operations. These systems range from relatively simple billing systems to fairly complex systems that incorporate a variety of procedures beneficial to both clinicians and administrators, such as those developed at the Texas Institute for Rehabilitation and Research in Houston, where early pioneering work in computerized rehabilitation information systems use has occurred over the last decade (Sanderson et al., 1975).

To meet its own growing demand for readily accessible research, clinical, and administrative information, the Rehabilitation Institute of Chicago (RIC) in 1976 embarked on the development of the computer-based Rehabilitation Information System (REHABIS), to provide clinical, economic, and sociological information critical to the efficient functioning of a comprehensive rehabilitation services system.

In its initial design structure, REHABIS was to be primarily a historical patient data system intended to monitor the factors of rehabilitation intervention, outcome, and the resultant costs. It was anticipated that the system could serve not only the needs of the Institute, but that it might also aid health care planners in the community as well.

Since system development initiation, the system has evolved into linked data bases of some 300 variables, on about 3,000 subjects, with capacity to expand both variables and patient population through networking. Because patient data are gathered at several time periods during and post rehabilitation, the system allows comparison of patient functional ability at different points in time, to facilitate clinical evaluation and planning.

System Description

Design and Operation. The information system was designed to provide continuous monitoring of the fundamental informational elements in the medical rehabilitation process, such as: 1) demographic characteristics of patients; 2) outcome of the rehabilitation process in terms of individual level of life functions; 3) rehabilitation process elements, related to type and number of services provided; 4) cost of rehabilitation. Overall, the REHABIS data base consists of some 300 such factors. Data input is derived from three major sources: medical records, financial records, and specific research projects which provide a follow-up component.

The information is coded and entered into the system; the format and structure of the REHABIS data base is seen in Figure 1. The current patient data base population consists of

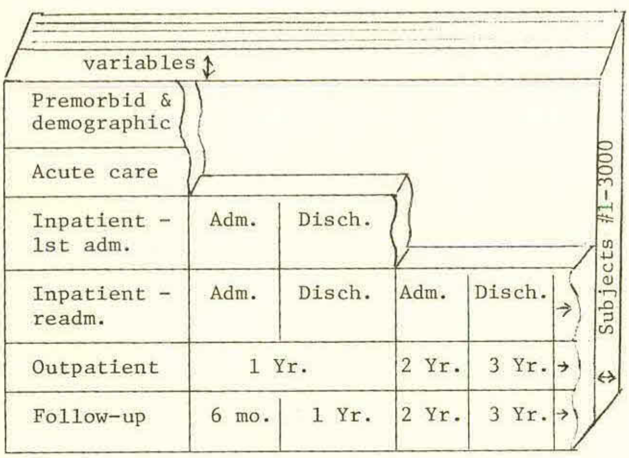

Figure 1. REHABIS data base structure: patient record organization

3,000 first admission inpatients admitted to RIC during 1973-1978. Each patient data set can potentially contain six types of records: premorbid, acute care, initial inpatient admission, subsequent inpatient admissions, outpatient contacts, and periodically monitored follow-up information.

The formulation of the data base items was developed through a delphi process (Martino, 1972). The process was modified somewhat to assure more simplified response procedures and better prioritization of items for inclusion in the data collection system. The initial composition of items was derived from existing rehabilitation monitoring systems in other comprehensive medical rehabilitation centers (CMRCs) to better represent the information needs of a variety of rehabilitation disciplines. Formal voting on the item composition was conducted to structure and prioritize the specific items for final inclusion in the data base. Five separate voting passes were conducted with administrators, physicians, and paramedical clinicians and each group was requested to suggest new items for inclusion. Subsequently, formal as well as informal meetings were conducted with a variety of individuals to further strengthen and refine specific variables and to discuss the actual utilization of the proposed data base items. The final proposed data base composition was then submitted to a committee composed of representatives from the various departments to establish the actual variables that would ultimately be collected and monitored by the system.

The REHABIS data base structure was designed to incorporate not only several types of patient records but to also provide several types of input, output, processing, storage and linkage modalities, as seen in Figure 2. The different data entry modalities allow collection of pertinent information from these potential sources: medical and financial records and follow-up collections.

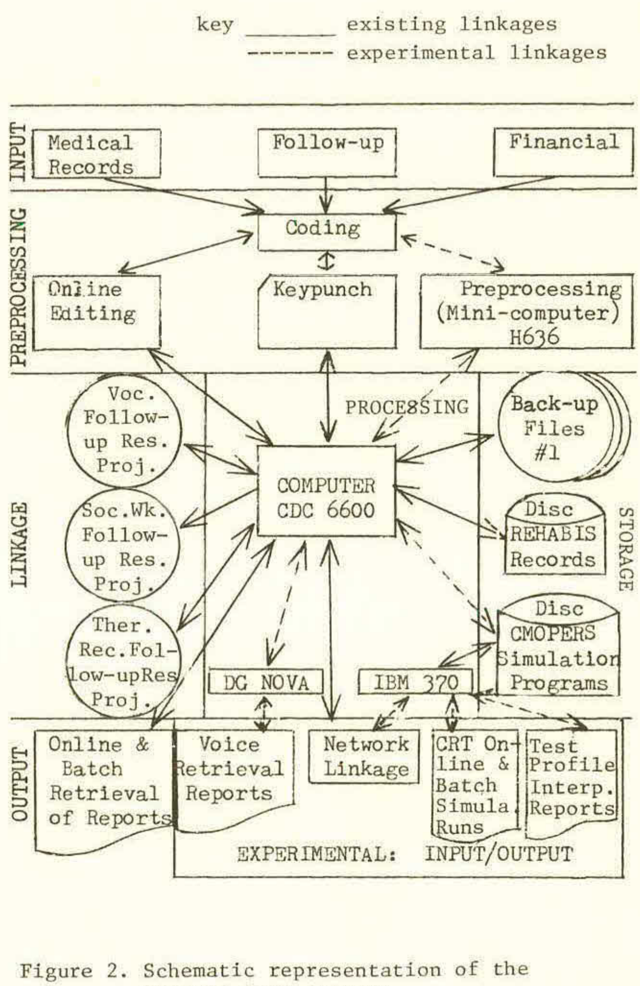

Figure 2. Schematic representation of the REHABIS data linkage

After coding, data entry to the computer is through the keypunching mode, although future methods of entry being considered are on-line data entry using a mini-computer preprocessing link; and mark-sense entry directly from individual clinical departments.

Storage and Processing. The REHABIS data base is housed at the Northwestern University Computing Center's CDC 6600 although earlier experiments linking the data base with PROTRAN and SPSS as well as simulation via DYNAMO have been tested on the IBM 370 computer.

The REHABIS data are stored on magnetic disc during normal daily operations and retrieval can occur either through batch processing or from telephone linked terminals in time-sharing mode.

Periodically, the data sets are dumped to backup tape storage to prevent information loss resulting from hardware, software, or human related errors. Variables can be specified for retrieval, either separately on-line or through a report generating program. All nonconfidential data items are directly accessible for statistical analyses and tabulations.

Several complex computer software systems comprise the processing components of REHABIS. The Scientific Information Retrieval System, SIR (Robinson et al., 1977), constitutes the storage and retrieval components; the Statistical Package for the Social Sciences, SPSS (Nie et al., 1975) programs, constitute the statistical components. Two additional systems have been explored to provide additional capability for the system. The Profile Transformation System, PROTRAN (Helm, 1965), is planned to provide narrative reporting of numerical profile interpretation. The language, DYNAMO (Pugh, 1973), is being considered to allow development of computer-based simulation models. Further, combinatorial data sets can be created from separate analysis runs and stored as individual files on disc, via SPSS save file programs for further manipulation by other computer programs not directly linked to the system. Such data sets can also be sent to remote computer locations through networking for further manipulation of accumulated data from several centers.

Utilization

The various REHABIS data outputting possibilities range from simple detail records listing and summary records listings to complex statistical analysis.

Most often the requested outputs are for descriptive data such as cross tabulation and frequency distribution histograms. Other requested reports draw upon simpler inferential statistics such as correlations, means, and standard deviations. Planning and evaluation decision reports sometimes require much more complex statistical analyses such as regression, factor analyses, or discriminate function analyses.

A variety of RIC management, research, and clinical departments, as well as organizations outside RIC have used information from the data base. The RIC Research Department is using REHABIS data to provide the patient selection mechanism in several research projects. The REHABIS data sets have also been linked with smaller, more specialized research data bases, to form a much larger and more intensive data pool from which normative and cross tabulation information can be derived.

The Institute's Administration is using REHABIS data for formal reporting to the insurance industry of costs and duration of comprehensive rehabilitation for various disabling conditions. The Development Department has used the data base to generate an update on characteristics of accident disabled individuals, and the Public Affairs Department has made use of REHABIS data in informational brochures and in public presentations of hospital activity.

The Medical Records Department, the Institute's Medical Audit Committee, and several clinical departments are using REHABIS data to refine auditing criteria as well as for the periodic auditing required by hospital accreditation agencies. Individual physicians and the Nursing Department are using REHABIS data listings for information on individuals and groups of patients for specific research and clinical studies. The Occupational Therapy Department has used REHABIS to generate information to study the relationship of functional gain to cost of therapy as well as to explore the relationship of amount of recovery in hemiplegic patients in relation to amount of time between onset of disability and initiation of rehabilitation (Giambalvo and Harasymiw, 1977). The Speech Pathology Department has used the data base to study speech severity ratings for hemiplegic patients. The Psychology and Social Work Departments have utilized the information for studying and presenting specific disability group outcome trends.

The REHABIS data have also been used by agencies outside of RIC. A suburban special recreation organization has used REHABIS data to point out the need for special recreational facilities in the community; a suburban village government board has received information from the system to be used for improving transportation services for the disabled in the community; students connected with RIC have used REHABIS statistical information in clinical research projects; and a rehabilitation systems analysis consulting firm evaluating departmental treatment cost/effectiveness has also used the information system. Finally, research papers presented at several national rehabilitation medicine and allied health conferences during the past year have used basic REHABIS data.

Future Development

While the initial focus of REHABIS was to facilitate patient information dissemination within RIC, the future potential of REHABIS is more encompassing in terms of rehabilitation planning, evaluation and service coordination in the rehabilitation community at large.

The expanded scope for utilization includes further exploration in the areas of integrative analysis, networking linkages, development of a formal disability specific registry system, and simulation.

The area of integrative analysis utilizes the multidisciplinary aspects of REHABIS. Hypothesis testing by clinicians pertaining to rehabilitation process and outcome decisions can be examined across several discipline areas simultaneously when assessing the effectiveness of the rehabilitation process. For example, looking at the patient's vocational potential, severity of disability, and functional capability, as well as the time and cost of services in concert can often provide much more meaningful information for rehabilitation decision making than looking at any one data set. Thus, such questions as: "What is the cost benefit ratio of rehabilitating a 35-year-old male quadriplegic?" might be considered in terms of probability statistics based on existing data sets, which could match a given patient's characteristics with previously rehabilitated individuals and determine the ratio as well as the confidence intervals. For greater sensitivity, however, it is obvious that such probability estimates need large, possibly multicenter data sets. Such large multidisciplinary, multicenter data sets made available through networking could allow clinicians, administrators and researchers to explore a large number of hypotheses.

While synthesis of individual patient factors gathered within the various rehabilitation disciplines contributes much to the picture of understanding the overall process of rehabilitation it seems logical to look at these variables across several centers as well. This greater generalizability across interorganizational as well as interdisciplinary parameters would provide considerable strength in rehabilitation decision making whether at the individual patient, discipline, or organizational level. Establishing linkages through networked information systems would make it possible to exchange information between widely separated and perhaps qualitatively different facilities and agencies. It is likely that just as the interplay of several disciplines can enhance the rehabilitation planning and evaluation process so too can rehabilitation information utilization be enhanced by linkage of several centers with their own multidisciplinary data sets. As a result, it seems relevant to develop a formal intercenter data networking research proposal which would outline the technical procedures to develop and link several information systems into an integral rehabilitation information network.

Through this type of networking it would be possible to organize formal disability specific registry systems which could serve as a general clearinghouse of rehabilitation patient and service information. This approach not only could have the advantages of greater speed in information exchange, but would also provide more varied and comprehensive data from which rehabilitation centers could compare aspects of their center's performance with practices at other facilities (Harasymiw and Albrecht, 1976). It is conceivable that such an approach might contribute valuable insights into the improvement of the overall rehabilitation delivery systems.

Lastly, it is likely that clinical, administrative, and research "hunch" testing by rehabilitation practitioners will become more frequent with greater access to large patient data bases and greater exposure to computer based simulation. Conceptual hunches thus could be tested for internal consistency by simulation or by looking at outcome of simulations prior to proposing changes in treatment or administrative procedures (Harasymiw and Horne, 1976).

Bibliography

Deland, E.C., and Waxman, B.D., Review of Hospital Information Systems, G.A. Bekey and M.D. Schwartz (eds.) Marcel Dekker, Inc., New York, 1972.

Flagle, C.D., "On the Requirements for Information Systems in Hospitals." Proc. of Conf. on Automatic Data Processing in Hospitals, Elsinore, Denmark, 1966.

Giambalvo, B.D., and Harasymiw, S.J., "The Relation of Treatment Latency to Rehabilitation Outcome." Paper presented at the Occupational Therapy Annual Conference, San Juan, Puerto Rico, October 1977.

Harasymiw, S.J., and Albrecht, G.L., "Evaluation of Comprehensive Medical Rehabilitation Centers by Use of Cost/Function Indicators." Paper presented at the American Congress of Rehabilitation Medicine, San Diego, California, November 1976.

Harasymiw, S.J., and Albrecht, G.L., "Admission and Discharge Indicators as Aids in Optimizing Comprehensive Rehabilitation Services." Scandinavian Journal of Rehabilitation Medicine, in press.

Harasymiw, S.J., and Horne, M.D., "Planning and Evaluation of Rehabilitation Services." Paper presented at the National Rehabilitation Association Conference, Cincinnati, Ohio, October 1975.

Harasymiw, S.J., and Horne, M.D., "Computer Simulation of Psychological Test Profile Interpretation." Proc. on 9th Annual Simulation Symposium 9:83-88, 1976.

Helm, C.E., "Simulation Models for Psychometric Theories." Proc. on American Federation of Information Processing Society 27, Part 1, Spartan Books, Washington, D.C., 1965.

Martino, J.P., Technological Forecasting for Decision Making. American Elsevier Publishing Co., Inc., New York, 1972.

Nie, N.H., Hull, C.H., Jenkins, J.G., Steinbrenner, K., and Bent, D.H., SPSS: Statistical Package for the Social Sciences, McGraw-Hill, Inc., New York, 1975.

Pugh, A.L., III., Dynamo II User's Manual. The M.I.T. Press, Cambridge, MA., 1973.

Robinson, B.N., Anderson, G.D., Cohen, E., and Gazdzik, W.F., SIR: Scientific Information Retrieval User's Manual. SIR, Inc., Evanston, 1977.

Sanderson, M.R., Rossi, C.D., and Spencer, W.A., "Information Processing to Improve Service Delivery." In Selected Research Topics in Spinal Cord Injury Rehabilitation, M. Fuhrer (ed.) DHEW, RSA, Supporting Grant 16P5681316-13, 1975.

Watkins, R.A., and Harasymiw, S.J., "The Predictive Validity of Certain ADL Items as They Relate to Occupational Therapy Service in a Comprehensive Medical Rehabilitation Environment." Paper presented at the Occupational Therapy Conference, San Juan, Puerto Rico, October 1977.

CLINICAL MTHOD TO MEASURE RESIDUAL LIMB VOLUME

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This study reports on a method that uses circumferential measurements and programmable calculator to compute total and incremental volume of the residual limb and to compare the accuracy of this scheme with water immersion and contourgraph method.

A series of three tests were performed. In the first test, the new method and immersion method is compared using casts. In the second test, volumetric measurements of casts and sockets are compared using both methods. In the last test, comparison between contourgraph and the new method is evaluated using A/K stumps.

The data obtained using the new method compares precisely with the data obtained by using analytical methods such as contourgraph and water immersion method.

CATEGORY:	INTENDED USER GROUP:
Device Development ☐ Research Study ☒	AVAILABILITY OF DEVICE:
STATE OF DEVELOPMENT: Prototype ☐ Clinical Testing ☐ Production ☐	AVAILABILITY OF CONSTRUCTIONAL DETAILS:
AVAILABLE FOR SALE: Yes ☐ No ☒ Price:	FOR FURTHER INFORMATION CONTACT: Mete I. Yalcinkaya 1333 Moursund Ave. Houston, Texas 77030

Introduction

In trying to solve the current prosthetic fitting problems, the shape and volume of the amputee's loaded or unloaded residual limb are two important parameters (1). The prosthetist requires an accurate measure of the residual limb so that the prosthetic socket can be fabricated and modified to accommodate limb shrinkage. Radiographic (2) and electronic pressure transducer (3,4) methods have been tried to achieve a precise assessment of the prosthetic fit but neither of the methods has achieved acceptance by amputee clinics.

Since the majority of problems with amputee fittings is due to residual limb shrinkage or weight fluctuation, (about 45.3 %) (4), accurate measurement of volumes and volume distribution in residual limbs and sockets has been recognized as being helpful in evaluating prosthetic fit and development of instrumentation to measure volume changes accurately and quickly in a clinical setting has been given a high priority for research and development (5).

The purpose of this paper is to present a mensuration method using circumferential measurements and a programmable calculator to compute incremental volumes of residual limbs.

Methodology

A direct mensuration method that uses only circumferential measurements at selected stations on the limb and the linear measurements appeared to be advantageous. Inherent in this scheme is that successive cross sections are parallel and similar in geometry.

The volume can then be approximated by the following formula:

$$V = h/3\ (B_1 + B_2 + \sqrt{B_1\ B_2}) \qquad (1)$$

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where B_1, B_2 are cross sectional areas and h is the linear distance between them.

Assuming that the cross section of the residual limb is circular, the volume contained between any two cross sections is given by:

$$V_i = \pi h/3\ (R_1^2 + R_2^2 + R_1 R_2) \qquad (2)$$

where R_1, R_2 are radii of two consecutive cross sections and h is the linear distance between them. (See Figure 1) Rewriting this formula in terms of the circumferences one obtains:

$$V_i = (1/12\pi)\ (C_k^2 + C_j^2 + C_j C_k)\ (h) \qquad (3)$$

where C_j, C_k are circumferences at the measuring sites and h is the distance between two sites. The total limb volume is then calculated as the sum of the incremental volumes.

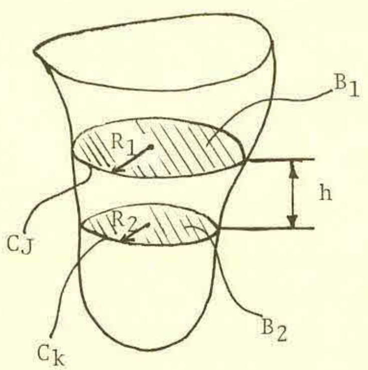

Figure 1. Model of the residual limb indicating various parameters used in text.

In many amputee clinics an ordinary tape measure is used to measure circumferences and these measurements are influenced by the tone of the tissue. The pressure that the tape exerts on the stump varies with the tension on the tape and hence, the state of tissue becomes a major factor in altering the measuring accuracy. This prompted the design and fabrication of a digital tape-measure which uses a Negator[R] spring to apply the same tension on the tape regardless of who makes the measurements.

Validation and results

Three tests were performed to evaluate the effectiveness of the direct mensuration technique. The accepted but cumbersome immersion technique was compared in the first test. This test used sixteen casts of residual limbs. The volumes of these casts were measured by immersing them in water and by using the tape measure technique. Both incremental and total volumes were then calculated for both techniques. The mean of the difference between two techniques was 0.63 in.^{3} with a standard deviation of 11.29.

In the second test five socket molds were used. The volumes of these molds were obtained by filling them with water and by the tape measure technique. The mean of the difference between these two techniques was 0.02 in.^{3} with a standard deviation of 4.07.

In the third test, the residual limb volumes of eight above knee amputees were calculated using the tape measure technique and the contourgraph method developed at Texas Institute for Rehabilitation and Research (TIRR). The stumps were measured by a prosthetist, and by an amateur using the tape measure technique; the sensitizing of the technique to tape tensioning was then assessed. The mean of the difference between the contourgraph and the experts measurement was 8.21 with a standard deviation of 7.59. The mean of the difference between the amateur and contourgraph was 5.47 with a standard deviation of 12.71.

When the percent errors were each calculated for each test, the first test resulted in an error of 0.40%, the second test resulted in 0.1% and the third test resulted in an error of 1.9%.

Discussion

The data obtained in the three tests indicate that the tape measurement technique and other more analytical techniques compare well as the percent errors are within the experimental error.

The proposed method has been found to be clinical technique to assess limb and socket volumes which are useful in fitting patients with soft, flaccid tissue and the patients who have undergone weight changes in their residual limbs in a very simple, accutate and quick way.

The methodology proposed in this paper provides the prothetist with a algorithm to make volumetric measurements of residual limbs and the socket volumes by using a conventional tape measure.

Acknowledgements

This research was sponsored in part by the Rehabilitation Engineering Center of the Rehabilitation Services Administration Grant # 23P 57888/6.

References

1. E.N. Zuniga, L.A. Leavitt, J.R. Cuzzi, A.L. Muilenburg, R.E. Herron, T.A. Krouskop, "Shape and Volume Measurements of Stump and Prosthetic Socket of Lower Extremity Amputees Using a Stereometric Form Sensor (Contourgraph)," Proceedings of the Fourth Annual Conference on Systems

and Devices for Disabled held in June 1-3, 1977 at Seattle, Washington, pp. 192-195.

2. C.B. Taft, "Radiographic Evaluation of Stump Socket Fit," Artificial Limbs, vol. 13, ppl 13-40, Autumn, 1969.

3. F.A. Appoldt, L. Bennett, R. Contini, "Stump Socket Pressure in Lower Extremity Prosthesis, "J. Biomechanics, vol.1, pp. 247-257, 1968.

4. L.A. Leavitt, E.N. Zuniga, "Gait Analysis - Prosthetic Function in a Series of Above-Knee Amputee, "Final Report at T.I.R.R., Sept., 1971.

5. P. Brand, V. Mooney, "Effects of Pressure on Human Tissue, "report on the workshop on the Effects of Pressure on Human Tissues held on March 24-26, 1977 at USPHS Hospital, Carville, Louisiana.

Appendix

The algorithm to calculate the residual limb volume using T1 58 or T1 59 programmable calculator with PC 100 A printer is given below. The program only prints the circumferences and total volume, and displays incremental volumes. The program has the capacity to calculate at 1 or 2 inch increments.

CODE	KEY	COMMENTS
42	STO	
02	02	C_k, top circumference
33	X_2	
85	+	
43	RCL	
01	01	C_j, next circumference
33	X^2	
85	+	
43	RCL	
02	02	
65	X	
48	EXC	
01	01	
95	=	
55	÷	
01	1	
02	2	
55	÷	
89	π	
95	=	
65	X	
43	RCL	
03	03	h, increment
95	=	
44	SUM	V_i, increment Volume
00	00	
43	RCL	
02	02	
99	PRT	

CODE	KEY	COMMENTS
32	XIT	
81	RST	
76	LBL	
13	C	Circumference with 1 inch increments
32	XIT	
01	1	
42	STO	
03	03	
32	XIT	
81	RST	
76	LBL	h_{tip}, tip height
14	D	
42	STO	
04	04	
43	RCL	
01	01	C_n, last circumference
33	X^2	
55	÷	
89	π	
65	X	
93	.	
07	7	
05	5	
85	+	
43	RCL	

91	R/S	
76	LBL	top circumference
11	A	
42	STO	
01	01	
25	CLR	
42	STO	
00	00	
43	RCL	
01	01	
99	PRT	
91	R/S	
76	LBL	circumferences with 2 inch increments
12	B	
32	XIT	
02	2	
42	STO	
03	03	

04	04	h_{tip}, tip height
33	X^2	
95	=	
65	X	
43	RCL	
04	04	
65	X	
89	π	
55	÷	
06	6	
95	=	
44	SUM	V_{tip}, tip volume
00	00	
43	RCL	
04	04	
99	PRT	
98	ADV	
43	RCL	
00	00	V_{total}, total volume
99	PRT	
91	R/S	

The user instructions for T1 58 and T1 59 algorithm is given below:

Step-Enter	Press	Display	Print
1. C_1, top circumference	A	C_1	C_1
2. C_2, through C sequentially (2 inches apart)	B	$C_2..C_n$	$C_2..C_n$
3. C through C'_n sequentially (1 inch apart)	C	$C'_2..C'_n$	$C'_2..C'_n$
4. h_{tip}, tip height (if tip enter 0)	D	h_{tip}	h_{tip}
			V_{total}

A NEW CONDUCTIVE WALKWAY FOR THE LOCALIZATION OF FOOT POSITION IN GAIT ANALYSES+

R. Bloch++ and S. Szarka

from the Department of Bioengineering, Chedoke Rehabilitation Centre and McMaster University, Hamilton, Ontario, Canada.

The conductive walkway enables on-line analysis of such gait parameters as step-length, stride-length, base-width, toe-out as well as duration of swing- and stance-phase for each foot. The instance and position of each foot are determined from measurements of the electrical field, created in the conductive walkway material by two sequential current sources on the sole of each shoe.

Preliminary measurements have localized the foot-position to within 7.5 cm from the true position on a 122 cm x 488 cm walkway. Improvement in accuracy is expected from the use of an on-line computer. The gait parameters will be useful in the planning and evaluation of orthopedic surgery and prostheses, and for the documentation and diagnosis of gait disturbances.

CATEGORY: Device Development ☒ Research Study ☐	INTENDED USER GROUP: Patients with gait disorders. AVAILABILITY OF DEVICE: Not at present
STATE OF DEVELOPMENT: Prototype ☒ Clinical Testing ☐ Production ☐	AVAILABILITY OF CONSTRUCTIONAL DETAILS: Not at present
AVAILABLE FOR SALE: Yes ☐ No ☒ Price: N/A	FOR FURTHER INFORMATION CONTACT: Dr. R. Bloch Chedoke Hospitals P.O. Box 590 Hamilton, Ont. L8N 3L6

During the past twenty years, the ability to analyze human gait quantitatively, has made tremendous progress through the application of new technology (1).

The instantaneous positions of limbs and the trunk as well as the angles of the joints have been determined by cinematography (1), flash photography (1), video (2) and Charge Coupled Device (3) (CCD) imaging, Sel-Spot scanning (4) as well as by mechanical (5) and polarized light goniometry (6).

The forces occurring during ambulation have been measured by force platforms and several other types of transducers. Muscle activity has been recorded by both surface and intramuscular electromyography (7). Also, the instants of foot contact have been derived from footswitch signal analysis. Step length has been measured employing ladder networks (8).

+Supported by a grant from the National Research Council of Canada

++Canadian Life Insurance Association Scholar

Despite the technological advances, these objective tools have not found general acceptance in clinical practice. The few institutions which employ such modern techniques, do so primarily for the evaluation of new therapeutic techniques, or to provide answers to fundamental questions, rather than for the evaluation of clinical problems.

Two key reasons for this seeming neglect of objective tools are:

1. The high hardware costs and the special manpower required for the successful realization of the various techniques.

2. The unfamiliarity of most physicians with the motion parameters obtained by the use of these tools: hip-knee angle-angle diagrams (9), footswitch records and electromyographic (EMG) records.

General description

Any clinically useful measurement should provide diagnostically relevant parameters which are familiar to the orthopedic surgeon and physician. Examples include step length, step-base, and toe-out. The acceptable method should also be simple to use, not demanding complex set-up and laborious calibration procedures. We have designed such a method and its equipment which meet many criteria pertinent to clinical pathokinesiology.

In this method, the subject carries two electrodes tacked, or otherwise fastened to the heel and forefoot of each of his shoes. With these electrodes, the subject walks along a conductive walkway. (Fig. 1).

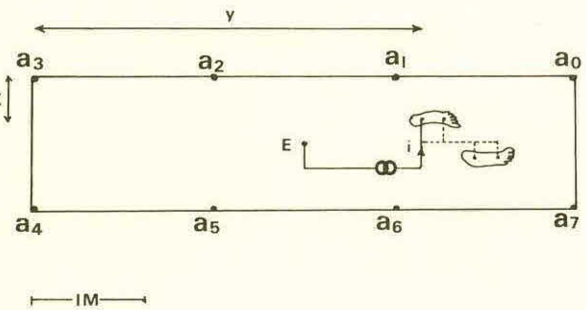

Fig. 1. Schematic diagram of walkway with position of two feet and electrodes. The current flows from one of the four foot-sole electrodes to electrode E, in the centre of the mat. Potentials are measured relative to electrode a_0 at positions a_1 to a_7.

Each of the four foot electrodes sequentially acts as a current source, and an electrode in the centre of the walkway serves as the sink. Eight pickup electrodes along the boundary of the walkway sense the potentials created by the current source-sink configuration. From these potentials, foot position and timing information is determined; without the need for separate footswitches.

The walkway is a rectangular sheet of electrically conductive plastic*, 3 mm. thick and measuring 1.22 by 4.88 metres. While the volume conductivity of this material is constant and can easily be measured, the surface resistance between the sheet and the contacting electrode materials varies and is difficult to control. To make the electrode potential measurements relevant, the surface contacts must act either as current sinks or current sources, or they must present a high impedance to the walkway surface, thereby avoiding the uncertain contribution of the surface resistance.

Theoretical considerations

The electrical potential field is created by a current sink and a current source in the homogenously conductive material. The field configuration can be calculated by applying the Poisson equation. Because of the previously mentioned surface contact problem it is easier to realize Neumann-, rather than Dirichlet-boundary conditions. Even though the Poisson equation solution for rectangular Neumann-boundaries is well known, the resulting polynomials converge slowly (10) and it becomes difficult to solve for the foot contact position.

We took a different approach, that of conformal mapping to transform the inside of the rectangle, in the z-plane, into the upper-half of the w-plane (Fig. 2).

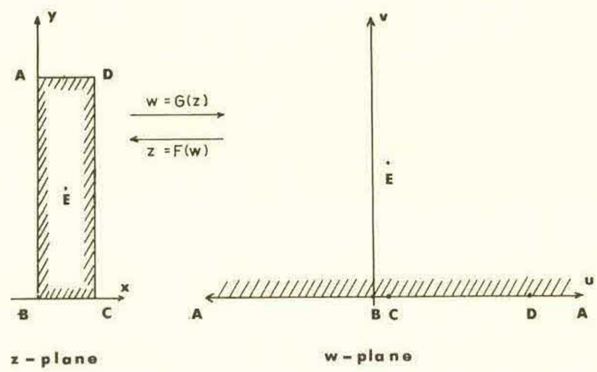

Fig. 2. Schwarz-Christoffel transformation for pathway, mapping the inside of the rectangle onto upper half-plane and the rectangular boundary on the u-axis.

The u-axis thus becomes the new boundary. This transformation is achieved by application of an elliptic function of the first kind: (11)

$$w = \left[\mathrm{sn} \left(\frac{Kz}{a}, k\right) \right]^2 \quad \text{where } k = .007469, \quad K = 1.571, \quad a = 1.22 \text{ metre} \qquad (1)$$

In the w-plane, the Poisson equation has a simple, closed solution. Ideally, measuring the field at two suitably chosen points along the boundary, should suffice to determine the position of the source. However, in the real physical environment, the measurements are contaminated by extraneous electrical noise, inhomogeneities of the conductive material and other factors. So as to reduce the noise related errors in the calculated source position, we have enlisted redundancy by measuring the potential at 7 points relative to a_0. A linear least squares method is used, which reduces to two sums for the position (u, v) in the w-plane:

*Velostat, 3M Company

$$u = c_0 + \sum_{n=1}^{7} (e^{\alpha \cdot V_n} - 1) \cdot c_n \quad (2)$$

$$(v^2 + u^2) = b_0 + \sum_{n=1}^{7} (e^{\alpha \cdot V_n} - 1) \cdot b_n \quad (3)$$

The potentials V_n are measured at the pickup points along the boundary. The constant α is determined by the electrical properties of the walkway and the total current. The coefficients $c_0 \ldots\ldots c_7$ and $b_0 \ldots\ldots b_7$ have been calculated from the walkway geometry and the position of the stationary electrodes.

Once the w-plane position of each shoe contact is found, this location can be transformed back into the z-plane by using a simple polynomial method to calculate the elliptic integral--the inverse of the elliptic function.

Results

Preliminary measurements were performed with a digital voltmeter. The positions were calculated on a programmable hand held calculator. Four points were used. The calculated position deviates from the true position by 7.5 cm. in the average. These errors are partly due to calibration of the voltmeter, current fluctuations and inhomogeneities in the walkway material.

These problems are considered in the design of the prototype.

Physical implementation

We are currently working at the hardware implementation of the above method. The four foot electrodes are sequentially chosen as current sources by a multiplexor. The current is derived from a constant current source. For each source choice the potentials at the electrode positions are measured sequentially. The calculations will be done by an on-line PDP 11/10, but the calculations are easily within the realm of a microcomputer. The computer will calibrate the potential measurements every 15 ms. If needed, material dependent field deformations can be corrected for, by means of a look-up table.

Summary

We have proposed a solution and shown its feasibility, for the clinical problem on online footstep position analysis. We have used well understood complex analysis and numerical methods. A prototype is under construction.

References

1) Murray, M.P., "Gait as Total Pattern of Movement Including a Bibliography on Gait", Am. J Phys. Med. 46(1): 290-333 (1967).

2) Winter, D.A. et al., "Television-Computer Analysis of Kinematic of Human Gait", Comp. Biomed. Res. 5: 498 (1972).

3) Brugger, W. and Milner, M., "Computer-Aided Tracking of Body Motions Using a CCD-Image Sensor", To be published in Medical and Biological Engineering.

4) Woltring, H.J., "New Possibilities for Human Motion Studies by Real-Time Light Spot Position Measurement", Biotelemetry 1: 123-146 (1974).

5) US Armed Forces, "Electrogoniometric Records of Knee and Ankle Movements in Pathologic Gait", Med. J. 11: 424 (1960).

6) Grieve, D.W., "A Device Called the Polgon for the Measurement of the Orientation of Parts of the Body Relative to a Fixed External Axis", Proc. Physiol. Soc. 10-11 (Jan. 1969).

7) Basmajian, J.V., and Bentzon, J.W., "Electromyographic Study of Certain Muscles of the Leg and Foot in the Standing Position", Surg. Gynec. Obstet. 98: 662-6 (1954).

8) Wall, J.C. et al., "A Method of Measuring the Temporal/Distance Factors of Gait", Biomedical Engineering 409-12 (Dec. 1976).

9) Grieve, D.W., "Gait Patterns and the Speed of Walking", Biomedical Engineering 119-22 (March 1968).

10) Morse, P.M. and Feshbach, H., "Methods of Theoretical Physics", Vol. I: 712, McGraw Hill Co. (1953).

11) Ibid Vol. II: 1252.

12) Ibid Vol. II: 1180.

ELECTROGONIOMETRY AS A TOOL FOR CLINICAL GAIT EVALUATION

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Locomotor rehabilitation requires repeated evaluation of walking ability. Objective measurements of anatomic joint motion during walking can contribute to this evaluation process. Electrogoniometers are convenient for making such measurements because results are obtained immediately, with no requirement for data reduction. Unfortunately, conventional electrogoniometers tend to restrict normal joint motions, and they require careful alignment with anatomic joint axes for accurate results. A simple mechanical linkage has been devised that transmits the angular motion to be measured, while freely absorbing all other motions. This linkage forms the basis for an electrogoniometer that is self-aligning and non-restricting. Design details are described that are intended to facilitate practical use of the device in a rehabilitation clinic.

CATEGORY: Device Development ☒ Research Study ☐	INTENDED USER GROUP: Locomotion researchers and rehabilitation clinicians
STATE OF DEVELOPMENT: Prototype ☒ Clinical Testing ☒ Production ☐	AVAILABILITY OF DEVICE: Not currently available in manufactured form AVAILABILITY OF CONSTRUCTIONAL DETAILS: Drawings are available from the author
AVAILABLE FOR SALE: Yes ☐ No ☒ Price:	FOR FURTHER INFORMATION CONTACT: Biomechanics Laboratory Department of Mechanical Engineering University of Calif., Berkeley, CA 94720

Introduction

Rehabilitation of people with locomotor disabilities requires repeated evaluation of their ability to walk. First it is necessary to identify what is interfering with their walking, then to determine what type of treatment is most effective, and finally to judge periodically whether the patient's ability to walk is getting better or worse. At present, such evaluations are largely subjective, relying on information from the patient and observations by the clinician.

Objective measurements provide an additional source of information that has great potential value for gait evaluation. Measurements of gait provide quantitative descriptions, in numeric or graphic form, that are fundamentally different from the subjective observations normally used for gait evaluation. A recorded measurement provides information about the patient's gait that can be of value for the following reasons:

1. It permits visualization of parameters that are too fast or too subtle for the eye to see.

2. It permits visualization of relationships between parameters.

3. It provides a common basis for discussion--all members of the clinic team can look at the same information as they discuss and assess the patient's ability to walk.

4. It permits explicit communication about the patient's gait to other people not present.

5. It provides a kind of permanent memory, allowing precise assessment of changes in the measured quantities with time and treatment.

Gait measurement systems intended for clinical use must be quick and easy to apply, or they will not be suitable for routine patient care. In locomotion research laboratories, many different measurement techniques have been used to study a wide range of variables involved in the complex neuro-musculo-skeletal processes of walking (1) (2). Outside the research laboratory, and particularly in a rehabilitation clinic, it is generally not feasible to measure everything of interest. Restrictions of both the scope and the complexity of measurements are necessary in order to avoid overburdening the patient and the clinic staff. The following general requirements are suggested as an aid to selection of the most appropriate variables for measurement in any specific gait evaluation project.

1. Measurements must be reliable and repeatable.

2. They must show gait parameters that are relevant to the disability being examined.

3. They should be presented without delay in clear, easily interpreted visual form.

4. A permanent copy of the results should be immediately available for inclusion in the patient's medical records.

Electrogoniometry

Measurements of the angular movements of anatomic joints are of basic importance to any objective description of gait and are relevant to virtually all gait evaluation tasks because joint motions are the fundamental elements by which locomotion is accomplished. Electrogoniometers are of great interest and great potential practical value for clinical measurements of gait because they are relatively low in cost and easy to use, and they can provide direct measurements of anatomic joint motions over many successive gait cycles without time delay, without parallax errors, and without the need for complex data processing. For those patients who are not disturbed by measuring devices touching the body, electrogoniometry is undoubtedly the simplest and most direct method for recording angular motions of anatomic joints.

Electrogoniometry involves the measurement of anatomic joint motion by means of an electrical-output rotary-motion transducer mounted on the patient over the anatomic joint whose motion is to be recorded. The simplest electrogoniometer is a potentiometer fitted with two extended arms, one attached to the housing and one to the rotating shaft of the potentiometer (3). In the use of such an instrument, one arm is attached to the body segment proximal to the anatomic joint being measured and the other arm is attached to the body segment distal to the joint. Such a simple goniometer presents two serious problems in use:

1. The goniometer is a simple hinged joint that moves in a single plane about a rigidly defined axis. Most anatomic joints have more complex motions. When the goniometer is superimposed on an anatomic joint, it restricts the joint to motion in a single plane, thereby interfering with normal out-of-plane motions and altering accustomed patterns of walking.

2. Accurate measurements require accurate coaxial alignment between the anatomic joint axis and the potentiometer axis to insure that the goniometer arms rotate through the same relative angle as the corresponding anatomic body segments. In practice, it is difficult to achieve such an alignment at most anatomic joints, and almost impossible to maintain it during motion.

These two interrelated problems make the conventional electrogoniometer quite unsuitable for measurements of flexion angles at hip, knee, and ankle joints, which is unfortunate because these joint motions are the most significant kinematic elements contributing to forward progression of the body during alternating bipedal locomotion (4).

Numerous refinements of the conventional electrogoniometer have been undertaken to overcome its limitations. Trnkoczy and Bajd describe a design with extra joints in the arms that permits goniometric measurements of flexion angles at hip, knee, and ankle joints (5). This instrument requires careful alignment with anatomic joints, but it minimizes the number and extent of body contact points, a practical advantage for clinical use. Chao describes a variety of efforts to use electrogoniometry for the collection of joint angular motion data in three dimensions (2). The device to be described below is based on an earlier design (6) that makes use of freely jointed coupling linkages to selectively transmit desired motions for measurement, while absorbing all other motions.

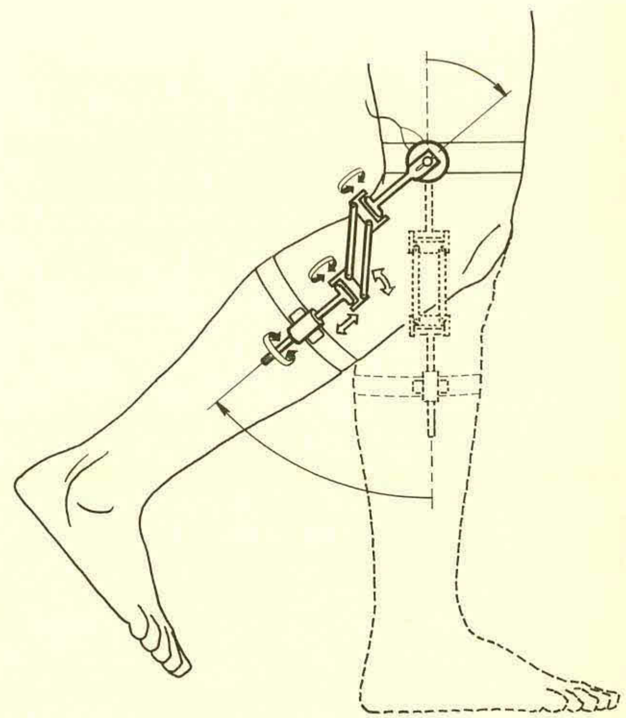

Figure 1. Schematic representation of the self-aligning goniometer. A specially devised coupling linkage transmits the flexion angle, θ_k, from the shank to a rotary transducer mounted on the thigh, while simultaneously absorbing all other relative motions. An exaggerated misalignment between transducer axis and knee axis shows how the motions indicated by the broad arrows permit the linkage to accommodate misalignment. This accommodation also insures that the device cannot restrict motion of the anatomic joint.

The self-aligning goniometer

To facilitate practical and reliable use of electrogoniometry at hip, knee, and ankle joints, self-aligning linkages have been devised at the Biomechanics Laboratory that accurately transmit the angles being measured while absorbing all extraneous linear or angular relative motions that may result from misalignment between corresponding measurement and anatomic axes. See figure 1. These linkages are the basis for a type of electrogoniometer that is incapable of resisting anatomic joint motions in any plane, is not dependent upon accurate alignment with anatomic joints for accurate measurement, and consequently is free of the two fundamental problems of conventional electrogoniometers. At the Biomechanics Laboratory, self-aligning linkages have been developed for angular measurements in one, two, or three dimensions, but those for one dimension, illustrated in figures 1 to 4, are the simplest and therefore the most practical to consider for routine clinical use.

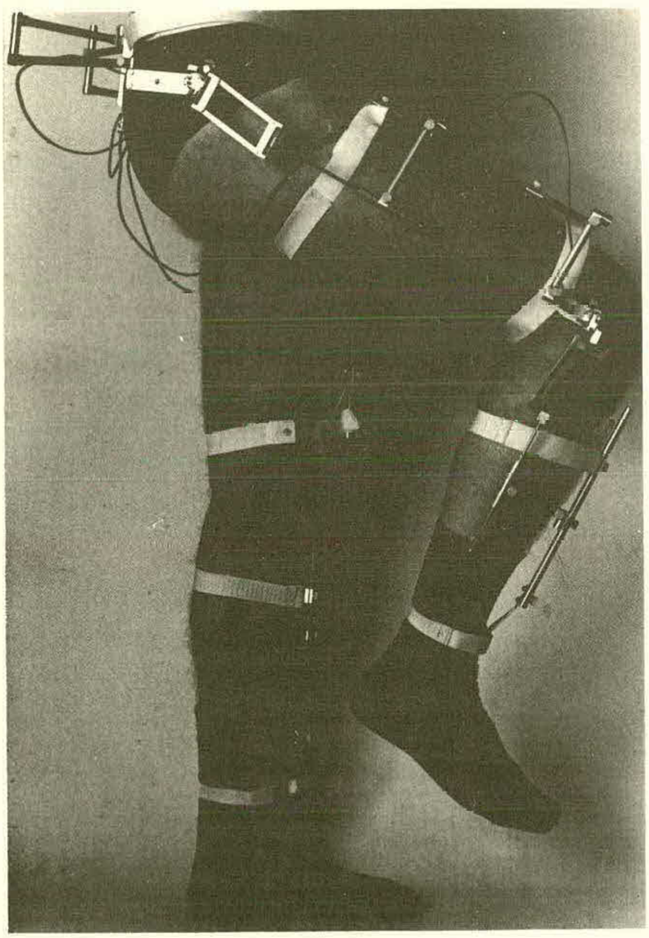

Figure 2. Side view of self-aligning goniometers for simultaneous flexion angle measurements of both hips and both knees, showing the method of attachment to thigh and shank, and the adjustable supports for potentiometers and linkage guides.

The self-aligning linkages do not eliminate the necessity for attachments to the body; accurate application of the linkages depends upon accurate connections to the two body segments adjacent to the joint being measured. Any relative angular motion in the plane of measurement between an attachment frame and the corresponding body segment will constitute an error in the measurement. This problem is not unique to goniometry, but is common to all measurement systems that use anatomic surface features for reference marks, including photographic and electronic optical tracking methods. In practice, the difficulty of eliminating relative motion between attachment framework and body segments remains the greatest limitation to accurate measurements.

Attachment, alignment, and accuracy

The method of attachment to body segments must be planned with care in order to minimize relative motions of the attachments, to minimize added mass, to avoid interference with normal movement of soft tissue, to allow ready adjustment to a wide range of patients, and to clearly define the planes of measurement.

No matter where the motion transducer may be located on a body segment, the plane of measurement will be perpendicular to the axis of transducer rotation. The angle measured by the transducer will be a two-dimensional projection, onto the plane of measurement, of the true angle between body segments. Some care is appropriate, therefore, to locate the transducer so that the plane of measurement parallels the plane of motion of the joint being measured. For one-dimensional measurements, small amounts of angular misalignment have little effect, but when two- or three-dimensional measurements are under taken, the orientation of the planes of measurement to each other and to the anatomic structures of the body must be accurately defined in order to permit unambiguous interpretation of the measurements.

In using the self-aligning goniometer, it generally is desirable to locate measurement axes close to the corresponding anatomic axes in order to minimize the relative motions that must be accomodated by the self-aligning linkages. Accuracy of measurement is not significantly affected by parallel misalignment between measurement and anatomic axes, however, as long as the ranges of accommodation of the linkages are not exceeded.

The most satisfactory method of attachment to long slender body segments such as thigh or shank is to provide a lightweight, rigid, adjustable structure that has two encircling contact bands spaced as far apart as practical. In other words, the contacts should be as close to the ends of the body segment as possible, without interfering with motion of the joints. See figures 2 and 3. Attachment to the pelvis is accomplished as shown in figure 4 by forcing a flat reference surface firmly against the sacrum with an encircling band that passes below the anterior superior iliac spines. On non-obese patients, angular motions of these attachment frames relative to the corresponding body segments in the plane of measurement can be reduced to the order of 3 degrees on the thigh and pelvis, and even less on the shank. In view of the relatively

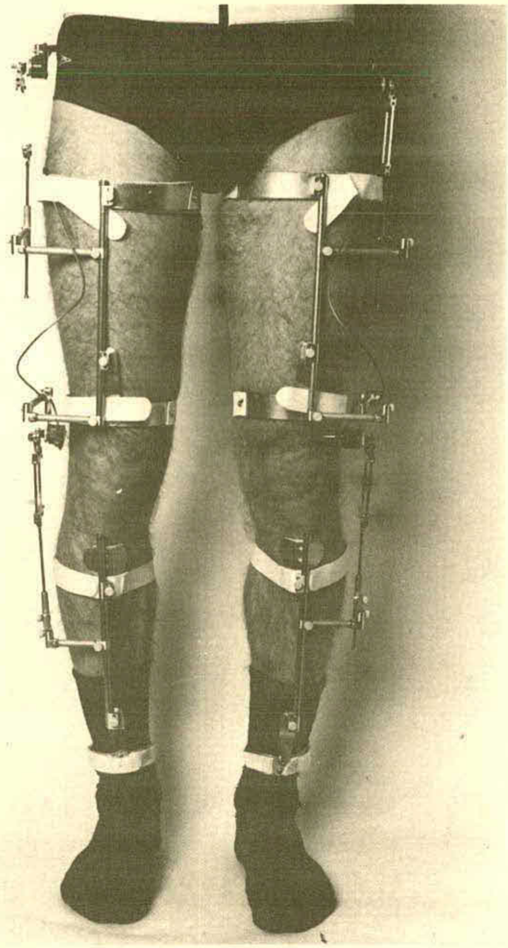

Figure 3. Front view of the self-aligning goniometers showing close fit of linkages to the body.

large magnitudes of these attachment errors, conventional precision potentiometers would appear to be suitably precise to serve as the angle transducers. The self-aligning linkages themselves contribute a negligible error when care is taken in their construction, less than 1/4 degree for deflections of the parallelogram linkage less than 45 degrees.

The chosen method of construction makes possible adjustable, modular, attachment frames that can be quickly fitted to a wide variety of patients. Adjustable links on the attachment frames allow the potentiometers to be positioned in the region of the anatomic joints. The potentiometers are set for zero output when the long tubes that form the main structure of each attachment frame are parallel in the side view. If, during fitting of the frames to a patient, care is taken to position each tube parallel to the estimated long axis of the corresponding body segment (by bending the distal aluminum strap visible in figures 2 and 3), the potentiometers will have zero output at full extension of each joint. All adjustment axes on the frames are located at right angles to the measurement axes to insure that this zero setting of each potentiometer will be preserved during fitting of the system to an individual patient.

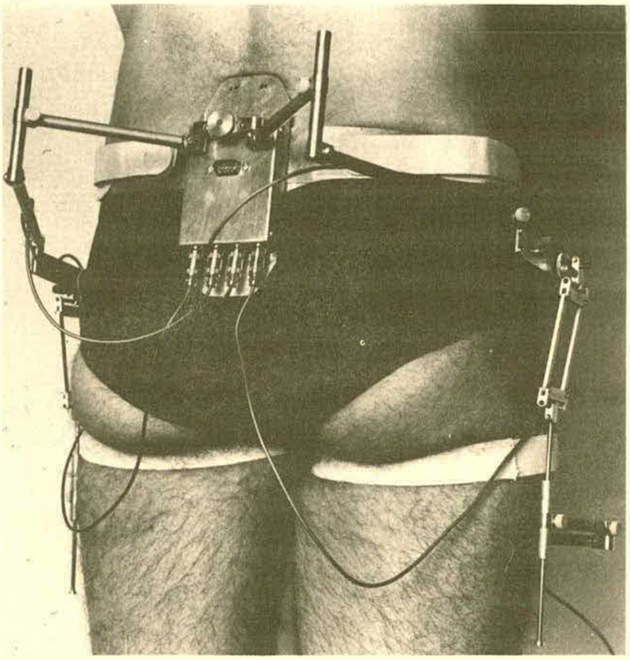

Figure 4. Rear quarter view of the pelvic attachment for the hip flexion goniometer. The waist-band forces a padded flat surface securely against the sacrum. Note that the axes of all the adjustment joints are at right angles to the measurement axis, allowing adjustment to different sized patients without changing the goniometer zero setting.

By far the most challenging attachment problem is the elimination of relative axial rotation of the thigh attachment on the thigh. Relative axial motions in excess of five degrees are commonly observed because of the mobility of the skin over the large muscle mass that surrounds the thigh, and the lack of any prominent skeletal structures to index upon. In contrast, the shank attachment frame can be made to index on medial and lateral melleoli and thereby achieve more rigid axial fixation. The insertion of pins into bones for position reference is no longer regarded as an acceptable experimental procedure at most institutions.

Relative axial rotations are not of much significance when only the flexion angles are being measured, but for three dimensional measurements, the inability to attach measuring devices accurately to the thigh in the axial rotation direction makes it impossible to accurately define a spatial coordinate system for measurement. Without a clearly defined, unambiguous coordinate system it is a questionable exercise to try to measure axial rotation or ad- abduction at the knee or hip, even though suitable transducers exist.

Transducers

Conductive plastic "Econopots" made by New England Instrument Co. of Natick Massachusetts are used for transducers in the self-aligning goniometers. A computer calibration system has been developed to provide high-resolution checks of potentiometer nonlinearities. A unity-gain follower amplifier is permanently mounted on each individual potentiometer to provide a low-impedance output of ± 10 volts. Each potentiometer with attached amplifier is calibrated to a standard sensitivity to permit transducer interchange without recalibration. This precalibration eliminates the need for calibration on the patient, and provides a much more precise and reliable calibration than can be obtained on the patient.

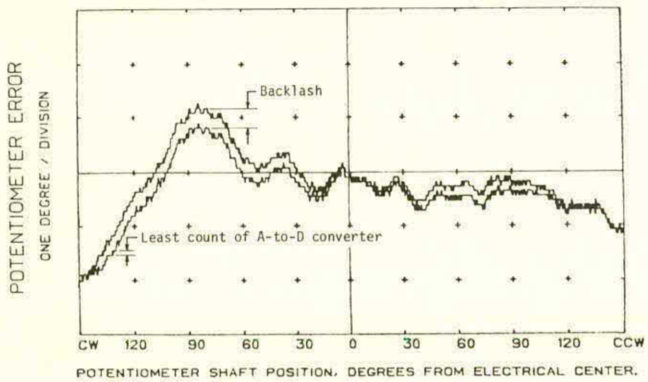

Figure 5. Typical calibration curve for a precision potentiometer with conductive plastic resistance element. The vertical scale represents deviation of the potentiometer output from perfect independent linearity. Errors result from nonuniformity in the resistance element, backlash in the wiper, and limited resolution of the analog-to-digital converter that is used to measure potentiometer output.

The reference used for calibration of the potentiometers is a 1000 pulse-per-revolution Baldwin bidirectional optical encoder. The shaft of the potentiometer to be calibrated is rigidly and concentrically attached to the shaft of the reference encoder, so the two can be slowly rotated together. The output of the potentiometer is fed into the computer through the Analog-to-Digital (A to D) converter, the output of the encoder through a special digital input interface. During calibration, the computer program first locates the electrical center of the potentiometer by watching for a zero output from the A to D converter. The program then proceeds to keep track of the position of the optical encoder. The desired output of the potentiometer (for perfect calibration) can be calculated from the known position of the reference encoder, while the actual output is observed at the output of the A to D converter. A simple subtraction yields the potentiometer error, which is displayed as in figure 5. The excitation current through the potentiometer is adjusted to obtain the best possible calibration.

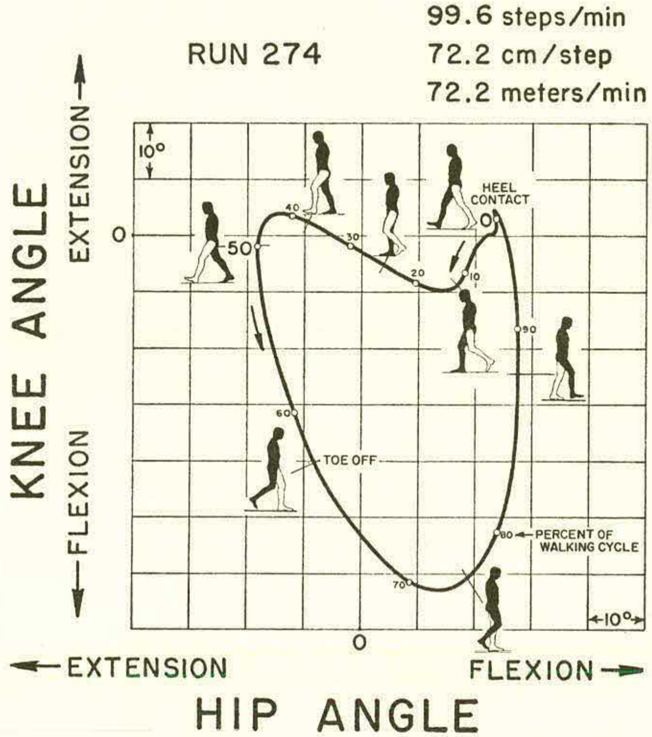

Figure 6. Hip-Knee angle/angle diagram for the right leg of a normal subject, averaged over 20 walking cycles. Zero values represent the positions of hip and knee during relaxed standing. Any changes in the way hip or knee is moved during walking will alter the shape of the diagram, dramatically illustrating changes in hip-knee coordination.

Display of measurements

One of the hindrances to clinical use of objective measurements of gait has been the difficulty of presenting the measurements quickly in a format that is meaningful to the clinical staff. Grieve has spoken eloquently to this problem (4). One of Grieve's suggestions was the plotting of hip and knee measurements against each other, as shown in figure 6, rather than as functions of time. Such a presentation more clearly shows relationships between the two variables, a desirable feature for joints as intimately interrelated as hip and knee. This type of display has the further advantage that no synchronization signal is necessary to obtain accurate superposition of successive gait cycles. The latter point may not seem very important, but it insures accurate superposition of successive walking cycles and is a significant practical asset, particularly in a busy clinical setting.

To permit clinical testing of the self-aligning goniometers, a portable display unit was built that generates hip-knee angle diagrams for left and right legs simultaneously on a Tektronix Type 603 display monitor as shown in figure 7. Permanent copies of the displays are obtained for the patient's record with an oscilloscope camera using Polaroid film.

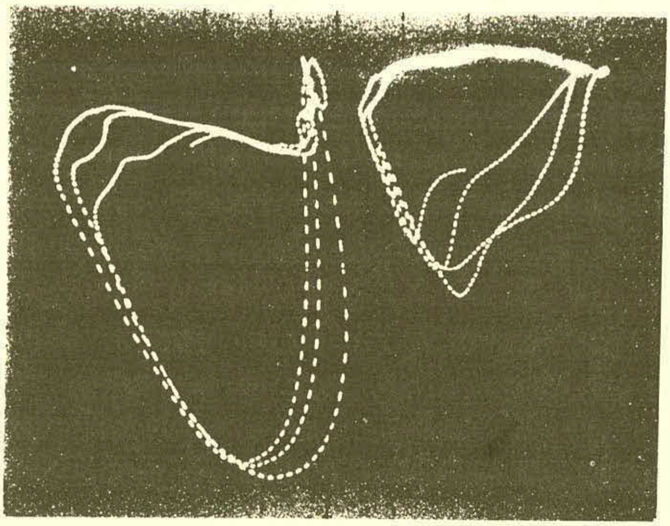

Figure 7. Hip-Knee angle diagrams for a subject with restricted mobility of the right knee. Coordinate system is as in figure 6. The two bright spots represent full extension of hips and knees as defined in the text.

This equipment, along with associated instruments for measuring walking speed and step rate, has been undergoing clinical trials since the summer of 1976 in the gait clinic of the Department of Orthopaedic Surgery, University of Uppsala, in Sweden. Patients examined have included candidates for total hip or knee replacement, both before and after surgery whenever possible, and above- and below-knee amputees. This clinical trial is nearing completion and will be reported in the near future.

Conclusions

Clinical trials on more than twenty joint-replacement patients indicate that the self-aligning goniometer described above offers a practical tool for clinical measurement of flexion angles of hip and knee joints during walking. The self-aligning characteristic of the coupling linkages prevents restriction of anatomic joint motions, thereby minimizing any alterations of the patient's accustomed gait by the instrument. The self-aligning feature also eliminates the necessity of achieving or maintaining precise alignment with anatomic joints in order to achieve accurate measurements, thereby simplifying set-up on the patient and greatly improving repeatibility and reliability of the measured data.

The method of body attachment used for the self-aligning goniometers is believed to provide the best accuracy that is possible with measuring instruments that contact soft tissue. Precalibration of the potentiometer sensitivity eliminates the need for calibration on the patient, thereby improving accuracy and simplifying the set-up process. Presetting of the potentiometers, so that electrical outputs are zero when the joints are at full extension, insures that not only the shapes of the measured curves, but also their absolute values, will be meaningful.

The fact that the measured variables are presented instantly, and in electrical form, allows for maximum versatility in the display and recording of results to best suit the needs of a particular evaluation project.

It should be emphasized that all gait variables are influenced to some degree by changes in walking speed, step length, or step rate. Such changes are to be expected during successful rehabilitation of locomotor disabilities. The collection and interpretation of <u>any</u> gait data must take into account such changes, or confusion is inevitable.

Acknowledgements

This project was made possible by a grant from the United States Veterans Administration, and that support is gratefully acknowledged.

References

1. Cavanagh, P. R., "Recent Advances in Instrumentation and Methodology of Biomechanical Studies," Biomechanics VB, Proc. 5th Int. Cong. of Biomech., Jyvaskyla, Finland; Univ. Park Press, Baltimore, pp. 399-411, 1976.

2. Chao, E. Y., "Experimental Methods for Biomechanical Measurements of Joint Kinematics," CRC Handbook of Engineering in Medicine and Biology, E. Bahniuk & A. Burstein, Eds., in press.

3. Karpovich, P. V., Herden, E. L., and Asa, M. M., "Electrogoniometric Study of Joints," Armed Forces Medical Journal, 11:4, April 1960, pp. 424-450.

4. Grieve, D. W., "The Assessment of Gait," Physiotherapy, 55:452-460, 1969, p. 457.

5. Trnkoczy, A. and Bajd, T., "A Simple Electrogoniometric System and Its Testing," IEEE Trans. Biomed. Eng'g, May 1975, pp. 257-259.

6. Lamoreux, L. W., "Kinematic Measurements of Human Walking," Bul. Prosthetics Research, BPR 10-15: 3-84, 1971, p. 34.

DEVELOPMENT OF A DRIVER EVALUATOR - TRAINER AID FOR THE HANDICAPPED

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Abstract

An indoor driver evaluator-trainer aid vehicle was developed to quantify students' ability and progress in learning to drive. In general, the instrumentation for each control was built to measure operating force and elapsed time. The system consists of functional ignition and gear shift control; instrumented steering wheel, hand controls for brake and acceleration; and elapsed response time meters for each control. The controls allow the major driving functions to be evaluated in their interactive mode and trained using variable mechanical resistance elements.

CATEGORY:	INTENDED USER GROUP: Spinal Cord Injured (C5 or below)
Device Development ☒ Research Study ☐	AVAILABILITY OF DEVICE: Limited
STATE OF DEVELOPMENT:	
Prototype ☒ Clinical Testing ☐ Production ☐	AVAILABILITY OF CONSTRUCTIONAL DETAILS: Open
AVAILABLE FOR SALE:	FOR FURTHER INFORMATION CONTACT: Authors
Yes ☐ No ☒ Price:	

Introduction

Through technology, persons with severe disability have been able to achieve mobility independence. An important measure of their independence is their ability to drive personal licensed vehicles (automobile, van, or truck)(1,2).

The Occupational Therapy Departm - at Woodrow Wilson Rehabilitation Center has been evaluating drivers for several years. All persons requiring a medical authorization for driving are being evaluated. This involves many disabilities. In evaluation, those persons with partial or complete quadriplegia (C5 or below) requiring hand controls have become a particular challenge. The Keystone Vision Equipment, the AAA Driver Education System, and the Aetna Drivotrainer Simulator are used to evaluate clients. Reaction time and night vision are easily tested, but the Drivotrainer has had to be modified to accomodate driving from wheelchair. Recently, the evaluation program has been upgraded by the addition of an occupational therapist as a driver education instructor who is also an evaluator and trainer. Fifty percent of her time is spent doing on-the-road evaluation and training for the severely disabled clients.

Although these tools are alternatives and adequate for some clients they did not provide enough information to predict the abilities of the more severely disabled clients like the quadriplegic. The simulator became more useful as an exercise device rather than an evaluation tool. In particular the above equipment failed to evaluate the simultaneous functions required by "on the road" driving. A new system was needed which would allow the quantification of the major driving functions in their interactive mode. In addition to evaluation, the instrumentation would have to be capable of monitoring patient progress.

The resulting design criteria was:

- a realistic method of testing and monitoring of driver performance in braking, steering and acceleration.
- training within the spacial restrictions of the driver compartment.
- provision of visual or auditory feedback during testing and training.

Following these criteria, the instrumentation should provide the guidance to establish levels of human performance necessary to permit a severely disabled individual to operate a personal licensed vehicle safely.

Controls and Instrumentation

During vehicle operation the driver's ability to apply the necessary forces to accelerate, to brake and to steer are not sufficient by themselves as evaluative tools. The completion of a driving task within a certain interval of time and the capability to maintain certain force levels over that time interval are fundamental to proper handling of the vehicle. The basis of our instrumentation is the simultaneous measurement of exerted force and duration since driving strongly relies on the interdependence of control force, displacement and timing.

Force monitoring of the driver's use of the vehicle controls indicates the course from onset to completion of the driving task. Figure 1 shows an idealized force-response curve as it is experienced in the acts of braking, steering or other control tasks. The time from a visual stim-

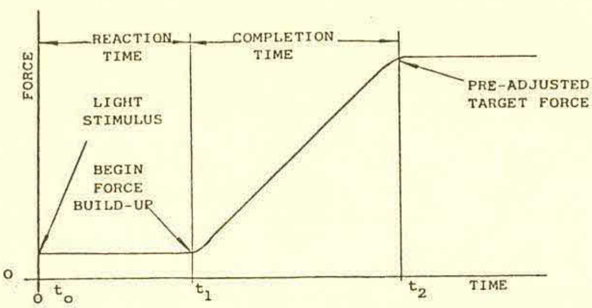

Figure 1. Idealized Force-Response Curve Generated By The Driver In the Course of A Driving Task.

ulus (at t_o) to the beginning of force build up (at t_1) is a well defined measure of the initial reaction time ($RT=t_1-t_o$). The end point is taken when the pre-adjusted target force is reached. The time to this end point (t_2) is that for reaction plus complete force build up, and the difference ($CT=t_2-t_1$) is the measure of the task completion time (CT).

The instrumented controls were installed in an A.M.C. Pacer* located indoors and adapted with push-rightangle-pull (Gresham Slimline) hand control (see Figure 2). The engine and automatic transmission were removed and the steering system was disconnected from the wheels, allowing space for modifications. The speedometer was modified to be functional by a D-C motor drive, speed controlled from the accelerator pedal. A tri-color traffic light simulator, positioned on the front hood of the car and controlled by the tester, was added to initiate the testing sequences. The key activated ignition system and gear shift was modified to enable all electrical components of the system to operate.

The principle instrumentations involve the brake, accelerator and steering controls. Braking and acceleration measurements are accomplished by the standard hand control apparatus activating timers to measure, in tenths of seconds, the response time of braking. One timer measures the

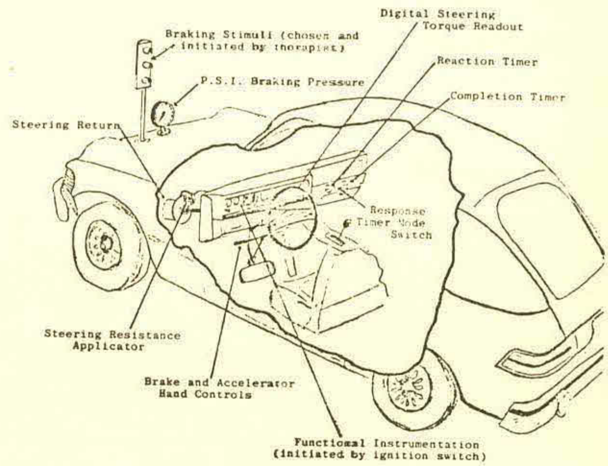

Figure 2. The instrumented driver evaluator - trainer aid vehicle used for assessment of handicapped driver performance.

length of the reaction time, RT. This counter is started simultaneously with the light stimulus and is stopped when the brake is just activated. The same action stopping the reaction timer will start the second timer measuring the duration of the completion time, CT. It ceases counting when the driver achieves a pre-adjusted target pressure level in the brake system. A visible pressure meter to monitor, in pounds per square inch, the levels of pressure which the driver applies to the brake, has also been installed.

Utilizing the functional speedometer, the tester can assess the driver's ability to maintain constant equivalent speeds while using the accelerator portion of the hand control. Since a common difficulty in learning to drive with push-rightangle-pull hand controls is the erroneous dual application of brake and throttle, an audio error warning has been included to show defaults when this situation occurs.

The potential driver's performance at steering can be evaluated by an added friction-drag torque meter and timer. With a mechanical resistance adjusted by the therapist on the steering column, the left and right steering torque applied by the driver can be measured. The measurement is a function of the angular displacement of the rotary potentiometer, driven by the steering column, and the torque magnitude is displayed as a visual feedback on a digital readout. Through the use of a mode selector switch the previous timers can be reprogrammed to record the reaction and completion time for a full turn of the steering wheel in either direction.

Mode of Operation

Orientation, evaluation, further driver training, and if necessary, supportive therapy are the sequential elements of the training program utilizing this instrumentation. After his appropriate transfer into the vehicle and his proper positioning with the application of seat belts, the driver is given a preliminary orientation to the vehicle and its controls. This procedure involves acquainting the driver with the ignition key, hand controls, steering wheel, turning signals and the wiper switch. Following this orientation, a primary test is administered to assess base-line values of the driver's performance. The primary evaluation is an examination of three main functions as measured using the described instrumentation, in this order:

1. The ability to maintain constant speed at several levels;
2. The response time involved in braking after the appearance of the red visual cue from the traffic light simulator; and
3. The angular displacement of the steering wheel against several torque resistances and the time required for a complete turn in both left and right directions.

Having reviewed the individual's performance on the test, the examiner can recommend "on the road" evaluation or, if necessary, further "in house" training using the system in that mode. If the student is under eighteen years of age, he is enrolled in the state driver education course. In the case of those potential drivers who need the follow-up "in house" training period, they are given a week of additional familiarization with the instrumentation in the evaluator-trainer aid vehicle and supportive therapy to improve their use of the controls. Subsequent to this training the driver is again evaluated. Pending an improvement in the results of the re-examination of the driver's performance at the controls, the student is then referred for "on the road" instruction to the occupational therapist. This possibly leads to a road test and licensing. Diagrammatically, the organization of this program is shown in figure 3.

Summary

A driver evaluator-trainer aid vehicle was developed to quantify students ability and progress in learning to drive. In general, the instrumentation for each control was built to measure force and elapsed time. The system consists of functional ignition and gear shift control; instrumented steering wheel, hand controls for brake and acceleration; and expired time meters for each control.

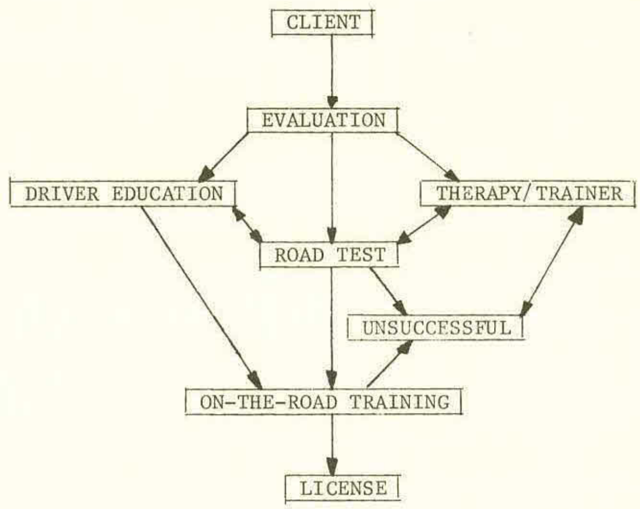

Figure 3. The organization of the handicapped driver training program.

Student evaluation is in progress and performance data on upper-level disabilities using this aid is being accumulated and will be presented when the utility of the system has been demonstrated. It is anticipated that, with this equipment the Woodrow Wilson Rehabilitation Center will be able to better predict the severely disabled person's ability to drive.

*The Woodrow Wilson Rehabilitation Center gratefully acknowledges the American Motors Corp.'s donation of this automobile used in the program.

References

1. Gurgold, G.D. and Harden, D.H.: Assessing the Driving Potential of the Handicapped. American Journal of Occupational Therapy, 32 (1): 41-46, 1978.

2. Long, C., II: The handicapped driver, a national symposium. Journal of Rehabilitation, 40: 34-38, 1974.

REST TIME MONITOR: A PORTABLE DEVICE FOR MONITORING TIME OUT OF BED FOR REHABILITATION PATIENTS

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Joseph Canzoneri, D.Sc., and John V. Wright
Texas Institute for Rehabilitation and Research*

Unobtrusive, daily monitoring over extended periods of time represents a promising but relatively unexplored approach to patient assessment. This paper describes a portable device, the Rest Time Monitor (RTM), which measures one simple, but basic activity---the amount of time that a patient is out of bed each day. The RTM consists of pressure-sensitive ribbon switches located under the patient's mattress and a small, electronic box which counts, stores and displays time spent in (or out of) bed in hours and minutes. Three years of experience with a non-portable RTM system used to monitor spinal cord injured patients at TIRR have indicated that this kind of information is useful for clinical and research purposes. The portable unit has been developed to expand these applications to additional patients and non-institutional settings.

CATEGORY: Device Development ☒ Research Study ☐	INTENDED USER GROUP: Patients recovering from severe disabilities.
STATE OF DEVELOPMENT: Prototype ☐ Clinical Testing ☒ Production ☐	AVAILABILITY OF DEVICE: 12 months AVAILABILITY OF CONSTRUCTIONAL DETAILS: 3 months
AVAILABLE FOR SALE: Yes ☐ No ☒ Price:	FOR FURTHER INFORMATION CONTACT: Lauro S. Halstead, M.D. T.I.R.R. 1333 Moursund Avenue Houston, Texas 77030

Unobtrusive longitudinal monitoring of patient activities using miniaturized instruments represents a promising but relatively unexplored approach to the problems of patient evaluation in rehabilitation. Within other areas of medicine, longitudinal monitoring has been used for years to measure physiological signals in both research and clinical settings. More recently, the availability of miniaturized, inexpensive electronic technology has made it possible to free the subject from the artificial constraints of cumbersome equipment and evaluate less obtrusively how the patient performs under every day circumstances.[1] The methodologies for this approach have been firmly established in other fields of medicine and the contributions have been substantial.[2] It is our belief that if suitable devices can be developed a similar potential exists in applying the principles of longitudinal unobtrusive monitoring to assess various patient activities in rehabilitation.

The purpose of this paper is to describe a new device, the Rest Time Monitor (RTM), which was specifically developed to monitor in an objective, quantitative and unobtrusive manner the amount of time a patient is in or out of bed during hospitalization and after discharge when at home.

Instrument design

The RTM is a simple, self-contained portable device which consists of two major components: (1) pressure-sensitive ribbon switches (tapeswitch ®) located under the patient's mattress and (2) a small electronic box, approximately 2¼" x 4"x1" which counts, stores and displays time in hours and minutes and which can be mounted anywhere on the bed. The switches are from 12 - 18" long and enclosed in clear polyethylene envelopes. Each envelope contains three to four switches connected in parallel and each bed is fitted with three separate envelopes located under the head, shoulders and pelvis regions.

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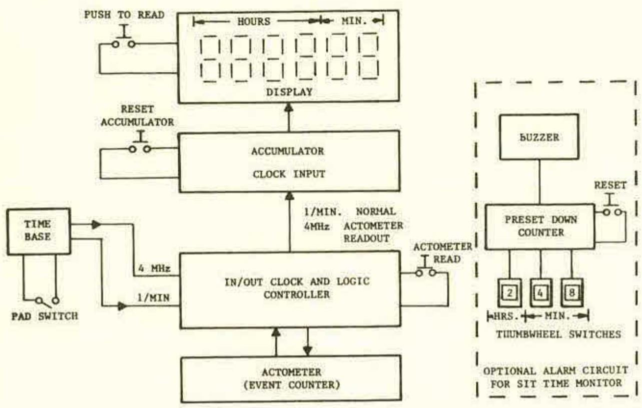


Figure 1. RTM BLOCK DIAGRAM

Figure 1 shows a block diagram of the components in the electronic box. When one or more of the switches is closed, the circuit is completed and a time base clock begins output to an accumulator which in turn drives the display. At the same time, the clock begins output to a cumulative counter or actometer which consists of several integrated circuit chips. Each count is equivalent to one minute and total of over 34,000 hours can be potentially stored. As shown in Figure 2, the external surface of the box includes a plexiglass window which displays up to 6 LEDS or a maximum of 9,999 hours and 59 minutes, a protruding button to activate the LED display and two recessed buttons to zero the display and read-out and zero the actometer. It is important to note that when the display is reset to zero, the contents of the actometer are not disturbed. In addition, a function switch can be added which permits time to accumulate when the ribbon switches are open (yielding time out of bed data) or when the switches are closed (time in bed data). Finally, power is supplied by two alkaline cells which under normal operating conditions need to be replaced every three months.

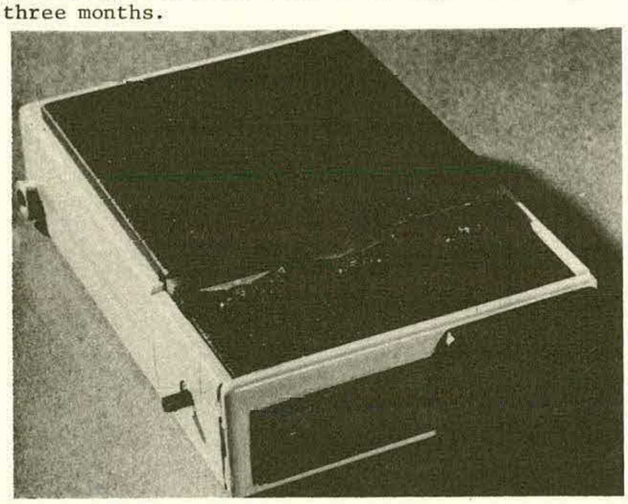


Figure 2. Close-up of RTM

Advantages and disadvantages

Chief among the portable RTM's advantages are simplicity of design and operation and ease of use. It is compact, operates continuously, consumes little power, and when properly installed, requires only routine reading and resetting of the display and storage functions and periodic checking of the batteries. Data from the device is straightforward and easily obtained at any time. Switch pads or envelopes are concealed, and the device can be attached wherever it is convenient to read and out of the way of possible bumps or impacts.

System-specific limitations include battery life and, more importantly, integrity of switches and connections. These must remain sensitive enough to behave in a consistent manner over relatively long periods of time, yet durable enough to withstand the shearing forces involved when, for instance, the head of a hospital bed is raised which scrapes and squeezes the switch pad. Proper positioning of the device and switch pad is critical. Another potential drawback is specificity. The device is activated whenever a heavy object comes in contact with the mattress surface and therefore does not discriminate between persons or objects causing switch closure.

Finally, there are some limitations inherent in the characteristics of the data obtained. First, in order for longitudinal data to be meaningful, it must be collected and analyzed over an extended period of time, e.g., over the entire course of a patient's out of bed program. Second, proper interpretation requires familiarity with similar activity profiles. For example, it is difficult to interpret time out of bed data for a patient without knowing what similar data looks like for similar patients. This suggests the need for normative data by age and sex for different diagnostic categories.

Applications

A prototype, non-portable RTM system has been in operation at the Texas Institute for Rehabilitation and Research since 1974, and in-hospital time out of bed data has been collected on over fifty spinal cord injured patients (over 500 weeks of data). The type of data obtained from the RTM is illustrated in Figure 3 which shows a typical curve of time out of bed (TOB) for a C-5 quadriplegic subject. Based on five treatment days for each hospital week (Monday through Friday), the figure shows the weekly ranges and average number of hours out of bed per day for each week. His out of bed program extended over 14 weeks or 80% of his hospital stay. During this period, time out of bed increased from an average of one hour per day during the first week of mobilization to an average of 8.6 hours per day during the final week of hospitalization. The overall shape of the curve provides a general picture of his week-by-week progress during the rehabilitation program.

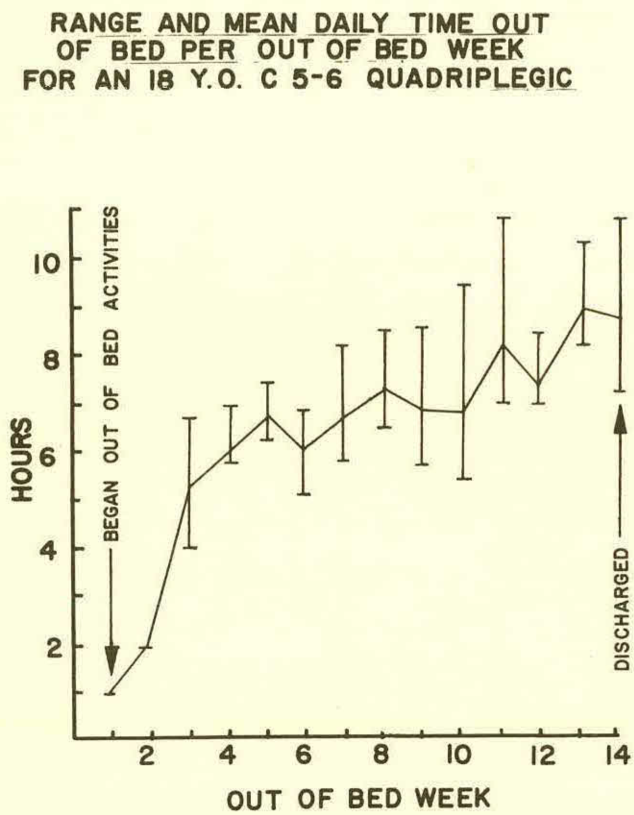


Figure 3.

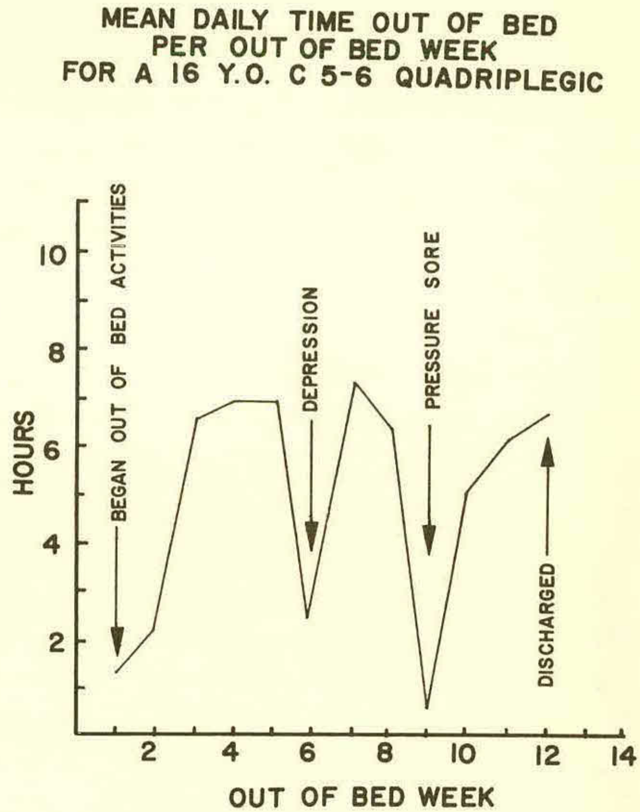
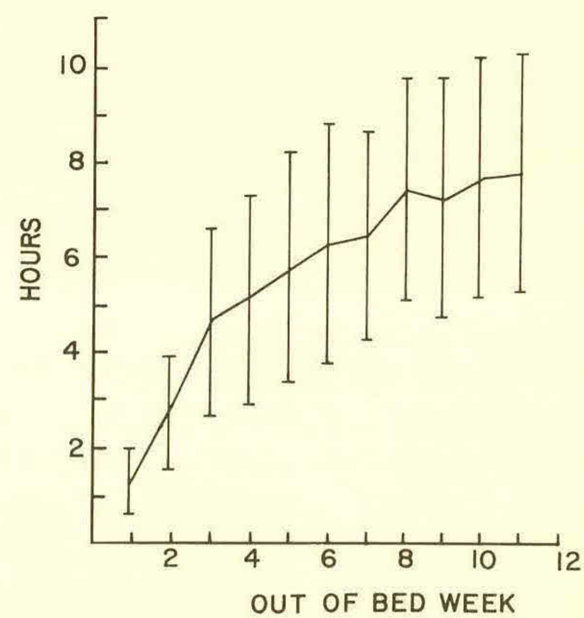


Figure 4.

Figure 4 demonstrates a common relationship seen in TOB measurement with significant physiological and psychological events for a 16 year old C 5-6 quadriplegic. The precipitous decreases in TOB in weeks six and nine were related to an episode of depression and the development of a superficial pressure sore respectively. In each case, the recovery from these setbacks was rapid and the patient returned to pre-complication levels of performance.

Figure 5 represents a preliminary attempt to develop a "standard" time out of bed curve for all patients with spinal cord injury undergoing comprehensive rehabilitation. This so-called "standard" curve shows the average daily means and standard deviations of TOB for each week for 22 patients who completed their rehabilitation programs without major complications. A major complication was defined as any problem which caused an interruption in the patient's program resulting in a decrease in average daily time out of bed for the week of more than 50% of any previous week.

STANDARD TIME OUT OF BED CURVE[1]

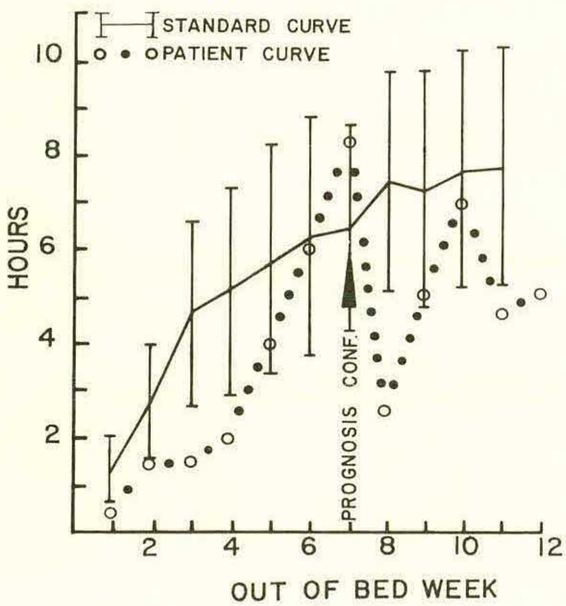


[1] MEAN AND S.D., DAILY TIME OUT OF BED FOR 22 SCI PATIENTS WITHOUT COMPLICATIONS

Figure 5.

Figure 6 shows how the "standard" curve can be used as a point of reference in monitoring the progress of an individual patient. In this case, week-by-week TOB for a 17 year old C-5 quadriplegic is plotted directly onto the "standard" curve which helps highlight major changes and deviations. As can be seen, TOB was at least one standard deviation below "normal" for the first four weeks of mobilization and then rapidly rose during the next three weeks. During week seven, the patient had a prognosis conference which was followed by an episode of depression reflected in a sharp drop in TOB in week eight. Although the patient increased his TOB again in subsequent weeks, he never regained a "normal" level of performance when compared to the "standard" curve.

COMPARISON OF TIME OUT OF BED CURVE FOR A 17 Y.O. C 5 QUADRIPLEGIC WITH THE STANDARD CURVE[1]



[1] MEAN AND S.D., DAILY TIME OUT OF BED FOR 22 SCI PATIENTS WITHOUT COMPLICATIONS

Figure 6.

Figure 7 demonstrates TOB for 22 subjects (indicated by solid dots) who completed their rehabilitation program without a complication compared with 14 subjects (indicated by open circles) who experienced one or more complications as defined above. Although both groups had similar levels of TOB during the first three weeks, the complication group was consistently a little more active until week four when its TOB rose sharply to 7.1 hours compared to 5.2 hours for the other group. In subsequent weeks, TOB for the complication group dropped to 6.0 and then 4.7 hours and thereafter remained consistently below the non-complication group with two exceptions for the remainder of hospitalization.

COMPARISON OF TIME OUT OF BED FOR SCI PATIENTS WITH AND WITHOUT COMPLICATIONS

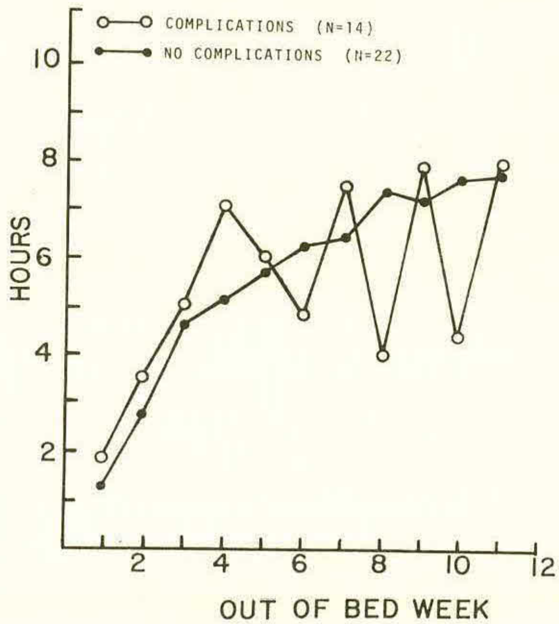


Figure 7.

Finally, Figure 8 shows a comparison of actual TOB and scheduled TOB for a C 6-7 quadriplegic. The shaded area represents the extent to which this subject exceeded planned TOB expected of him by the treatment team. Preliminary data from this patient and others suggest that the size and extent of the discrepancy between scheduled and actual TOB may be a good predictor of post-discharge adaptation and performance.

The portable RTM described here has not been used in-hospital to gather rest time data because of the satisfactory performance of the larger, cumbersome but more sophisticated RTM system. A preliminary investigation has, however been conducted comparing the two methods, with the portable RTM yielding approximately a 95% agreement rate with the RTM system over a two week period.

It is anticipated that the portable RTM will be of most use in post-hospital follow-up, first as a research tool, in evaluating long-term activity and readjustment patterns following spinal cord injury, and then as a means of routinely providing valuable clinical health status information to medical care providers responsible for follow-up.[3]

It is true that advances create additional problems. But, problems create challenges. Challenges stimulate effort and effort produces solutions. The cycle goes on and on."

John S. Young, MD
Executive Editor,
Model Systems' SCI Digest
Winter, 1980

COMPARISON OF ACTUAL AND SCHEDULED TIME OUT OF BED FOR A C 6-7 QUADRIPLEGIC

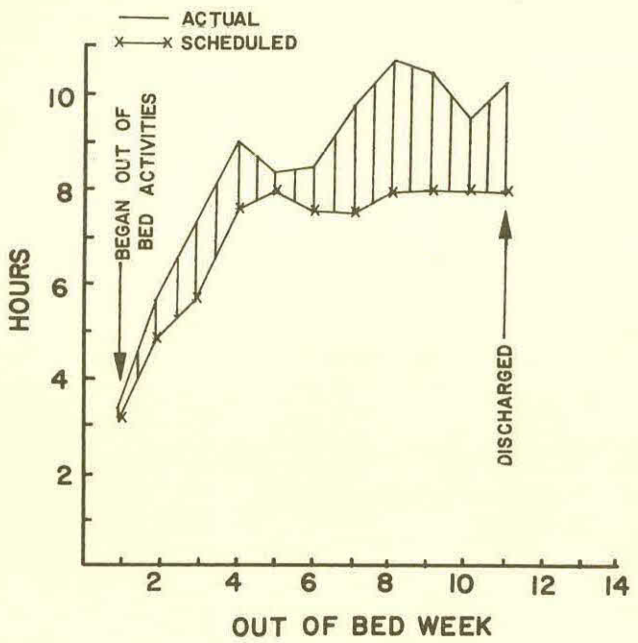


Figure 8.

Conclusion

A newly developed electronic device has been described which, at the most basic level, counts, stores, and displays the amount of time that a pressure-sensitive switch has been either opened or closed. It is well-suited to measuring certain behavioral parameters of spinal cord injured or other rehabilitation patients, both during and after the course of formal hospitalization. The device was designed to be portable, thus allowing use in the hospital or other institutional setting and in the home. Durability, ease of use, and unobtrusiveness were other prominent design criteria. The relevance of the data to be obtained from such a device is based upon the assumption that what patients do is a sensitive and direct indicator of their health status.

References

1. Wolff, H.S., Biomedical Engineering, London, Weidenfeld and Nicolson, 1970.

2. Danilevicus, Z., "Telemetry---Best Detective in Tracing CHD," JAMA 229: 1475-1476, 1974.

3. Halstead, L.S., "Longitudinal Unobtrusive Measurements in Rehabilitation," Arch. Phys. Med. Rehabil., Vol. 57, 189-193, 1976.

MECHANICAL HAND FOR COMMUNICATION WITH DEAF-BLIND PERSONS

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A mechanical communicator enables anyone to "talk" to a deaf-blind person without knowledge of special languages and without direct physical contact. Depressing the keys of a standard typewriter keyboard causes a mechanical hand to form the characters of the universally used one-hand manual alphabet. The hand is an output device capable of control by any form of telecommunications using the ASCII code.

The hand is readable by the sighted deaf through visual recognition and by the deaf-blind through tactual recognition. It is currently undergoing user evaluation.

CATEGORY: Device Development ☒ Research Study ☐	INTENDED USER GROUP: Sighted deaf, deaf-blind, and beginning students in sign-language. AVAILABILITY OF DEVICE: 1 year
STATE OF DEVELOPMENT: Prototype ☒ Clinical Testing ☐ Production ☐	AVAILABILITY OF CONSTRUCTIONAL DETAILS: On request, reimbursement for copying
AVAILABLE FOR SALE: Yes ☐ No ☒ Price:	FOR FURTHER INFORMATION CONTACT: Charles J. Laenger, Sr. Southwest Research Institute 6220 Culebra Road San Antonio, Texas 78284

Introduction

Almost all communication with deaf-blind people is by direct physical contact. We must (1) "write" in their hands, (2) use the one-hand manual alphabet in which case they embrace our hand (fig. 1), or (3) permit them to put their hands on our mouth, jawbone, and throat to "lip" read (the Tadoma method). Blind persons can still receive information through their hearing senses and deaf persons have visual capabilities, but the deaf-blind have neither sense for backup. Consequently, many deaf-blind persons are functionally retarded just because of information deprivation. Although an actual census is not recorded, it is estimated that there are more than 10,000 deaf-blind persons in this country alone.

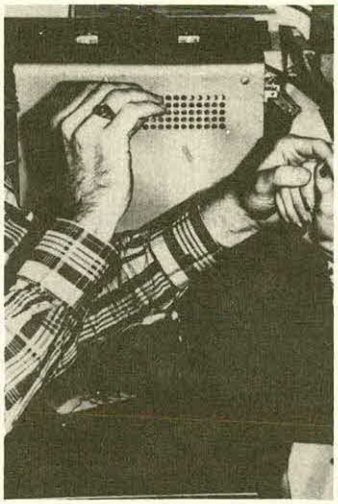

Figure 1.

Numerous technical approaches have been tried in an effort to solve the communication problem. Mechanical and electrical transducer arrays using digital imaging and Morse Code are being tried, but each faces problems of the reader having to learn a new code. In many cases, the skin cannot discriminate small scale sensations due to neurological diseases associated with their blindness.

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A few years ago, SwRI engineers conceived the idea of mechanizing the characters of the manual alphabet, the most universally understood language of deaf-blind persons. A project was begun to assemble a feasibility demonstration prototype to test the concept.* Based upon the results of the feasibility prototype effort, it was felt that a mechanical hand for forming the one-hand manual alphabet at conversational speeds was feasible. From discussions with deaf-blind consultants, interpreters, and educators of the deaf-blind, a variety of potential applications were seen. These were as follows:

- A simple device to enable non-signers to communicate with deaf-blind people.
- A device for teaching deaf-blind children sign language.
- A "talking book" driven by a tape recorder.
- A telecommunicator for the telephone or teletype machines or linked with other mechanical hands.

Design considerations

The performance of the feasibility prototype hand indicated the needs and a plan for development of the improved version. Needed was a standard set of characters for the one-hand manual alphabet and a study of what hand size, shape and inclination was most easily read by the deaf-blind.

During the feasibility program, it was noticed that the deaf-blind consultants did not recognize mechanical versions of published pictures of the symbols. It was also noted that deaf-blind persons and interpreters varied in the way they signed. It appeared that the motion of the sender's hand influenced recognition of the symbol. The attitude of the hand, whether rotated or inclined, appeared to be of significant importance. To determine the most universal signs and methods for making them, members of the design team visited the National Center for Deaf Blind Youths and Adults in Sands Point, New York; San Antonio College's staff of interpreters for deaf students; and Southwest Center for the Hearing Impaired in San Antonio.

The resources of the program did not allow an extensive, formalized study of the shape, size, and anatomical characteristics of a hand which influence symbol recognition. Instead, deaf-blind individuals at each organization visited were asked to identify one or two people they thought had the most easily read hand size and shape. Based on that survey, a model was selected to be used as the standard in size and shape for the new design.

*Funded cooperatively by the Internal Research Panel of SwRI and The Ewing Halsell Foundation.

Mechanical design

The mechanical hand assembly consists of a driver sub-assembly (D), a rotable forearm (F), and the hand (H) which is attached to the forearm through a wrist mechanism (fig. 2). The driver sub-assembly consists of two modules (M) attached to form a central linkage cavity (LC) (fig. 3). Each module contains eight linear solenoids which drive the fingers and thumb. At each end of the cavity is attached a rotary solenoid (RS) for rotating the arm and flexing the wrist.

The paired linear solenoids (LS) are connected through adjustable links to a rocker arm (R) mounted on a shaft which protrudes into the cavity (LC). Another rocker arm is secured to the cavity end of the shaft. The ends of the rocker arm accept snap clevises similar to those used in model airplanes. The clevises are screwed onto threaded cable terminals to provide cable length adjustment. The cables transmit the pull of the solenoids to the fingers through the wrist over a series of pulleys.

The fingers have three segments equivalent to the proximal (PP), middle (MP), and distal phalanges (DP) of a human hand (fig. 4). All fingers are identical except in the lengths of the first and second segments. The segments are interconnected by two copolymer links (CL) which are arranged to produce a uniform curling of the fingers as they move from fully extended to fully flexed. The links slide along the midplane of the finger between laminated 1/16" thick aluminum plates (LP) (fig. 5).

Finger flexion and extension is controlled by a single push-pull link (PL) attached to the rear upper corner of the first segment. When pushed, it rotates the finger downward into the flexion position; when pulled, it extends the segment. The link is actuated by two cable pulls, each cable attaching to sliding rack gears separated by a fixed axis pinion gear. All elements are enclosed in an aluminum housing (AM). When the upper rack gear is pulled by the cable, it moves rearward pulling the finger into its extended position. A pull on the lower cable moves the lower rack rearward, rotating the pinion gear, driving the upper rack forward, which rotates the finger into the flexed position.

The first segment interconnecting link is fixed to the palm by a clevis. This clevis is in fact a sliding link inside the finger actuator assembly (AM). A dowel pin fitted into the clevis protrudes through a slot in the bottom of the actuator assembly and through the palm. The pins of all four fingers fit into a sliding cam (LFC) of Delrin on the underside of the palm (fig. 6).

The cam is controlled by two cables which slide it forward and backward. When in the rearward position, the flex clevis is in its normal position to produce uniform flexure of the fingers. When the cam is moved forward it produces a "limited flex" condition, required to form only the letter "E".

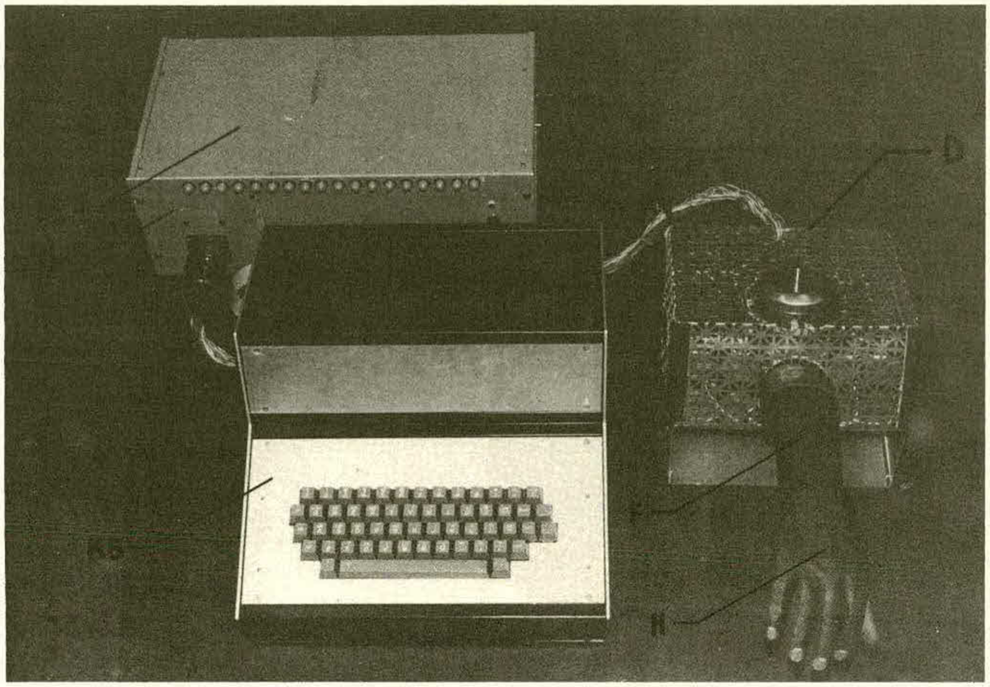


Figure 2.

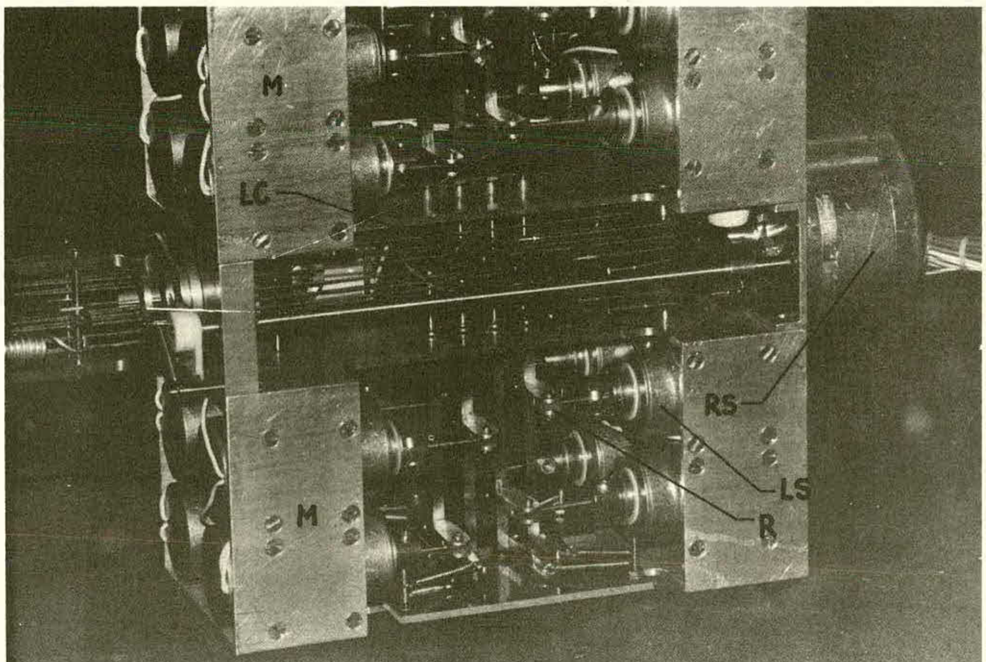


Figure 3.

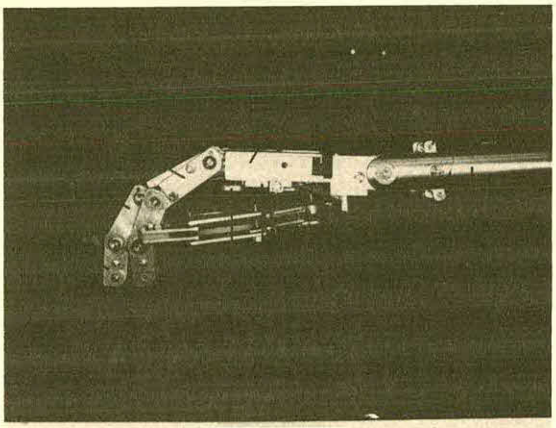


Figure 4.

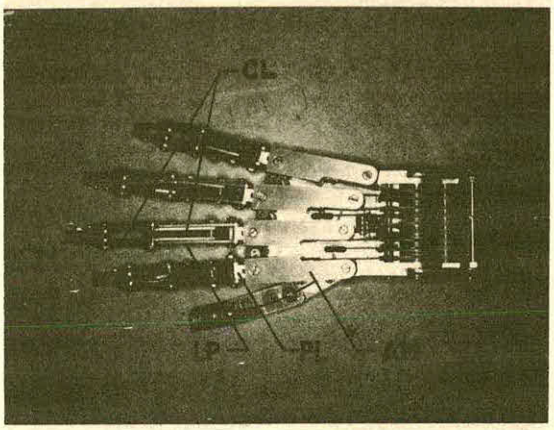


Figure 5.

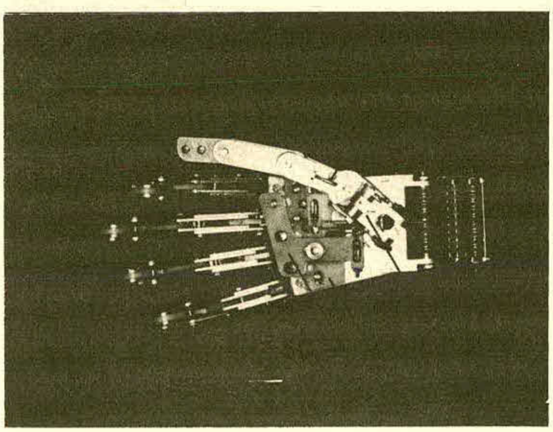


Figure 6.

A second sliding cam (SC), similar to the limited flex cam (LFC), is also attached to the underside of the palm plate and produces finger spreading and crossing. The finger is pivoted about a vertical shaft with an arm of the bracket extending through a slot in the side of the housing. A shaft in this arm passes through slots in the palm plate and limited flex cam (LFC) and fits into the spread cam (SC).

The design of the thumb and its operation are essentially the same as the fingers. It consists of three laminated segments with interconnecting links (refer to Figure 4 and Figure 6). The links produce equal angular rotation of each segment relative to the preceeding segment. The major difference in the thumb is that the flexion/extension cables attach directly to the first thumb segment rather than through a gear mechanism. The first segment contains a combination cable clamp and tension adjustment (TA) for terminating the cable. When the extension cable is pulled, the thumb moves away from the fingers to a "thumbs up" or "hitch hiker" position. The flexion cable moves the thumb across the face of the palm until its tip is near the base of the little finger.

The thumb is attached to the palm plate by a double axis hinge (DH). It rotates about one axis as it flexes and extends. A second axis governs the inclination of the thumb to the palm and the plane of the motion in flexion/extension. Since the planes of motion of the thumb and fingers intersect, finger touching by the thumb is easily attained by letting the thumb's flexion be stopped when it touches the desired finger.

The wrist mechanism provides both wrist flexion and cable length compensation (refer to Figure 4 and Figure 6). It has four rows of pulleys (PR); two rows mounted on shafts through the forearm and two rows of smaller pulleys mounted on a rotating frame (RF). A rotary solenoid rotates the frame, causing the paired rows of small pulleys to move vertically which has the dual effect of flexing the wrist while maintaining balanced tension in all finger cables.

The hand is attached by the wrist to an eight-inch long forearm (F), machined from a two-inch diameter stainless steel tube. The majority of the tube is removed to form two side bars. The ends of the bars are bored for the ball bearings of the wrist and the front pulleys of the wrist mechanism.

The end of the arm opposite the hand (proximal) remains tubular. The tube end is machined to a one-and-one-half inch diameter to form a shoulder to which is attached a ring gear. A retaining ring groove is machined near the end where the forearm enters a flanged bronze bearing. The bearing fits into the central cavity (LC) of the driver assembly and is secured with a snap ring.

The arm rotates in the bearing, driven by a sector gear. The sector gear, (which meshes with the ring gear), is located under the forearm. It is attached to a drive shaft which connects it to a rotary solenoid (RS) at the rear of the driver assembly. The rotary solenoid produces up to ninety degrees of arm rotation.

Control electronics

The letters or numbers to be formed by the hand are selected by pressing the appropriate key of a standard electric typewriter keyboard (KB) (see Figure 2). This produces a six bit, American Standard Code For Information Interchange (ASCII) binary code and a "strobe" signal. The ASCII code identifies the letter while the strobe signal notifies the timing and control circuits that a new character has been entered.

The ASCII code is converted by specially designed logic circuitry having thirty-six outputs. Each of the output lines corresponds to a letter or a number from zero to nine. The output line corresponding to the letter selected by the keyboard is energized and remains energized (a given period of time) or until another letter is entered. The execution and holding time intervals, initiated by the keyboard strobes, are governed by an adjustable electronic timer. The holding time may be adjusted from two-to-five seconds.

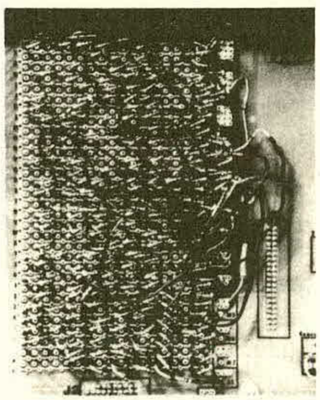


Figure 7.

The thirty-six characters go to the solenoid selection matrix portion of the programming board (SSM) which is accessible by removing the rear panel of the console (fig. 7). The character lines terminate in a series of eighteen miniature pin jacks. Selection of solenoid combinations for a given character is done on the programming board. To select a solenoid, a connection is made from the pin jack on the appropriate solenoid line. The connection is made with a diode having pins on each lead (DJ). The other solenoids needed to form a given letter are connected to that character line by additional diode jumpers.

Each character line jack is adjacent to another pin jack which penetrates the board and connects to one of eighteen lines which run vertically on the back surface of the board. These lines control power transistors that switch the large currents needed to drive the hand solenoids. The solenoid driver circuits and the 32 VDC power supply for the solenoids are contained in a separate enclosure. A series of lights are mounted in the front panel to indicate which solenoids are energized.

Additional control of solenoid activation is provided by a series of timing modules (TM) located adjacent to the solenoid matrix on the programming board. These modules provide either (1) a delay in the activation of the solenoid; (2) a momentary activation of the solenoid; or (3) an alternating on-off-on activation of the solenoid. The modules also have pin jacks to which the diode jumper from the character line is attached. The length of each delay or momentary actuation is selectable.

Functional description

The mechanical hand is a reasonably accurate anthropomorphic replica of a human hand in proportion, joint function, and digit range of motion. A polyethylene cosmetic glove, intended as a covering for a passive hand prosthesis and molded from the cast of a real hand, aligns well with the positioning of the fingers, thumb, and joints of the mechanical copy. By passive manipulation, the hand can be formed into an accurate representation of each of the 26 alphabetic and 10 numeric characters of the one-hand manual alphabet.

As a solenoid driven machine, the hand forms the characters by combination and timing of 18 fixed positions of its various components. Each of the four fingers has four positions, the resting attitude and three driver configurations. From its rest position, it may be fully flexed into the palm, fully extended straight, or cupped into a combined position called limited flexure. In its neutral condition, each finger is spring balanced in an attitude whereby each of its three joints forms a 120° angle. The thumb rests at a similar attitude, but is driven only to full flexure or full extension. It can be stalled in flexure upon contact with any of the four fingers. Each of the fingers and thumb also rotates to either side of a neutral position about on axis perpendicular to the base joint. This allows for spreading apart and crossing of adjacent fingers as well as attraction and repulsion of the thumb relative to the palm. Displacement is approximately 8° to either side of neutral in the forefinger, up to 12° in the ring and little fingers and blocked in the middle finger. Maximum angular displacement of the thumb is 45° out of the plane of the palm.

To achieve formation of all characters, not only do the fingers and thumb articulate but the wrist flexes, (or extends) and the arm rotates. Wrist flexure is accomplished by driving the cable length compensator mechanism. The entire hand-arm assembly rotates about a central axis at the driver end of the forearm (the equivalent of the elbow position). Both wrist flexure and arm rotation angles are adjustable up to 45°.

Speed of mechanical response is largely dependent on rotational inertia of the component, friction incurred by rotating and sliding members and by resistance to cable flexure. Primarily relating to component mass, finger movement is slightly quicker than thumb movement which is proportionally quicker than wrist flexure and arm rotation. Since all movements are returned by springs, the rate of return is approximately the same as activation. Actual response time has not been measured accurately but is approximately 0.75 seconds for the slowest movement.

In addition to static positions of the hand components, certain movements must be sequenced in order to form many of the characters. The solenoid drivers are activated with one of three timing functions: immediate full on, momentary, or delayed. The full holding duration of each character is adjustable from 2 to 5 seconds. Momentary pulses vary from 0.2 to 0.8 seconds, and a delayed pulse lags by up to 1.0 second but is held on for balance of the full duration.

By combining choices of solenoid drivers and sequence of activation, all of the prescribed characters can be formed. A matrix of activation codes appears in Table I. Each character is represented by a unique activation code which includes which solenoid will be energized, in what order, and for how long.

	THUMB				FOR		MID		RNG		LTL		PLM		PLM		WR	
FUNCTION	EXPAND	COMPRESS	EXTENSION	FLEXION	EXTENSION	FLEXION	EXTENSION	FLEXION	EXTENSION	FLEXION	EXTENSION	FLEXION	SPREAD	CROSS	LIM FLEX	FLEX OPP.	FLEXION	ROTATION
A	·					·		·		·		·				·		
B	·			d	·		·		·		·					·		
C		·	·													·		
D				d	·													
E															d			
F				d					·									
G																		d
H																		d
I																		
J																		d
K																		
L																		
M																	d	
N																	d	
O																		
P																	d	
Q																	d	
R																		
S																		
T																		
U																		
V				d														
W				d														
X				d														
Y																		
Z		·		d				·					m d	m		·	d	
1		·		d	·			·		·		·				·		
2		·		d	·		·			·		·	·			·		
3	·		·		·		·			·		·	·			·		
4	·			d	·		·		·		·		·			·		
5	·		·		·		·		·		·		·			·		
6		·		d	·		·		·				·			·		
7		·		d	·		·				·		·			·		
8		·		d	·				·		·		·			·		
9		·	·				·		·		·		·			·		
10	·		·			·		·		·		·				·	d	d

Table I.

An example of a more complex function is the letter 'K'. Striking the 'K' key on the input keyboard activates the electronic decoding from input to output code. The extension solenoid for the forefinger receives a full holding power signal raising the forefinger into extension. At the same instant, a signal is sent to the ring and little finger to flex. The flexure solenoid for the thumb is energized on a delay causing the thumb to flex inward under the extended forefinger until it stalls against the relaxed middle finger. The pattern is sustained for the remainder of the character holding time (fig. 8).

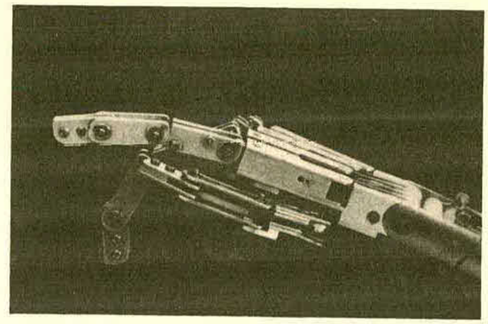


Figure 8.

In addition to the mechanical output of the solenoid drivers, a linear array of corresponding indicator lamps (IL) is arranged across the front panel of the system power supply (PS) (refer to Figure 2). This array serves as a trouble-shooting resource as well as a constant reminder of the electronic output code which is available for other forms of output besides the mechanical hand. The lighted array itself has the potential for being learned as a communication code for sighted deaf persons.

User evaluations

At the time of this writing, there have been only a few hours of deaf-blind use of the mechanical hand communicator. On first contact, our consultant readily recognized about 50% of the 36 characters. Mechanical adjustment and reprogramming have corrected for several of the misunderstood characters. The resting attitude of the hand is not comfortable for the reader and wrist flexion and rotation are more extreme than necessary.

It is important to note, however, that all initial criticisms can be responded to without design changes. It is anticipated that continuing practice and adjustment will result in consistent recognition of all characters by the consultant. Pending successful attainment of that goal, the system will be deployed to deaf-blind rehab centers for long-term evaluation.

DEVELOPMENT OF PROTOTYPE EQUIPMENT TO ENABLE THE BLIND TO BE TELEPHONE OPERATORS

Susan H. Phillips

Sensory Aids Foundation*

The goal of this project was to determine if a blind telephone operator could perform the job of Traffic Service Position System (T.S.P.S.) operator within the performance requirements set by Pacific Telephone Company for sighted operators. Sensory Aids Foundation in conjunction with Telesensory Systems Inc. contracted and built an interface to the standard T.S.P.S. console, utilizing a voice output system. The resulting prototype system has been successfully tested and two totally blind individuals have been successfully placed within the Pacific Telephone Company as full-time T.S.P.S. operators.

This project demonstrates that blind people will now be competitive for job placement within the Bell System.

CATEGORY: Device Development [X] Research Study [X]	INTENDED USER GROUP: Blind Bell Telephone System operators
STATE OF DEVELOPMENT: Prototype [X] Clinical Testing [X] Production [ ]	AVAILABILITY OF DEVICE: For availability, contact AT&T AVAILABILITY OF CONSTRUCTIONAL DETAILS: Construction of prototype handled by Telesensory Systems Inc., 3408 Hillview Ave., Palo Alto, CA
AVAILABLE FOR SALE: Yes [ ] No [X] Price:	FOR FURTHER INFORMATION CONTACT: Susan Phillips, Sensory Aids Foundation 399 Sherman Ave., Suite 4 Palo Alto, California 94306

Introduction

Sensory Aids Foundation, a non-profit corporation, and the California Department of Rehabilitation established a program in September 1975 to develop new employment opportunities for job-ready persons who are blind. The program provides for the expansion of entry-level occupations through the application of sensory aids and the development of new adaptive devices. During the first thirty months of the Innovation and Expansion Project, 85 blind and partially-sighted individuals have been placed in a variety of new employment settings.

One of the primary engineering projects initiated by Sensory Aids Foundation was the development of prototype interface equipment for blind T.S.P.S. (Traffic Service Position System) operators. The goals of this project were to open the T.S.P.S. operator position with Pacific Telephone Company to blind people and to enable them to perform the job competitively within the standards set by the Telephone Company for sighted employees.

The T.S.P.S. is the specific console used by Pacific Telephone Company long distance telephone operators to perform their jobs. Generally, the T.S.P.S. computer handles all calls requiring operator assistance, with the exception of "information" number requests. Sensory Aids Foundation contracted with Telesensory Systems Inc., Palo Alto, California, to build two prototypes of T.S.P.S. console overlays which monitored nixie tubes and 72 lighted indicator lamps and buttons with voice output systems, utilizing the Votrax Voice Synthesizer. The voice output prototypes would give to the blind operator audible information that a sighted operator sees. This information is necessary for the blind operator to recognize the state of the console and to service customer requests.

*Sensory Aids Foundation, 399 Sherman Ave., Suite 4, Palo Alto, California 94306, (415) 329-0430.

A second important part of the project was to modify the job station equipment, other than the T.S.P.S. console, so that it could be efficiently used by the blind operator.

Operators must continually refer to handwritten notes, in order to remember names when making person-to-person or collect calls, rate and route information for overseas calls, and other information used in filling out manual billing tickets. A suitable device was needed for telephone operators. Equipment on site could not be noisy.

Project Methods

The various elements of the T.S.P.S. interface system are illustrated in Figure A-1.

At the top of the figure is the T.S.P.S. console itself. It consists of the Nixie Tube Display and the operator control panel with lighted pushbuttons and indicators. The overlay is placed directly over the operator control panel. Each button on the overlay is made from clear acrylic and is provided with a phototransistor to sense if the button is illuminated. Because the buttons are transparent, the status of the console may be determined by a sighted operator. This is important both in training and when the supervisor needs to assist in handling a call.

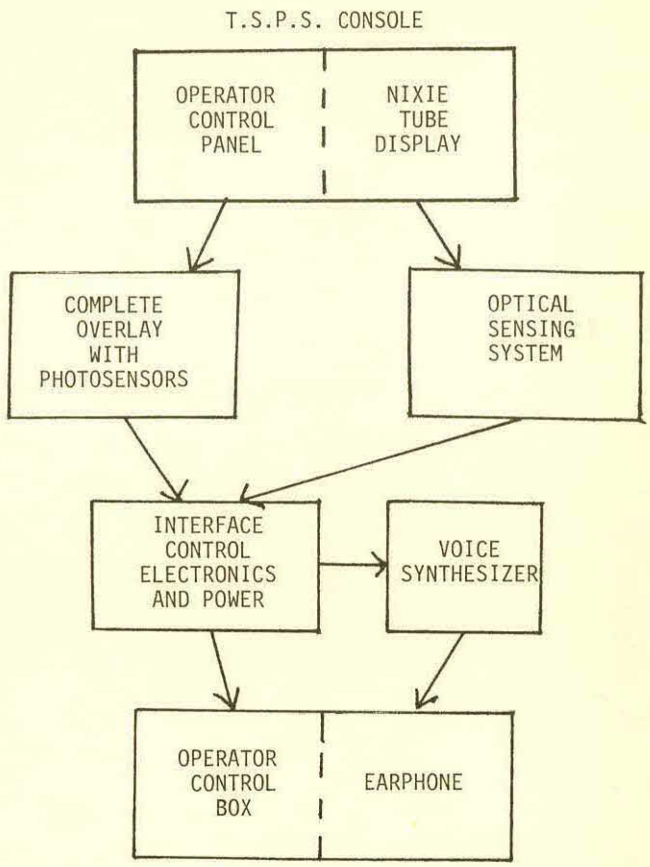


Figure A-1 Prototype T.S.P.S. Interface Equipment - Schematic

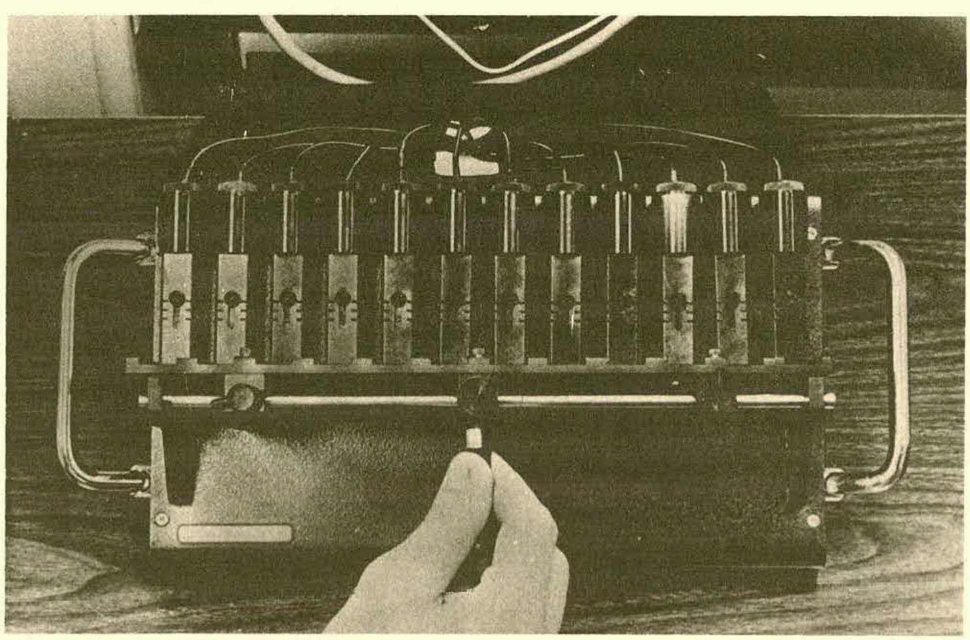
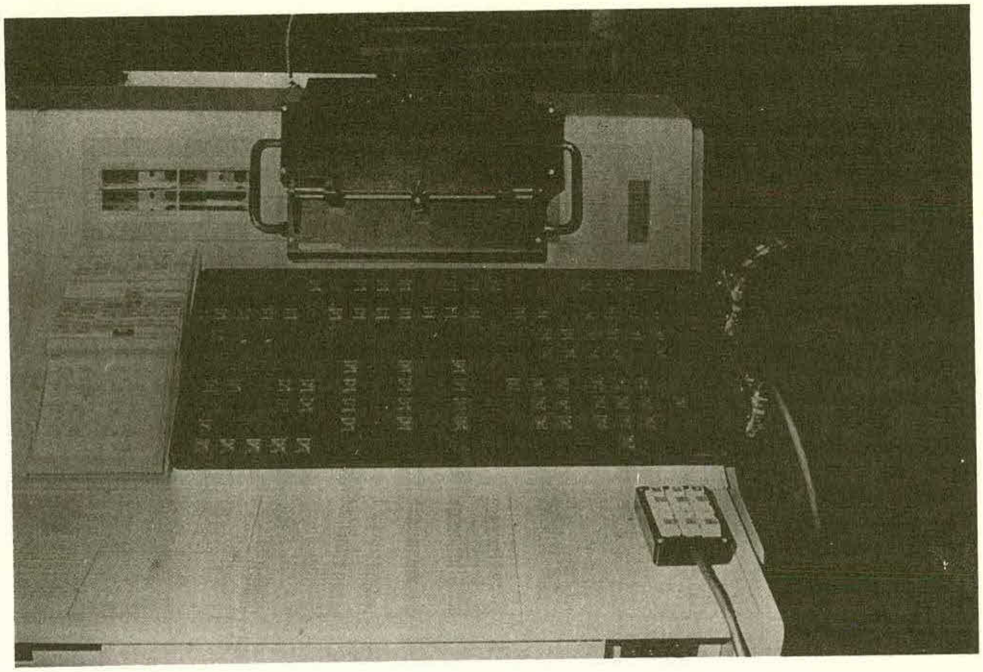
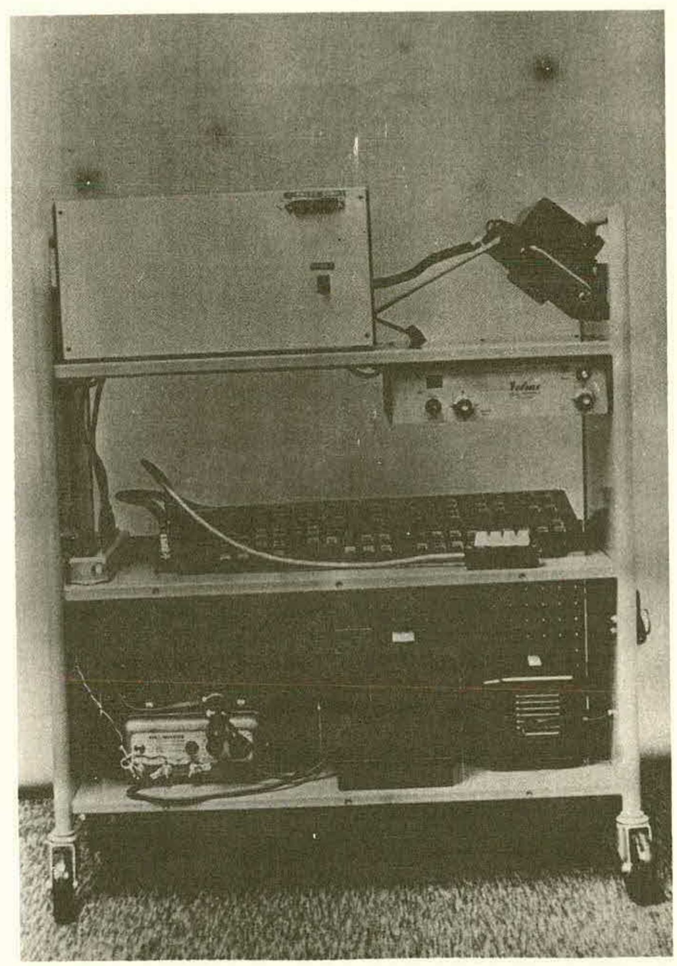


Figure A-2 Nixie Tube Display



Above: Figure A-3 T.S.P.S. Console with Overlay and Control Box

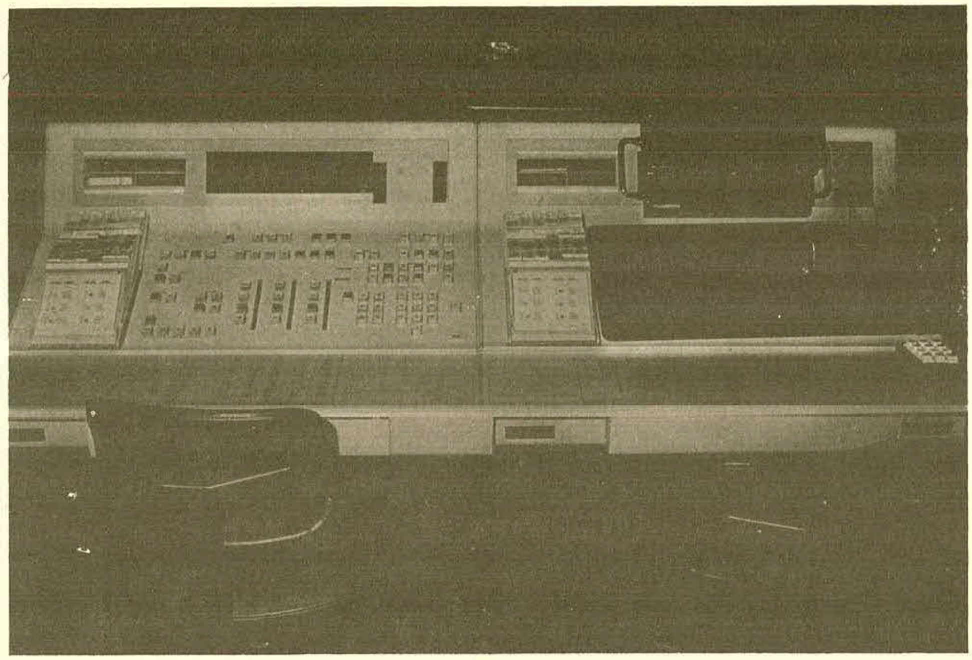
Right: Figure A-4 T.S.P.S. Interface Equipment on Cart



The Optical Sensing System is placed into the recess formed by the housing of the nixie tube display, as illustrated in Figure A-2. This system is composed of 12 identical modules, each sensing a single nixie tube, and thus avoids the difficulties of mechanical scanning. The system is both removable and portable; an adjustment is provided to align the Optical Sensing System to a particular console.

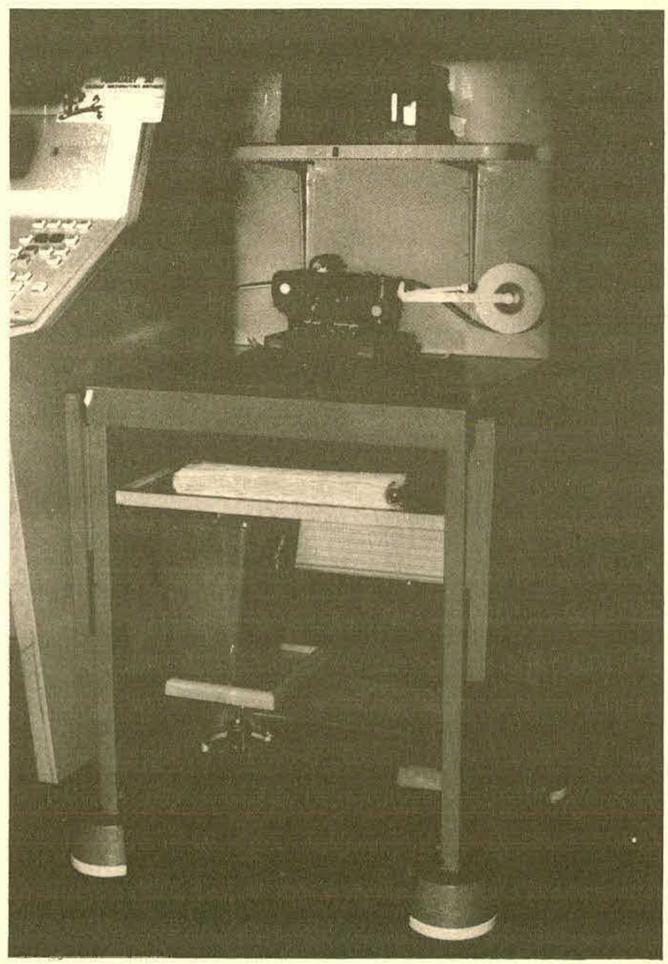
The Interface/Control Electronics Module accepts commands from the Operator Control Box, processes data from the Optical Sensing System and console overlay, and generates suitable output to a Votrax Voice Synthesizer. The output from the Votrax is presented to the operator via a second earphone. With this control box, the operator can manually interrogate various sections of the console or read the nixie tube display, as illustrated in Figure A-3.

The entire system is carried on a moveable cart with self-contained power supply, as illustrated in Figure A-4. The output of a 12 volt DC battery is converted to 115 AC by an inverter and provides enough power for at least 8 hours of continuous operation. A battery charger is also provided so that the entire system may be recharged when not in use or at the end of the shift.



Above: Figure A-5 T.S.P.S. Console Position

Right: Figure A-6 Typewriter Cart with Brailler and Brailled Materials



System Operation

As a call comes in to the T.S.P.S. console, appropriate lamps light up which signal the kind of call, class, and charge. For a blind person to service the incoming call, these visual cues must be transformed into spoken words.

A step by step outline of the process is as follows:

a) An incoming telephone call stimulates a specific pattern of lamps to light on the T.S.P.S. panel;
b) The computer recognizes which lamps are lit via photosensors on the overlay;
c) The computer determines which words should be spoken;
d) The computer signals the Votrax and speech begins.

Spoken words from the Votrax give the blind operator the cues which the sighted operator obtains visually. These cues are necessary to make the appropriate response to the customer.

Figure A-5 illustrates the T.S.P.S. console position for two operators. The right side has the interface prototype equipment for the blind operator.

Additional Equipment Modification

In order to overcome problems in note-taking referred to earlier, a quiet, sturdy, small brailler was purchased from the Royal National Institute for the Blind, London, England. Information stored on plastic cards used by all T.S.P.S. operators, including area codes, operator codes, numbers of business offices, repair services, and emergency numbers were brailled in a format designed by the Sensory Aids Foundation staff. Figure A-6 indicates the position of the brailler and brailled reference material on a typewriter cart. The cart is stationed next to the T.S.P.S. console throughout the day for the blind operator. A template (Manock Comprehensive Designs, Palo Alto, Calif.) was designed to enable the blind operator to complete the Mark Sense computer ticket. The blind operator was then able to transfer information from the braille notes to the billing ticket by lifting the template over the ticket and using a Mark Sense pencil to mark appropriate digits.

Project Results

A comparison of the length of training and job performance of these two individuals versus those of sighted T.S.P.S. operators are listed in Tables I and II.

Table I demonstrates that the period of initial training required was longer for both blind operators. *However, the length of initial training was prolonged in both instances due to equipment modifications. It is anticipated that future training time will be similar to those of sighted individuals.

Table II shows that the quality and quantity of job performance by both blind operators has been comparable to that of sighted operators.

Utilizing prototype consoles and the adaptive equipment described earlier, two totally blind individuals have been placed as T.S.P.S. operators in the Mountain View, Calif. Pacific Telephone office in the past 12 months.

TRAINING

		Non-Sighted	
	Sighted Avg.	3-21-77 Student No. 1	7-11-77 Student No. 2
Initial Training (days)	11.5	22*	16
Continuation Training (days)	1	2	2
Remedial or Subsequent Training, 1977 Practice Changes (hours)	1.5	3	Given in initial training

Table I

PERFORMANCE

		Sighted Avg.	3-21-77 Student No. 1	7-11-77 Student No. 2
Quality (% accurate) After Training	June 1st mo.	95.0	97.5	96.7 Aug.
Office Average Internal Observation	July 2nd mo.	98.1	100.0	96.8 Sept.
	Aug. 3rd mo.	98.6	97.8	100.0 Oct.
	Sept. 4th mo.	98.3	98.6	94.5 Nov.
	Oct. 5th mo.	N/A	97.1	
	Nov. 6th mo.	96.5	94.3	

Table II

The objectives of this pilot project have been successfully completed; prototype equipment has been successfully designed and tested. Officials of the Bell Telephone System have responded favorably to plans aimed at incorporating blind T.S.P.S. operators into the Bell System.

Acknowledgements

I wish to express appreciation to A.J. Sword, M. Linvill, J. Azevedo and D. Farr for providing technical assistance and photographs, and to C. Anderson for secretarial assistance.

EXPERIMENTAL SIMULATION OF AN OPTICAL CHARACTER RECOGNITION, SPEECH OUTPUT READING MACHINE FOR THE BLIND

Rob Savoie, Ph.D., and Pat Erickson, M.S.

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This paper describes a project to investigate an Optical Character Recognition Speech-Output Reading Machine for the blind. A standard minicomputer accepts optical images derived from the electronic camera of an Optacon Reading Aid and converts these images to character streams representing letters of recognized words. A second computer then converts the letter strings to spoken words.

The system operates in real-time at reading rates over 150 words per minute with the electronic camera moved either manually or automatically.

CATEGORY: Device Development ☐ Research Study ☒	INTENDED USER GROUP: The Blind AVAILABILITY OF DEVICE: 1980
STATE OF DEVELOPMENT: Prototype ☒ Clinical Testing ☐ Production ☐	AVAILABILITY OF CONSTRUCTIONAL DETAILS: Not Available
AVAILABLE FOR SALE: Yes ☐ No ☒ Price:	FOR FURTHER INFORMATION CONTACT: Paul Liniak, Telesensory Systems, Inc., 3408 Hillview, Ave., P.O. Box 10099, Palo Alto, California 94304 Telephone 415/493-2626

Introduction

A major vocational and educational limitation resulting from blindness is the lack of access to printed information by blind people. Direct-translation* reading aids, such as the Optacon[1] and Stereotoner[2] help to alleviate this problem by providing flexible, independent access to all types of printed matter. Evidence of the value of direct-translation reading aids is the presence of over 4,000 Optacon units in the field.

Despite the success of direct-translation devices, reading rates are too slow for many important applications, because the blind user must perceive and interpret a complex, dynamic code presented tactually or audibly. Significantly higher reading rates, as well as enhanced ease of learning and a larger potential user population, would occur if the reading machine could re-code the information into a form more easily understood. It is widely felt that the ideal reading machine would read aloud to the user with full word spoken speech.

Spoken word output offers significant performance advantages in a reading machine for the blind: it can be understood at 200 word-per-minute rates (compared to Braille reading rates averaging under 100 words per minute and direct translation reading machine rates averaging under 50 words per minute) and it can be understood by almost everyone (compared to Braille which can be read by only 10% of the blind). These advantages can not only significantly enhance the capabilities of present users of reading aids for the blind, but also expand the number of people potentially helped from tens of thousands to hundreds of thousands.

The concept of a speech output reading machine for the blind has been seriously discussed for over 25 years[3], and a number of research

*A "direct-translation" reading aid provides a tactile or auditory facsimile of printed characters for the user to recognize. The facsimile is usually derived from images sensed by a small electronic camera which can be moved by hand.

efforts have been made[4]. As early as 1967, the Optacon engineering group was concerned with the feasibility of an accessory unit that would plug into the Optacon and speak words as the user scanned them with the Optacon camera[5]. The Optacon engineering group felt that it was particularly important that any such accessory unit augment the capabilities of the Optacon rather than substitute for them. In conjunction with a speech output accessory, the two most significant Optacon features are:

1.) direct-translation output, and
2.) camera capable of being hand-scanned.

As the desired output is simply the reading aloud of the source material, it may be asked: "Why burden the human user with moving the scanning probe?" "Why not just use an automatic mechanical scanner as in an Optical Character Recognition (OCR) page reader?" "Why provide a tactile output?" "Why not just use speech output which is much faster?" Although an automatically scanned, speech output reading machine is clearly the most desirable configuration for some applications, it is inappropriate or unsuitable for others. In fact, TSI believes that no single reading machine configuration is suitable for all reading needs. Let us first see why hand scanning is a useful option.

Blind people need the capability of reading text books and novels ("bulk reading"), for which automatic scanning with speech output is optimal: the page format is well-specified and unvarying, the text consists of English words, and there is little need to skip. For other applications, however, this mode of reading is woefully inadequate. Consider, for example, the difficulties of consulting a reference book with a machine that automatically scans. A student attempting to learn the principle export of Uruguay or the definition of "cumulus" would be continually frustrated by the required sequence of operation: locate a new page, insert the book in the scanner, and listen to the spoken output to see if the page is correct. A quicker and more natural approach would involve selectively scanning the camera by hand, perhaps using the tactile display to locate major headings, column locations, etc. With this approach the student could rapidly thumb through the reference book, selectively reading (with speech output) a phrase here and there, to locate the desired source.

Hand-scanning is also appropriate for source materials containing articles that are continued from page to page, as in newspapers and magazines. Beyond this, a crucial need in human reading is the ability to browse--to reread, skip, back up, change pace, go back a few pages if desired, and so on, all at will and without conscious effort. Hand scanning capability allows the user much closer interaction with the text and more active participation in seeking out information than is possible with automatic scanning.

Let us now consider the value of providing an independent direct-translation output in addition to speech output. An obvious use for the Optacon's direct-translation output is for handling those reading situations for which OCR does not work. For unrecognized type fonts or mathematical notation, the Optacon would be used in the normal way to read the text. The tactile output would also be needed for reading material which does not have a corresponding verbal description, such as interpreting line drawings or maps. But, the tactile array is also important in conjunction with speech output for it is the means by which hand scanning is possible. In order to scan a camera by hand, the blind person needs feedback about the position of the camera in order to maintain accurate tracking, to locate format information such as column boundaries and pictorial entities, and to change lines. The tactile array provides this feedback in a natural way. Reading rates would be much faster than tactual reading because the user would use the tactile array only to control the camera, and would not need to interpret the letter shapes because this function would be performed by the OCR/speech output.

Description of the TSI reading system

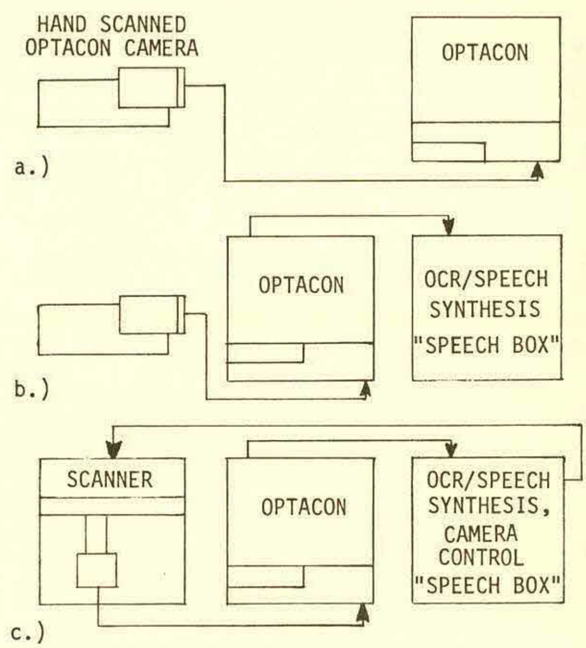

Figure 1. Reading Machine Configurations

Figure 1 illustrates the range of possible reading system configurations based on a direct-translation reading aid such as the Optacon. At the simplest (and least expensive) level, is the stand-alone Optacon, Figure 1a. Small, lightweight and battery powered, it can be used for a variety of reading tasks as a conveniently portable aid. And, as we have indicated, it must be used for some reading tasks, such as mathematics or material printed in unrecognized fonts. A higher level of integration is represented by Figure 1b, in which the Optacon is used in conjunction with an accessory that provides OCR and spoken speech output. Since the accessory functions are entirely electronic, it could probably be made the size of a typewriter, and could also be relatively portable.

In the most automatic (and expensive) version (Figure 1c), the camera would be connected to an automatic page scanning device under control of the electronic accessory unit. This configuration would basically perform the automatic reading function. Because of its size and weight, it would probably not be conveniently portable. It would probably be most suited to reading fairly standardized material at a single location, such as a school, library, or a place of employment. But, its modular components (less scanner) would be easily removable and transportable (for example, to home at the end of a school day) for reading at other locations. An additional feature of a modular system is that it allows the reading machine to be configured specifically for the needs and capabilities of the user. For example, the diabetic blind might need the automatic scanning feature because of their impaired tactual skills might limit their ability to hand scan. On the other hand, a student might prefer hand scanning because of its portability.

Apparatus

As shown in Figure 2, we use three computers to implement our laboratory speech output Reading Machine. The main computer is a DEC PDP-11/34 with 64K words of memory. The PDP-11 has the usual complement of standard peripheral devices such as terminals, a line printer, disk drives and digital and analog I/O interfaces. This computer performs the OCR function, receiving image information through its parallel digital input port and sending ASCII codes for recognized words through a standard serial I/O port. The optical image information is derived from a standard Optacon and is "preprocessed" by a small interface using a Motorola 6800 computer. The 6800 computer supplies the preprocessed images to the PDP-11.

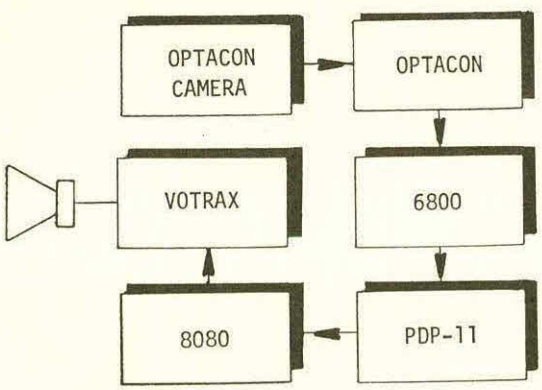

Figure 2.

The ASCII-encoded words recognized by the PDP-11 are sent simultaneously to a video terminal and to a speech synthesis computer, based on an Intel 8080. The speech synthesis computer implements a program called "McIlroy's Rules", which produces an output code string representing the sounds to be spoken (phonetic transcription) in response to an input code string representing the letters of the word. The phonetic code strings are then sent to a Votrax commercial speech synthesizer, which produces the speech signals to drive the loudspeaker.

For experiments involving automatic scanning of pages, we use a modified X-Y plotter which can be programmed to perform a raster scan of an ordinary page of print.

Methods

1.) Implementation of OCR

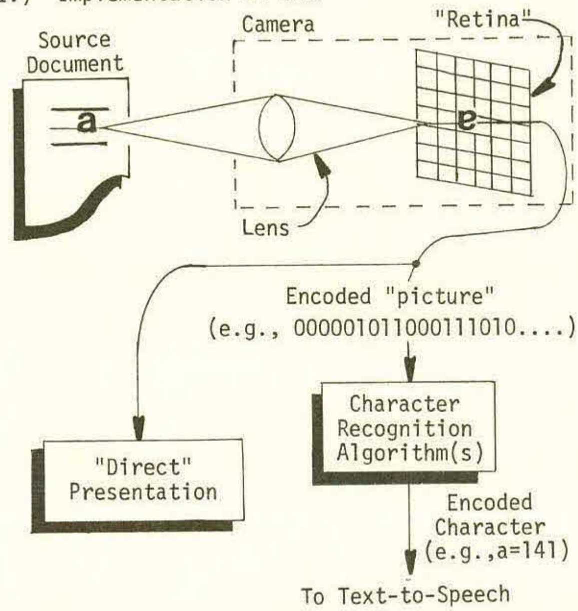

Figure 3.

Figure 3 shows an overview of the OCR problem. A source document is scanned (automatically or by hand) with the Optacon camera. An area about the size of a letterspace is imaged onto the electronic photomosaic, or "retina". The retina converts the optical image into a series of binary electrical signals representing the light and dark levels of the picture. This binary representation of the picture is presented both to the tactile array ("direct" presentation) and to the OCR logic.

A major goal of our OCR program has been to devise algorithms that have the potential to be implemented using relatively inexpensive hardware, in order to assure that the results of this research project will have applicability to the latter development of cost-effective reading equipment.

In general, we use a serial-parallel approach involving multiple independent characterizers to effect OCR. Each independent characterizer is a separate program that computes a specific operation. The programs communicate with each other periodically, but otherwise run independently. In our experimental system, all programs run in TSI's PDP-11 computer taking turns. (This is called "multiprogramming"). In a product, we may have independent hardware for the various processors. (This is called "multiprocessing"). The advantages of multiprocessing are:

a) Each processor can be a small, slow, simple processor (e.g., a "microcomputer") since it only has a small job to do. The cost of such processors is very low.

b) The hardware of each processor can be tailored specifically for the processing task to reduce cost.

c) Capabilities can be expanded by adding processors if needed. No extant features need be sacrificed by such expansion.

The main OCR algorithms are primarily decision-intensive as opposed to computation-intensive. The main purpose behind this intentional bias is that decisions can typically be performed faster and with cheaper hardware than can computations.

One processor is devoted to character segmentation (determining character boundaries). Although an "all-white" column is normally a reliable indicator of a character boundary, characters often touch one another because of poor print quality or specks, etc., in which case no "all-white" column occurs, and additional logic is required to located the boundary. This problem is particularly important in a blind reading machine where there is no control over the quality of the source document.

The decision-making procedures, which also (logically) synchronize the independent processors and control the transfer of information from one processor to another, incorporate a common-memory communication area to allow full independence of the various processors. A portion of this common memory area is devoted to the character voting table, or "ballot". Each processor that performs an OCR function can vote for the character(s) of its choice. Weights can be placed on these votes according to the processor's confidence level. Usually there is a clear winner among the candidate characters (typically, only one character receives any votes). If there is ambiguity, however, the "word" processor utilizes contextual constraints of the English language (so called "n-gram statistics") to resolve the ambiguity.

2.) Implementation of Text-to-Speech

After the words are recognized they must be spoken; the means for accomplishing this is called "text-to-speech" conversion. This conversion actually involves two processes--linguistic analysis and acoustic synthesis. The linguistic analysis takes a word in the form of standard ASCII characters and converts it into a string of phonemes. We use an 8080-based microcomputer to accomplish this. The acoustic synthesis is done by a commercially available speech synthesizer called a Votrax. It converts the phoneme strings into speech waveforms which it then speaks.

The linguistic analysis is an implementation of McIlroy's rules[6]. It is written in assembly language and partially in PL/M, and occupies 12K bytes of memory. When it receives a word from the OCR programs, it first examines it for certain special cases, such as words which contain no vowels, which it then spells. It then does some preprocessing in order to handle suffixes and locate potentially long vowels, such as the "i" in bite. Then it applies its rewriting, or "letter-to-sound" rules. These rules are either simple spelling changes (e.g., "pn" at the beginning of a word can be rewritten as "n") or they may actually convert a word fragment into a phonemic representation, (e.g., the dipthong "eu" is equivalent to the Votrax phonemes "y","u"). The "rules" are actually a table of word fragments and their rewritings. To pronounce a word, the table is first searched for the longest fragment that matches the begnning of the word. This fragment of the word is then rewritten, and the process is repeated until the entire word has been rewritten as phonemes. The phoneme string is then sent out to the Votrax.

Our implementation contains about 500 rules which pertain to word fragments. It also contains about 200 rules which transform entire words directly into phoneme strings. These rules serve as an "exceptions dictionary" for words with particularly anomalous pronunciations such as "two" or "once". A few of these rules handle standard abbreviations such as "etc.".

This method of text-to-speech conversion is particularly useful for our hand-scanned reading machine application. First of all, it operates on a word-by-word basis, so that the person who is scanning hears the word as soon as the camera passes over it. If he has trouble understanding the word, he can immediately rescan the word. Secondly, McIlroy's rules will try to pronounce anything! Since the input to the program is text that comes from our OCR system, it sometimes contains mistakes which result from mis-recognition and/or poor tracking. A text-to-speech system which relied entirely on a dictionary lookup would be unable to cope with such misspellings.

Discussion

The experimental reading system has been operational for several months, and we have begun a program of evaluation. Initial indications are that the hand scanning feature will prove to be extremely valuable to blind users. Figure 4 shows a blind operator using the Optacon to scan text as she hears it spoken aloud at over 100 words per minute.

Current engineering efforts are directed to improving the performance of the system and to re-designing for reduced cost. Our goal is to have a cost-effective, portable reading machine in production by 1980.

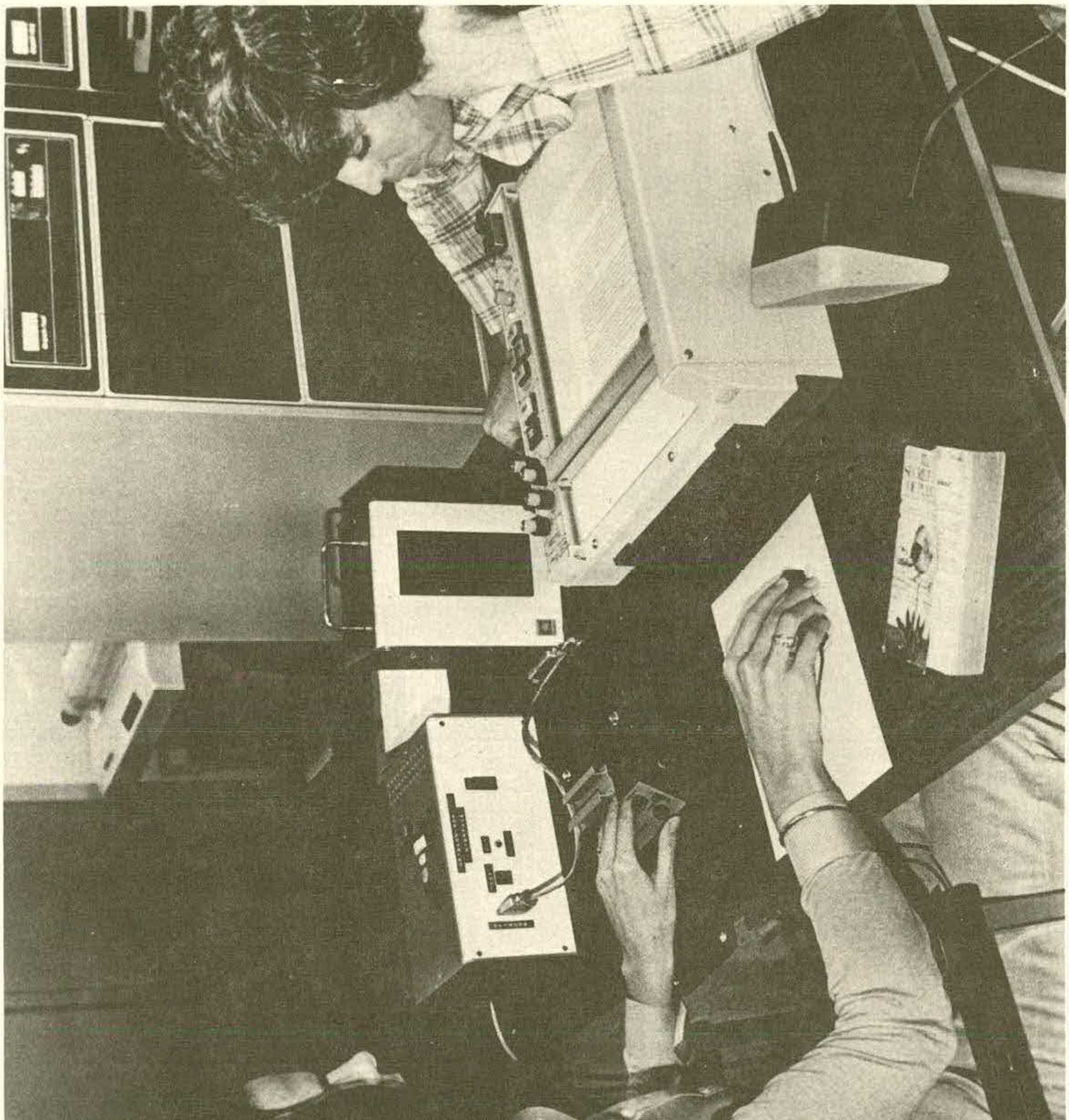

Figure 4

Acknowledgements

This work was supported by the National Science Foundation, under Grant No. APR76-20814. Dr. Scott Allen of the National Institutes of Health provided us with the McIlroy's Rules Program. Tony Sword of TSI performed some of the initial computer programming. Helen Golden of TSI helped in the experimental phase.

References

1. Linvill, J.G. and J.C. Bliss, "A Direct Translation Reading Aid for the Blind", Proc. IEEE, 54 (1966) pp. 40-51.

2. Smith, G.C. and H.A. Mauch, "Summary Report on the Development of a Reading Machine for the Blind", Bull. Prosthetics Res., Vol. BPR 10-12 (1969), pp. 243-271.

3. Cooper, F.S., "Research on Reading Machines for the Blind," in Blindness, Modern Approaches to the Unseen Environment, Paul A. Zahl, ed., Princeton U. Press (1950), pp. 512-543.

4. For a general survey, see P.W. Nye and J.C. Bliss, "Sensory Aids for the Blind: a Challenging Problem with Lessons for the Future", Proc. IEEE, 58 (1970), pp. 1878-1898.

5. Munson, J.H., R.E. Savoie, R.P. Shepard, R.W. Stearns and J.C. Bliss, "Systems Study of an Interactive Computer-aided, Text-reading Service for the Blind Available through any Telephone," Final report SRI Project 7517, October 1970 (NIH Grant No. 5 R01 EY 00450-02).

6. McIlroy, M. Douglas, "Synthetic English Speech by Rule", Bell Labs Computing Science Report #14, March 1974/

RECENT DEVELOPMENTS ASSOCIATED WITH THE SENSORY QUILL

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This paper summarizes the development of the Sensory Quill, from initial point of motivation to commercial availability. Also discussed are future modifications of the instrument, to better meet a wider audience.

CATEGORY: Device Development ☒ Research Study ☐	INTENDED USER GROUP: Blind, Partially-sighted, and Dyslexic
	AVAILABILITY OF DEVICE: Mechstat, Incorporated
STATE OF DEVELOPMENT: Prototype ☐ Clinical Testing ☐ Production ☒	AVAILABILITY OF CONSTRUCTIONAL DETAILS: Mechstat, Inc.
AVAILABLE FOR SALE: Yes ☒ No ☐ Price: Individual Model $295.00 Institutional Model $745.00	FOR FURTHER INFORMATION CONTACT: Mechstat, Incorporated 830 N.E. Loop 410 #210 San Antonio, TX 78209

A research project which was begun some six years ago has now come to partial conclusion. Six years ago blind and partially sighted students in college had no ready access to drawings and charts which were offered sighted students by way of chalkboard or textbook display. At that time efforts to offer some sort of tactual replica of such drawings and charts were limited to construction of balsa wood models, clay models, string, wire, aluminum scratched on the backside in mirror-image fashion, or the Sewell Drawing Kit. All of these approaches were quite inadequate, lacking spontaneity and with very little offered the blind participant other than tactual observation.

In an effort to respond to needs of blind college students, Dr. D. R. Traylor, Ms. Pat (Martin) Pound, and Mrs. Madeline Jones began researching various methods by which a blind student could have immediately a raised line drawing of whatever appeared on the classroom chalkboard and, more importantly, develop a capability that allowed the blind student to give rise easily and quickly to his own raised line interpretations, drawing on the "up-side" of the surface, not in mirror-image fashion on the back side.

Within a few months of the project initiation a prototype instrument was available. It accomodated a large sheet of paper, about 22 inches by 28 inches and was machined from aluminum. The instrument allowed any user to move a stylus across paper and gain a raised line wherever the stylus touched the paper.

The design of the prototype was complex because of the size of the paper and the requirement that movement of the stylus had to occur with little resistance due to inertia or friction. The paper was placed in position by aligning the edges with vertical stops positioned on the frame of the instrument. A rectangular frame then dropped on the perimeter of the paper as one lever was thrown, simultaneously pinning and stretching the paper. Beneath the paper surface was a motor mounted on an x-y axis carriage. The motor operated at better than 5000 RPM, driving a small hammer upward from below the surface of the paper. Receiving the hammer thrust from above the paper was a hand-held stylus with a small channel in the foot of the stylus. The channel freely turned 360° and as the stylus was pressed to the paper, a raised dot occurred with each thrust of the hammer into the channel. Engineering was such that the hand-held stylus moved freely about the paper surface and, in every position, the hammer beneath the paper was immediately below the channel. The prototype provided a significant progressive step, but suffered from the severe disadvantage of high reproductive cost.

Following the development of the initial prototype, evaluative efforts began. Some of these efforts have been reported in papers delivered at prior conferences on Systems and Devices for the Disabled (1), (2), (3). Much was learned as to the applicability of this new instrument to satisfy the needs of the blind. All ages congenitally and adventitiously blind, in school, at work, in recreation can benefit from the Sensory Quill.

A second stage of applied research bears on the queston of economics. It is one thing to develop an instrument which offers remarkable advance; it is another to offer it to a restricted population at an economically feasible price. This stage of research on the Sensory Quill is now completed. Redesign of the instrument has been completed, allowing retention of the desired capabilities at a modest price to the consumer.

Discarded from the original prototype was the complicated and expensive paper clamping device. Also discarded was the x-y axis carriage mount. However, for future computerized duplication, the x-y axis assembly is available as a fully developed characteristic of this prototype tactual drawing device.

Some of the alterations which have been assimilated into the redesigned Sensory Quill include:

(a) Drawing surface size is 11 inches by 11½ inches.

(b) Height of line raised can be altered.

(c) One model is portable (Illustration 1).

Experience established that most users did not effectively use a surface as large as that offered by the original prototype. Indeed, approximately the span of two hands is the effective area to be offered. Since Brailon is commonly available to blind individuals and agencies serving the blind, a standard Brailon size of 11 inches by 11½ inches was chosen.

It is important to alter line height for purposes of differentiation. Also, depending upon the users hand weight, and on the resiliency of the material to be deformed, the height of deformation should be adjustable.

Since some users need the Sensory Quill for job-related activities, some for unrestricted personal use, and for a variety of other reasons, one model was designed to allow portability. To gain portability, some weight was reduced from the institutional model. A result is that the portable unit has not the structural strength of the institutional unit.

Another feature of the redesigned Sensory Quill is that, by adjusting the height of line, 3 or 4 mil aluminum foil can be deformed by the institutional model, providing masters for heat-vacuum processes. It should be noted that a sheet of Brailon can be used again and again with the Sensory Quill, erasing raised images with a vacuum heat process.

Future modifications on which research is now being performed include:

(1) Adding color to the raised line, allowing more effective use by the partially sighted.

(2) Development of a prototype double unit in which one unit duplicates the other unit instantly.

(3) Preparation of sophisticated maps with varying line height and width.

It is clear that individuals with other perceptive difficulties, such as dyslexia, can benefit from using the Sensory Quill. By providing a colored line, to reinforce the tactual observation of the raised line, even more effective utilization of the Sensory Quill can occur by those who have some sight.

The need for a double unit stems from needs of three populations. Elderly individuals who lose sight and sometimes hearing would have a new communication device which allows script writing, drawing, games and other personally satisfying activities. A second population includes blind teachers of the blind. The single unit requires the blind teacher and the blind student each to try simultaneously to feel the same line as it is being raised. This causes too many fingers to seek the same place. A third population is that of the deaf-blind. An entirely new communication device would be thus available to this population, useful in school, job, or personal satisfaction.

Finally, attention is now being given to individuals whose needs are special. Blind computer programmers need to flow chart and to evaluate the flow charts of others. With the Sensory Quill, this is possible. However, a different sized writing surface is desired, offering some redesign problems. Other job-related activities will lead to other modifications as the needs are determined.

Several recent articles which offer an indication of the range of settings and situations in which the Sensory Quill, on the basis of our experience, can be effectively used are (4), (5), (6).

References

1. Traylor, D. R., "The Heugel Quill: A New Tactile Development for the Blind," Pro. 1972 Carnahan Conference on Electronic Prosthetics, 147-149, December 1972, Univ. of Kentucky.

2. Traylor, D. R. and Jones, Madeline, "The Heugel Quill: Another Alternative for the Visually Impaired," Pro. 1974 Conference on Engineering Devices in Rehabilitation," May 2-3, 1974, Biomdedial Engineering Center, Boston, Mass.

3. Traylor, D. R., Jones, M. M., Hedgcoxe, P. G., "Tactile Learning Devices for the Blind - Sensory Quills," Pro. of the Fourth Annual Conference on Systems & Devices for the Disabled, 175 - 177, University of Washington, Seattle, Washington, June 1 - 3, 1977.

4. Berla, E. P. and Butterfield, L. H. Jr. "Tactile Political Maps: Two Experimental Designs," J. of Visual Impairment and Blindness, Vol 71, No 6, 262-264, June 1977.

5. Oldbury, D. and Schulz, P. J., "The Blind Traveler and Public Transportation," J. of Visual Impairment and Blindness, Vol 72, No 1, 26, January 1978.

6. Santin, S. and Simmons, J. N., "Problem in the Construction of Reality in Congenitally Blind Children," J. of Visual Impairment and Blindness, Vol 71, No 10, 425-430, December 1977.

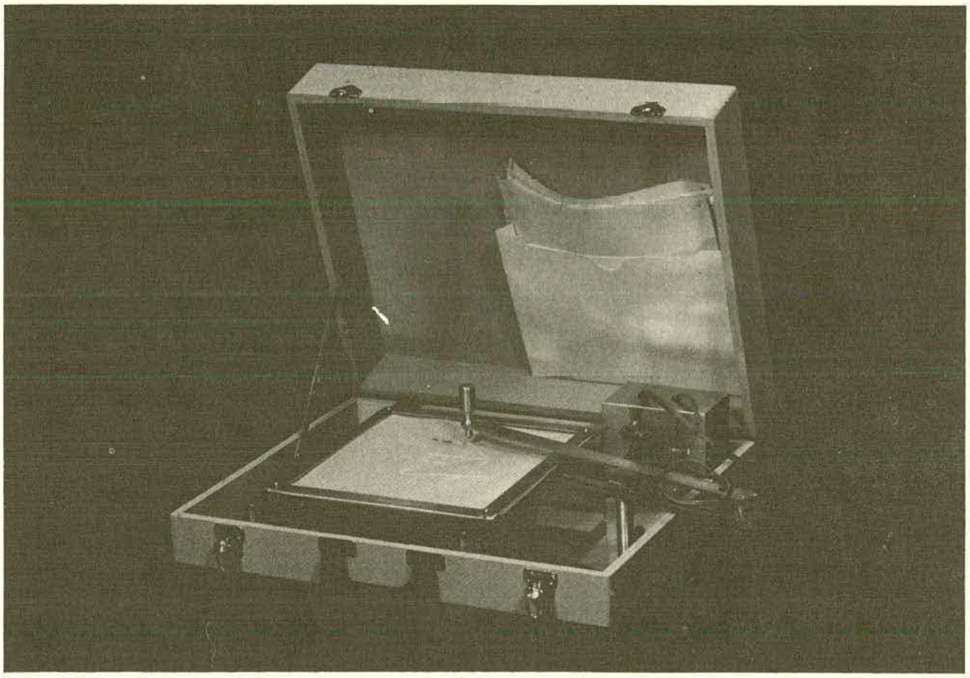

Illustration 1. Individual Model of Sensory Quill

Using a Computer Message System for Promoting Reading and Writing in a School for the Deaf

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50 Moulton Street
Cambridge, Massachusetts 02138

Abstract

Deaf children usually have great difficulty with English. A significant problem in teaching written English to the deaf is providing students with opportunities to use it for their own purposes: for communicating with friends or teachers. As soon as the hearing child learns to speak, English becomes a source of power and control. Deaf children miss this strong early motivation to learn English. We have been using a computer-based message system to provide written communication for students, teachers, and staff in a school for the deaf. Our initial experience suggests that this is an effective way to motivate deaf children to write. Further, it is providing a good research vehicle for studying the development of written language in deaf children.

CATEGORY:	INTENDED USER GROUP: Schools with deaf and other low-language level children.
Device Development ☐ Research Study ☒	AVAILABILITY OF DEVICE:
STATE OF DEVELOPMENT:	
Prototype ☐ Clinical Testing ☒ Production ☐	AVAILABILITY OF CONSTRUCTIONAL DETAILS:
AVAILABLE FOR SALE:	FOR FURTHER INFORMATION CONTACT:
Yes ☐ No ☐ Price:	Richard Rubinstein Bolt Beranek and Newman, Inc. 50 Moulton Street Cambridge, Massachusetts 02138

Introduction

The vast majority of the prelingually deaf do not acquire the same fluency in English as their hearing peers. The resulting serious reading deficiencies (fewer than half of them exceed the 5th grade reading level) markedly reduce the deaf person's access to general information and public communication. If we are to teach written English to deaf children, we must stimulate writing for communicative (not exercise) purposes, and we must have a clear understanding of how written English develops in deaf people.

While hearing children grow up with the experience of using their language to control others long before they encounter school lessons, the prelingually deaf child usually gets most or all of his English (and often his sign language) in school, where the predominant role of language is responding rather than initiating or controlling. Until English is of service to the child, his spontaneous use of it will be minimal. Moreover, there is good reason to believe that language in the absence of communicative purpose simply cannot develop. Thus, while part of the problem of teaching the deaf child written English is his lack of knowledge of the spoken language, it is also partly a problem of providing some context in which the language can become useful.

We have developed a new aid for teaching the deaf: electronic mail. Our experience with a computer-managed message system for deaf children has shown it to be a very powerful tool for motivating them to write. Students at our experimental site, without coaxing and without artificial rewards from the computer, have been sending volumes of mail to each other in the form of love letters, insults, funny notes, invitations to play together and the like. They have also been leaving private messages for teachers such as requests to sleep over at the teacher's house. It appears that one strong motivation for using the message system is that it allows private communication to remain truly private, unlike messages in sign language that are open to anyone who can see the conversation, or writing which is usually done at the request of a teacher whose role is to find and correct mistakes. Another way of looking at this system is that it has served to turn written English into a usable and useful form of communication instead of a school exercise.

*The work described in this paper is funded by the Office of Education, Bureau of Education for the Handicapped, under Contract No. OEC-300-76-0525, "Demonstration of the Use of Computer Assisted Instruction with Handicapped Children."

Experience at the school

A PDP-11 computer, installed at the school site, supports the message system as well as other learning activities. Each student, teacher, and staff member at the school has a personal computer mail box: The messages that are deposited in a mail box are available when the person logs in to the computer. Users may send mail to individuals or to lists of people. They may also request copies of messages for themselves.

Children in two different classroom environments are involved in the project. The lower school is organized as an open classroom with six topical activity areas and serves about 30 children ages six through twelve. These children have a substantial amount of freedom in choosing which areas they go to, and are free to change areas during the day. In the upper school, a group of about 25 older children, ages twelve to sixteen, are taught in a more traditional setting including scheduled classes in specific subjects such as reading, math, geography, and design. The electronic mail system we designed had to be able to operate successfully in both environments.

In the open classroom, the terminals are associated with activity areas, and may or may not permit the use of the MAIL system at the teacher's discretion. Thus MAIL may be available only in certain areas such as the reading area. Children who want to send mail or check their mail boxes may select these areas. MAIL remains the most popular of the computer activities offered, and is a definite attraction of those areas which offer it. In the upper school (older children), the terminals are outside the classrooms. Students frequently sign up to use the computer when not in class, or leave a class with the teacher's permission to do computer work related to the class. After limited initial instruction, students can use MAIL without supervision, leaving the teachers free to conduct classes. Electronic mail is particularly popular with the older children.

These children are producing written language as they never have before. The teachers report that the children use the computer to write messages freely. Furthermore, the teachers, who see only those messages that are addressed or shown to them, have been impressed with their length and detailed content.

The adults in the school also use the message system sending messages to each other and to students as part of school activities and for personal communication. Thus, children see riting as a useful, adult activity, not merely an academic exercise. The fact that some children and staff spend part of their time at other schools in a main-streaming program makes this communication facility all the more valuable. Electronic MAIL makes it convenient to leave private messages for people even when they are not present to receive them.

We believe that the autonomous use of this system for communicative purposes is one of its principle values to the student, and thus have not encouraged its use in assigned class activities. Others trying electronic mail are cautioned that the spontaneity of the interaction is very important and that assignments may be detrimental.

Analysis of student messages

At this writing, children at the school have been using the computer mail system for about four months. The results have been both interesting and exciting. For the purposes of analysis, we have kept copies of all messages sent or received by students. Great care has been taken to preserve privacy in this recording process and, for the protection of the interests of the children and staff at the school, all identifying information is eliminated from the record.

The selection shown in Figures (1) and (2) is reasonably representative of messages sent by children at the school, but there is too much variation to represent the full range in a few examples.

Perhaps the most important observation we can make is that these letters exist at all. Since the beginning of January, over 600 letters were sent by a group of children who usually wrote little when given an assignment and almost nothing spontaneously. Girl 29's statement "I don't understand what succeeding mean" and Boy 29's response to Girl 12 "You are beautiful!!!! Why cute me? Why crazy me?" show genuine concern for communication (Figure 1).

FIGURE 1

```
To: {Teacher 9}
From: {Boy 2}       18-Nov-77 12:20 PM
Dear {Teacher 9},
     I touched Florida. Florida feels very hot.
                         Love {Child 22}

To: {Teacher 4}        04-Nov-77 12:03 PM
From: {Boy 2}
  this is fun! i meant computer! keep mailing on me!
                                        love,
                                             {Boy 2}.

To: {Boy 29}
From: {Girl 12}      23-Nov-77 10:27 AM
 HI {Boy 29},
YOU ARE VERY CUTE..
YOU ARE VERY CRAZY.
   LOVE {Girl 12}

To: {Girl 12}
From: {Boy 29}       29-Nov-77 11:22 AM
Dear {Girl 12}
    You  are  beautiful!!!!
Why
     cute  me  ?  Why  crazy  me  ?      Bowling
to come  yes or no ?  Do you want to go  and   get  ice
 cream  yes or no ?  I want to go to your  house.
                          love
                                {Boy 29}

To: {Teacher 3}
From: {Girl 3}        05-Dec-77 08:59 AM
             Hi ! I was happy to get your ietter . I don't
  understand what succeeding mean . The answer your questoin
are  I want to goto The keefe high school. and yes, I like
the teacher upstairs . I don't have a boyfriend. I think
{Girl 32} want to write to you. I think she want to know your
 address .  {Boy 26}  said you are handsome . I think you are
cute . Piease write to me . love, {Girl 3}
```

FIGURE 2

```
To: {Girl 3}
From: {Girl 10}       04-Nov-77 10:54 AM
     How are you? I am fine. {Girl 13} dont like you!
  I will sleep over {Girl 13}s house .

To: {Boy 9}
From: {Girl 10}       04-Nov-77 11:03 AM
 Why you broken new my necklace.
 I dont like you broken new my necklace!

To: {Girl 13}
From: {Girl 10}       04-Jan-78 12:12 PM
   HI {Girl 13},
        WHY  YOU DON'T WANT GO TO SWIMMING. I LIKE TO GO TO
   SWIMMING.
  DO YOU LIKE {Girl 4}? DO YOU LIKE {Girl 3}    ?
   I LIKE YOU MUCH!!!
    DO YOU WANT TO SLEEP OVER MY HOUSE? I WANT TO SEE YOUR DOG.
   I SAID "HI" YOUR MOTHER AND FAMILY. I LIKE TO YOUR FAMILY.
   YOU ARE CRAZY!!!!! HA HA HA HA HA HA HA HA HA
HA!!!!!!!!!!!!!!!!

To: {Teacher 2}
From: {Girl 10}       05-Dec-77 12:17 PM
             Dear {Teacher 2's last name},
                Hi! How are you? I am fine. Do you think all right
   {Girl 19} and me will sleep over your house. I never visit you
   house. Do you like lots of animals? I love gerbils,dogs
   mices. That's all. Do you have any dogs or cats? I know
   your favorite animals!!! Do you like downstair? I don's like
   downstair. I like to upstair. I want you go upstair again!!!
   Your son {name} is cute!!! Your wife's name? I don't know
   your wife. I think your wife and son are nice!!
   You are nice too!!!!!!! Where was you born? I was in
   {town name}, Ma. I live in {town name}. I know you live in
   {town name} {Teacher 7} live there.
```

Equally striking is that many of the messages are long and, with time, some children are writing still longer and longer letters. A formal analysis isn't needed to observe the change, not only in volume, but in structure and style between the letters Girl 10 sent on November 4, and the letter she sent a month later (Figure 2). Her January letter, written in a particularly silly mood, is evidence that the improvement is not due solely to the fact that the December letter was addressed to a teacher. She writes more, asks questions that expect a response, and "plays" with her English, using wild (and good) punctuation, and more casual and varied constructions. These samples don't show the formatting games she played with her name, frequently typing it diagonally across the page at the end of her letters.

We believe that this greater use of written English is valuable practice despite the uncorrected errors. Supporting this view is the observation of the teachers that several of the children (in particular, Girls 3 and 10) have recently shown stunning improvements in their writing. It is not possible, at present, to know how much of this improvement is due directly to their writing and how much is due to a greater sense of personal investment during English class resulting from their writing experience.

Conclusion

Over the course of the experiment we will be studying the structure of the writing of these children, looking for characteristics that might be helpful in designing better curricula for teaching written English to the prelingually deaf student. The way in which our data have been collected should make it possible to move beyond the mere analysis of syntactical errors into a more exciting, and most likely more fruitful, modeling of the English of deaf children. From a slightly more narrow perspective, we are hopeful that an analysis of these data will be of diagnostic value in designing programs for these specific children. We will look for changes in language and use these developmental indicators as one evaluation of the language curriculum.

For the moment, the most important observation is that the computer mail system is providing a new medium for communication for these deaf children, one which they use freely to their own ends. It is a first step towards making written English the powerful tool it should be -- for, rather than against, deaf people.

A REFRESHABLE BRAILLE DISPLAY FOR TSPS TELEPHONE OPERATORS

D. Rowell, G.F. Dalrymple, J. Olsen
Mechanical Engineering Department
Massachusetts Institute of Technology

A refreshable Braille display has been connected to a telephone central office computer-driven operator's console. A blind operator has been trained to operate the console and she has demonstrated that a suitably trained blind operator can perform such a job on a competitive basis.

CATEGORY:	INTENDED USER GROUP: Blind - vocational rehabilitation
Device Development ■ Research Study □	AVAILABILITY OF DEVICE: Not presently available
STATE OF DEVELOPMENT: Prototype □ Clinical Testing ■ Production □	AVAILABILITY OF CONSTRUCTIONAL DETAILS: Constructional details limited by contractual agreement.
AVAILABLE FOR SALE: Yes □ No ■ Price:	FOR FURTHER INFORMATION CONTACT: Prof. Derek Rowell Building 1-112 M.I.T., 77 Mass. Ave. Cambridge, MA. 02139

Introduction

The TSPS[1,2] (Traffic Service Position System) operators in the Bell System now handle the majority of operator-assisted calls, with the exception of special calls (overseas, maritime and mobile) and directory assistance. The number of telephones served by the TSPS network is rapidly increasing. As of mid-1977, approximately 62% of all Bell System customers were serviced by TSPS, with plans for complete service by TSPS operators by the end of 1978[3].

This paper describes a collaborative project between the Southwestern Bell Telephone Company (SWBT), Little Rock, Arkansas, Arkansas Enterprises for the Blind, Inc. (AEB), and the Sensory Aids Evaluation and Development Center, M.I.T., to demonstrate the vocational potential of a specialized braille console in the provision of new job opportunities for the blind.

The TSPS work station uses a complex visual display to cue the operator as to the status of calls being handled. The console has approximately 80 lamps and push-buttons under the control of a central computer, and a 12 digit numeric display for information such as numbers (called and calling), time of day, charges, etc.

The problems encountered in developing a braille console for the visually impaired operator included the specification of a display format that presented the console status to a blind operator, the problem of note taking (for example, remembering names and numbers of customers), access to a large bank of printed information (emergency numbers, etc.), and the preparation of manual billing tickets for calls that cannot be handled automatically.

The responsibilities within the project were divided among the three collaborating groups. The system design and development was undertaken at M.I.T. The development of training and support materials was the responsibility of AEB and SWBT. The system has been in use for more than one year and has adequately demonstrated that blind persons can perform competitively in vocational situations requiring information retrieval, provided a non-visual display can be connected to the system.

Development of the braille TSPS display

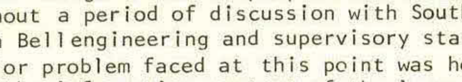
The braille console is shown in Figure 1, alongside a TSPS console. The microcomputer-based system continuously scans the status of the TSPS console and numeric display, and presents the status information on a 12 character dynamic

Figure 1. Operator at braille display equipped TSPS console. The abacus and Banks braille writer have been replaced by braille scratchpad.

braille display. The operator's right hand is resting on the braille display.

The design of the display format evolved throughout a period of discussion with Southwestern Bellengineering and supervisory staff. The major problem faced at this point was how to reduce the information content of the lamps to a form that could be encoded into a small number of braille cells. It was decided that the minimum acceptable number of characters would be the number of digits in the numeric display, namely 12. A study of the flow of TSPS calls revealed that for most calls, it was possible to cluster groups of the lamps into meaningful message sets. After extensive experimentation, using a specially developed TSPS simulator, a set of console status-levels were defined and used as the basis of constructing a series of messages to be presented to the operator in the form of mnemonics or English words. The hierarchy and specification of the message structure was based upon the normal sequence of actions to be taken in handling most calls.

As an example, consider the case when the operator must notify a pay-phone customer that his time on a long distance call has expired. The mnemonic form of the message displayed is:



N C N 1 +

indicating a Notify task, from a CoiN phone, where the customer dialed direct 1 + (area code) + number. As the call progresses beyond this point, the braille display is updated to reflect changes in the console status. The majority of such changes occur as a result of direct operator actions; in these cases the display acts as a verification of the correct action.

For many calls, it is important that the blind operator be able to interrogate the state of any lamp on the console, or the numeric display. A series of push-buttons was provided so as to allow manual interrogation of a status level, or the many special function lamps on the console.

The system design was undertaken on a specialized microcomputer system. Prototype software was developed on a minicomputer and down-line loaded to the microcomputer for evaluation. The TSPS console simulator was used to create hypothetical calling sequences for evaluation of software performance on the occurrence of exceptions to the normal flow. Throughout this development phase, which took several months, Bell System personnel were continuously consulted to make sure that all contingencies had been covered.

Early in 1977, it was decided that the system evolution had reached a stage that warranted evaluation under actual operating conditions. A new microcomputer, with permanent program storage, was developed and the system was installed in Little Rock, Arkansas, where it has operated reliably since.

The early field experience showed two areas requiring further development. First, the TSPS system itself is in a continual state of evolution and new lamps and functions are being added to all consoles every few months. This has required both hardware and software changes to the braille system to accommodate the TSPS changes and will, in all probability, require future changes. Second, the problem of note-taking by a blind operator was found to be significant. Initially, an abacus and braille strip embosser were provided, but subsequently a braille keyboard was interfaced to the microcomputer to allow the operator to store messages within the computer memory and later display them on the braille display. On the present system, 27 such 12 character messages can be stored. If more are entered, the first ones are lost. This addition to the system has proven to be very valuable.

System hardware

The elements of the braille console are shown in Figure 2. The microprocessor configuration was based upon the Motorola M6800 family. The system may be conveniently broken into four major functional blocks:

1. Input interfaces to the TSPS console. The Bell system logic levels required extensive level shifting to make them compatible with the normal TTL levels. The TSPS environment is electrically "noisy", requiring both hardware and software filtering. The console lamps were interrogated under program control; the numeric display lines operate under interrupt.

2. Braille display system, with output latches, solenoid drivers and braille cells[4].

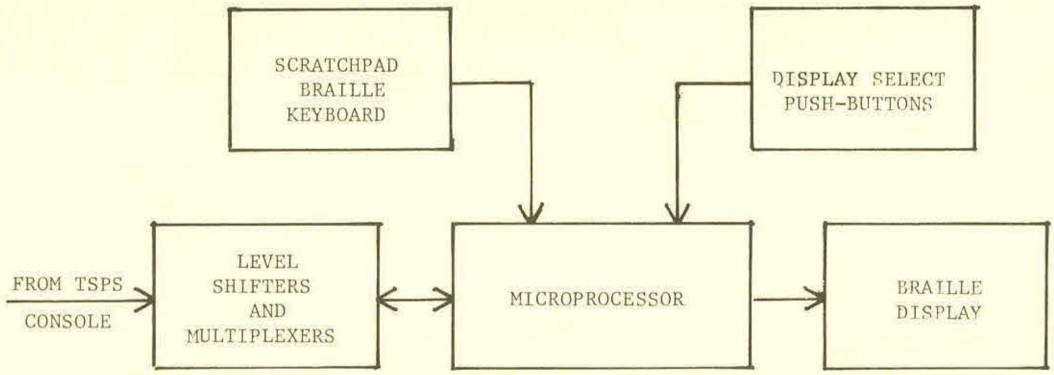


Figure 2. Block diagram of TSPS braille display

3. Microcomputer system. The operating software requires 3k bytes of read-only memory, and 512 bytes of read-write memory for temporaries and note-taking scratch pad.

4. Operator input interfaces, including the braille entry terminal and the display control push-buttons.

The unit is hard-wired to the TSPS console and sits beside it at the same height as the desk area. In normal operation the braille display is read with the right hand, with either hand used for operating the TSPS console.

Field evaluation

A single blind operator has been trained in the use of the system, and has worked at the braille console since on a normal work schedule since mid 1977. Additional aids in the form of a Rolodex braille file of normally printed TSPS information, and a special template to assist in the preparation of manual billing tickets were provided.

In the first six month post-training evaluation period, the operator performed consistently at a productivity level above the office average. The latest data indicate a productivity of 26% above the average operator. While conclusive judgments cannot be based upon a single operator, this high performance level demonstrates that the braille display format used in this system contains all of the necessary information to allow a blind person to compete directly with sighted peers in this vocational setting.

Conclusion

This study has demonstrated the possibility of a new vocational opportunity for the blind. The TSPS operator position is one that has the possibility of employing a significant number of blind persons, provided a means of information presentation can be developed.

Acknowledgments

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References

1. Funck, R.H., "Designing the Traffic Service Position Console", Bell Laboratories Record, pp. 202-211, June 1964.

2. A series of papers in Bell System Technical Journal, Vol. 49, No. 10, December 1970, pp. 2417-2732, describes the system in detail.

3. Arnold, T.F., "TSPS goes to the country", Bell Laboratories Record, pp. 147-153, June 1977.

4. Dalrymple, G.F., "TSPS Braille Display", Braille Research Newsletter, J.M. Gill and L.L. Clark, editors, University of Warwick and the American Foundation for the Blind, No. 6, pp. 78-81, October 1977.

DEVELOPMENT OF THE FLUIDIZED-BEAD WHEELCHAIR CUSHION

J.E. Lyddy* and J.P. O'Leary**

A wheelchair cushion that incorporates a supporting material made from a mixture of lubricated styrene beads ("fluidized" beads) has been developed from a concept originally presented by S. Bajema. Preliminary tests with normal subjects have shown that the cushion is effective at reducing peak pressures. This paper describes the fluidized-bead cushion and the empirical specifications that were developed to guide its selection and design. A list of other cushion types is presented along with a brief summary of the disadvantages or each design. The results of preliminary testing are also described.

CATEGORY:	INTENDED USER GROUP: Any wheelchair cushion user.
Device Development ☒ Research Study ☐	AVAILABILITY OF DEVICE: Limited production at this time due to required custom-fitting.
STATE OF DEVELOPMENT:	
Prototype ☒ Clinical Testing ☒ Production ☐	AVAILABILITY OF CONSTRUCTIONAL DETAILS: Enclosed.
AVAILABLE FOR SALE:	FOR FURTHER INFORMATION CONTACT: J.Lyddy.
Yes ☒ No ☐ Price: $40 approximately	

Introduction

Identification of an acceptable cushion is an important step towards independence for many wheelchair users. The cushion provides in interface between the disabled person and the wheelchair and can have a significant impact on the length of time that the user can sit each day without developing problems. This length of time directly affects the extent of the activities in which the user can partake. For at least some wheelchair users, the cushion can determine the potential for employment and education.

A survey of the available cushions and relevant literature revealed that while many different types of cushions exist, the ideal cushion has not yet been developed. None of the cushions prevent decubitus ulcers from forming--the ultimate goal. All designs trade off certain specifications in order to achieve others. To initiate the process of developing an alternative type of cushion, we first identified problems with the available models through discussions with experienced individuals: users, physicians, therapists, and engineers. From this information, empirical specifications for an ideal cushion were synthesized, then tested against the experienced individuals, and modified. (Empirical specifications were developed since insufficient information was available to formulate precise specifications.) These specifications were then used to evaluate numerous concepts--some developed by the authors and some developed by others. A concept originally presented by S. Bajema (1), appeared to offer characteristics closest to that of the empirical specifications. Since this fluidized bead concept had not been developed into a marketable product, we decided that the availability of such a cushion would offer an alternative product for disabled persons. The results of a preliminary user trial and pressure measurement studies on normal individuals are encouraging. Limited production of the cushion has begun. More work is necessary to perfect the design. More clinical trials are needed to document further the efficacy of this cushion and to develop a system for fitting the cushion to individual needs.

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Empirical specifications

The following specifications appear to be significant:

The area of the skin surface area in contact with the cushion should be maximized. It is generally agreed that pressure is the principal cause of decubitus ulcers (pressure sores)(2). Although the details of the mechanism forming decubiti is not completely understood, it is known that pressure contributes to tissue destruction in three ways. Pressure occludes blood vessels that supply oxygen and nutrients to the skin. Prolonged occlusion can cause ischemia and eventually necrosis. As pressure increased, the time required to produce tissue destruction is reduced. Pressure can also cause mechanical destruction of skin. The level of pressure required to cause this kind of destruction to normal tissue is much higher than that encountered during sitting. However, tissue that has been damaged by ischemia is more susceptible to mechanical disruption. The third type of pressure damage has been described and referred to as "autolysis" by P.W. Brand (3). When pressure is intermittently applied to tissue an inflammatory reaction develops. It is theorized that the repeated application of pressure causes the cells to release enzymes which cause tissue destruction.

It is evident that the incidence of decubiti can be decreased by reducing pressures encountered during sitting. The average pressure (P) is defined as the total force (F) over the total area (A): $P=F/A$. Since the total force, the body weight being supported, is essentially a constant, a reduction in average pressure is achieved by increasing the skin surface area to support this weight. Maximizing skin surface area will minimize the average pressure applied to the skin.

Pressure should be distributed equally over the entire sitting area. The pressure can be reduced to a minimum over the entire sitting surface area by equalizing the pressure at all points.

Shear forces acting parallel to the skin should be reduced to a minimum. Shear is caused principally from friction on the skin that acts to mechanically disrupt the skin layers. In addition, since blood vessels cross skin layers, shear forces can pinch off the blood supply and contribute to tissue ischemia.

The cushion cover should be breathable. Increased temperature and humidity contribute to tissue damage in the presence of pressure. A cover that allows air circulation maintains a cooler and drier environment for the skin.

The cushion should provide a stable sitting surface. Many disabled persons requiring wheelchairs do not possess the trunk support to sit on an unstable support.

The cushion cover should be washable. A number of disabled individuals have problems with incontinence. Urine and feces are particularly destructive to skin tissue. In addition, a soiled cushion is socially unacceptable. A cushion cover that can be washed in place or easily removed for cleaning is essential.

The cover should resist degradation from urine and feces.

The cushion should maintain its characteristics in all environmental conditions. In order to use a cushion for outdoor activities it is essential that its normal performance not change in high or low temperatures and humidity.

The cushion cover should not burn readily. In case a cigarette is accidentally dropped onto the cushion, the cover should retard burning.

The cushion should be lightweight. A heavy cushion reduces mobility, requires the user to wheel more weight, and makes transfers more difficult.

The thickness of the cushion should be kept to a minimum. The thickness of the cushion should be compatible with the user and the wheelchair in order to maintain the proper relationship between arms/arm rests, hands/wheel rims, and feet/foot rests. Wheelchairs are usually designed with a minimal allocation for cushion thickness.

Summary of cushion types

A review of the available types of cushions is summarized as follows:

Elastic Foam--The major drawback of these foams is that they exert increasing force as compression increases. Bony prominences that protrude into the cushion thus receive the highest pressures, increasing the likelihood of decubiti. These foams tend to lose elastic properties with age and bottom out. They are inexpensive.

Viscoelastic Materials--Following compression, these materials exhibit elastic properties and thusly the same deformation-pressure relationship described above. Elastic foams that have been impregnated with viscous fluids are heavy.

Air--These cushions have single or multiple inflatable cells. The user is usually responsible for maintaining proper inflation which may not be satisfactory. Air leaks can be unsafe. The stability of the cushion depends upon the particular design.

Water--These cushions are unstable for many people. They are heavy and difficult to transfer. The bladder containing the water supports the user in a manner similiar to a hammock; causing high frictional/shear forces on the skin. Leakage is sometimes a problem.

Gel--These cushions are approximately as heavy as water but more stable and without the leakage problem. Gel cushions are usually expensive. The hammock-type cover provides most of the support.

Custom-Molded Seats--These seats usually have a rigid frame and are molded to the contours of the individual. They are usually lined with a foam layer with a deformation-pressure characteristic. The seats limit motion when molded to fit closely. If the user does not sit in exactly the correct position, higher pressures than normal are experienced. These seats are very expensive.

Selection and description of the fluidized-bead concept

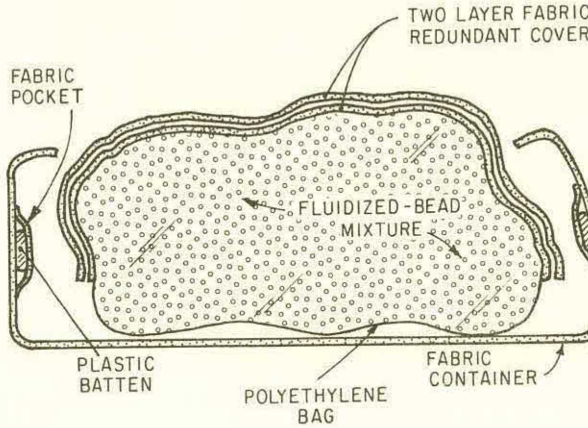
The empirical specifications have been used to evaluate the viability of numerous concepts--some originated by the authors and others identified in the literature. The experimental design originally presented by S.L. Bajema (1) was judged to offer the best cushion characteristics of all those evaluated. However, this concept was never developed beyond the experimental design presented in 1974. Further refinement and testing were necessary to evaluate the short- and long-term effects of the cushion on the patient (and vice versa), and to design a product that could be distributed to those disabled who could potentially benefit from this cushion.

A cross-section of the fluidized-bead cushion is shown in Figures 1a and 1b, before and during sitting, respectively. Figure 2 is a photograph of a handful of the fluidized-bead mixture and may provide a "feel" for the properties of this mixture. The cushion is filled with a fluidized-bead misture enclosed in a polyethylene bag of 0.005" thickness. The beads are small styrofoam spheres averaging 1/16" in diameter, with an average density of 3.4 lbs per cubic foot (Arco Dylite,steam expanded to a specific gravity of 0.05). A silicone lubricant is mixed with the microspheres until a thin film of lubricant coats each sphere. The mixing proportions are 99% beads and 1% lubricant by volume (80% beads and 20% lubricant by weight). The lubricant is Dow Corning DC 2000/ 10,000 centistokes viscosity. The viscous lubricant allows each bead to roll over contiguous beads, creating a mixture that has a viscosity similar to mashed potatoes, although much lighter in weight.

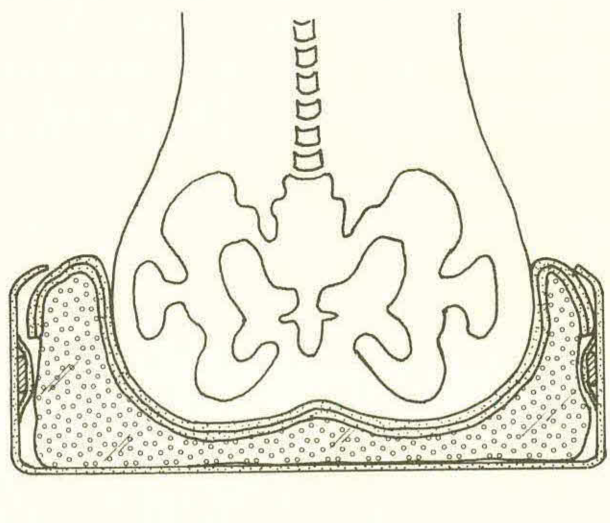
The bag full of beads is placed inside a fabric container with an open top. This container is made from nonelastic denim fabric. The side walls are further stiffened with battens, 1/8" thick polypropylene strips that fit into fabric pockets sewn into the interior walls. These battens work like battens in a sail. While they stiffen the side walls to help make the container rigid, they do not exhibit the disadvantages of solid side walls.

A double thickness denim cover is placed over the polyethylene bag and tucked loosely inside between the bag and outer container. The cover is larger than the open area on top of the cushion--and is thus redundant. The reason for this design can be seen in Figure 1b.

When the user sits on the cushion the buttocks sink into the fluidized beads. Since the redundant cover is only loosely attached it readily follows the user's contours and pulls up from the sides. The user sinks into the bead misture and pushes the beads against the stiff sidewalls. Since the beads are contained by the outer fabric, they prevent the user from "bottoming out," assuming the correct volume of beads is contained in the bag. This design allows the user to be supported by the viscous fluidized bead mixture, and not by a taut hammock-like cover used in most other designs. In this design tension in the cover is not required to contain the interior fluid. Note that the body is not floating on the fluidized beads. The bead mixture is acting more like a pile of material, similar to a haystack.



a.



b.

Figure 1. Cross-section of the fluidized-bead cushion.

a. Basic elements of cushion construction.
b. Cushion shown supporting user. Note that as user sinks into cushion bead mixture is pushed out against walls of fabric container, and redundant cover follows freely.

Figure 2. Photograph of a handful of the fluidized-bead mixture.

The design of the double thickness cover allows insertion of other materials between the two layers of denim if needed. Through experience, many users have identified interface materials that work well for them. For example, if the user is incontinent, a particular waterproofed or absorbent material may be desirable. Also, some users prefer to sit on sheepskin. These materials can easily be contained between the two denim layers if it is convenient.

The characteristics of this cushion can be understood by comparing it against the list of empirical specifications. The surface area of the skin in contact with the cushion is increased because the user sinks into the fluidized-bead mixture, causing the beads to flow up around the hips and thighs.

Given the fluid-like properties of the mixture which is supporting the user, a more uniform distribution of pressure can be achieved. Higher pressure points develop only temporarily since the supporting mixture is forced away from these areas causing a lowering of the pressure.

Since the fluidized-bead cushion has a redundant cover that does not provide any support for the body, shear forces are negligible.

The empirical specifications indicate that the cushion should breathe to reduce temperature and humidity along the skin contact area. The cushion does not completely satisfy this specification. An impermeable bag was required to retain the lubricant and to prevent the bead mixture from becoming soiled from incontinence. The beads also are a good insulator. Two layers of cotton denim have been used to construct the cover. The two covers allow insertion of other materials. In fact, the loose construction of the cover allows complete replacement with other materials if desired by the user. More research is necessary to investigate this subject further.

The cushion provides a stable sitting surface. This is an especially important characteristic for users who lack upper trunk support.

Since the cushion cover is constructed of denim it is easily washable and cleaned in a washing machine. The rest of the fabric container can similarly be washed but it is usually necessary to remove the plastic battens first. Washing helps prevent degradation from urine and feces.

Performance characteristics of the cushion are maintained under extremes of heat and cold. The cushion can be used in sub-freezing temperatures since the cushion materials do not freeze nor act as a heat sink.

The cotton denim fabric used to construct the cushion will burn slowly. Chemical treatments are available to prevent this cotton from burning as a result of a match or a cigarette at an increased cost. Opinions are split as to whether this is necessary. More investigation into this area is needed.

The cushion weighs between 1.5-2.5 lbs, depending upon the volume of beads required for the individual. The light weight of this cushion allows for an easy transfer, easier mobility in a manual wheelchair and extends the range of a motorized chair.

The total thickness of the cushion is 5" before the user displaces the bead mixture. The volume of beads is adjusted for each user to permit a maximum penetration of 4" down into the cushion. This raises the user's buttocks 1" above the wheelchair seat which does not affect propulsion by the handrims. The knees are raised 2" above the seat. Some adjustment of the footrests may be necessary.

The cost of the cushion materials and fabrication is low. The volume of beads has to be adjusted for user size and weight to produce the desired maximum depth penetration of 4". More research is needed in this area to develop a relationship to correlate body measurements to the volume of beads required. This relationship would allow construction from a prescription, further reducing cost.

Preliminary evaluation of the fluidized-bead cushion

The cushion has been evaluated by 6 disabled users, 3 of whom have used the cushion for more than 1 year. In addition, pressure measurement studies have been conducted on 13 non-disabled subjects to compare the changes in pressure distribution with increasing depth of penetration of the buttocks into the cushion. To provide a standard for comparison, pressure measurements were also taken while the subjects sat on a 3" polyurethane foam cushion.

User Trial. A preliminary trial was run to test user reaction to the cushion. Although 6 disabled people began using the cushion, 3 discontinued using it for reasons unrelated to the cushion itself. The other 3 users have been sitting on the cushion for more than 1 year. A total experience of 50 user-months has been logged. All users either had decubiti in the past or were considered high risk.

One user has complained of excessive temperature and humidity along the skin contact area. This problem has not yet been resolved. Other users have not experienced this problem.

Although a 2 mil thick polyurethane bag was used by Bajema (1), this was not found to be durable enough to last beyond a few weeks of full-time use. A 5 mil thick polyethylene bag has proven satisfactory.

One user felt that the cushion was sloppy in appearance due to the loose fitting cover. Some alternative ways of attaching the cover have been tried without success at this point. Although some thought is still being given to this problem, the redundant cover is inherent in this design.

Overall, users are generally satisfied with the cushion. None developed decubiti. However, a well-controlled clinical study would be needed to evaluate the effectiveness of this cushion in reducing the risk of decubiti for a larger population.

Pressure Studies. The cushion was positioned inside of a simple 17" x 17" plywood frame of 3 sides that was constructed to simulate a cushion being supported against the sides and back of a wheelchair. As in a wheelchair the front was left open for the legs. All tests on the cushions were conducted using this frame.

Pressure measurements were taken under the right ischial tuberosity since this is believed to be the area of maximum pressure(4). A flexible pressure transducer with 9 measurement cells, each 1" in diameter and arranged in a 3 x 3 matrix, was used to obtain the data. (This transducer was developed by the authors and is also being presented in another paper at this conference (5).) Before beginning the measurements, the right ischial tuberosity was located and the middle cell was positioned over this area. The transducer was fixed to the subject's pants to assure the same geometric relationship between the anatomy and the transducer throughout the study. The subject then sat on a cushion in the standard position--back inclined at 10° and resting against a wall, arms crossed and resting on the thighs, knees bent with calves hanging straight down with feet unsupported.

The subjects first sat on the standard 3" polyurethane foam cushion, then on two fluidized-bead cushions. One had a large volume of beads which prevented the subject from penetrating more than 2" into the cushion, and the other had the volume of beads adjusted to allow a penetration of 4".

Pressure measurements were taken of 13 normal subjects while sitting on these 3 cushions by using a 9 cell (3 x 3) matrix transducer (5). The average pressure for each of the 9 positions is graphed in Figures 3a and 3b for the polyurethane foam and the 4" optimized fluidized-bead cushion, respectively. The results of sitting on the 2" fluidized-bead cushion are not shown but were similar to those on the polyurethane cushion. The

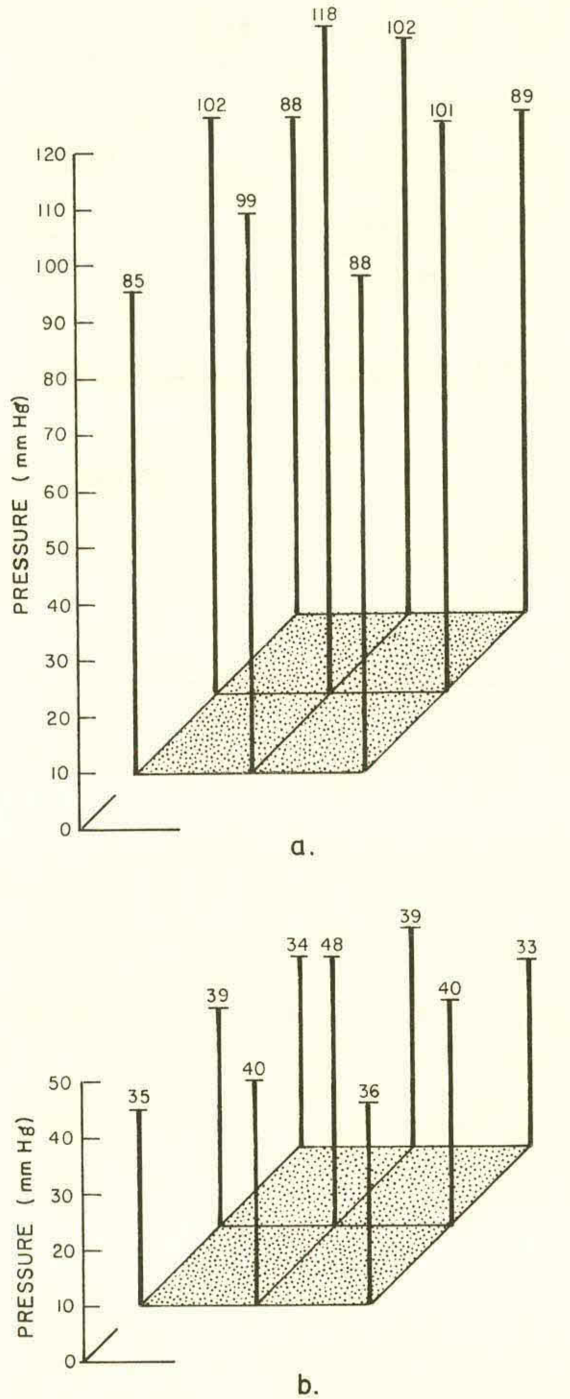


Figure 3. Average pressure readings under 13 normal subjects. (The central reading was taken under the right ischial tuberosity, and the other 8 readings were taken from area immediately surrounding this central location.)

a. Average pressures while sitting on 3" polyurethene foam cushion.
b. Average pressures while sitting on fluidized-bead cushion to a penetration depth of 4".

maximum average pressure, found to be under the ischial tuberosity, was 118 mm Hg for the foam and 48 mm Hg for the 4" beads. The pressures on the bead cushion are also distributed more equally. The pressures surrounding the maximum vary from 33-40mm Hg on the bead cushion, and 85-102 mm Hg on the foam. The higher pressures and greater differences in pressures indicate that more of the load is borne by the ischial tuberosity when on the foam and on the 2" bead cushion. These findings demonstrate the role of increased surface area in reducing peak pressures.

The lower pressures encountered when the subjects sink deeply into the fluidized-bead mixture are still higher than capillary pressure, measured to be in the range of 16-33 mm Hg (6). So it is unlikely that the fluidized-bead cushion will prevent decubiti from forming. But it may lower the risk for people who are prone to decubiti, and it may extend the sitting time of others who must curtail their activities to relieve pressure.

References

1. Bajema, S.L., "Ischial Tuberosity Pressure and Seat Cushion Design." Proceedings, 1974 Conference on Engineering Devices in Rehabilitation, May 2-3, 1974.

2. Kosiak, M., Kubicek, W.G., Olson, M., Danz, J.N. and Kottke, F.J., "Evaluation of Pressure as a Factor in the Production of Ischial Ulcers." Archives of Physical Medicine and Rehabilitation, October,1958.

3. Brand, P.W., "Pressure Sores--The Problem." Bedsore Biomechanics, Edited by R.M. Kenedi, J.M. Cowden, and J.T. Scales, University Press, 1976.

4. Reichel, S.M., "Shearing Force as a Factor in Decubitus Ulcers in Paraplegics." JAMA February 15, 1958.

5. O'Leary, J.P., Lyddy, J.E., "A Nondistorting, Transducer for Measuring Pressure Under Load-Bearing Tissue." Proceedings of the 5th Annual Conference on Systems and Devices for the Disabled, June 7-9, 1978.

6. McLennan, C.E., McLennan, M.T., and Landis, E.M., "The Effect of External Pressure on the Vascular Volume of the Forearm and Its Relation to Capillary Blood Pressure and Venous Pressure," J. Clin Invest., May 1942.

FLOTATION THERAPY UTILIZING CAMPER'S AIR MATTRESS IN THE PREVENTION AND TREATMENT OF DECUBITUS ULCERS

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Irene G. Liggett, R.N., B.S., PHN
Corine G. Wilson, R.N., B.A.

This paper is based on a two year study and five years of experience with approximately 250 patients. A system was refined utilizing an inexpensive camper's air mattress filled with water to aid in the prevention and/or healing of decubitus ulcers by relieving pressure over the patients bony prominences. The medical and nursing staff have enthusiastically endorsed this device as a valuable effective adjunct to the established protocol of care of the immobile and/or severely disabled patient most prone to develop decubiti. It saves nursing time, and is a readily available, manageable piece of equipment. The system can be used not only in hospitals, but also in homes and is so inexpensive that every individual who needs preventive care or treatment for decubiti, need not be denied one.

CATEGORY:	INTENDED USER GROUP:
Device Development ☐ Research Study ☒	Immobile and severely disabled patients prone to decubitui.
STATE OF DEVELOPMENT:	AVAILABILITY OF DEVICE: Anytime at Sears Department Store
Prototype ☐ Clinical Testing ☒ Production ☐	AVAILABILITY OF CONSTRUCTIONAL DETAILS: Written hospital procedure available
AVAILABLE FOR SALE:	FOR FURTHER INFORMATION CONTACT:
Yes ☒ No ☐ Price: Approx $30.00	Rose Amberg, Assoicate Director, Nursing Education Glenn Dale Hospital Glenn Dale, Maryland 20769

INTRODUCTION

Physicians and nurses have long been plagued by the development of decubitus ulcers in their treatment of the severely disabled patient. The literature for well over a century has been replete with the descriptions of their cause, symptoms and many varied types of treatment. Not so well documented has been the prohibitive cost of healing a decubitus ulcer and with high rising medical costs this becomes extremely important. One area hospital estimates cost at $1,000. per inch diameter to heal.[1] Coyle estimates $5,000 to $7,000.[2] Others estimate the cost of medical and nursing care of a single pressure sore at $2,000 to $10,000 in addition to extended suffering of patient and his family.[3] A 1966 study estimated that each decubitus adds an average of $5,000 to the cost of medical care.[4] (Imagine what today's inflation would do to that figure!)

The severity of damage and the danger to the limb due to decubiti is an aspect of medical and nursing care that requires knowledge, time and money. Decubiti can be as detrimental to the patient's physical and mental health as the most acute disease, and can be most frustrating to take care of for those responsible for the patient's care.

DISCUSSION

As members of the Nursing Education Section of a Long Term Care Facility, we have long been concerned about the devastating effects of decubiti on many of our newly admitted patients. We have also seen too many times, the heartbreak of a patient ready for discharge or vocational rehabilitation have activities delayed for 4-6 months due to the development of decubiti.

Over the years our hospital has used devices familiar to most medical agencies such as turning frames, flotation pads, alternating pressure mattresses, water beds, etc. in order to reduce pressure on bony prominence, prolonged pressure being the major cause of decubiti. All such devices are expensive, require increased time for nursing care and in many cases have not been effective in solving the problem.

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Corine G. Wilson - Inservice Instructor - Glenn Dale Hospital.

We had been researching for some method that would provide effective prevention and/or shorten treatment time of existing decubiti. This method should also provide maximum patient comfort without making demands on an already overtaxed nursing staff.

Two faculty members learned about the use of a simple camper's air mattress filled with water to relieve weight on the patient's bony prominences at the Roxbury Massachussetts Veterans Administration Spinal Cord Injury Hospital in 1970, and also at an exhibit at the American Congress of Rehabilitation Medicine, Denver, Colorado in 1972.

We did a pilot study at our hospital for two years (1972-1974) with fifty patients in the age range 22-83 years. The diagnosis were varied CVA, paraplegics, quadraplegics, severely debilitated aged, etc. The medical and nursing staff as well as patients were most surprised and pleased with the impressive results.

1. All patients had healed or were in the process of healing.
2. Patients placed on mattresses for prevention did not develop any signs of break down.
3. No complications i.e. contracturers, nausea, etc. were noted.

The evaluation comments of the staff were unbelieveably enthusiastic.

As a result of this study, we have now utilized over 200 mattresses with approximately 250 patients. It is now accepted as part of the protocol for routine decubitus prevention and treatment along with other medical and nursing measures.

Patients and families are now requesting us to instruct them for use at home. We have also instructed a Visiting nurse as to its use with a bed ridden patient at home.

We have found that the longevity of the mattresses are usable between 1 1/2 - 2 years. At the initial expense of $27.00 *the cost comes to a few cents each day - cheap enough so that it is available for every patient in need of one. As with any other good tool, it must be used properly to insure expected effectiveness. On the basis of five years experience we are advocating the following procedure:

*We recommend the Sears Roebuck Model #6-70901.

WATER FILLED AIR MATTRESS PROCEDURE

GLENN DALE HOSPITAL
GLENN DALE, MARYLAND
NURSING DIVISION
PATIENT CARE MANUAL

1. Obtains from Central Supply room.
   a. Air Mattress
   b. Special tubing with faucet attachment, including clamps.
   c. Large plastic bag.
   d. Towel.
   e. Pliers and screwdriver.
2. a. Selects nonelectric bed *on which patient is to be placed.
   b. Pushes bed to mixing faucet.
   c. Folds sheet in half, placing it on top of mattress.
   d. Places unfolded air mattress on top of sheet (head portion of mattress not filled).
   e. Places plastic bag and toweling under valves to catch dripping.
   f. Opens valves using pliers on lower portion of air mattress.
   g. Attaches tubing to valve.
   h. Attaches faucet attachments to mixing faucet.
   i. Tightens clamp on tubing leading to mattress valve -- tightens clamp on mixing faucet. Turn faucet on low tepid H_2O.
   j. Fills air mattress approximately 2½-3 inches in depth with H_2O (180-250 pounds of water).
   k. Checks mattress for bouyancy using palms of hands, exerting body weight. Proper bouyancy ascertained when contact cannot be made from top of water filled air mattress to bottom surface.
3. Bed Making
   a. Apply large sheet covering entire water filled air mattress; include water filled air mattress and mattress itself.
   b. Tuck in head portion beneath mattress.
   c. Tuck in sides loosely, but smooth without affecting bouyancy.
   d. If needed, turning sheet may be applied, chucks, diapers, etc. Bath blanket may be used in place of big sheet if patient complains of chillness.
   e. Apply top covers like ordinary hospital bed.
4. Caution sign
   a. Obtain 5"x8" index card.
   b. Label in big letters with felt tip pen, "CAUTION! Patient on water filled air

*we have recently purchased an electric bed on which water filled air mattress can be safely used.

mattress: Use no pins or electrical appliances."

5. Reconsituting Mattress

a. Check once weekly for proper bouyancy-- If contact can be made from top surface of water filled air mattress to bottom, reconstitute mattress by adding more water.
b. Needed Materials:
   1. Tubing with funnel
   2. Pitcher
   3. Plastic bag
   4. Towel
c. Fill pitcher with water using tubing with attached funnel, plastic bag and towel to bedside.
d. Open valve of air mattress with pliers and attach tubing with attached funnel. Place plastic bag and toweling under valve.
e. Fill mattress. Usually 2-6 quarts needed to obtain proper bouyancy.
f. Close mattress valve with pliers.
g. Remake bed.

6. Cleaning

a. Clean sheet may be applied underneath mattress by folding water filled air mattress in half top to bottom (2 people needed).
Apply sheet folded in half lengthwise. Remove and tuck soiled sheet under mattress. Apply new sheet to top of mattress. Flip water filled air mattress on itself bottom to top. Remove soiled sheet. Pull and smooth clean sheet. Flip mattress to original position.
b. Clean mattress for reuse by sudsing with Betadine solution and water or soap and water. Rinse and dry with towel. (Do not use Vesphene one-stroke. Vesphene will destroy surface of mattress).

7. Transporting Mattress

a. Use surgi-lift. Flip mattress in same manner as applying clean bottom sheet underneath water filled air mattress and apply bathing sheet under mattress. Also use large sheet on top of bathing sheet to protect mattress from sharp metal edges of surgi-lift. Transport mattress with surgilift to new bed.

8. Patching.

a. Circle area to be patched with ball point pen. Cleanse area with alcohol. Apply glue from Boxers Pool Repair Kit and Vinyl Patch. Reinforce patch with masking tape. Write on tape, "Do Not Remove".
b. Tire repair kit may be used. Mattress must be emptied and dried. Tire repair glue does not adhere when mattress is wet. Cleanse circled area with alcohol sponges. Apply glue and patch. Place heavy object over tire patch. Dry overnight. Refill mattress with water.

9. Prophylaxis

a. Add 1500 cc's Betadine Solution when filling mattress.

FILLING THE MATTRESS

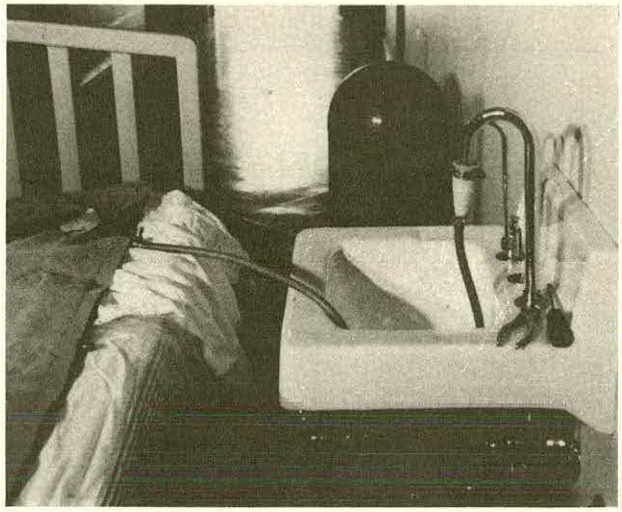

Fig. 1 TUBING ATTACHED TO MIXING FAUCET

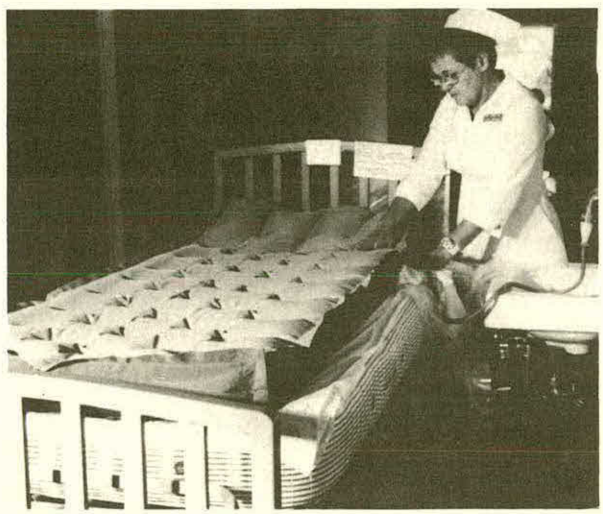

Fig. 2 FILLING THE MATTRESS

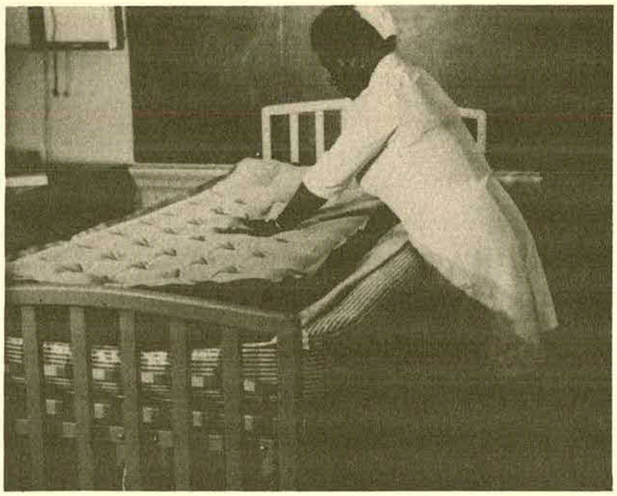

Fig. 3 CHECKING FOR BUOYANCY

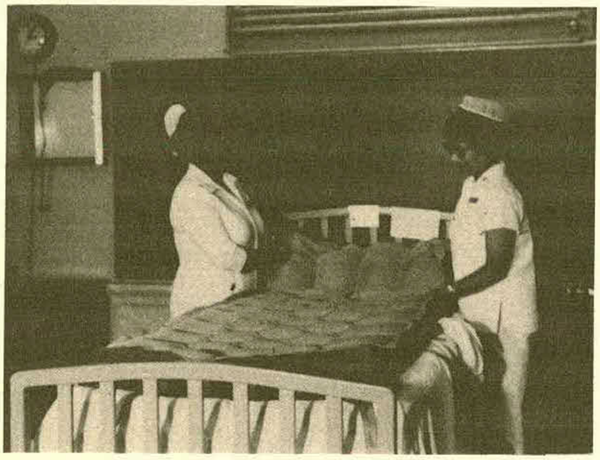

Fig. 4 FLIP THE MATTRESS TO CHANGE SHEET UNDER THE WATER-FILLED AIR MATTRESS (2 People)

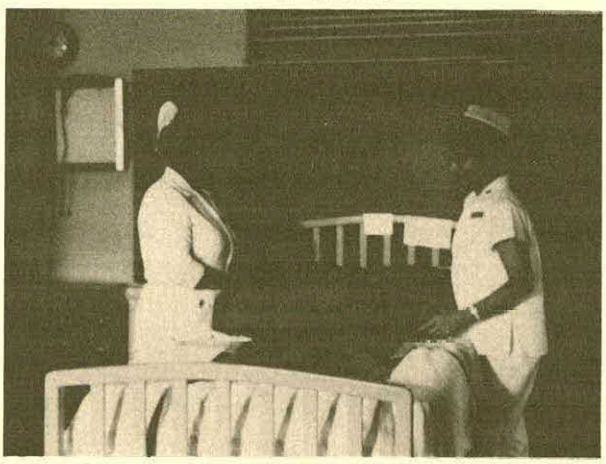

Fig. 5 FLIP MATTRESS OVER. FREE TOP HALF OF THE BED TO CHANGE SHEET

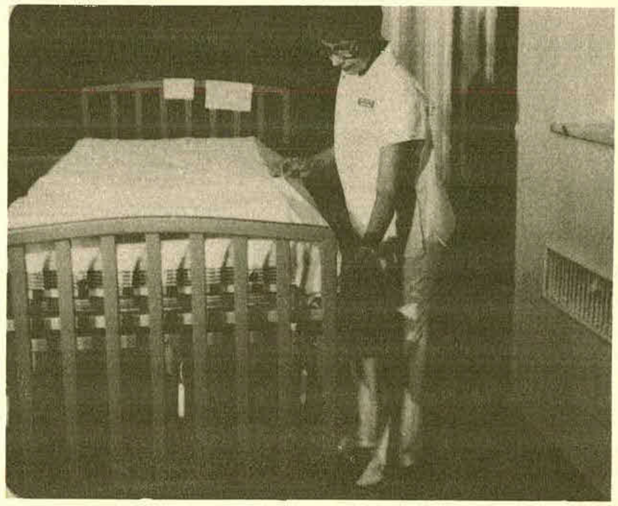

Fig. 6 MAKE BED. TUCK TOP SHEET LOOSELY. IF TOO TAUT YOU LOOSE BUOYANCY EFFECT.

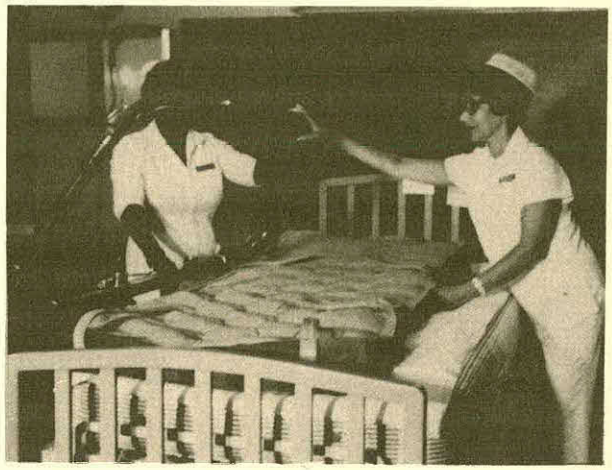

Fig. 7 TRANSFER THE WATER-FILLED AIR MATTRESS TO ANOTHER AREA USING THE SURGILIFT

Fig. 8 DO NOT ATTEMPT TO MANUALLY LIFT MATTRESS IT WEIGHS FROM 180 TO 250 LBS.

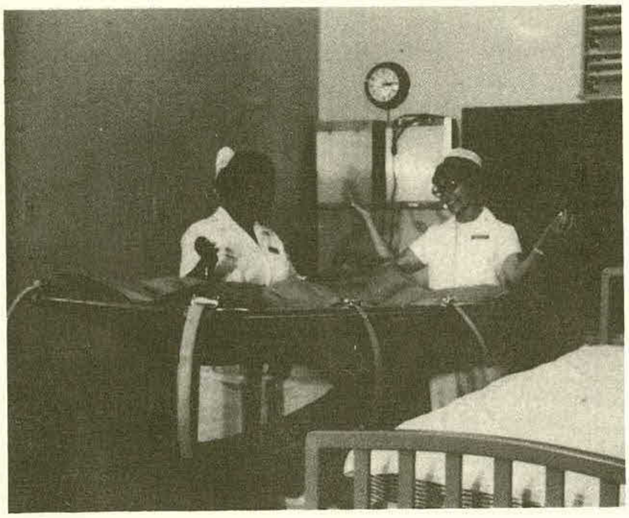

Fig. 9 LOOK MA-- NO HANDS!!

SUMMARY

For the past 5 years a water-filled camper's mattress has been used with 250 patients for the prevention and/or treatment of Decubitus Ulcers. While it is not a replacement for good nursing care, it relieves pressure against bony prominences to promote faster healing. In many cases it is used to prevent them from occurring and/or reoccurring.

It saves nursing time, and is a readily available, inexpensive piece of equipment enthusiastically endorsed by our medical and nursing staff and patients who have used them.

REFERENCES

1. Montebello Hospital, Baltimore, Maryland; "Procedure on Care and Rx of Decubitus Ulcers," unpublished procedure.

2. Coyle, Thomas M.D., Decubital Prevention, Easter Seal Rehabilitation Center, 226 Mill Hill Avenue, Bridgeport, Conn. 06610

3. Spence, W. R. & Others, "Gell Support for Prevention of Decubitus Ulcers," Arch. Phys. Med. Rehabilitation 48: 283-88, June 1967.

4. Siegel, Richard J., et.al. "Use of the Water Bed for Prevention of Pressure Sore", Plastic & Reconstructive Surgery, January 1973, pp. 31-37.

ACKNOWLEDGEMENTS:

The authors gratefully acknowledge the wonderful cooperation and enthusiasm of the Nursing and Medical staff and patients throughout the study and throughout the years we have been using the water filled camper's air mattress.

FOAM-IN-PLACE SEATING FOR THE SEVERELY DISABLED
Preliminary Results

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The Foam-In-Place approach to customized seating is an attempt to bypass most of the labor intensive conventional techniques, by permitting the direct foaming of contoured seating supports against the individual himself. Two component polyurethane soft foam is injected into a mold which has one stretchy side against which the individual is positioned. The self-pressurizing foam envelopes the support areas of the body and quickly gels ready for de-molding. Interfacing the foam components with a wheelchair completes the fabrication process which can be completed in less than two hours. 4 hrs. to do complete w/c mod.

CATEGORY:	INTENDED USER GROUP:
Device Development ☒ Research Study ☐	AVAILABILITY OF DEVICE: Limited
STATE OF DEVELOPMENT: Prototype ☐ Clinical Testing ☒ Production ☐	AVAILABILITY OF CONSTRUCTIONAL DETAILS: Limited
AVAILABLE FOR SALE: Yes ☐ No ☒ Price:	FOR FURTHER INFORMATION CONTACT: D. A. Hobson, P. Eng. Technical Director Address above

Background

The importance of proper seating for those confined to the seated position throughout their daily activities has been stressed in recent years. Much more remains to be done in terms of designing proper seating systems and making them available to those within the handicapped population that so urgently need them.

The high cost of pressure sores, combined with interruption of the living process associated with patients with sensation loss, (primarily paraplegics and quadriplegics) has inspired better solutions to the distribution of seating forces under areas of insensitive tissue and bony prominces. Both standardized and semi-custom wheelchair cushions have improved in recent years (1). These developments have parallelled basic studies that have provided an understanding of the basic causes of tissue breakdown that results from pressure sustained above tolerable levels for excessive time periods (2,3,4). The basic concept used is to distribute forces over larger weight-bearing areas of the pelvis and thighs. This approach results in a reduction of the pressure levels applied to the susceptible tissue areas, so that sitting may be safely maintained over longer time periods. A second approach, which has received much less emphasis, is to allow high pressures to exist but to permit them to be sustained only for short periods of time. This latter approach is a departure from the total contact concept, and thereby potentially permits air circulation and related temperature/humidity control at the tissue/seat interface (5).

In addition to the above mentioned paraplegic and quadriplegic populations there is another larger group of severely disabled individuals requiring specialized seating. This group is comprised of severely handicapped children and young adults with disorders resulting from cerebral palsy, muscular dystrophy, and multiple sclerosis, and other less common neuromuscular anomalies. These disorders often result in severe obliquities of the pelvis, contractures of hip and knee joints, and scoliosis of the spine. These individuals usually have full sensation, and therefore comfort and maintenance of good body alignment in the seated position is the primary goal; rather than protection of insensitive tissue as in the former group. To provide the required comfort and body alignment, forces of considerable magnitude often must be applied to specific areas on the pelvis and trunk. To maximize comfort, these forces must be maintained at the lowest possible levels. Considering these factors and the additional complications resulting in lack of neuromuscular control, total contact support appears to offer the greatest potential. Seating for the severely handicapped cerebral palsied and muscular dystrophy population has traditionally involved the custom-making of inserts which fit into a standard wheelchair (6,7,8,9,10). The amount of customization achieved is related to the capabilities of the seating technician, orthotist, or therapist responsible for specialized seating. Because of the specialized nature of customized seating, the cost is usually high. As a result, the services are generally available only through a few larger rehabilitation facilities which have sufficient volume and funding to justify the required specialized staff and facilities.

Presently, there are three established approaches that attempt to obtain customized total contact seating for the severely handicapped. The first approach, and the most widely used, is the "cut and try" approach. Body supports are handcarved from blocks of foam on a trial-and-error basis. Once an adequate contour has been obtained, the foam supports are then fastened into a receptacle (usually plywood) which interfaces the foam pieces with the wheelchair. Once it has been assured that an adequate shape has been obtained, several methods (vinyl, stretch fabrics) are used to cover the foam shapes to provide durability and aesthetics. Obviously, this approach is time consuming and requires a reasonably high degree of technical skill to obtain good total contact supporting surfaces.

The two remaining approaches used to get custom-fitted seating components are slightly more involved. The one approach ("wrap-and-try" approach) follows the principles used in prosthetics and orthotics, which begins with taking a positive plaster mold. Over the prepared plaster mold a plastic laminate or plastic vacuum-formed seat or back component can be fabricated. The foam lining material used, or the plastic itself, will usually allow for minor adjustments to accommodate for any areas of discomfort. The final approach has attempted to simplify the above technique by eliminating the plaster wrap (11). This technique (which is termed the "dilatency casting approach) uses a large air-tight bag filled with polystyrene beads into which the patient is positioned. Evacuation of the air from the bag will cause it to become rigid so that the solidified molded bag can then be used as the receptacle to make the plaster mold. Final fabrication of the seat or back follows the steps outlined in the previous approach.

Both of these latter approaches are also time consuming, but usually result in improved total contact seating supports. Unfortunately, they also result in large complex mold shapes over which there is usually difficulty forming a final plastic seating component. Also, a high degree of technical skill is required to obtain a proper positive plaster mold of the body shape. Additional technical skills are also required in order to fabricate the final plastic product using either thermal forming or thermal setting plastic materials.

The Foam-In-Place Technique

Basically, the Foam-In-Place (F.I.P.) approach is an attempt to bypass most of the handwork associated with the above approaches, thereby simplifying customized seating so that the needs of much larger numbers can be met in an economical manner. The F.I.P. approach permits the direct foaming of contoured seating support components using the individual himself as the mold. In this manner the mold-making and final fabrication steps associated with the previous approaches are bypassed. The first known attempt at the F.I.P. seating was carried out in the Rehabilitation Engineering Department at the Shriner's Hospital in Winnipeg, in which spinal support components for muscular dystrophy children were fabricated. Subsequently, the concept has further developed at the Rehabilitation Engineering Center in Memphis to include both seat and back components for a wider range of disability types. It is this latter development that will be discussed in this presentation.

The F.I.P. technique uses a foaming frame into which a series of standardized seat and back molds can be inserted (Fig. 1). The box shaped

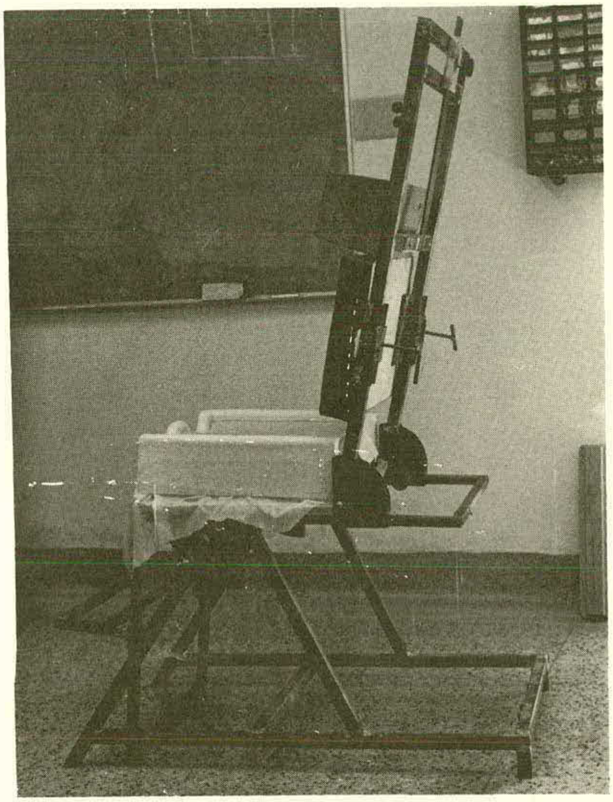

Fig. 1

molds are fabricated from polyethylene plastic and are closed on all sides except one. A sheet of thin latex sheeting (5 ml) is lightly stretched over the open side of the mold. This stretchy surface will then be in direct contact with the patient during the foaming process. Once in position in the foaming chair and seated upon the latex skin, a two-part polyurethane foam is injected into the back of the mold (Fig. 2).

Fig. 2

Fig. 3

The injection hole is then closed off and the reaction between the two foam components causes the foam to rise up and force the latex skin around the shape of the patient. Within ten minutes the foam gels into a soft foam cushion and the patient can then be removed from the foaming frame. In the same manner both foam seat and back components can be fabricated to contour perfectly to the shape of the individual. That is, the individual provides the mold shape for contouring the supporting foam surfaces, and the polyethylene mold provides the shape of all other surfaces of the foam. This latter point is important, since the standardized outer shapes of the foamed components permit rapid interfacing into wheelchairs or other wheeled bases. That is, in addition to a series of standardized molds which cover the total range of body sizes, there is a matching series of receptacles that receive the final foam components, so that they may be placed securely in a variety of wheeled bases (Fig. 3).

Since almost all of the customary handwork associated with producing the customized foam components has been eliminated, the final product can be obtained quickly, and with a minimum of technical skills. Initial experience has indicated that customized foam components can be produced and interfaced into a wheelchair in less than two hours.

Discussion of Results

Initial successes have been achieved with approximately twenty-four cases over the past year involving primarily children with severe pelvic and spinal deformities associated with their cerebral palsy. The material used has been UpJohn - CPR Division, 1947 polyurethane foam. This material is a self-skinning closed-cell foam which appears to be a durable material for seating and spinal supports.

In addition to the reduced time required for seat fabrication, several other advantages have been noted. Intimate contouring to the pelvis permits better maintenance of the midline position and improved force distribution over the sitting surfaces. This improved force distribution has drastically enhanced seating comfort in several cases, especially when a moderate to severe pelvic obliquity was present. Good pelvic positioning also provides the support base and stability necessary to then move upward to control the spine. In several cases the spine has been repositioned to a more midline position by use of the F.I.P. back section. Spinal support is being carefully monitored through the use of before and after x-rays, combined with a regular follow-up program. In general, both improved comfort and maintenance of body alignment has been achieved through the use of the Foam-In-Place components.

One major limitation to date is the inability to obtain asymmetrical shapes; such as a larger anterior projection on only one side of a back support, or a seat with a larger anterior pommel. However, it is unlikely that these limitations will nullify the usefulness of the F.I.P. approach for many applications.

In addition to trials with cerebral palsy patients, several cautious attempts have been made with paraplegics. We stress the need for caution in this application due to the presence of insensitive tissue and the propensity for development of pressure sores with this group. Pressure readings, using the Simedics pressure gauge, have indicated that the force distribution under the ischial tuberosities results in a pressure less than 50 mm hg. Although these readings appear to be within tolerable levels for an active paraplegic patient, we do not know if the material will "pack out", or if any adverse affects will be caused by additional heat and humidity build-up, or by increased pressures that may be caused by the individual not being seated in exactly the same position in which he was initially foamed. It is these questions and others that must be answered before wider use can be recommended for the paraplegic and quadriplegic populations.

Future Possibilities

It is anticipated that this is only a beginning to an increasing scope of possibilities for customized foam seating for the disabled population. For example, it has become generally acknowledged that the sling-type seat in the standard wheelchair does not provide adequate seating support and comfort for many severely handicapped individuals. Future generation wheelchairs may very well incorporate seating arrangements that readily provide an option for customized components. Also, many individuals cannot use regular seats or chairs in their offices, homes, or vehicles. Providing an optional customized seat that may be used in various locations, may be desirable for some individuals.

Our immediate plans call for refinement of the Foam-In-Place procedure in areas of improved mold design and foam injection techniques. Wider evaluation trials with individuals with paraplegia and quadriplegia will be carried out. In particular, pressure distribution and heat and humidity build-up will be given close observation in future trials. Finally, several other centers will be contacted and encouraged to participate in the clinical evaluation of the Foam-In-Place system, by carrying out local trials within their patient populations.

References

1. Workshop on Effects of Pressure on Human Tissues. U. S. Public Health Service Hospital, Carville, Louisiana. March 24 - 26, 1977.
2. Kosiak, Michael et al: Evaluation of Pressures as a Factor in the Production of Ischial Ulcers. Arch.Phys.Med. Oct., 1958. Pgs. 623-629.
3. Kosiak, Michael: Etiology of Decubitus Ulcers. Arch.Phys.Med. Jan. 1961. Pgs. 19-29.
4. Kosiak, Michael: Etiology and Pathology of Ischemic Ulcers. Arch.Phys.Med. Feb., 1959. Pgs. 62-69.
5. Kosiak, Michael: A Mechanical Resting Surface: Its Effects on Pressure Distribution. Arch. Phys. Med. 57:481-484, Oct., 1976.
6. The University of Tennessee, Crippled Children's Hospital School, Activities Report #1, September 1974 - June 1976.
7. First Annual Report, The Rehabilitation Engineering Center, Children's Hospital at Stanford, 1975.
8. Interclinic Information Bulletin, Volume XVI, Nos. 7 & 8, July, 1977.
9. Ontario Crippled Children's Centre, Annual Report, 1972 - 1973.
10. Shriners Hospital for Crippled Children, Winnipeg Unit, Activities Report #1. June, 1969 - December, 1971.

A MICROCOMPUTER-BASED CONTROL AND COMMUNICATION SYSTEM FOR THE SEVERELY DISABLED

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A microcomputer-based environmental control and communication system for the severely disabled has been developed. By puffing and sipping on a tube the user can store messages in computer memory and control a number of peripheral devices. A scanning method of operation is employed in which characters are selected for message building or control purposes from lists displayed on a CRT. An interface system is presently being developed to allow the computer to control peripheral devices by transmitting coded signals over the power mains.

CATEGORY:	INTENDED USER GROUP:
Device Development [X] Research Study [ ]	Severely disabled persons
STATE OF DEVELOPMENT:	AVAILABILITY OF DEVICE: Not available
Prototype [ ] Clinical Testing [X] Production [ ]	AVAILABILITY OF CONSTRUCTIONAL DETAILS: Available upon completion of project
AVAILABLE FOR SALE:	FOR FURTHER INFORMATION CONTACT:
Yes [ ] No [X] Price:	Northwestern University Rehabilitation Engineering Program 345 East Superior Street Chicago, Illinois 60611

Introduction

This paper describes a microcomputer-based environmental control and communication system for severely disabled people. By puffing and sipping on a tube the user can compose and store messages in computer memory for future reference or output and control a number of peripheral devices, including a line printer and telephone.

For some time we have felt that the application of digital computer technology was the key to the development of a comprehensive and flexible assistive system that went beyond providing the basic needs of environmental control. Computer software programmability allows the use of a general hardware package which may be efficiently configured to best serve the needs of individuals suffering from a wide range of disabilities. With the advent of inexpensive microcomputers, the cost effective production of such systems is now possible.

Our involvement with computer-based assistive systems began around 1974 with the construction of a minicomputer-based vocational system for evaluation by a disabled woman on our staff. This prototype system has been modified and expanded greatly since its initial conception and the experience gained from its evaluation has been very important in the development of the microcomputer-based system described here.

System hardware

A block diagram and photograph of the system are shown in Figs. 1 and 2 respectively. User input is via a pneumatic switching interface. By puffing or sipping on a tube the user closes one of two normally open switches which respond to small pressure deviations (0.02 PSI) either above or below atmospheric pressure. System status is displayed on a cursor addressable CRT terminal.

A Motorola M6800 microprocessor-based computer with 8K of RAM (random access memory) is used. At the present time the control program is loaded from magnetic tape whenever the system is brought into operation. In the future, the program will be resident in non-volatile EPROM (erasable programmable read only memory). One serial (printer) and two parallel (CRT; puff and sip input/device control output) ports are used for communication between the computer and peripheral equipment.

The computer transmits data directly to the line printer and CRT. An interface system is presently being developed which will allow the .

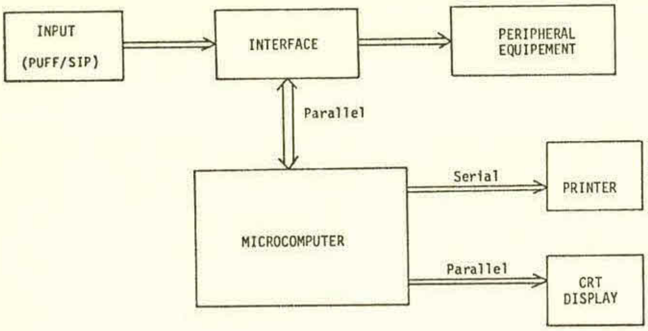

Fig. 1 Block diagram of microcomputer-based control and communication system.

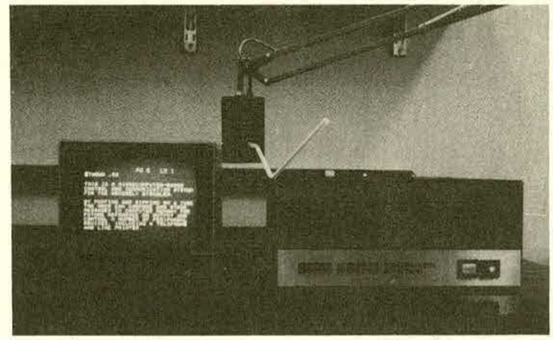

Fig. 2 Microcomputer and CRT display.

computer to control other devices (e.g. lights, television, telephone, etc.) by transmitting signals over the power mains. This system is discussed in greater detail later in this paper.

System operation

This system utilizes a scanning method of operation. Letters, numbers or symbols are selected by the user from a list displayed on the CRT. Selection of a character causes that character to be stored in computer memory as part of a message or modifies the system activity or state in some prescribed manner. Scanning was selected as the method of input selection because of its generality. A flowchart detailing system operation is shown in Fig. 3.

The lists from which the user selects characters have the following 10 character format: * C_1 C_2 C_3 C_4 C_5 C_6 , # @. Only one list is displayed at a time. When a list is initially displayed, the cursor is positioned over the first character (*). Puffing advances the cursor one character at a time along the list, resetting to the beginning when the end of the list is reached. A sip input when the cursor is positioned over a character causes that character or the action associated with it to be selected.

There are two basic modes of operation,message building and command/editing. In the message building mode, letters, numbers, symbols and punctuation marks are displayed for selection in groups of 5 characters and a space in positions C_1 through C_6. In the command/editing mode, characters displayed in positions C_1 through C_6 represent output or editing actions.

The CRT display has a 16 line by 32 character format. The lists from which selections are made appear only in one of the top two lines. The third display line is the "buffer line". Messages are built one line at a time with selected characters being written into a 32 byte segment of computer memory which is displayed as the buffer line. The bottom 13 lines comprise a "page" of data and display the contents of a 416 byte segment of computer memory. The present system is configured for 10 pages of data storage, any of which may be displayed on the CRT. User generated text in the buffer line may be stored in any line on any of the pages. Similarly, any line on any page may be "lifted" back into the buffer line for editing purposes. The number of the page presently being displayed and the line on that page on which certain editing functions will act if selected are displayed in the top line of the CRT.

In the message building mode the lists from which selections are made appear in the second line of the display. The first character in the list is positioned over the buffer line location into which the character selected next will be stored. An exception to the above occurs when characters are being entered into the last nine positions of the buffer line, in which case the list of choices is longer than the remaining number of available positions. When this occurs a number is displayed in the top right hand corner of the CRT indicating the position into which the character selected next will be placed.

When building a message, if the desired letter or symbol is not in the displayed group, a new group of letters may be obtained by sipping with the cursor in the first position. Repeated sipping displays other new groups of letters. The speed with which a specific letter may be selected depends on the number of scanning and input actions required for its selection. This system employs an anticipatory method for letter presentation which decreases the average number of scanning and input actions required for letter selection by taking advantage of the probabilistic nature of letter occurrence in the English language.

Shannon[1] showed that the probability of correctly predicting a letter of text is increased significantly if one or more of the preceding letters is known. The probability of correct prediction increases as the number of known letters increases. This probabilistic relationship is the direct result of redundant letter sequences induced by the complex syntax rules of human languages. Crochetiere et al[2] were the first to propose that message building speeds could be maximized by exploiting this language redundancy.

The method used here presents letters for selection based on their conditional probabilities of occurrence given the knowledge of the preceding letter. The most probable letters are located in positions requiring the least time to select. The conditional probabilities may be calculated from readily available data for digram frequencies, the frequency of occurrence of two letter sequences. With this method, a significant increase in the message building rate has been experienced. A more detailed discussion and analysis of the anticipatory scanning method used in this system is given by Rombola and Childress[3].

The last three symbols in the list format represent branching points to different functional modes. Special message building symbols, including numbers and punctuation marks, can be obtained by selecting the symbol "," in the eighth position. Selection of the symbol "#" puts the user in an editing mode where changes in the buffer line text can be initiated. Buffer line editing functions include backspace, tab across with or without erasure, reset to the beginning of the line, line erasure and an "enter line" feature where the contents of the buffer line are written into a line on the page presently displayed on CRT. The special symbol and buffer line editing lists are displayed on the CRT just above the buffer line, as are the letter groups for message building.

Selection of the symbol "@" puts the user in the command mode. The lists associated with this mode appear in the top left-hand corner of the CRT display. From the command mode a second editing mode may be called. Capabilities include displaying any page of memory on the CRT, clearing any page, storing the contents of the buffer line in any line on any page and lifting the contents of any line into the buffer line. Additionally, a "set tab" feature exists for setting the number of spaces skipped when tabbing in the buffer line editing mode.

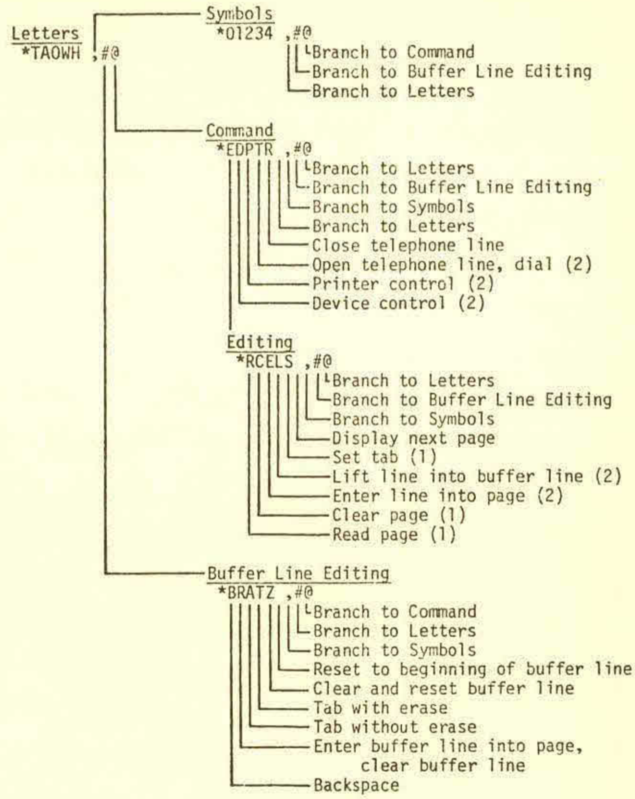

Fig. 3 Flowchart detailing system operation. (1) and (2) indicate number of digits needed in a numerical modifier to completely specify the corresponding command.

From the command mode, device operation is also controlled. Text stored in memory may be output to a line printer. A telephone line may be opened or closed and telephone numbers dialed from computer memory. Timing for the dialing operation is generated by computer software. Latching and momentary AC power to other devices is also controlled from the command mode.

Many of the operations initiated in the command mode require one or two digit modifiers for complete specification. Upon selection of a command requiring a modifier, the list

*01234 ,#@

is displayed. Digits 5 through 9 may be displayed by sipping over "*". For a two digit modifier, the most significant digit is selected first. Following modifier selection, an activate symbol is selected and the operation specified is performed.

Distributed control system

In the development of this computer-based system, we realized the need for a way of connecting the computer with external equipment. Connection could be made by wires, but our previous work with environmental control systems has shown that such an interconnection method has many disadvantages. These include (1) difficulty of installation, (2) unsightly, cluttered appearance, (3) expensive connectors and (4) decreased portability and flexibility. To overcome these disadvantages we are developing a system which will send signals for controlling peripheral equipment over the power mains. Receiver modules located at each peripheral will decode the signals and selectively control peripheral operation. Such control eliminates wires, simplifies installation and makes the movement of a peripheral from one location to another as simple as unplugging it and its receiver from one wall socket and plugging them into another. The concept of such a system is not new, having been used in intercom systems for some years. Manufacturers in the computer hobbyist market are investigating the development of similar devices.

A block diagram of a prototype system that has been built and is presently being tested is shown in Fig. 4. One of sixteen coded frequency modulated signals is transmitted over the power mains in response to a computer command. The individual receiver modules at different sockets demodulate and decode the transmitted signal. The receiver or receivers configured for the transmitted code respond. Latching and momentary control of 120V 60 Hz power is possible with the prototype system as well as control of simple switching operations at lower power levels.

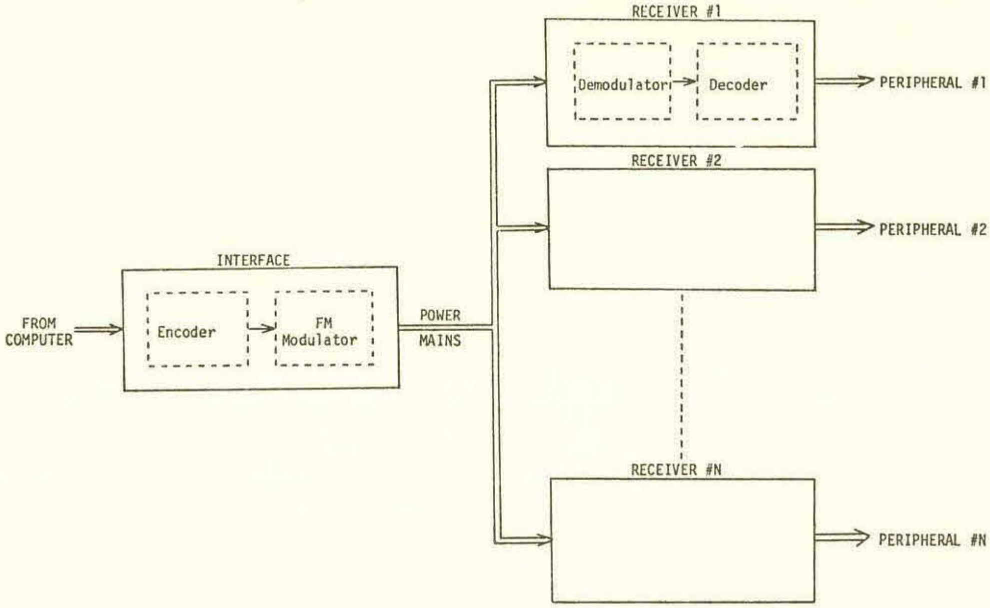

Fig. 4 Distributed control system for peripheral control.

Present plans call for the development of a stand-alone version of this system for persons not requiring or desiring the extra features associated with the computer-based system.

Conclusions

Further developmental work is planned to expand and improve the flexibility of this system. Configurations that will accept other types of input and selection methods, such as automatic scanning with single switch control and direct selection with a joystick control, are being considered. Software which would allow the user to interact with and program a different comptuer via telephone hook-up is also being considered.

Present plans call for the construction of several more of these systems for evaluation by disabled persons. Based on our experiences with a similarly configured minicomputer-based system that has been used by a disabled member of our staff for three years we are optimistic about its acceptance as an effective and reliable aid. We feel that the number of ways in which this system may be configured to serve the vocational and avocational needs of the handicapped is essentially unlimited. This system demonstrates the viability of utilizing digital computer technology in sophisticated systems for the handicapped and we hope its development will benefit many disabled individuals.

References

1. Shannon, C.E., "Prediction and Entropy of Printed English", Bell System Tech. J., Vol. 30, 1951, pp. 50-69.

2. Crochetiere, W.J., Foulds, P.A., and Sterne, R.G., "Computer Aided Motor Communication," Proceedings of 1974 Conference on Engineering Devices in Rehabilitation, Boston.Massachusetts, May, 1974, pp. 1-5.

3. Rombola, G., and Childress, D.S., "Computer-Based Control and Communication System for Severely Disabled Persons", Proceedings of the National Electronics Conference, Vol. XXI, Chicago, October 1977, pp 362-366.

A COMMUNICATION DEVICE FOR THE APHONIC MOTOR-DEFICIENT INDIVIDUAL

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Described is a microprocessor-based device which enables a non-vocal, motor-deficient individual to communicate with others by means of a visually displayed alphanumeric message not exceeding 20 characters in length. The use of two display screens - one facing the user and one the respondent - permits eye contact between both parties during the communication process. A variety of algorithms are available for constructing the message. A thermal printer produces, on demand, a hard copy of the displayed message. The device can be operated off the conventional 110 V power supply or off an in-place battery pack where portability is a desirable feature. The assembled unit weighs 5.5 lbs.; the battery pack an additional 3.0 lbs. Cost of a fully assembled unit (excluding batteries) in production runs of 25 units is estimated at $400.

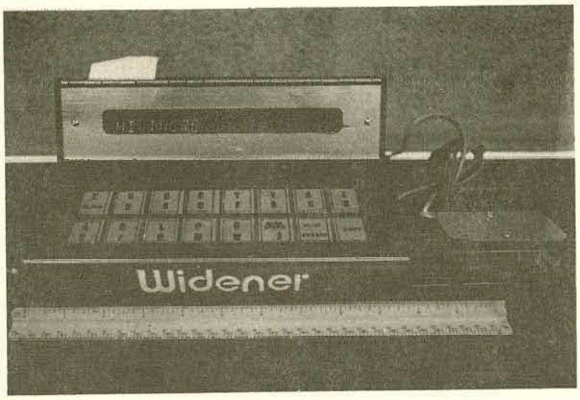
CATEGORY: Device Development ☒ Research Study ☐	INTENDED USER GROUP: Non-vocal motor deficient individuals. AVAILABILITY OF DEVICE: 4 Months
STATE OF DEVELOPMENT: Prototype ☒ Clinical Testing ☒ Production ☐	AVAILABILITY OF CONSTRUCTIONAL DETAILS: Not at present.
AVAILABLE FOR SALE: Yes ☐ No ☒ Price:	FOR FURTHER INFORMATION CONTACT: Sanford W. Groesberg Widener College Chester, PA 19013

Introduction

This paper describes a device designed to provide communication capability for aphonic individuals unable, because of motor deficiency, to either write by hand or operate any of the conventional communication devices (e.g., a typewriter). Although devices of this sort have been developed (1,2), the microprocessor based system described here is capable of functioning in a number of different modes so as to accommodate the specific needs and objectives of a wide spectrum of prospective users.

The Communicator transmits information by displaying an alphanumeric message on a pair of fluorescent screens. The message on the two screens is identical, except that one screen faces the user and the second away from the user. This enables user and respondent to maintain eye contact during the communication process. The display screen accommodates a maximum of 20 characters, each 0.36 in. high. A message entry board is located on a sloped surface facing the user. A useful feature of the Communicator is a thermal printer which will, on instruction, produce a hard copy of the message appearing on the display screen at the time. The message is printed on 2 inch wide paper tape in 5 x 7 dot matrix characters approximately .125 inch high. A second feature incorporated in the Communicator is an RS-232 IN/OUT port which enables the unit to be used as a computer terminal. This added capability offers the user many potential advantages such as access to computer assisted instruction systems, and more importantly, opportunities for employment in a wide variety of computer-related vocations.

A photograph of the assembled unit (showing the two display screens) appears below.



Algorithms for constructing messages

Either of two general algorithms can be employed as the method for constructing the message. In one, the user spells out a message by selecting one character at a time in sequence and appending each in its turn. In the second, which is based on the utilization of intermediary code symbols, the user selects for display a predetermined string of characters (not exceeding 20 in length) chosen from a stored bank of messages. The codes may be in the form of pictographs for the mentally retarded and/or non-spellers; Bliss symbols for individuals in language acquisition programs; or abstract symbols for more sophisticated users capable of interacting with computer systems. The change-over from spelled to coded algorithms is effected by means of a panel mounted toggle switch which activates the appropriate memory block in a replaceable PROM microprocessor chip.

Algorithms for selection of entries

Having decided on the general algorithm for constructing messages, it is next necessary to decide on the modality whereby the user is enabled to select from among the available set of entries (alphanumeric characters, pictographs, et al). Depending on the level of user capability, either of three modes can be employed; here designated as the Prompt mode, the Encoded Scan mode, and the Direct Select mode. In the Prompt mode of operation, a pair of characters (whether used for purposes of spelling or coding is immaterial) is presented on the extreme right end of the display screen for a preset time interval. The leftmost of the two characters is "active" and actuation of a switch by the user during this interval causes the corresponding stored entry to be displayed. The rightmost of the two characters alerts the user to the next character slated to become active during the succeeding time interval. In addition to the entry characters, four characters are reserved for operational instructions as follows:

a) delete the most recent entry

b) activate a built-in attention-getting buzzer

c) print out (and/or transmit via an RS 232 interface) the message presently appearing on the display screen

d) clear the display.

The cycling rate at which characters are presented for prompting can be adjusted over a span ranging continuously from 75 seconds down to one second.

In the second cueing modality, the Encoded Scan mode, the Communicator makes use of a message board located on the front panel facing the user. The board contains 16 squares, each measuring 3/4 inch x 1 inch, arranged in two rows of 8 columns. Each square is imprinted with 2 characters (or pictographs). Mounted on the board are 10 light emitting diodes (LEDs), one above each of the 8 columns and one to the left of each of the 2 rows. The Communicator cycles repetitively through the 8 columns until one is chosen by user actuation of the selector switch, after which two further selections are made (in part by default) for one of the two rows and then for one of the two characters in the message board entry square.

In the third cueing modality, the Direct Select mode, the user makes a selection by touching the appropriate entry square. This mode is designed for those individuals possessing reasonably good motor control and thus able to make contact with a concealed proximity switch covering a target area of 3/4 inch x 1 inch. This mode is very much like using a typewriter except that it offers certain advantages: (1) no physical contact force is required for actuation, (2) the message can be edited prior to printout or transmission, (3) the displayed message can be viewed from front and back, (4) the message can be displayed remotely on a TV monitor, (5) the message can be transmitted telephonically via a MODEM setup, (6) the system can be operated in a symbol coded mode. Operation in the Prompt and Encoded Scan modes involves user actuation of a switch in order to select for display the desired cued entry. The switch can be adapted to suit the user's most facile motor capability (e.g., palm touch, head tilt, limb movement, breath control, etc.). The Direct Select mode does not require intercession of a selector switch.

Specifications

The Communicator is housed in an instrument cabinet of contemporary styling measuring 12 inches wide, 10 inches deep and 5 inches high (See photograph). The assembled unit without battery pack weighs 5.5 lbs. and operates off conventional 110 V., 60 Hz lines via a power cord supplied with the unit. Addition of the battery pack (3.0 lbs.) makes the unit fully portable. A handle is incorporated for ease in carrying. The rechargeable nickel-cadmium battery pack provides up to 3 hours of continuous operation between charge cycles. Recharging is conveniently achieved by plugging the battery pack into any wall outlet via the unit's power cord. A cost analysis based on production runs of 25 units indicates that, at present day component prices, a fully assembled unit (excluding battery pack) can be produced at a cost of $400.

Field testing

The above described Communicator is a refinement of an earlier design which has been undergoing field tests at the Widener Memorial School for Handicapped Children, Philadelphia, PA. The unit has been used by two non-vocal motor-deficient male students capable of spelling. Both are cerebral palsied individuals, one 15 and the other 16 years of age. One uses a hand actuated selector switch; the other actuates the switch with his elbow. Both subjects are understandably thrilled at discovering a modality for engaging in two-way communication with teachers and peers. In addition, their motivation in learning tasks has been heightened; moreover — and this is an unforeseen finding — their reaction time has decreased markedly as a result of practice with the Communicator in the Encoded Scan mode (their motor-deficiencies preclude operation in the Direct Select mode).

Controlled field tests are currently being planned. These will be conducted by Widener faculty members at three different institutions for handicapped children.

References

1. Vanderheiden, G. C. and Grilley, J. (Eds.), "Non-Vocal Communication Techniques and Aids for the Severely Physically Handicapped", Univ. Park Press, 1976.

2. Vicker, B. (Ed.), "Non-Oral Communication System Project", Univ. of Iowa Press, 1974.

APPLICATION OF THE OCULAR TRANSDUCER TO THE ETRAN [1] COMMUNICATOR

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University of Denver

An ocular controlled Etran Communicator has been developed and is described. It is intended for use by high level quadriplegics, cerebral palsied individuals, stroke victims or other severely disabled individuals who retain good eye movement control. This is true even if the individual has poor or no head movement control. In spite of its sophistication and high level of utilization, it is a simple unobtrusive device and is applicable to both communications and control applications. While it is not yet commercially available, it is expected that it could be manufactured and sold for about $2,000 for the basic unit. Since there are applications for eye movement detectors, outside the handicapped field, it should be even more cost effective for potential manufacturers.

CATEGORY: Device Development [X] Research Study [ ]	INTENDED USER GROUP: Severely disabled non vocal AVAILABILITY OF DEVICE: Not available
STATE OF DEVELOPMENT: Prototype [ ] Clinical Testing [X] Production [ ]	AVAILABILITY OF CONSTRUCTIONAL DETAILS: Not available
AVAILABLE FOR SALE: Yes [ ] No [X] Price:	FOR FURTHER INFORMATION CONTACT: George Rinard, Denver Research Institute P.O. Box 10127, Denver, Colorado 80208

Introduction

Communications for individuals who are severely handicapped and non-vocal is very difficult. Often only the eyes remain unaffected and become the sole means for communication. This may take the form of eye movements to indicate yes/no answers to questions. This can be extended to use the yes/no answers to indicate letters of words, guessed words and finally complete sentences.

An ocular transducer, designed to detect the corneal reflection of an infrared source and produce coherent signals suitable for communication/control purposes, has been developed [2]. Interfaces with several devices suitable for use in an ocular control based system for use by the handicapped, have also been developed. These include a proportional wheelchair drive and recline control, a T.V. "Pong" game and a T.V. computer terminal [3],[4]. The T.V. terminal may be utilized for its intended purpose, or as an interactive communications device.

Acknowledgement:
This initial development of the Ocular Transducer was sponsored by National Institutes of Health Grant 5 RO 1 AM10763.

The ocular transducer is shown in Figure 1. The description of the transducer is given in the references [2] [3]. The output from the transducer is a ten bit digital signal representing the x- and y-position of the cornea of one eye of the user. This signal is used in the modified T.V. terminal to control a cursor and select the characters to be "typed".

The modified video display of the T.V. terminal is shown in Figure 2. The upper half of the screen is the data field which contains the characters that have been "typed". The lower half of the screen is the character field and the alphanumeric characters which are displayed replaces the keyboard in the unmodified T.V. terminal. The character to be "typed" is selected by positioning the character cursor on the desired symbol and providing a strobe signal to "type." The strobe signal is derived from a miniature vibration microphone attached to the glasses frames which detects slight clicks of the users teeth.

The control signals that are derived from the ocular transducer depend on the position of the eyes relative to the head. Thus, if an individual has good control of eye movements and either his head can be controlled or held stationary, he can

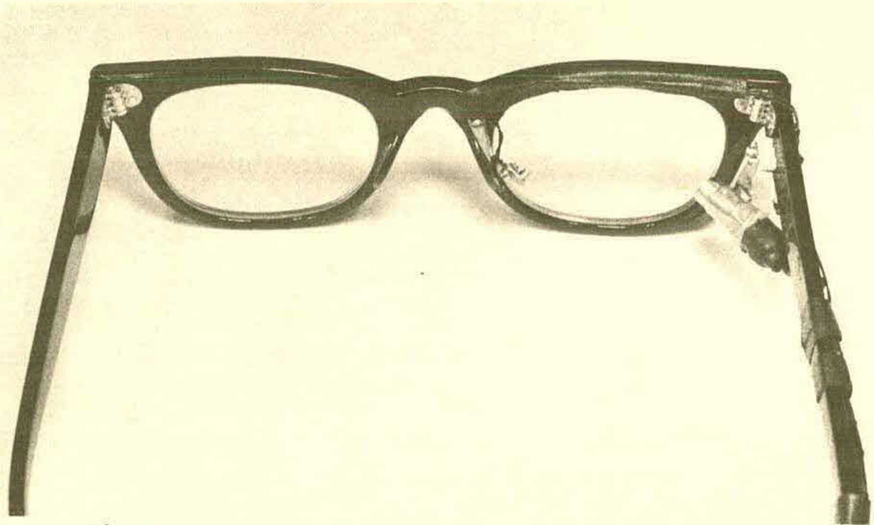

Figure 1. Eyeglasses with Optics to Monitor Eye Position

utilize the device, however, individuals with poor or spastic head movements find the device hard to control.

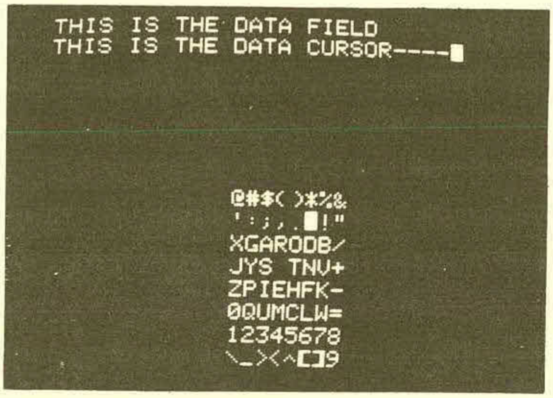

Figure 2. TV Terminal Video Display

There are many individuals who are non-vocal and have poor or spastic head movement. For this reason attempts were made to make the display stationary with respect to the glasses on which the ocular transducer is mounted. This can probably be done in a number of ways utilizing miniaturized optics. However, another approach was tried and found to be practical. This method is based on the Etran display method developed by Eichler [1]. This method utilizes a coded sequence of eye movements. Usually this is accomplished by means of a board which is held between the handicapped individual and the other person with whom he is communicating. The other person decodes the eye movements to receive the message. The Etran display can offer a more efficient means of interactive communication for severely handicapped non-vocal individuals than other means that are often used, since it allows direct selection of characters. However, it requires a rather large board and a receiver trained in its use.

The ocular transducer has been utilized to decode the eye movements and present the message in a form almost anyone can receive. In addition the ocular controlled Etran system can be interfaced to devices like typewriters, computers and environmental controls.

The Communicator

The modified Etran display is shown in Figure 3. This array has been designed so that the simplest movements correspond to the characters that occur most frequently in the written English language (E, O, Yes, Space, T, S, No and I). The blanks in the display can be used for most often used words which may vary with the individual. One

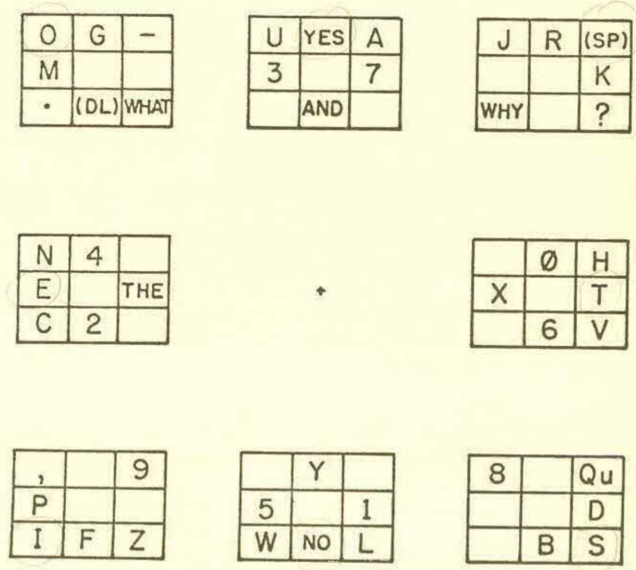

Figure 3. Modified Etran Display

character could also be a second page of sixty-four characters (or controls) to be used by the individual. In use the eyes are first fixed on the box which contains the desired letter. Next the eyes are fixed on the area of the board which corresponds to the position of that character in the box. There are eight (8) boxes each of which have eight areas (the center areas are not usable) which allows a total of sixty-four (64) possible characters. This is the same number of characters allowed on the 8 x 8 display shown in Figure 2. An "N" may be indicated by the following fixation of the eyes: center (starting position) (1.) left center (2.) left top (3.) center. The center position is always the last position and indicates the character has been selected. Thus, it is also the starting position for the next character. When a character's position in a box corresponds to its box's position in the display, one need only return to center after the box is chosen. "E" for example would be encoded as follows: center (starting position) (1.) left center (2.) center. These positions have been reserved for the most frequently used characters. The frequency of occurrence is given by Foulds [4].

The Etran technique together with the ocular controlled communicator eliminates many of the shortcomings of each. Since the individual is in direct control of the device and since characters may be displayed or printed the need for active involvement of the other person is no longer necessary. Since he is in control of the device he can signal when he has a message to be read. The signal, (a bell etc.) can be one of the sixty-four (64) characters. The Etran display of 3 by 3 locations is simpler than the 8 by 8 utilized originally for the sixty-four (64) character display and can be implemented without the need for a video display.

The nine positions of the display were identified by affixing a 3 by 3 array of small dots on the lens in the glasses frame on which the ocular transducer is mounted. These dots are perceptible even though the eye cannot focus this closely. The result is fuzzy grey areas which are translucent and do not otherwise interfere with vision located in the position of these dots. The user learns the encoded position of the characters. This is easily done since he can look through the center of the dot matrix region at an Etran display board. After he learns the positions, the board is no longer necessary.

The system was implemented by software programming on an Intel 8080 microprocessor. This allows the system to be altered easily to try different configurations. The entire display can be easily changed, for example, by changing the input data. The size of the display can also be changed and thus alter the degree of eye movement required. A further advantage of software implementation is that the dwell time required for a position to be selected is easily changed to meet an individual's abilities. Filtering is also possible in cases where eye movement is spastic.

The dot matrix on the eye glasses were found adequate for position reference. However, they did not allow feedback to indicate that the position had been selected. To provide such feedback the program was modified and a simple output device added to provide audible signals when a position was selected. Each of the eight positions, exclusive of center, was assigned a note on the musical scales. This was found to be adequate in providing feedback and may possibly replace the dot matrix altogether or vice versa.

Testing

Several non-handicapped individuals have tested the system and found it feasible to control and easy to learn. The system essentially eliminated the need for good head control and good results were obtained utilizing eye movement only.

Concluding Remarks

The use of the Etran display technique simplifies the ocular controlled communicator. It makes it practical for a broader and more severely handicapped group of individuals. In spite of its sophistication and high level of utilization, it is a simple unobtrusive device and is applicable to both communication and to control applications. It is estimated even in small commercial quantity ocular control systems could be manufactured and sold for less than $2,000 for the basic communicator and the system can be expanded for other applications as the need arises.

It is interesting to note that the number sixty-four (64) which is the number of possible characters for the ocular controlled Etran encoder is the same as the minimum number of phonemes for speech. While this has not yet been done, the possibility for direct eye control of spoken language may be feasible.

References

[1] Participant Resource book - 1975

National Workshops on Non-Vocal Communication Techniques and Aids, Trace Center, University of Wisconsin, Madison, Wisconsin.

[2] Rinard, G., and Rugg, D., "An Ocular Control Device for use by the Severely Handicapped," 1976 Conference on Systems and Devices for the Disabled, Boston, Mass., June 1976.

[3] Rinard, G., and Rugg, D., "Current State of Development and Testing of an Ocular Control Device," Fourth Annual Conference on Systems and Devices for the Disabled, Seattle, Washington, June 1977.

[4] Foulds, R., Baletsa, G., and Crochetiere, W., "The Effectiveness of Language Redundance in Non-Verbal Communication," Conference on Devices and Systems for the Disabled, Philadelphia, Pennsylvania, April 1975.

PRELIMINARY REPORT ON EYECOM, AN EYE MOVEMENT DETECTION AND DECODING SYSTEM FOR NON-VOCAL COMMUNICATION

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EYECOM, a non-vocal communication system which allows the user to generate characters by coded use of eye movements has been built in clinical prototype form. It utilizes standard corneal reflection optics mounted on a spectacle frame, and implements a two-of-eight code similar to ETRAN. It is intended to provide severely motor-impaired individuals with an alternative to scanning communication systems. The technological demands of an encoding eye-movement communicator are relatively simple. Our system requires fewer and less expensive components, and less precise location of optics with respect to the head than systems based on high resolution determination of instantaneous gaze direction. Expansion of the present system to a three-of-eight code allowing a vocabulary of 512 items - including at least 400 words and phrases - will require only simple electronic modifications.

CATEGORY:	INTENDED USER GROUP: Non-vocal severely motor impaired
Device Development ■ Research Study □	AVAILABILITY OF DEVICE: Not presently available
STATE OF DEVELOPMENT:	
Prototype □ Clinical Testing ■ Production □	AVAILABILITY OF CONSTRUCTIONAL DETAILS: Presently withheld, pending evaluation and modification of prototype design.
AVAILABLE FOR SALE:	FOR FURTHER INFORMATION CONTACT: Michael J. Rosen Building 31-063 M.I.T., 77 Mass. Ave. Cambridge, MA. 02139
Yes □ No ■ Price: Prototype components cost ∿ $300	

Introduction

The project described below is aimed at meeting the communication needs of severely motor impaired non-vocal individuals. We have in mind, specifically, people whose muscular control deficit below the neck is so profound that simple on-off input to a scanning* mode device is the limit of their limb-use capability. The present work investigates the coded use of eye movement - or, more accurately, gaze direction - as a hypothetically advantageous approach to communication and control in cases of such a handicap.

Gaze direction is appropriate for consideration as a device-control signal in several respects. Voluntary control of the extra-ocular muscles and the vision necessary for sensory feedback are often unimpaired in individuals handicapped below the neck to the extent described above[1]. Physiological control of gaze direction is characterized by particularly high speed and fine spatial resolution while making relatively low power demands on the organism. The constant mechanical load imposed by the eyeball inertia on the extra-ocular muscles facilitates rapid learning of "quasi-open-loop" positioning ability (whereas the limbs may be subject to unpredictable applied forces requiring greater attention to physiological feedback channels for accurate position control).

The simplest technique for monitoring gaze direction is direct observation by another person[2,3]. It is easily verified that an observer can reliably identify which of a matrix of target points is being fixated by an individual facing him/her when adjacent targets (in a plane between the two individuals) require as little as 10° change in gaze angle. The practical implication of this is that an ETRAN-like board[2] for encoded non-vocal communication can contain enough distinguishable targets in a comfortably small viewing area to allow a large coded vocabulary without tediously long coding sequences. For example, eight fixation targets on a 3 x 3 matrix (with the center open) can easily be mounted on a 18 in x 24 in board for viewing at ∿ 36 in from the non-vocal user. These targets provide 64 distinct sequences of two gaze directions and 512 sequences of three gaze directions!

* For definitions of this and other standard non-vocal communication terminology used in this paper, see, for example, reference 11.

The obvious disadvantage of direct observation of eye movement is the necessity of another person being present to perform the sensing, decoding and recording functions. (Our original subject with an ETRAN-like board initially rejected it because of his conviction - fortunately erroneous - that these tasks would be too challenging for the individuals with whom he wished to communicate[4].) An eye movement based communication system which allows handicapped individuals to produce printed text independently and in a format familiar to unimpaired individuals must include an objective, opto-electronic Gaze Angle Monitoring system.

There are, of course, several recognized techniques for transduction of gaze angle and a considerably larger number of specific G.A.M. systems. A detailed review of both optical and myoelectric sensing methods and their practical realizations has been published by Young and Sheena[5]. Many of these G.A.M. systems were intended for physiological and man-machine systems research and are correspondingly complex and expensive. Applications to communication and environmental control in rehabilitation engineering have been reported, however, by Rinard and Rugg[6], Warren[7] and Stassen[8]. While these studies share the rationale sketched above, they differ in conceptual or practical details from the work described below.

EYECOM - conceptual design

We have designed and constructed a prototype of an encoding-mode non-vocal communication system utilizing objective monitoring of gaze angle. The optical components are small and light enough to be mounted on a standard spectacle frame. (See Figure 1.) The standard corneal reflection geometry[5] is employed and the integrated circuit image detector used is the same as that chosen by Rinard and Rugg[6] for their wheel chair steering system. The user enters the code for a desired vocabulary item by fixating upon the correct sequence of "targets" arranged in a 3 x 3 matrix. These may be actual reference spots displayed on the spectacle frame or, hypothetically, learned gaze directions having no real target. Eight of the "targets" represent code digits 1 through 8, while the straight-ahead (matrix center) gaze is decoded as an "enter" command.

Figure 1. Prototype of EYECOM. Note status indicators and thumbwheel switch to set minimum gaze dwell time.

Conceptual design choices were made according to several criteria. The simplest alternative strategy for use of detected gaze direction as an input signal would have been on-off control. In this scheme, a particular eye movement or angle is interpreted electronically as a switch closure which stops an automatic scanning sequence. This approach suffers, however, from the usual disadvantages of scanning systems (slow speed and a practical limit on size of displayed vocabulary) and probably represents a considerable underutilization of the capability of the extra-ocular muscle control system for rapid, accurate, two-dimensional movement.

Another hypothetical alternative to encoded use of eye movements is directed scan control; opto-electronic discrimination of four discrete gaze directions ("up", "down", "left" and "right") can be used to control the direction of cursor movement on a vocabulary display matrix. The other more technologically demanding approach is, of course, generation of two continuously varying analog signals representing the "x,y" coordinates of gaze direction. These signals can be used, presumably, for "remote direct selection", i.e. proportional control of cursor position on a display matrix. These last two strategies share several apparent drawbacks. Unlike an encoding system, they require that the entire vocabulary be displayed in order that a cursor may be steered over it for item selection. (Conversely, an encoding system requires at most the display of fixation targets since the code may be memorized. Code display is, of course, necessary during the learning phase.) This requirement sets a practical limit on vocabulary size which is not imposed in encoded-entry systems.

More importantly, cursor-position control by either approach requires constant visual attention to the present and intended cursor position. In the case of directed scan, the user's task of maintaining the required eye-head angle while tracking the cursor's movement on the display requires accurate movement of the head in coordination with eye movement. This motor demand renders the system useless to a considerable fraction of the potential users defined above. In the case of proportional control of cursor position, the same sort of head position adjustment is necessary unless precise, reproducible location of the head with respect to the display is maintained. Assuming this can be accomplished in a comfortable, cosmetically acceptable, clinically practical way - a very large assumption - it is at least theoretically possible to calibrate the G.A.M system so that "the cursor goes where you look". The accuracy with which this calibration must be maintained increases, of course, as the number and density of vocabulary matrix items increases. Even a slight out-of-adjustment condition creates a situation in which the user must bring the cursor to a desired matrix element without letting himself look at it - looking instead slightly away from it. This requirement, and more generally the necessity of constant visual attention was felt to impose an unacceptably high "mental load" on the user.

In contrast, encoded use of gaze direction requres only repeated attainment of a very small number of fixed eye angles with respect to the head. Since the target points are fixed with respect to the head, head position itself is irrelevant to code entry. The well-documented ease with which people perform such visual "target-capture" tasks with little conscious effort is exploited. Furthermore, by dividing a substantial portion of visual space into a very coarse (3 x 3) matrix, our system allows considerable latitude around each target point within which the system still recognizes the intended gaze direction. This amounts to a built-in tolerance for movement of the detector components with respect to the head. In other words, if the spectacle frame is worn on a particular occasion slightly scewed compared to its previous use, chances of correct sensing of intended gaze direction are much better than they would be for a system requiring repeatable discrimination of tens or hundreds of different gaze angles.

Operational details

The image detector is a 1/8 inch square chip in a 16 pin DIP manufactured by Cromemco. All 1,024 light-sensitive points of this chip are repeatedly scanned electronically (by a Cromemco control circuit) to test their state of illumination. The effect of illumination is cumulative during each sequence of 16 scans (1 "frame") at the end of which all points are reset to zero and the next scan sequence begins. As each point is addressed, its state of illumination is compared with a fixed threshold voltage. At each point where sufficient intensity has been present from the start of the present frame, the threshold is exceeded and a "video pulse line" goes briefly high during the scan of that point. If a particular point has been subjected to relatively more light than its neighbors, it drives this line high during earlier scans of a frame. Each point is scanned 512 times/sec.

Our own circuitry (entirely TTL integrated components) makes use of this rule-of-operation to locate the instantaneous position of the corneal image on the detector. See Figure 2. This position varies in a fixed simple way with gaze angle. The intensity of the infra-red source (Texas Instrument TIL24) and the absorbing properties of the gelatin filter (Kodak No. 87) interposed between eye and detector are chosen so that only the corneal image is bright enough to cause a video pulse during the first or second scan of the points it illuminates. Ambiant illumination, however, causes video pulses only during later scans of each frame. The first stage of our circuit, then, finds the corneal image position by noting the coordinates of the point being scanned when a video pulse occurs. By only searching for pulses during the first or second scans of a frame, less intense ambiant illumination is prevented from causing spurious codes entries.

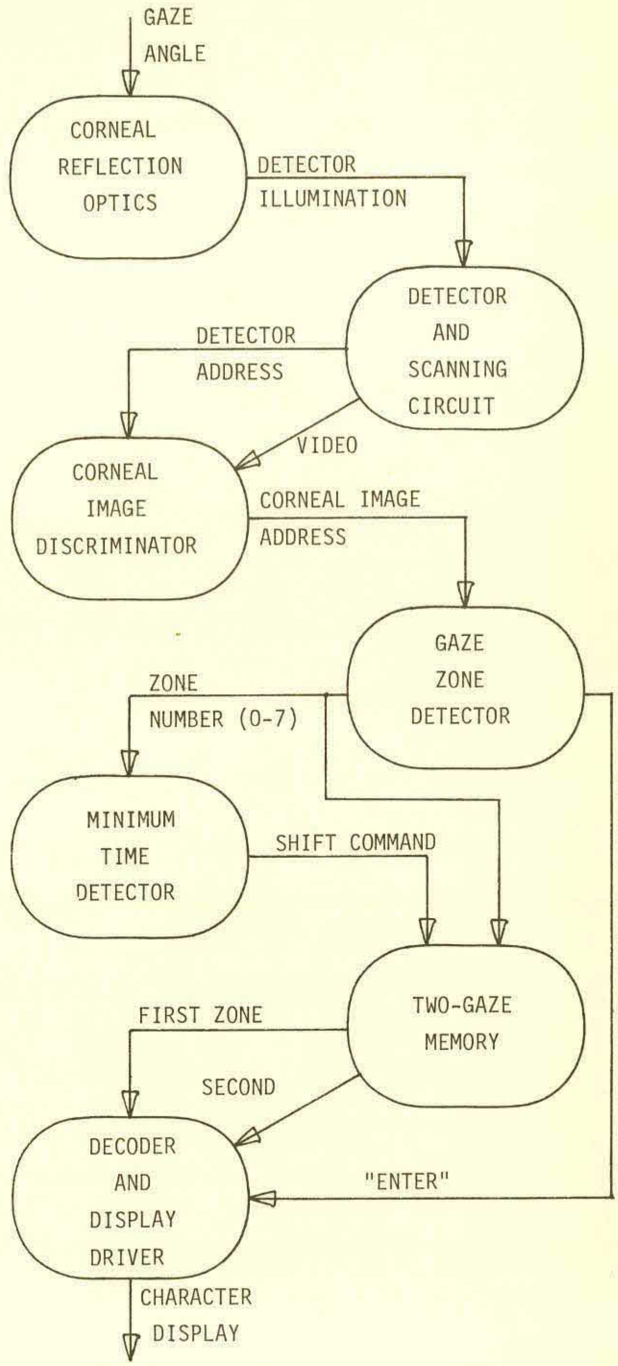

Figure 2. Functional block diagram. See text for details.

From the image location so determined, the circuit checks a custom-programmed memory to establish in which of the 9 gaze direction zones the user is presently fixating and then times the maintenance of that gaze direction. The minimum amount of time required for the circuit to treat a maintained gaze angle as a code entry is set by means of a rotary switch on the EYECOM cabinet. Values range from 1/3 second to 3 seconds. When the minimum "dwell time" is reached, timing of the next maintained gaze angle is begun. The user is signalled by a brief flash of two LED's mounted on the spectacle frame when he/she has held a particular eye position long enough for it to be recognized as intentional. The circuit keeps track of the last two gaze direction codes duly entered. When an "enter command" is given by means of an appropriately maintained straight-ahead gaze, this sequence is electronically decoded to display the character intended by the user. The dwell time and enter gaze requirements are designed to minimize the occurrence of unintended character outputs resulting from transient and/or "non-communicative" eye movements. "Correction" of mistaken gaze directions is accomplished simply by ignoring them and making sure that the last two eye positions before Enter were as intended.

Another feature of EYECOM intended to prevent decoding of non-communicative eye movements is the "standby mode". By entering a control code, i.e a particular diagonal pair of gaze directions, the user can place the system in an unresponsive state. The only one of 64 possible gaze pairs to which the circuit will respond when in standby is the other control code which returns it to its decoding status. "Standby" and "on" indicators are also located on the cabinet front panel. In its present form, the EYECOM itself displays a single character on its own 5 x 7 dot matrix and outputs parallel ASCII simultaneously at a rear panel jack for updating more elaborate text displays and printers.

EYECOM presently implements a sixty-two element vocabulary consisting of letters, numbers, punctuation marks and other symbols (the standard 64-item ASCII subset with the "standby" and "on" codes substituted for ^ and \ ). This code is displayed in two equivalent forms in Figure 3. The chosen pairing of gaze sequences with vocabulary items, while to some extent arbitrary, was intended primarily to facilitate initial learning by incorporating obvious mnemonics and to increase long-term efficiency of use by associating frequently used items with "easier" gaze sequences. (More detailed discussion of these considerations as applied to an ETRAN-like communication board may be found in Rosen et al.[9]) One option which will be tested during clinical evaluation is incorporation of the code, displayed in "nested subdivision" form, into the spectacle frame. This is easily accomplished optically be reducing each group of eight characters shown in Figure 3a to a 1 mm square transparency. This is well within the limits of "microfiche" technology. The eight bits of film are then mounted in front of one spectacle lens positioned so as to serve as the gaze direction targets. Clear vision at such a short distance from the eye is accomplished by interposing a small diameter, high power lens (e.g. Edmund Scientific No. 94725, 5 mm diameter, 8 mm focal length) between each piece of transparency and the eye as shown in Figure 4.

Several short- and long-range plans have been made for additional features and expansion of capabilities of EYECOM to be attempted if initial clinical evaluation goes well. These include the following:

1. The user should be given control of the required dwell time setting by means of a specialized gaze sequence for shortening and another for lengthening.

2. Implementation of a 3-digit, 512-item code will be evaluated. While the hard/software problems are trivial, questions of vocabulary choice and organization, and teaching and display of such a large code are substantial. The vocabulary might be organized as eight "pages" of 64 items each. The

A	B	&
C		$
Y	(	SBY

(Group 0)

.	?	
;		:
,	!	1

(1)

J	G	E
%		F
ON	)	K

(2)

N	+	0
<		9
T	-	8

(3)

("ENTER")

2	*	S
3		>
4	/	R

(4)

H	[	@
P		"
O	M	Q

(5)

7	6	5
=		--
L	I	D

(6)

#	]	Z
'		W
X	V	U

(7)

(a)

GAZES 1st 2nd	CHAR.	GAZES 1st 2nd	CHAR.	GAZES 1st 2nd	CHAR.	GAZES 1st 2nd	CHAR.
0 0	A	2 0	J	4 0	2	6 0	7
0 1	B	2 1	G	4 1	*	6 1	6
0 2	&	2 2	E	4 2	S	6 2	5
0 3	C	2 3	%	4 3	3	6 3	=
0 4	$	2 4	F	4 4	>	6 4	--
0 5	Y	2 5	ON	4 5	4	6 5	L
0 6	(	2 6	)	4 6	/	6 6	I
0 7	SBY	2 7	K	4 7	R	6 7	D
1 0	.	3 0	N	5 0	H	7 0	#
1 1	?	3 1	+	5 1	[	7 1	]
1 2		3 2	0	5 2	@	7 2	Z
1 3	;	3 3	<	5 3	P	7 3	'
1 4	:	3 4	9	5 4	"	7 4	W
1 5	,	3 5	T	5 5	O	7 5	X
1 6	!	3 6	-	5 6	M	7 6	V
1 7	1	3 7	8	5 7	Q	7 7	U

(b)

Figure 3. Alternative displays of code presently implemented by EYECOM. (a) "Nested Subdivison" format which specifies code and provides gaze targets. (b) List format; note relationship to (a).

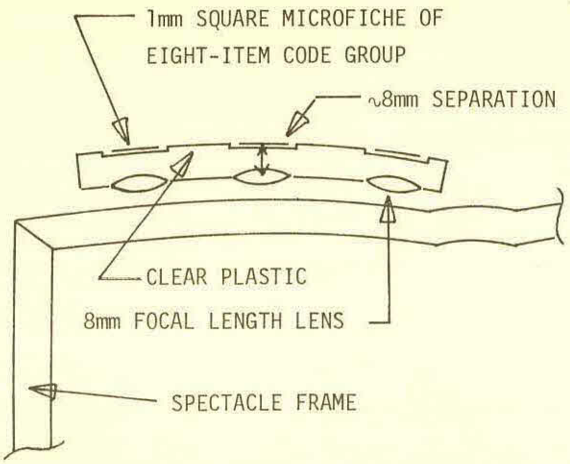

Figure 4. Optics for code display integral with gaze target presentation. The spacing between a viewing lens and its code transparency must be accurately set to permit clear vision with a comfortable state of focus of the eye.

first gaze of each three-gaze entry specifies, in effect, the page number while the next two gazes specify the desired item on that page. Page 1 might be the same as the present 64-item array of single characters, while the remaining seven would presumably be occupied almost entirely by whole words or even frequently-needed text. In addition, the vocabulary might be distributed among the pages according to specialized topics so as to minimize the need to jump frequently from page to page. In this case, the operational rule might be as follows: once an item on a particular page is selected, the user remains on that page, needing only two gaze directions for item selection, until a control code is entered providing access once again to any item on any page.

3. The reduction of the size and hardware cost of the EYECOM circuitry might be accomplished by design of a microprocessor-based stand-alone version or by treating EYECOM as an input device to UNICOM, a more general purpose communication and control system described elsewhere in these proceedings[10].

Acknowledgments

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References

1. Berenberg, W., Project Director, Harvard-M.I.T. Rehabilitation Engineering Center: personal communication.

2. Luster, M.J. and Vanderheiden, G.C., "Preliminary Annotated Bibliography of Communication Aids", in Participant Resourcebook, 1975 National Workshops on Non-Vocal Communication Techniques and Aids, Trace Center, Univ. of Wisconsin, 1975.

3. Rosen, M., Drinker, P. and Dalrymple, G., "A display board for non-vocal communication encoded as eye movements", Proceedings of the 29th ACEMB, Boston, 1976.

4. Rosen, M. Drinker, P. and Dalrymple, G., "A display board for non-vocal communication encoded as eye movements", Proceedings 1976 Conf. on Systems and Devices for the Disabled, Boston, 1976.

5. Young, L.R. and Sheena, D., "Survey of eye movement recording methods", Behavior Research Methods and Instrumentation, V(5):397-429, 1975.

6. Rinard, G. and Rugg, D., "An ocular control device for use by the severely handicapped", Proceedings 1976 Conf. on Systems and Devices for the Disabled, Boston, 1976.

7. Warren, R.E., "Progress Report: A research program for the physically handicapped to develop independence via "build-it-yourself" kits and practical instruction in engineering technology", Report R-1074, Charles Stark Draper Laboratory, Inc., Cambridge, MA., April, 1977.

8. Stassen, H.G., Man-Machine Systems Group, Lab. for Measurement Control, Dept. of Mechanical Engineering, Delft Univ. of Technology, the Netherlands; and Visiting Professor, Mech. Engineering Dept., M.I.T.: personal communication.

9. Rosen, M. Drinker, P., Dalrymple, G. and Berube, N., Instructional Text on an Eye Movement Communication Board, prepared for 1976 Vermont Workshop: Non-Vocal Communication Aids and Techniques.

10. Rowell, D., Dalrymple, G. and Olsen, J., "UNICOM: A universal communication and control system for the non-verbal motor impaired", submitted for 5th Annual Conf. on Systems and Devices for the Disabled, Houston, 1978.

11. Vanderheiden, G.C. and Grilley, K., Non-Vocal Communication Techniques and Aids for the Severely Physically Handicapped, University Park Press, Baltimore, 1977.

ANALOG CONTROL BY BREATH SIGNALS

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Pilot experiments were performed to explore the possibility of deriving analog control signals from pulmonary air flow. The subject, breathing into a pneumotachograph, controlled the position of a spot on a cathode ray tube via a signal proportional either to flow rate or to volume. The fastest output achieved was 4 levels/s and the most accurate one 2% of the total range. Complex rectilinear patterns, which were traced with ease, are presented for illustration.

Suggested applications include: communication with computer terminals, for which currently only "sip-or-puff" controls are in use; modulation of artificial larynx parameters, and wheelchair control.

CATEGORY: Device Development ☐ Research Study ☒	INTENDED USER GROUP: Severely paralyzed but with good control of breathing; laryngectomees
STATE OF DEVELOPMENT: Prototype ☐ Clinical Testing ☐ Production ☐	AVAILABILITY OF DEVICE: not available (prototype system under development) AVAILABILITY OF CONSTRUCTIONAL DETAILS: not at present
AVAILABLE FOR SALE: Yes ☐ No ☒ Price:	FOR FURTHER INFORMATION CONTACT: Dr. Andrew Sekey Dept. of Elect. Engr. & Comp. Sci. University of California, Santa Barbara, CA 93106

I. Introduction

While breath flow is commonly used for controlling handicapped aids, (see Section III), the signals so generated are typically restricted to two alternatives, corresponding to "sip" and "puff". The aim of this work is to illustrate via some pilot experiments the potential of the human breathing apparatus to generate analog control signals, i.e. continuous functions of time having a large number of distinguishable levels. Such a potential, if indeed available, should be exploited towards increasing the rate at which the handicapped person can communicate with his environment.

Figure 1 shows a simplified generic model of the overall man-machine system. In setting up this model we assume the following:
(a) The operator, who may be severely paralyzed, has a good control of his breathing.
(b) In addition, he can activate with some part of his body two microswitches for binary signalling functions.
(c) At least one form of sensory feedback is available to the operator.

In the experiments to be reported the feedback was visual; other forms of feedback have been employed in the past.

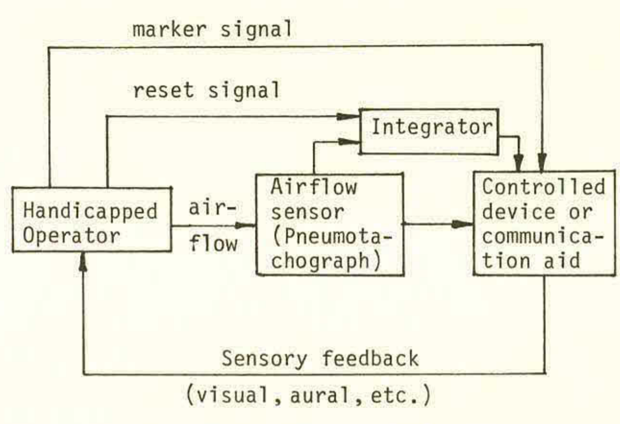


Figure 1. A generic model of a system incorporating airflow control

II. Analog Control Experiments

Experimental Arrangement

The subject of the pilot experiments to be described (the author) was seated in front of a storage oscilloscope and breathed via a Sanborn Pneumotachograph Mask, followed by a Model 270 Gas Pressure Transducer and 311A Amplifier, also by

Sanborn. Integration of the breath signal, when required, was accomplished by an EAI Pace TR20 analog computer. The output of the 311A was low-pass filtered with a single R-C having a 25 ms time constant. There was no formal training period - the results shown are those of some of the more successful attempts after a couple of hours' practice.

Control by Flow — Tracking

These tests were aimed at determining how well the subject could track a pre-recorded waveform on the C.R.T. with a spot moving at 5 cm/s, when the vertical displacement of the spot was made proportional to the rate of flow. Figures 2-4 show typical results. By comparing Figs. 2a and 2b we note that it was about equally difficult to maintain a constant rate by exhaling and by inhaling. Figure 3 illustrates the tracking of a slower sinewave, while in Figure 4 some results for a 2 Hz sinewave are shown, the fastest that seemed possible to track. (Note: the high-frequency ripples seen in these pictures is an amplifier artefact.)

It may be worth noting that though the vertical scale of Figure 2 is compressed in Figures 3 and 4 by a factor of 5, the "fuzzy region" - i.e. the range of spread in different attempts - is about the same. (Note, though, that the latter Figures reflect fewer attempts.) This suggests that the inaccuracy may be proportional to the range covered, rather than a constant.

Control by Volume — Positioning

By integrating the signal proportional to flow we get a signal proportional to volume, i.e. the total amount of air breathed in (or out) since the integrator was last reset. This type of control is intrinsically suitable for positioning, since it allows for iteration and requires no effort once a satisfactory position has been arrived at.

Figures 5 and 6 illustrate typical results. In Figure 5 the aim was to position the moving spot onto major graticule divisions above and below the center line alternately; this was accomplished seven times in 18 seconds. Figure 6 represents on

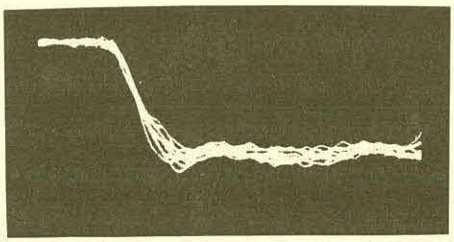


Figure 2a. Maintaining a constant flow by inhalation (10 attempts). Scan rate: 0.2 s/cm

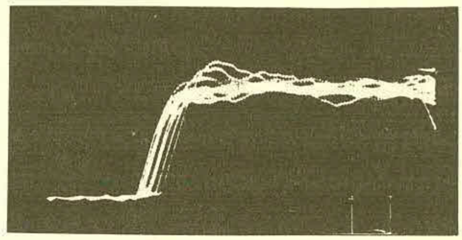


Figure 2b. Maintaining a constant flow by exhalation (10 attempts). Scan rate: 0.2 s/cm

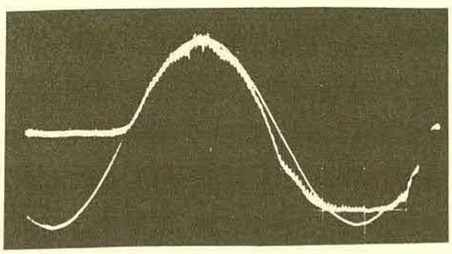
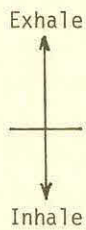


Figure 3a. Attempting to track by airflow a 0.68 Hz sinewave Scan rate: 0.2 s/cm



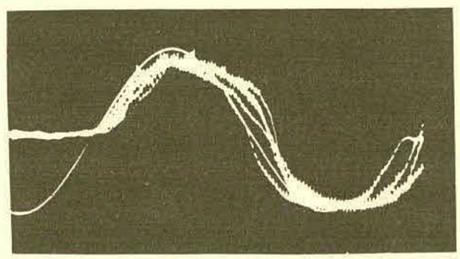


Figure 3b. Five attempts of the type shown in Figure 3a. Scan rate: 0.2 s/cm

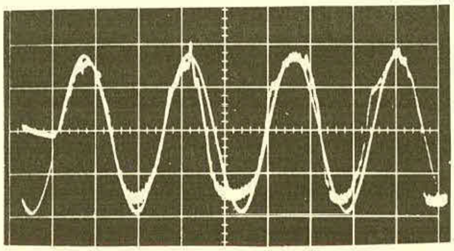


Figure 4a. Attempting to track by airflow a 2 Hz sinewave. Scan rate: 0.2 s/cm

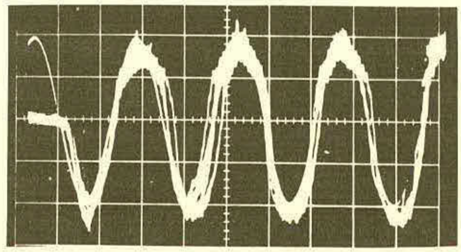


Figure 4b. Five attempts of the type shown in Figure 4a. Scan rate: 0.2 s/cm

an expanded time scale the sum of 5 attempts at two levels each. Observe that the spread is about two minor graticule divisions, i.e. about 6% of the range that could be traversed in 2 seconds.

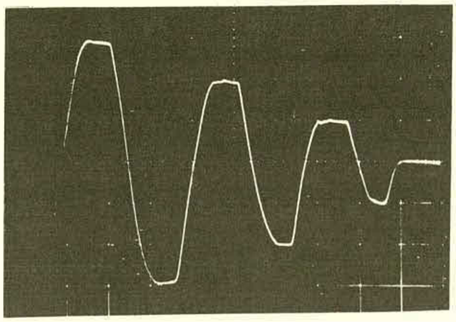


Figure 5. Generating the sequence of levels: +3,-3,+2,-2,+1,-1,0, by volume control.
Scan rate: 2 s/cm

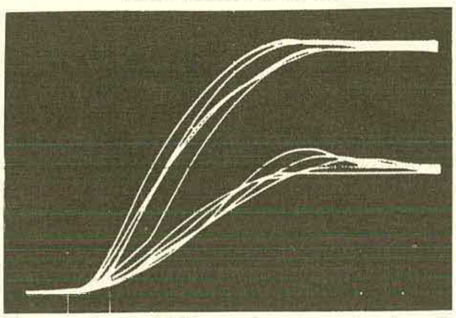


Figure 6. Settling at a constant volume level; 5 attempts each.
Scan rate: .2 s/cm

Positioning in both dimensions, illustrated in the next three figures, requires that the horizontal sweep of the oscilloscope be turned off. Instead, the air volume is made to control alternately horizontal and vertical displacement of the spot, with the switching between the modes effected by the "marker signal" of Figure 1.

Figure 7 illustrates the accuracy attainable by this method; the aim was for the spot to traverse the major axes exactly at the minor subdivisions. Figure 8 simulates a layout composition task: "letters" originally displayed with a 2 mm spacing along the main horizontal axis are "laid out", one by one, spaced 10 mm apart, along the vertical axis. The last of this series, Figure 9, is "Labyrinth", a flight-of-fancy composition consisting of a single uninterrupted line which, however, contains some "doubling back" sections. The time typically required for the completion of such tasks was around 2-3 minutes.

Finally, if one channel is arranged to be controlled by the flow signal while the other by the volume, one obtains patterns of the kind shown in Figure 10. Though the patterns that can be produced in this manner are more varied than those shown here, they are still limited both in shape and accuracy.

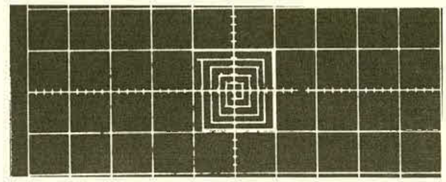


Figure 7. Pattern tracing by X-Y volume control

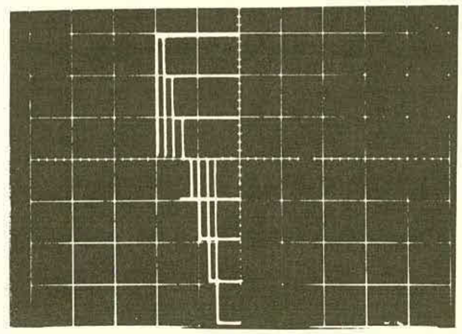


Figure 8. Simulated layout composition task by X-Y volume control

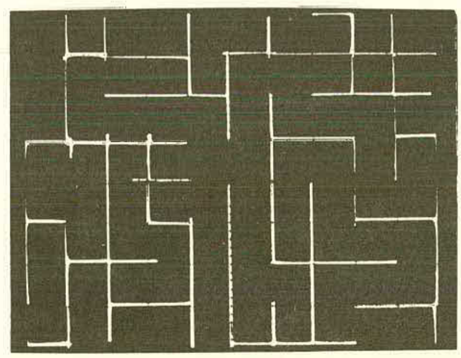


Figure 9. "Labyrinth" - a pattern created by X-Y volume control

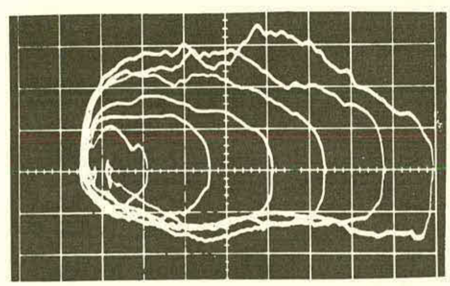


Figure 10. Flow-volume patterns.
Horizontal axis: volume
Vertical axis: flow

Speed and Accuracy Estimates

Based on the few results obtained so far, one can coarsely estimate the attainable performance parameters as follows:

	Speed	Accuracy
Flow Control	4 values/s	10-25% of range
Volume Control	0.3 - 0.5 values/s	2-5% of range

It is apparent that flow control is more rapid but rather inaccurate, while volume control is just the opposite. We note also an inverse relationship between speed and accuracy, in common with many control systems. (The accuracy for volume control could, in fact, be increased considerably at the expense of settling time, as witnessed by the precise use of measuring pipettes in chemistry.)

III. Applications of Breath Control

The two main areas of investigation in breath control for the handicapped, reported in the literature, are limited-vocabulary communication and wheelchair control.

Lywood and Vasa (1974) list a dozen previous works on communication aids, based on which they developed a system by which the handicapped person could introduce ASCII coded characters to a computer. The input has 2 levels (puff or suck), and 12 words/minute typing speed was attained after an average of 5 hours' training. Audio feedback, augmented during the training period with visual feedback, was employed.

In a more recent work by Traynor (1977) a special code akin to the Morse code was developed for the user, though the machine converted it to ASCII characters (with lower case alphabetic characters omitted). The single subject reported on, a young spastic quadriplegic woman, achieved an average speed of 30 characters per minute. Again, the feedback was auditory.

While in the above systems the subject produced only binary outputs (suck and blow), for wheelchair control a continuous range of values is desirable. Legal and Peteleski (1977) report on a wheelchair used by a 14-year old boy whose "spinal cord was severed at the C1-C2 level". They claim that "positive pressure would make a very functional velocity control".

Probably the most advanced approach is that currently taken by Howlett & Folkard (1977) in their MAVIS (Microprocessor based Audio Visual Information System), intended for the severely handicapped. Built around a Motorola M6800 microprocessor with a large memory, it uses an audio cassette recorder for data storage and an adapted color television for text and graphic display. Besides a normal keyboard input the device also accepts suck-blow control, albeit only in a binary (on-off) fashion. (Folkard, 1977.) MAVIS currently has a text editor program, which can also be used for person-to-person communication, as well as a programming language called PLUM (Programming Language for Users of MAVIS). The latter permits new modified program to be written quickly and easily, such as a program to write music in a simple notation (using a suck-blow input) and have it played and displayed in conventional stave notation.

Another sophisticated aid, though one not originally designed for airflow control, is by Scully (1978). This is a microcomputer based system for a cerebral palsy patient capable only of operating a switch with her knee; it permits her to select and display on a television screen any one of 1200 pre-stored words, or any other word spelt out by herself.

Our own work is currently directed towards interfacing the airflow control system described with a computer terminal, so that the operator could control (via volume) the position of a cursor on a C.R.T. Typical applications will depend on whether the terminal operates in an alphanumeric or a graphic mode:

Alphanumeric mode:

- Retrieval of textual material stored in computer files
- Text composition and editing
- Interactive studying; tests or examinations
- Conversation with other terminal users

Graphic mode:

- Drawing and modification of diagrams
- Graphic design
- Computer art
- Graph plotting

A different application may be found to artificial larynges. (Sekey, 1977). We proposed to tap the airflow at the stoma of a laryngectomee, and derive from it control signals for both the pitch and the intensity of an electronic phonation source. Here flow control seems more appropriate.

A further dimension may be added to the control capability by employing a split oral/nasal mask, such as e.g. the Electro-Aerometer made by the Danish company F-J Electronics A/S. Nasal flow may then govern, for example, the horizontal movement of a cursor, with the vertical position adjusted orally. Under these conditions one must, of course, provide the subject with means of turning off the various controls so as to allow him to just breathe...

In summary, we hope that analog control will prove to be a significant step towards the ultimate goal of enabling the severely paralyzed, in Traynor's (1977) elegant words, to "juggle text without juggling paper".

IV. References

Folkard, T. (1977). Personal Communication.

Howlett, J. & T. Folkard (1977): "MAVIS" (Unpublished description, also reported in the New Scientist, 13th October, 1977, p. 86.)

Lywood, D. W. & J. J. Vasa (1974): "Computer-terminal operating and communication aid for the handicapped", Medical and Biol. Engng., Vol. 12, pp. 693-696, Sept. 1974.

Legal, J. & N. Peteleski (1977): "A powered wheelchair for a high-level quadriplegic incorporating head and breath control and a respiratory support system", Fourth Annual Conf. on Systems and Devices for the Disabled, Seattle, WN, June, 1977.

Scully, T. (1978): "Microcomputer communication for the handicapped", People's Computers, Vol. 6, No. 5, March-April 1978, pp. 34-44.

Sekey, A. (1977): "Towards a speech support system for laryngectomees", Research grant application submitted to the N.I.H. and the Amer. Cancer Soc.

Traynor, C. D. (1977): "A breath-controlled computer data entry system", Fourth Annual Conf. on Systems and Devices for the Disabled, Seattle, WN, June 1977.

INITIAL EVALUATION OF THE IRM/NYU VOICE CONTROLLED POWERED WHEELCHAIR AND ENVIRONMENTAL CONTROL SYSTEM FOR THE SEVERELY DISABLED

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THE IRM/NYU VOICE CONTROLLED POWERED WHEELCHAIR AND ENVIRONMENTAL CONTROL SYSTEM IS UNDERGOING CLINICAL EVALUATION BY QUADRIPLEGIC PATIENTS. THE EXPERIENCE GAINED FROM THIS EVALUATION WILL BE INCORPORATED INTO A NEW AND MORE ADVANCED SYSTEM. INDICATED IMPROVEMENTS ARE: SIMPLIFICATION OF THE DISPLAY PANEL; GREATER PROTECTION AGAINST UNINTENTIONAL OPERATION FROM NORMAL CONVERSATION; VOICE CONTROL OF JOG TIME INTERVAL; AND INCREASED VOCABULARY TO PROVIDE ADDITIONAL FUNCTIONS. NO DIFFICULTIES HAVE BEEN EXPERIENCED WITH THE VOICE CONTROL SYSTEM IN THE PRESENCE OF TRAFFIC NOISE OR WITH NORMAL VARIATION IN INDIVIDUAL SPEECH PATTERNS. VOICE CONTROL OF A POWERED WHEELCHAIR REQUIRES A LONGER TRAINING PERIOD THAN BREATH CONTROL BECAUSE OF THE NEED TO READILY RECALL THE VOCABULARY AS REQUIRED. VOICE CONTROL OF THE ENVIRONMENTAL CONTROL SYSTEM IS SUPERIOR TO BREATH CONTROL BECAUSE IT PROVIDES MANY MORE DEGREES OF CONTROL FREEDOM.

CATEGORY: Device Development ☒ Research Study ☐	INTENDED USER GROUP: QUADRIPLEGICS AND OTHER SEVERELY DISABLED
STATE OF DEVELOPMENT: Prototype ☒ Clinical Testing ☒ Production ☐	AVAILABILITY OF DEVICE: AVAILABILITY OF CONSTRUCTIONAL DETAILS:
AVAILABLE FOR SALE: Yes ☐ No ☒ Price:	FOR FURTHER INFORMATION CONTACT: INSTITUTE OF REHABILITATION MEDICINE, N.Y. UNIV., 400 EAST 34TH STREET, NEW YORK, N.Y. 10016

RECENT PAPERS [1,2] DESCRIBED THE IRM/NYU VOICE CONTROLLED POWERED WHEELCHAIR AND ENVIRONMENTAL CONTROL SYSTEM FOR THE SEVERELY DISABLED. FIGURES 1 AND 2 SHOW THE PRINCIPAL COMPONENTS OF THE SYSTEM. THE SYSTEM IS NOW UNDERGOING EXTENSIVE CLINICAL EVALUATION BY QUADRIPLEGIC AND OTHER SEVERELY DISABLED PERSONS.

A TEST AREA HAS BEEN ESTABLISHED AT THE INSTITUTE WHERE PATIENTS LEARN TO OPERATE THIS AND OTHER SYSTEMS AS PART OF THEIR THERAPY. THE TEST AREA IS STAFFED BY EXPERIENCED OCCUPATIONAL THERAPISTS WHO ARE AVAILABLE TO TRAIN AND SUPERVISE THE PATIENTS. IN THE TEST AREA, THE VOICE RECOGNITION SYSTEM HAS BEEN EQUIPPED WITH THE PERIPHERAL DEVICES THAT A PATIENT MIGHT WANT TO HAVE IN HIS HOME (SEE FIGURE 2), FOR EXAMPLE: A DIAL TELEPHONE, TELEVISION SET, RADIO, DISTRESS ALARM, PAGE TURNER, READING LAMP, ETC.

TO DATE AT LEAST 10 QUADRIPLEGIC PATIENTS HAVE UTILIZED THE SYSTEM AND THE RESULTS HAVE BEEN VERY ENCOURAGING. THE SYSTEM HAS OPERATED TROUBLE-FREE SINCE ITS COMPLETION IN JULY OF 1977. DURING THIS PERIOD THE WHEELCHAIR WAS DISMANTLED AND FLOWN FROM NEW YORK TO DENVER, COLORADO AND BACK, AND SUBSEQUENTLY TRANSPORTED, WITHOUT CRATING, BY TRUCK FROM NEW YORK TO MIAMI AND BACK. THE EXPERIENCE GAINED FROM THE CLINICAL EVALUATION IS BEING INCORPORATED INTO A SPECIFICATION FOR A NEW AND MORE ADVANCED VOICE CONTROL SYSTEM. SOME OF THE PROPOSED IMPROVEMENTS (AND THE REASONS THEREFORE) ARE DESCRIBED IN THE FOLLOWING:

DISPLAY

<u>EXISTING SYSTEM</u>: ALL OF THE WHEELCHAIR CONTROL "DIRECTIONS" ARE PRINTED ON THE FACE OF A SMALL DISPLAY PANEL SHOWN ADJACENT TO THE RIGHT ARMREST OF THE POWERED WHEELCHAIR IN FIGURE 1. THIS PANEL IS SHOWN ENLARGED IN FIGURE 3. A SMALL INDICATOR LED (LIGHT EMITTING DIODE)

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FIGURE 1: THE IRM/NYU VOICE CONTROLLED POWERED WHEELCHAIR

IS LOCATED ON THE PANEL IN FRONT OF EACH WORD. WHEN THE PATIENT UTTERS A FIRST DIRECTION (FOR EXAMPLE, FORWARD) INTO THE MICROPHONE, THE LED IN FRONT OF FORWARD IS ILLUMINATED TO INDICATE THAT THE DIRECTION HAS BEEN RECOGNIZED. THIS PERMITS THE OPERATOR TO VERIFY A COMMAND BEFORE IT IS EXECUTED, PREVENTING THE POSSIBILITY OF HIS BEING SURPRISED BY AN UNEXPECTED ACTION. HE THEN UTTERS A SECOND DIRECTION (FOR EXAMPLE, GO), AND THE APPROPRIATE CONTROL CIRCUITRY IS ACTIVATED. THE TWO WORD SEQUENCES PROVIDE PROTECTION AGAINST MISRECOGNIZED AND POSSIBLE DANGEROUS COMMANDS AND ALLOW THE OPERATOR TO CHANGE OR CANCEL A COMMAND BEFORE IT IS EXECUTED.

PROPOSED IMPROVEMENT: CLINICAL EXPERIENCE WITH THE CHAIR HAS INDICATED THAT ONCE THE OPERATOR BECOMES FAMILIAR WITH THE OPERATION OF THE SYSTEM, CONTINUOUS STARING AT THE CONTROL PANEL DURING EACH MANEUVER BECOMES A HINDRANCE-- IT ACTUALLY SLOWS DOWN THE ABILITY TO MANEUVER. THIS SITUATION IS ANALOGOUS TO WHAT OCCURS WHEN ONE LEARNS TO DANCE. DURING THE LEARNING PHASE THE LEARNER WATCHES HIS FEET AT EACH STEP. AS SOON AS THE STEPS HAVE BEEN MASTERED, CONTINUED GAZING AT ONE'S FEET IS A HINDRANCE.

THE DISPLAY PANEL SHOWN IN FIGURE 3 WILL BE RETAINED FOR TRAINING PURPOSES. A SMALL AUXILIARY DISPLAY WILL BE MOUNTED ON THE GOOSENECK WHICH SUPPORTS THE MICROPHONE. THE DISPLAY WILL CONTAIN ONLY A "READ" AND "REJECT" INDICATOR AND AN INDICATOR FOR EACH OF THE THREE OPERATING MODES. THESE ARE PROBABLY ALL THE INDICATORS THAT THE TRAINED OPERATOR REQUIRES.

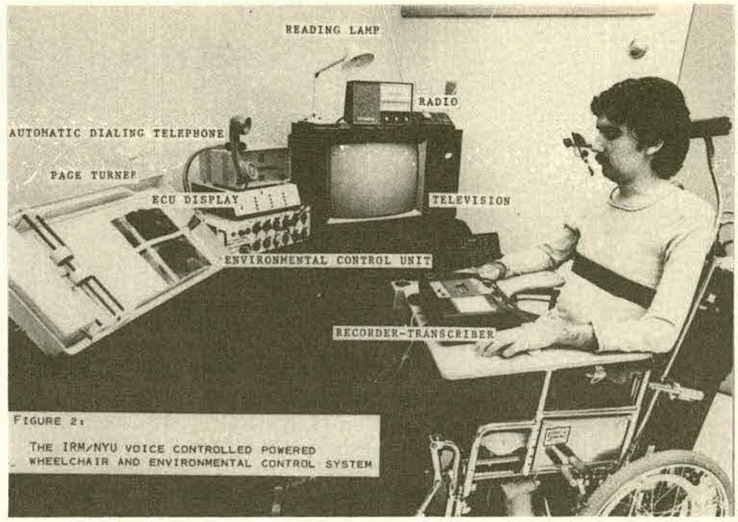


FIGURE 2: THE IRM/NYU VOICE CONTROLLED POWERED WHEELCHAIR AND ENVIRONMENTAL CONTROL SYSTEM

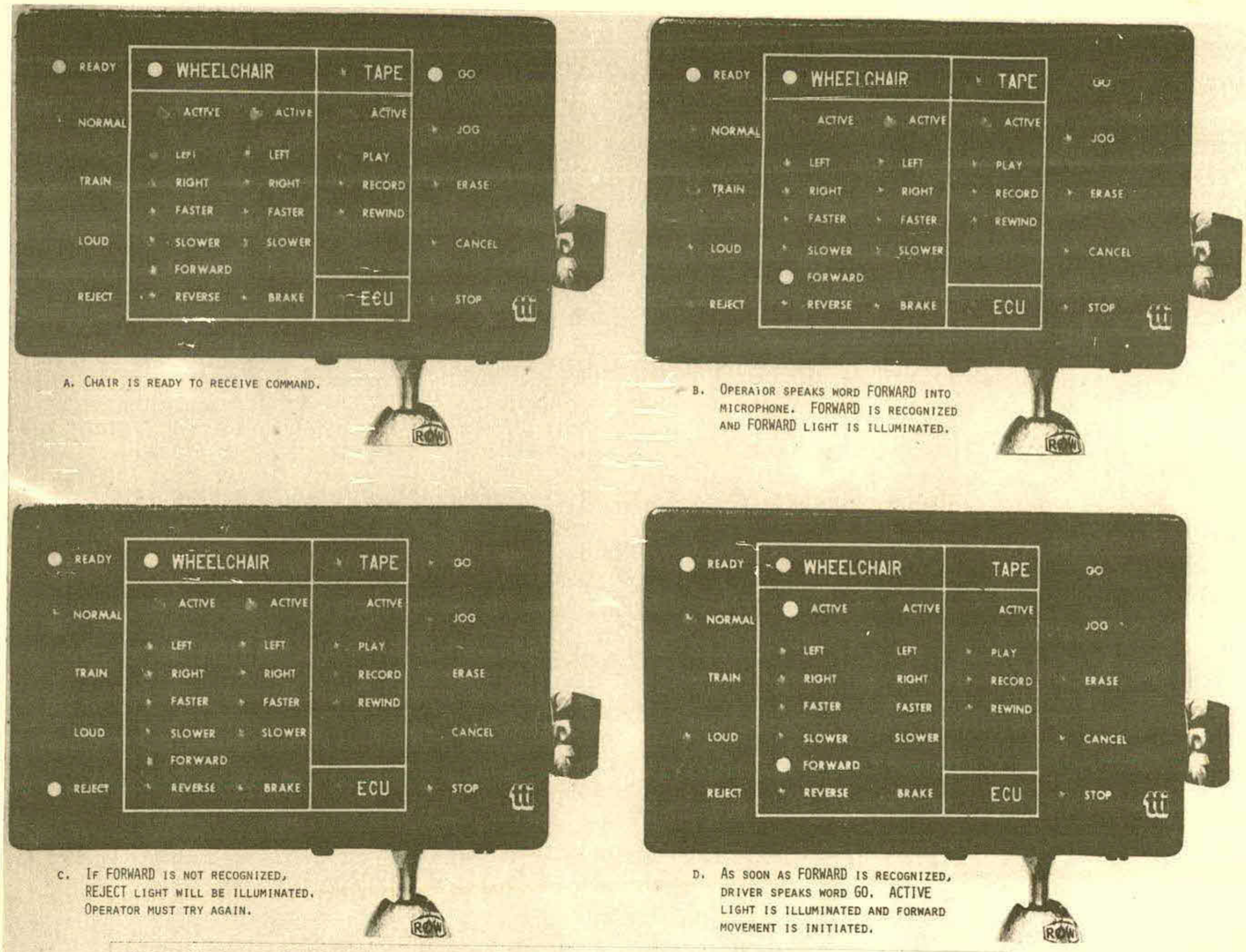
THIS SMALL PANEL, POSITIONED DIRECTLY IN FRONT OF THE OPERATOR, ENABLES HIM TO PAY STRICT ATTENTION TO WHERE HE IS TRAVELING. THERE IS NO NEED TO LOOK AT THE MAIN DISPLAY PANEL UNLESS A MALFUNCTION OCCURS.

FUNCTIONAL MODES OF OPERATION

EXISTING SYSTEM: EACH OF THE THREE FUNCTIONAL MODES OF OPERATION--WHEELCHAIR, TAPE RECORDER, AND ENVIRONMENTAL CONTROL (ECU)-- IS ACCESSIBLE WHEN THE UNIT IS TURNED ON. TRANSITION FROM ONE FUNCTIONAL STATE TO ANOTHER IS ACHIEVED BY SPEAKING THE WORD FOR THE FUNCTION FOLLOWED BY GO. FIGURE 4 IS A STATE DIAGRAM REPRESENTATION OF THE THREE FUNCTIONAL MODES OF OPERATION. THE CIRCLES REPRESENT THE POSSIBLE STATE OF THE SYSTEM. THE ARROWS SHOW THE POSSIBLE PATHS FOR CHANGING FROM ONE STATE TO ANOTHER. THE WORDS ALONG THE PATH SHOW THE VOICE INPUT NECESSARY TO CAUSE SUCH A TRANSITION.

PROPOSED IMPROVEMENT: THE POSSIBILITY EXISTS THAT THE OPERATING MODE MAY ACCIDENTALLY BE CHANGED BY EXTRANEOUS CONVERSATION OF THE OPERATOR. FOR EXAMPLE, SUPPOSE THAT THE VOICE CONTROLLED SYSTEM WERE OPERATING IN THE ECU MODE. THE OPERATOR MAY IN CONVERSATION USE THE SENTENCE, "THOUGH CONFINED TO A WHEELCHAIR, JOHN WAS ABLE TO GO EVERYWHERE." THE OPERATING MODE MIGHT SUDDENLY CHANGE TO THE WHEELCHAIR MODE, MUCH TO THE SURPRISE OF THE OPERATOR.

TO MAKE THE MODE CHANGE REQUIREMENT MORE RESTRICTIVE, IT IS INTENDED TO CHANGE TO A THREE-WORD SEQUENCE FOR CHANGING OPERATING MODES INSTEAD OF THE PRESENT TWO-WORD SEQUENCE. IT IS BELIEVED THAT THE THREE-WORD SEQUENCE WILL PROVIDE THAT REQUIRED SAFEGUARD. THE MODE CHANGE REQUIREMENTS COULD, IF DESIRED, BE MADE EVEN MORE RESTRICTIVE BY REQUIRING THAT THE MODE CHANGE COMMAND SEQUENCE BE RE-INITIATED IF MORE THAN A PREDETERMINED NUMBER



A. CHAIR IS READY TO RECEIVE COMMAND.

B. OPERATOR SPEAKS WORD FORWARD INTO MICROPHONE. FORWARD IS RECOGNIZED AND FORWARD LIGHT IS ILLUMINATED.

C. IF FORWARD IS NOT RECOGNIZED, REJECT LIGHT WILL BE ILLUMINATED. OPERATOR MUST TRY AGAIN.

D. AS SOON AS FORWARD IS RECOGNIZED, DRIVER SPEAKS WORD GO. ACTIVE LIGHT IS ILLUMINATED AND FORWARD MOVEMENT IS INITIATED.

FIGURE 3: COMMAND SEQUENCE FOR FORWARD MOVEMENT OF THE IRM/NYU VOICE CONTROLLED POWERED WHEELCHAIR.

OF REJECTS OCCUR DURING THE SEQUENCE. PRESENT EXPERIENCE SEEMS TO INDICATE THAT THIS GREATER RESTRICTION IS NOT NECESSARY.

"JOG" CAPABILITY

A. JOG TIME INTERVAL

EXISTING SYSTEM: THE SIX DESIRED WHEELCHAIR ACTIONS ARE: FORWARD, REVERSE, LEFT, RIGHT, FASTER, AND SLOWER. USE OF THE COMMAND JOG WILL CAUSE THE ACTION FOR ONLY A SHORT PERIOD OF TIME. THE DURATION OF THE JOG TIME INTERVAL CAN BE VARIED IN 10 STEPS FROM 200 MILLISECONDS TO 2 SECONDS. HOWEVER, THE DURATION OF THE TIME INTERVAL IS PRE-SET BY A THUMBWHEEL AND IS NOT UNDER THE OPERATOR'S CONTROL.

LEFT JOG AND RIGHT JOG WERE INCORPORATED INTO THE SYSTEM TO ENABLE THE OPERATOR TO MAKE MINOR COURSE CORRECTIONS WHILE ENROUTE. FORWARD JOG ENABLES THE OPERATOR TO "INCH" HIS WAY UP TO A TABLE. FASTER JOG OR SLOWER JOG PROVIDES THE OPERATOR WITH INCREMENTAL VARIATIONS OF SPEED.

PROPOSED IMPROVEMENTS: GREATER MANEUVERABILITY WOULD BE POSSIBLE IF THE OPERATOR COULD VARY THE JOG DURATION INTERVAL BY VOICE COMMAND. FOR EXAMPLE, WHEN TURNING FROM A STANDSTILL AT A GIVEN POWER SETTING, THE FRICTIONAL DRAG OF THE FRONT SWIVEL WHEELS CAUSES THE CHAIR TO MOVE AT A SLOWER SPEED THAN WOULD BE POSSIBLE IF THE TRAVEL WERE IN THE FORWARD DIRECTION. ONCE OUT OF THE TURN AND TRAVELING STRAIGHT, THE CHAIR WILL PICK UP SPEED PROPORTIONAL TO THE POWER SETTING. MANEUVERABILITY WOULD BE GREATLY IMPROVED IF THE OPERATOR COULD UTILIZE A LARGE POSITIVE INCREMENT OF POWER WHILE GOING INTO A TURN, TO BE FOLLOWED BY AN EQUAL NEGATIVE INCREMENT WHEN COMING OUT OF THE TURN.

THE "JOG" CAPABILITY WILL BE EXPANDED SO THAT THE OPERATOR MAY SELECT BY VOICE A SHORT, MEDIUM, OR LONG JOG DURA-

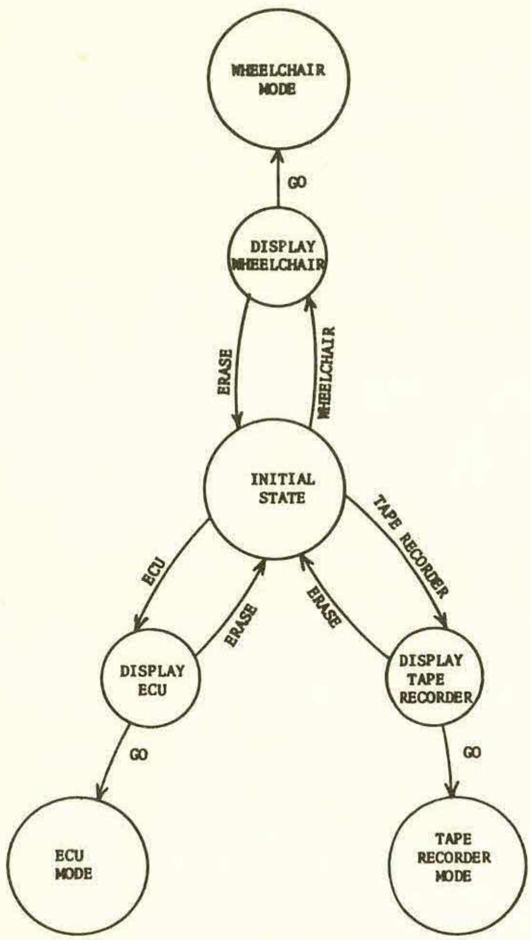


FIGURE 4: STATE DIAGRAM FOR THE THREE FUNCTIONAL MODES OF OPERATION OF THE IRM/NYU VOICE CONTROL SYSTEM

TION AS HE MANEUVERS. THE MEDIUM JOG WILL BE TWICE AS LONG AS THE SHORT JOG; THE LONG JOG WILL BE THREE TIMES AS LONG AS SHORT JOG. THE ACTUAL TIME DURATION OF THE SHORT JOG WILL CONTINUE TO BE ADJUSTABLE OVER A TEN TO ONE RANGE BY MEANS OF THE THUMBWHEEL SWITCH.

B. CONTINUED JOGGING

EXISTING SYSTEM: IN THE INITIAL DESIGN OF THE SYSTEM IT WAS THOUGHT THAT THE PROBABILITY OF WANTING TO JOG IN THE SAME DIRECTION A NUMBER OF TIMES IS NO GREATER THAN THE PROBABILITY OF WANTING TO ALTERNATE THE DIRECTION OF THE JOG. CONSEQUENTLY, USE OF THE WORD JOG CLEARS THE SECONDARY FUNCTION AT THE END OF THE JOG DURATION. THUS IT IS NECESSARY TO REPEAT THE DESIRED DIRECTION EACH TIME A SECONDARY JOG IS PERFORMED. FOR EXAMPLE, IF JOG IS USED AFTER RIGHT, AS SOON AS SINGLE INCREMENTAL MOVEMENT IS COMPLETED IN THE RIGHT DIRECTION, THE RIGHT COMMAND IS CANCELLED. IF IT IS NECESSARY TO CONTINUE TO JOG TO THE RIGHT, THE OPERATOR MUST REPEAT THE COMMAND RIGHT AND FOLLOW THIS WITH JOG.

PROPOSED IMPROVEMENT: PATIENTS HAVE INDICATED THAT THE NEED TO REPEAT THE COMMANDS RIGHT OR LEFT AFTER EACH JOG SERIOUSLY LIMITS THEIR MANEUVERABILITY, ESPECIALLY WHEN THEY ARE TRYING TO ENTER A NARROW DOORWAY FROM A NARROW HALLWAY. THE NEW PROGRAM WILL BE MODIFIED SO THAT THE SYSTEM WILL LOCK INTO A SECONDARY FUNCTION FOR PURPOSES OF JOGGING AND WILL REMAIN LOCKED IN UNTIL THE COMMAND ERASE IS GIVEN. THIS WILL PERMIT RAPID JOGGING IN THE REQUIRED DIRECTION.

VOCABULARY

EXISTING SYSTEM: THE PRESENT VOCABULARY CONSISTS OF 32 CONTROL WORDS OF WHICH EIGHT ARE DEDICATED TO THE WHEELCHAIR, FOUR TO THE RECORDER-TRANSCRIBER, FOURTEEN TO THE ENVIRONMENTAL CONTROL UNIT, AND FIVE (GO, STOP, ERASE, CANCEL, JOG) ARE APPLICABLE TO ALL THREE MODES.

THE EIGHT WHEELCHAIR CONTROL WORDS ARE WHEELCHAIR, LEFT, RIGHT, FORWARD, REVERSE, FASTER, SLOWER, BRAKE. NO CONTROL WORDS ARE AVAILABLE TO RAISE OR RECLINE THE BACK OF A WHEELCHAIR.

PROPOSED IMPROVEMENT: TWO ADDITIONAL CONTROL WORDS AND ASSOCIATED CIRCUITRY WILL BE ADDED TO THE SYSTEM TO RAISE AND RECLINE THE BACK OF A WHEELCHAIR WHICH HAS THE MOTOR DRIVEN MECHANISM FOR THIS FUNCTION. THIS WILL ENABLE THE USER TO ADJUST THE POSITION OF THE WHEELCHAIR BACK BY VOICE ALONE.

OTHER OBSERVATIONS AND COMMENTS

A. EFFECT OF ENVIRONMENTAL NOISE

THE EFFECT OF ENVIRONMENTAL NOISE ON THE IRM/NYU VOICE CONTROLLED SYSTEM HAS BEEN EVALUATED BY QUADRIPLEGIC PATIENTS AND ENGINEERING PERSONNEL IN A CLINICAL AREA 32 FT. LONG X 15 FT. WIDE X 7 FT. CEILING HEIGHT AND IN THE BUSY HALLWAYS OF THE REHABILITATION HOSPITAL AND ADJACENT RESEARCH WINGS. NOISE LEVELS OF UP TO 83 DB (AS MEASURED WITH A GENERAL RADIO MODEL 1551-B SOUND LEVEL METER) WERE GENERATED WITH FOUR RADIOS DISPERSED ABOUT THE AFOREMENTIONED CLINICAL FACILITY. THE RADIOS WERE TUNED TO TALK SHOWS AND AND MUSIC. NO DIFFICULTIES WERE EXPERIENCED IN UTILIZING VOICE COMMANDS. THE WHEELCHAIR WAS TAKEN OUT ONTO THE SIDEWALKS ADJACENT TO THE INSTITUTE (FIRST AVENUE AND 34TH STREET). THIS IS A VERY HEAVILY TRAFFICKED AREA IN MIDTOWN NEW YORK CITY. HERE TOO THERE WAS NO DIFFICULTY IN UTILIZING VOICE COMMANDS. HOWEVER, THE TYPE OF CONTINUOUS HIGH LEVEL NOISE PRODUCED BY THE ROTATING MIXING TANK OF A CEMENT TRUCK DID CAUSE SOME DIFFICULTIES WHEN THE CHAIR WAS VERY CLOSE TO THE TRUCK. THIS TYPE OF DIFFICULTY WAS ANTICIPATED IN THE DESIGN OF THE IRM/NYU SYSTEM, AND THE BREATH CONTROL capability previously reported[3] was incorporated into the voice control to provide an emergency override when necessary. (The breath control tubes are located in a convenient location very close to the microphone.) Thus when confronted by a failure of the voice control system (for whatever reason), the operator can continue on his way without any delay. This emergency override may be especially useful when the operator is attempting to cross a busy street and finds himself in close proximity to the siren of a police or fire vehicle.

B. Effect of Driving Surface

No difficulties were encountered with the voice controlled wheelchair on indoor surfaces including deep carpeting. City sidewalks, sidewalk cuts, ramps, and roads (even when bellied) are negotiated without difficulty. Irregularly sloping sidewalks are a problem and require an operator who is experienced with the voice control. The difficulty is inherent in the wheelchair itself since the front wheels are swiveled and tend to align themselves in different directions to accommodate the convolutions of the driving surface. These same wheels must be forced over the irregular driving surface by successively starting and stopping one or another of the rear driving wheels. An experienced operator can accomplish this task by proper utilization of the FORWARD JOG; RIGHT JOG; and LEFT JOG directions as required by the terrain.

C. Effect of Variation in Speech Pattern

In order to enhance the word recognition rate for each individual, the IRM/NYU system requires EACH operator to "train" the system to respond to his own characteristic pattern of pronunciation of the control vocabulary. This optimization is accomplished by the use of a training routine wherein the operator speaks 10 utterances of each word of the vocabulary into the system's memory prior to operation. The operator should try to vary his speech pattern to include the speech variations of which he is conscious.

The entire process requires as little as 5 minutes. This information is recorded and stored by a small tape cassette recording unit. This technique is extremely convenient when more than one individual utilizes the system as is the case at the Institute. Each operator prepares a tape and plugs it into the voice recognition unit as required. It has been our experience that tapes recorded 3 to 4 months previously operate properly, i.e. the speech patterns have not changed enough in this period to affect the voice recognition process. This has also been true for tapes that have been made in Italian, German, Mandarin Chinese and Cantonese Chinese. However, if a severe change does occur as is the case when an operator is suffering from a severe cold or respiratory infection, the chair is immediately "retrained" to accommodate the variation.

Some patients encountered difficulty with certain specific command words. For them, for example, RUN was more effective than GO, and TERMINATE was better than STOP. However, all of these differences are easily accommodated in the training routine. As has been noted by others[4], consistency in speech pattern increases as the operator gains experience in the operation of the system.

CONCLUSION

Prior to the development of the voice controlled system, quadriplegic patients at the Institute were trained to utilize the IRM/NYU Breath Controlled powered wheelchair and environmental control system. As a consequence, a number of patients have now become experienced in both the breath and voice controlled systems. At this early stage of evaluation, the natural reaction is to compare the two systems.

A brief consensus of patient opinion is:

1. The voice control requires a longer training period than the breath control because of the necessity to commit a vocabulary to memory and to be able to recall the proper control words at the appropriate time.

2. As a consequence of the above it appears easier to maneuver the breath controlled chair than the voice controlled chair.

3. Given adequate time to practice with the voice controlled chair, and assuming that the proposed improvements enumerated earlier are accomplished, the two wheelchairs would be equally maneuverable.

4. Voice control of the environmental control system is considered superior to the breath control because each peripheral device can be selected directly, thus eliminating the delay occasioned by the scanning routine utilized in most environmental control units. It is projected that this advantage would make voice control far superior to breath in future years when the anticipated increase in numbers of utilized peripherals becomes an actuality and the present minimal scanning delays become significantly longer. We are now beginning to

EVALUATE THE UTILIZATION OF VOCALIZED COMMANDS AT THE PATIENTS[3] BEDSIDE. WE ALSO BELIEVE THAT THE UTILIZATION OF VOICE CONTROL IN VOCATIONAL APPLICATIONS WOULD BE OF SPECIAL SIGNIFICANCE AS TIME IS MONEY IN A WORKING SITUATION.

FROM THE ENGINEER'S AND THERAPIST'S POINT OF VIEW, THE VOICE CONTROL IS SUPERIOR TO THE BREATH CONTROL BECAUSE IT PROVIDES MANY MORE DEGREES OF CONTROL FREEDOM, I.E., IT IS POSSIBLE TO PERFORM MANY MORE FUNCTIONS WITH A VOICE CONTROL THAN WITH THE BREATH CONTROL. FOR EXAMPLE, IN THE CASE OF THE IRM/NYU SINGLE TUBE BREATH CONTROL, IT IS NOT DIFFICULT FOR A PATIENT TO LEARN TO PRODUCE TWO REQUIRED LEVELS OF POSITIVE PRESSURE AND TWO NEGATIVE PRESSURES IN THE BREATH TUBE. THIS RESULTS IN ONLY FOUR DEGREES OF CONTROL FREEDOM. PATIENTS WERE NOT ENTHUSIASTIC ABOUT LEARNING TO PRODUCE THREE LEVELS OF POSITIVE AND NEGATIVE PRESSURE, AND SO TO OBTAIN MORE CONTROLS IT WAS NECESSARY TO ADD AN ADDITIONAL BREATH TUBE. HOWEVER, THE PRESENT VOICE CONTROL IS NOW UP TO 34 WORDS OR DEGREES OF CONTROL FREEDOM!

THE OCCUPATIONAL THERAPISTS LIKE THE VOICE CONTROL SYSTEM BECAUSE IT IS HYGIENICALLY BETTER. IT ELIMINATES THE NEED FOR BREATH TUBES OR STRAWS WHICH MUST BE CHANGED FROM PATIENT TO PATIENT, AND THE SPUTUM TRAPS. THE HYGIENIC ASPECT IS IMPORTANT ENOUGH THAT A SEPARATE DEVELOPMENT PROJECT HAS BEEN INITIATED TO DEVELOP A BREATH TUBE WHICH IS EASILY DISCONNECTED FOR CLEANING AND/OR STERILIZATION.

IN CONCLUSION, WE BELIEVE THAT VOICE CONTROL HAS A DEFINITE PLACE IN THE ARMAMENTARIUM OF INSTRUMENTATION FOR THE SEVERELY DISABLED. AS VOICE CONTROLLED INSTRUMENTATION IS FURTHER DEVELOPED AND UTILIZED BY PATIENTS, ITS VALUE FOR CONTROLLING LOCOMOTION, ENVIRONMENT, AND RECREATIONAL ACTIVITIES WILL BE FULLY REALIZED, AS WILL BE THE PSYCHOLOGICAL BENEFIT WHICH IT CAN IMPART TO THE DISABLED INDIVIDUAL.

ACKNOWLEDGEMENTS

THIS PROJECT HAS BEEN SUPPORTED BY GRANTS FROM THE CHARLES A. DANA FOUNDATION, THE HEARST FOUNDATION, MRS. HENRY L. MOSES, UNITED CEREBRAL PALSY RESEARCH AND EDUCATIONAL FOUNDATION, INC. AND THE REHABILITATION SERVICES ADMINISTRATION, DEPARTMENT OF HEALTH, EDUCATION AND WELFARE.

REFERENCES

1. RUSK, H.A., YOUDIN, M., SELL, G.H., CLAGNAZ, M., AND LOUIE, H., " VOICE CONTROLLED DEVICES FOR THE SEVERELY DISABLED," ACCEPTED FOR PUBLICATION IN JAMA.

2. YOUDIN, M., SELL, G.H., CLAGNAZ, M., LOUIE, H., AND KOLWICZ, R., " A VOICE CONTROLLED POWERED WHEELCHAIR AND ENVIRONMENTAL CONTROL SYSTEM FOR THE SEVERELY DISABLED," SUBMITTED FOR PUBLICATION TO THE ARCHIVES OF PHYSICAL MEDICINE AND REHABILITATION.

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," PROCEEDINGS OF THE 4TH ANNUAL CONFERENCE ON SYSTEMS AND DEVICES FOR THE DISABLED, SEATTLE, WASHINGTON, JUNE 1977, PP. 147-150

4. CLARK, J.A. AND ROEMER, R.B.," VOICE CONTROLLED WHEELCHAIR," ARCH.PHYS. MED. REHABIL. 58: APRIL 1977.

A MICROPROCESSOR ENVIRONMENTAL CONTROLLER FOR QUADRIPLEGICS

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McMaster University/Chedoke Rehabilitation Centre
Hamilton, Ontario, Canada

An environmental controller has been designed using consumer available components. Its flexibility, versatility, and reduced cost, are a direct result of using an isometric joystick, a microprocessor and software package in a configuration that lends itself very readily to change.

CATEGORY:	INTENDED USER GROUP: Functional Tetraplegics
Device Development ☒ Research Study ☒	AVAILABILITY OF DEVICE:
STATE OF DEVELOPMENT:	
Prototype ☒ Clinical Testing ☒ Production ☐	AVAILABILITY OF CONSTRUCTIONAL DETAILS:
AVAILABLE FOR SALE:	FOR FURTHER INFORMATION CONTACT: Ted Bojanowski Chedoke Hospitals P.O. Box 590 Hamilton, Ont. L8N 3L6
Yes ☐ No ☒ Price: N/A yet	

Introduction

In the past, environmental controllers for quadriplegics have been hardwired controllers or dedicated communications devices (4,5). Examples of the first case are devices for controlling various appliances, such as lights, radio, and television, and of the second; page turners or machines for typing (1). Some attempts have been made to integrate the two usually in a single cabinet, hand wired, and with programmed functions which are very difficult to change. This has resulted in systems that are inflexible and expensive, due to the limited number produced. A typical controller consisted of a matrix board whose size varied from machine to machine, each element in which corresponded to a specific function. The controller would scan the matrix, in various modes e.g.: horizontally, vertically, or diagonally, indicating the appropriate element with a lamp or L.E.D. and the patient would signal the end of a scan and an activation by means of a sip/puff or touch switch. The order of scanning was under the control of the machine, resulting in very slow and sometimes frustrating activity on the part of the patient if the incorrect element was chosen. The great expense was incurred due to the limited quantity of hardwired devices produced and due to the time required for program modification, if modification was possible at all.

The Micro-Computer Controller

With the advent of the microprocessor, "the computer on a chip", a radically different approach to the design of environmental controllers has resulted in another generation of machines. The controller developed in our laboratory, a microprocessor-based model, employs commercially available modules, currently on the consumer market; this makes the system relatively inexpensive (2). The programming is done in software which makes custom tailoring to a patient less expensive as well. The system can be broken down into the sections illustrated in figure 1.

Description of the System

The heart of the controller is an 8-bit 8080 microprocessor in the commercially available SOL-20 configuration offered by Processor Technology Corporation (3). The 8080 was chosen because it was recognized as an industry standard and because it was available on a commercial printed

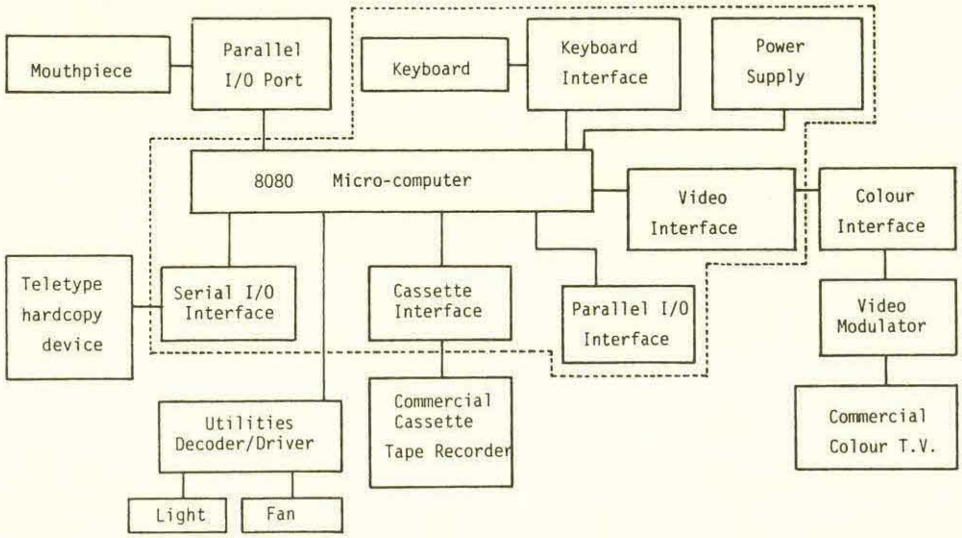

Fig. 1 Block Diagram of Environmental Controller

circuit configuration with all of the necessary support chips included to form a complete mass produced stand-alone computer.

This configuration, as well as additional support modules such as memory, floppy discs for extended memory and software packages is offered, fully constructed thorugh local "Computer-Mart" establishments in most large cities.

Our developmental system contained the 8080 microprocessor, a software monitor "Personality Module", built in Serial and Parallel I/O interfaces, a keyboard and associated interface and a T.V. interface all on one printed circuit board. The completed package contained the following items: the company's power supply, extender board to accommodate more plug-in modules and a case along with lab constructed mouthpiece transducer and associated A/D converters, colour generator, R.F. modulator, and commercial cassette tape recorder and colour T.V. set.

The aforementioned T.V. interface, in conjunction with the colour circuitry, R.F. modulator and commercial T.V. set, forms the display for the controller which replaces the conventional hard-wired matrix. In this system the grids and matrices are generated by the computer and may vary in size and shape depending on not only the number of elements of a sub group, such as Fan, Light, Toaster, etc. in the utilities group, but also on the capabilities of the particular patient in addressing the element.

Selection of the particular element in the grid is accomplished through the use of a computer-generated cursor, whose position and movement on the screen is completely patient controlled by an isometric joystick mouthpiece transducer. The mouthpiece consists of an acrylic rod, with a hole drilled down its centre and a conventional, removeable pipe stem at the user end. Close to the support and within the protective case which also contains the associated electronics and pneumatic switch (Fig. 2), are mounted four semiconductor strain gauges, 90° apart and connected as opposite pairs in two Wheatstone Bridges.

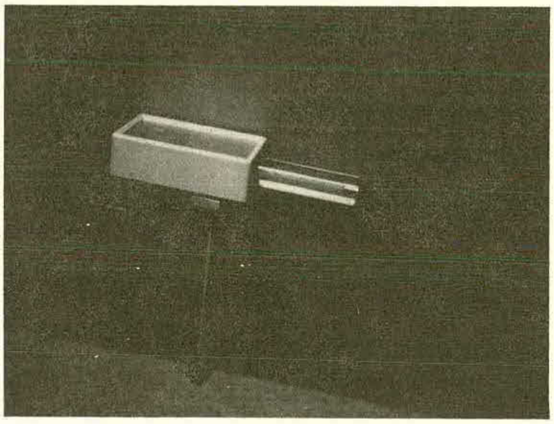

Fig. 2 Mouthpiece Transducer

These very sensitive transducers, in conjunction with the dimensions of the road, allow the forces on the piepstem to be monitored in 2-dimensions, without the physical movement of the pipestem. Just the forces exerted by the tongue or lips are enough to enable the selection of any element in the grid. The beam diameter, however, is large enough that should the mouthpiece be subjected to the forces of a great impact during the positioning by health care personnel, or dropped, the sensitive strain gauges would not be damaged. In the extreme case the pipestem might break, but provision has been made for its easy removal for cleaning or for the transfer of the mouthpiece to another patient. Since the end of the mouthpiece does not move appreciably and very litte force need be exerted, the patient need not grasp the pipestem with his teeth but can use his lips. It has been found that this greatly improves cursor control and reduces fatigue. The transducer was designed for use by the patient in the extreme situation; a functional tetraplegic. It can also be used by patients with less severe forms of paralysis.

The other blocks of the system are worthy of brief description. The data transfer rates of the Serial and Parallel interfaces are switch selectable and the pertinent software allows the controller to operate either in a stand alone mode, to be coupled to a hard copy device, such as a teletype, or to a larger computer (a PDP-11/10 in our case) as an intelligent terminal.

The cassette interface allows a commercial cassette recorder to act not only as a large capacity extended memory, but more so as an input for commercial consumer software programs such as the games; Star Trek and Lunar Lander and various mathematical packages. These are commercially available as pre-recorded cassettes for mass distribution at a nominal fee to computer hobbyists.

The television interface allows the computer operating parameters to be displayed and controller display matrix outputting to be accomplished on a standard television monitor. With the addition of a R.F. modulator (and optional colour circuitry if a colour display is desired), any standard television set as commonly found in most patient hospital rooms or in the home, with the R.F. modulator connected directly to the antenna terminals, can be used as a display device. Here, especially, the economic result of using a mass produced item becomes clear. The price of this portion of the controller is reduced and also servicing and repairs are made easier. Since the T.V. set is unaltered in any way, it can also be used in it more conventional entertainment mode.

A separate port was constructed for the interfacing of appliances to the utilities section. From one port of 8-bits, with decoding, a possible (2^8) 256 devices can be connected and controlled. Since the 8080 in it simplest I/O mode can accommodate 256 I/O ports and up to nearly (2^{16}) 64K I/O ports in the extreme case, more than enough lines are available for practical purposes. Here again is demonstrated the extreme flexibility of a microprocessor based system. At present, sixteen devices have been decoded and two, a light and fan, for demonstration purposes have been interfaced to the 117V. mains to be controlled. Interfacing is through relays, in accordance with Ontario Hydro standards for hospitals.

Since the system is computer-based, the software is of prime importance in typing together all of the blocks of the system. In conjunction with the 2K bytes of monitor the SOL, located in EPROM (Erasable, Electrically Programmed, Read Only Memory) on the "Personality Module" (3) which provides many of the display and output formatting and drivers, the controller software is located in less than another 2K bytes of memory. In the developmental system this was a portion of RAM (Random Access Memory) with cassette tape used as permanent storage. In the software development, hardware interface stage, the controller was used as the developmental computer. For final packaged versions of the controller, the program will be burned into EPROM. The keyboard can also be eliminated, further reducing the cost. With the memory needed for the television display, the total memory used to date is less than 5K bytes. The 8080 is capable of addressing 64K bytes. It is clear that the full capabilities of the microprocessor are nowhere near exhaustion at this point in terms of software storage. As more memory is needed, as in the case of a very large and expanded system, memory boards, which can be plugged in like modules, can be purchased commercially from the "computer mart". Thus, the physical size of the system can be tailored to the physical needs and economic capabilities of the patient.

The displays, and corresponding functions, presently programmed into the system are shown in figures 3, 4 and 5.

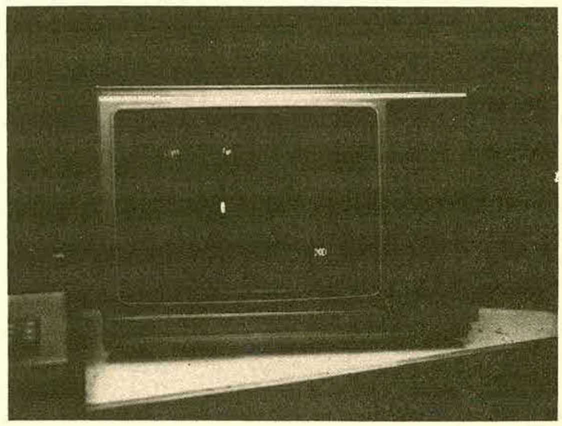

Fig. 3 Index Page Display

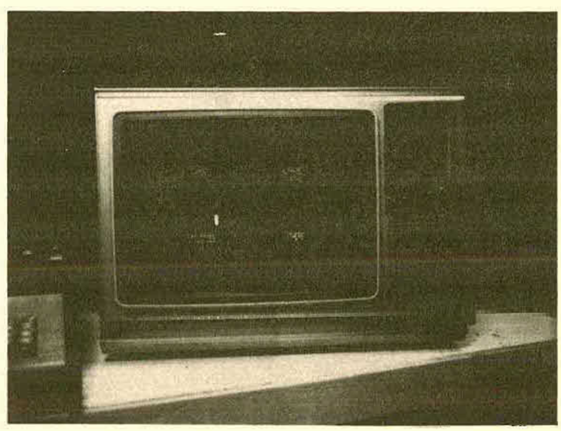

Fig. 4 Utilities Page Display

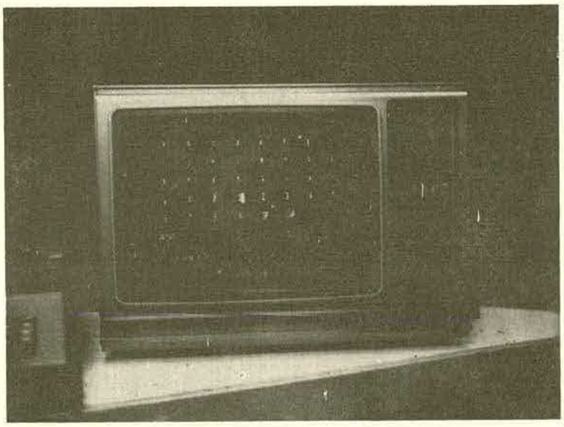

Fig. 5 Alphabet/Typing Page Display

Typically, if the patient desired to type a letter, he does so by first addressing the appropriate quadrant on the index page. By exerting a force on the pipestem he can easily move the cursor into the quadrant marked ALPHABET TYPING and by puffing, activates the machine to erase the old grid and replace it with the one shown in Fig. 5.

In the same manner, the appropriate letters, small and capital, numbers, and punctuation marks are chosen and text assembled on the four lines beneath the grid. These lines can be fully edited and corrected, and upon completion, be typed out on a hardcopy device by selecting the PRINT element of the matrix. In a similar fashion, appliances can be turned off and on. All referencing is done in terms of the index page (Fig. 3) and by selecting the proper category, further sub-indices and displays can be reached.

Results

Upon completion the system was tested with both normals and a quadriplegic patient. Because the operation of the utilities was fairly straight-forward, standard, five minute duration typing tests were administered, in the alphabet display/typing mode. After a number of practice sessions the patient, a high quad, could type approximately 25 character/min. with an 88% accuracy rate. At lower rates (20 characters/min) accuracies of 95% were achieved. A normal subject achieved 47 characters/min. with 96.7% accuracy. Further tests showed that for the quadriplegic, comfort in seating and mouthpiece positioning were the major factors in attaining speed and accuracy. More important than speed, however, was the patient's response to the system. He was very receptive to its use, adapting readily to it and he expressed the view that it was not boring. It appeared as a challenge to him. In the past, with other controllers, the patient had to wait for the machine to complete its cycle and so did not feel in total control of the device. With this system, the speed is dependent only on the patient (and in the early stages of use the speed of the machine's response had to be slowed down) and the onus is on him to choose what is to be executed next by his direct positioning of the cursor.

This random access of the desired function is a major source of the flexibility of the system in the patient's view. Software can be included that will allow an intelligent patient with a knowledge of computers, to program his own controller.

In conclusion, an environmental controller and communications device has been designed with a new philosophy in mind. Its modular approach, using commercially available blocks has resulted in a very versatile system at a reduced cost when compared with conventional controllers, and the nature of function selection by the patient, on a Random Access, has increased its flexibility manifold.

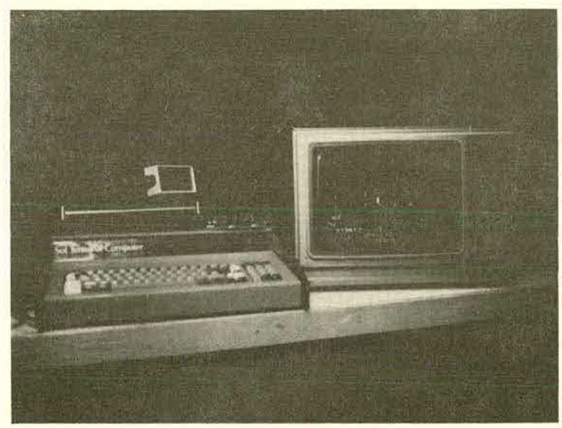

Fig. 6 Overall System

Acknowledgements

The support of the Physicians Services Inc. Foundation is gratefully acknowledged. One of the authors, Ralph Bloch, would like to thank the Canadian Life Insurance Association for a fellowship.

References

(1) Bloch, R.: "Design Considerations for an Environmental Control System for the Severely Handicapped" Proceedings of the Seminar on Electronic Controls for the Severely Disabled. Vancouver, British Columbia, Canada, 1974.

(2) Bojanowski, T.: "A Microprocessor Environmental Controller for Functional Tetraplegics" M.Eng. Thesis, in preparation, McMaster University, Hamilton, Ontario, Canada, 1978.

(3) SOL-20 Manual, Processor Technology Corporation, Emeryville, California, U.S.A., 1976.

(4) Staros, A; Peizer, E: "Veterans Administration Prosthetics Centre Research Report", Bulletin of Prosthetics Research, Department of Medicine and Surgery, Veterans Administration, Washington D.C., 1975.

(5) Vanderheiden, G.C.; Raitzer, G.A.; Kelso, D. P. and Geisler, C.D.: "A Portable Non-Vocal Communication Prosthesis for the Severely Physically Handicapped" Proceedings of the Seminar on Electronic Controls for the Severely Disabled. Vancouver, British Columbia, Canada, 1974.

COMPUTER ASSISTED COMMUNICATION SYSTEM

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Bell Laboratories, Inc., Murray Hill, New Jersey 07974

ABSTRACT

This paper describes a continuing series of experiments aimed at providing improved communications for non-vocal, motion-impaired people. Special keyboards, coupled with a computer which permits one or two keystrokes to call out a complete phrase, have been enthusiastically used by children at the United Cerebral Palsy Association in Edison, New Jersey. After a brief review of previous systems, the current one, which uses a stand-alone microcomputer, is described.

CATEGORY: Device Development ☒ Research Study ☒	INTENDED USER GROUP: Non-Vocal, Motion Impaired People
STATE OF DEVELOPMENT: Prototype ☒ Clinical Testing ☒ Production ☐	AVAILABILITY OF DEVICE: AVAILABILITY OF CONSTRUCTIONAL DETAILS: See below.
AVAILABLE FOR SALE: Yes ☐ No ☒ Price:	FOR FURTHER INFORMATION CONTACT: Mr. D. A. Giorgi Room 4A-231 Bell Laboratories, 6 Corporate Place Piscataway, NJ 08854

Introduction

Earlier versions of a computer assisted communication project have demonstrated that people with significantly impaired fine muscular control and without vocal speech can, with the computer's help, communicate at a level previously impossible. The manual skills required for normal use of a typewriter -- loading paper, sorting pages, correcting errors, filing and retrieving -- are beyond the capabilities of many handicapped people. A computer system with special keyboards, TV type displays, a page printer, an editor, and a file store circumvents these problems. This report describes a new system, taking advantage of new hardware and new software which has become available since this project was started in 1974.

One major advantage of this new model, which uses a UNIX*[3] operating system, is that it is open ended. That is, it is easy to add more and more sophisticated facilities as the development and abilities of the users warrant it. Having the UNIX operating system also makes it easy to add new input facilities. For example, the severely limited user might steer a cursor over a "keyboard" pictured on the upper part of the display. Properly designed this would make typing available to people unable to use even the special keyboard.

Other advantages are:

The new system is stand alone rather than being a low priority user on a busy remote time-sharing service.

There can be up to 4 simultaneous users with different levels of sophistication.

Hard copy is now available.

Earlier systems

The first experiment (1) used double keystrokes to recall previously stored high usage phrases. The results were so encouraging that a special computer terminal was developed and installed in early 1975 at the United Cerebral Palsy Association, Edison, New Jersey.

* UNIX is a Trademark of Bell Laboratories

Figure 1

A commercial terminal which uses a TV display with large letters was modified by adding a special keyboard, Figure 1. The keyboard has large easily depressed buttons, well separated and mounted behind an aperture plate. Some of the children can use a finger while others use a head pointer.

Professional speech pathologists at the United Cerebral Palsy Association conducted trial evaluations and were responsible for interactions between the CACS and the handicapped. User interactions have been reported[1] earlier with a brief description of the CACS MOD 2 version.

The studies and experiences learned from use of the prototype system evolved into a design for a stand-alone microcomputer system third edition MOD 3 which includes some new features and improved capabilities which will be described.

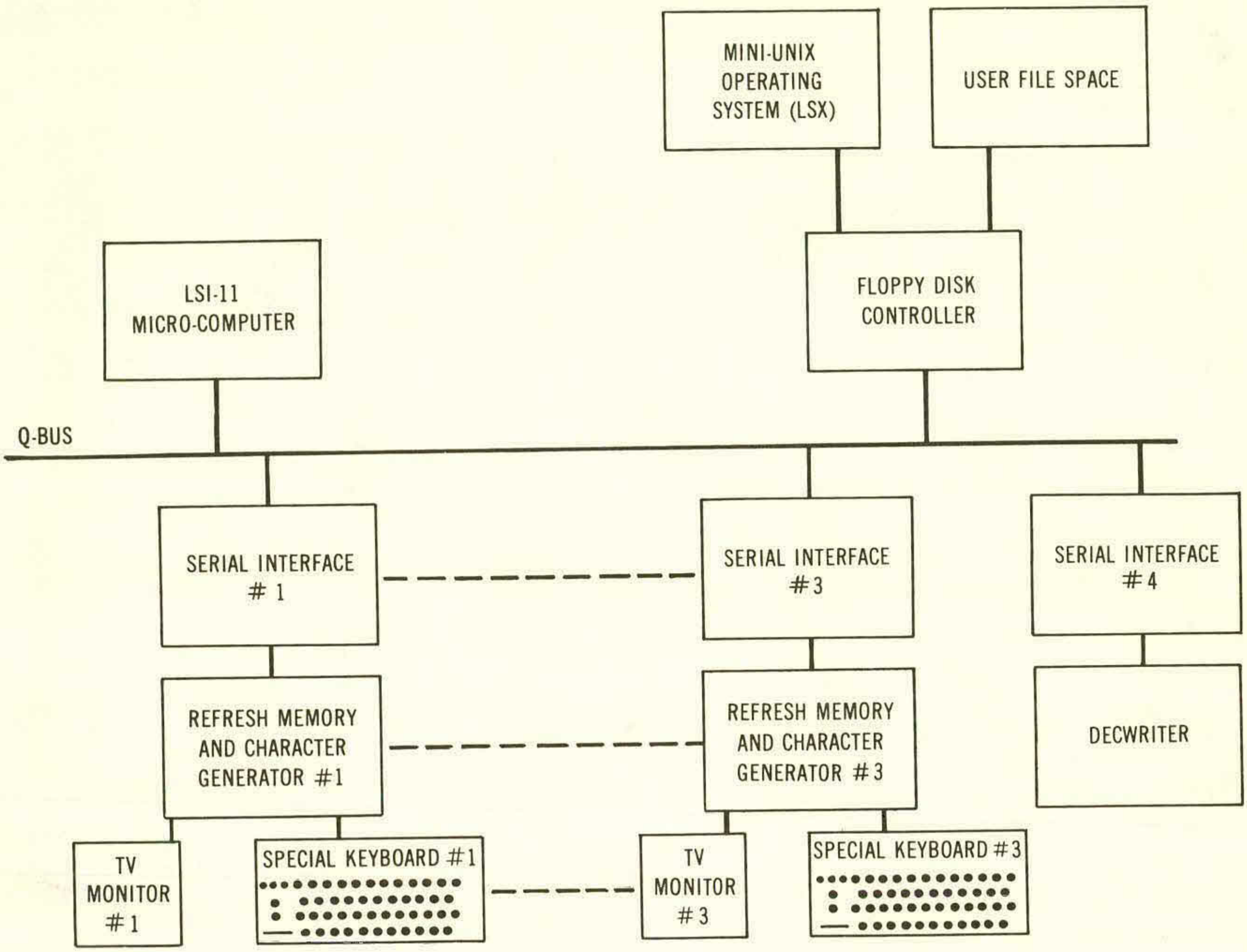
The New Computer Assisted Communication System (CACS) Mod 3

The declining prices of microcomputers and the continuing developments of efficient software has made it possible to develop a new stand-alone CACS. The new CACS is implemented on an LSI-11[2] microcomputer (see Figure 2) and runs on LSI UNIX (LSX).[3,4,5] The use of LSX as a stand-alone system makes CACS more economical and practical, improves terminal response time, and easily allows additional features to be added in the near future.

An LSI-11 with two Pertec floppy-disk drives, used for mass storage, has been assembled to interface with newly designed special keyboards, commercial TV monitors and printer. The keyboard is connected to the LSI-11 with a serial interface and a video generator to produce the display.

Software

The CACS object program runs in slightly less than 8 K bytes of memory. The source code is written in C language[6] and is about 1000 lines long. The use of LSX permits many UNIX programs to be used without modification, facilitating continued software support. For a single user,



COMPUTER ASSISTED COMMUNICATION SYSTEM (CACS) MOD 3
FIGURE 2

there are nearly 250 K available characters of combined active scratch pad, phrase book, message files, frequent use phrases, and word endings. For a four-user system, there are nearly 60 K characters per user.

Scratch Pad

The scratch pad is maintained on disk, so the limit is slightly less than the amount of space left on the disk. The scratch pad can be as large as 5000 or more characters for a multi-user system.

Phrase Book

The phrase book will allow a user to store nearly 1000 uniquely named phrases. Each phrase may be up to 255 letters long, including spaces and punctuation. There is currently no provision for protection of phrases, but if found necessary, will be implemented identically to the Fortran[1] version.

Message Files

The three message files provided for in the original CACS still remain, but there is no longer a limit, other than total spaces available, as to how long a message can be. This means that, instead of using all three message files for a single message, the user can put quite a long message into a single file. The only apparent difference (to the user) is that the "message file full" diagnostic would never occur.

Frequent Use Phrases

The internal form of the frequent use phrases has been changed so that it may be both updated and modified more easily, and by either the user or the therapist or instructor, instead of requiring assistance from a programmer.

Word Ending Letters

The word ending letters have also been redesigned for ease of modification by either the user or instructor.

Input Buffer

The size of the input buffer has also been increased. The new size is 255 characters, more than twice the previous size. This permits more text to be entered at a time (i.e.) with fewer keystrokes.

Text Printer

A new capability has been added which allows the user to have his message or text printed out on a commercial printer (Decwriter LA 305). This relieves the instructor from the task of providing handwritten copy to the user.

Possible Future Project Activities

1. CACS has some rudimentary editing commands which may not be versatile enough for a more advanced user. A major update would permit use of a UNIX text editor as a subsystem of CACS, providing an extremely powerful test preparation whereby the user can become a productive writer.

2. The inclusion of some computer games that would allow user-to-user interactions and test user reflexes.

Conclusions

The experiences learned from earlier studies has led to a practical stand-alone design, with standard interfaces, and components which can easily be purchased and assembled.

We believe, based on the experience with selected non-vocal,motor-impaired, cerebral palsy children at the Middlesex Center, that CACS has demonstrated:

1. a means for improving and expanding communication capabilities,
2. a tool for advancing educational training facilities, and
3. providing a means to develop skills which will lead to a more productive life.

It should be emphasized that the design, fabrication and support of the system was done by Bell Laboratories; professionals of the Middlesex Cerebral Palsy Center have and will continue to conduct trial evaluations and are responsible for interactions between the system and the handicapped individuals.

Acknowledgements

This project was done with and supported by the Frank B. Jewett Chapter No. 54, Telephone Pioneers of America, R. W. Ketchledge, president.

Many people have been involved in the CACS project since its concept in early 1974. During the early years of development, the following key people volunteered their talents and effort to the project organization, coordination, system design, special keyboard and other hardware interface design and software development: Messrs. H. D. Hurlburt, J. F. Nicholas and A. C. Price. More recently Messrs. R. W. Lucky, C. Christensen, D. R. Weller, R. V. Anderson, P. S. Kubik, C. V. Connolly and Heinz Lycklama have contributed to the new design interfaces, and rewriting of the software.

References

1. Tallman, T. M., Computer Assisted Communication System, Proceeding of the 1976 Conference of Systems and Devices, Tuffs University, Boston, Massachusetts, June 10 through 12, 1976.

2. Digital Equipment Corporation, LSI-11 Processor Handbook, 1976.

3. Thompson, K. and Ritchie,D. M., The UNIX Time-Sharing System CACM July 1974.

4. Lycklama, H., UNIX On A Microprocessor, to be published in The Bell System Technical Journal, July-August 1978.

5. Lycklama, H. and Christenson, C., A Minicomputer Satellite Processor System, to be published in The Bell System Technical Journal, July-August 1978.

6. Ritchie, D. M. and Kernighan, B. W., The C Programming Language, Prentice-Hall, Inc., 1978.

APPLIANCE TO CONTROL DROOLING IN CP CLIENTS AND OTHERS WHO LACK CONTROL OF SALIVA DUE TO ACCIDENT OR TRAUMA

Jerry R. Green

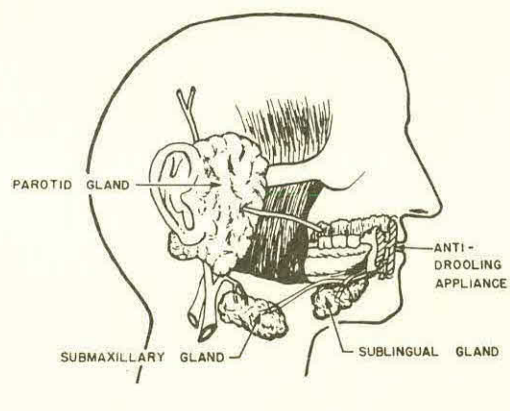
Cerebral Palsy Research Foundation of Kansas, Inc.

A device was designed to control drooling associated with the cerebral palsied and others who lack saliva control. The appliance is an orthodontic device which closes the mouth and creates a saliva reservoir which, in turn, develops a swallowing reflex. Simple and inexpensive (approximately $200), the device is fitted by an orthodontist and is worn by the client until his drooling is controlled and/or extinguished through reflexive swallowing. Up to the present time, two clients, one a child and one an adult, have utilized the device with successful results. The adult CP client has experienced a total extinguishment of his drooling and is now a viable candidate for vocational placement. The device has significant implications for those who are prohibited from functioning in vocational and/or social environments due to their drooling problem.

CATEGORY: Device Development ☒ Research Study ☐	INTENDED USER GROUP: Cerebral palsied and others who lack saliva control AVAILABILITY OF DEVICE: Immediate
STATE OF DEVELOPMENT: Prototype ☐ Clinical Testing ☒ Production ☐	AVAILABILITY OF CONSTRUCTIONAL DETAILS: Immediate
AVAILABLE FOR SALE: Yes ☒ No ☐ Price: $200	FOR FURTHER INFORMATION CONTACT: Cerebral Palsy Research Foundation of Kansas, Inc. 4320 East Kellogg Wichita, Kansas 67218

The problem

In many instances, drooling is noted in individuals with CP and, in some instances, those with traumatic brain injuries and strokes. It is basically due to the lack of innervation to the muscle groups involving sucking, chewing and swallowing. This group includes the lips, tongue, palate, other facial muscles as well as those of the pharynx. The loss of innervation may include both motor and sensory nerves which makes it difficult for the person to know when saliva collects and flows from his mouth. The major glands which produce and secrete saliva are the parotid, submaxillary and sublingual (fig. 1). There are other minor glands which also produce saliva. The parotid gland duct ends at approximately the second molar, the submaxillary duct ends inside the teeth, while the sublingual glands are immediately under the tongue.



SECTIONAL VIEW

ANTI-DROOLING APPLIANCE

FIG. I

Mode of operation

The concept of the appliance is essentially to close the oral opening, thereby building a reservoir of saliva and triggering off a swallowing reflex. It is designed to be held in by both the upper and lower teeth and to extend in an up-and-down measurement to the upper limits of the gum ridges. It extends laterally to the first molar on either side, therefore not extending past the salivary ducts of the parotid glands (fig. 2).

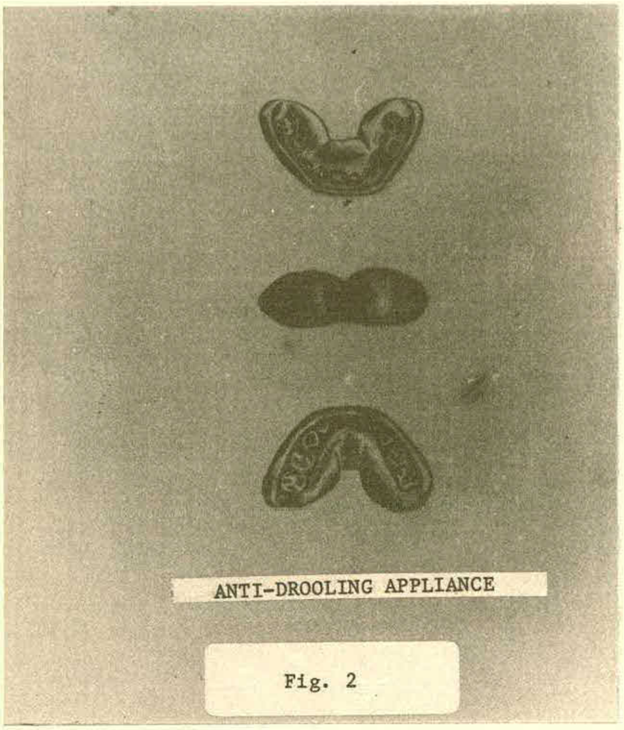


Fig. 2

State of the art

Research of the literature was performed prior to developing the appliance. Nothing could be found relative to appliances of this type. A great deal of information was found on surgical procedures which rerouted the salivary ducts toward the pharyngeal area (2,3). Some successes of this procedure were noted but the disadvantages were: (1) they could not take care of all the saliva which obviously is necessary to digestion, and (2) the individual continued to drool to some extent. The other disadvantage was the pain involved. The procedure did nothing to strenghten the muscles used in chewing, sucking, swallowing or normalize the reflex swallowing mechanism. In most cases, the person still drooled but to a lesser degree.

Applications and results

The idea for such an appliance was first conceived for a 13 year old, who as an infant had undergone severe head trauma due to a fall from a highchair. He drooled very heavily to the point that his shirt front and pants were saturated to the knees. This posed a number of problems. He was subjected to numerous colds. He was, most of the time, uncomfortable; he had an odor and he was also unable to check out books from the library or to do desk work. He was greatly embarrassed in public. Conventional techniques proved unsuccessful (4). This included using a vibrator on his lips, constant reminders to close his lips, having him on a special program of chewing, sucking and swallowing exercises designed to strenghten those muscles involved in closure and swallowing. These exercises were good only at the time of the exercise; however, no carry-over or spontaneity was noted.

Experimental observations

The second application of the device was associated with an adult cerebral palsied individual who drooled excessively. This severely disabled person was being considered for employment at Center Industries Corporation. His drooling precluded any serious consideration of him as a viable candidate for employment. His drooling created a health and safety hazard not only for himself but also for those around him. Additionally, his clothes were constantly wet which resulted in embarrassing odors and a general feeling of shame for the individual. Upon being fitted with the appliance, the client experienced a complete termination of his drooling after a few days (fig. 3).

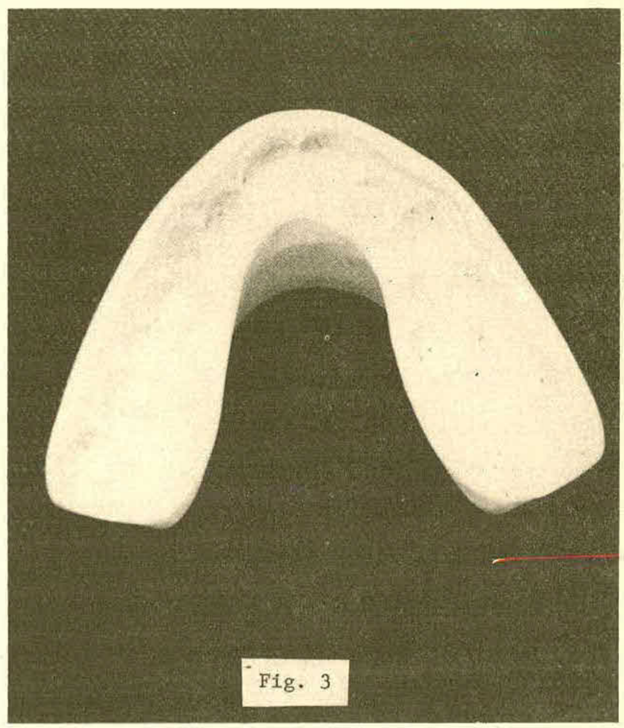


Fig. 3

Case history of drooling device application

The following data gives a chronological breakdown of this particular application:

12-07-77		Picked up his mouth piece - did not wear.
12-08-77	8:00 - 10:00AM	Wore mouthpiece with no drooling.

12-08-77	10:00 - 10:10AM	Removed mouthpiece for coffee break. Some drool ing noted by subject.
	10:10 - 11:30AM	Wore mouthpiece - no drooling.
	11:30 - 12:00PM	Removed mouthpiece for lunch.
	12:00 - 2:30PM	Wore mouthpiece-drooling started slacking off."
12-09-77	8:00 - 10:00AM	Wore mouthpiece with no drooling.
	10:00 - 10:10AM	Removed mouthpiece for coffee break. "I don't recall any drooling". Some drooling may or may not have occurred.
	10:10 - 11:30AM	Wore mouthpiece - no drooling.
	11:30 - 12:00PM	Removed mouthpiece for lunch. "Might have drooled a little."
	12:00 - 2:30PM	Wore mouthpiece - no drooling.
12-10-77		Did not wear mouthpiece at all this day, no drooling.
12-11-77		Did not wear mouthpiece at all this day, no drooling. Roommate observed "I saw a lot of difference in your drooling this weekend."
12-12-77	8:00 - 10:00AM	Wore mouthpiece with no drooling.
	10:00 - 10:10AM	Removed mouthpiece for coffee break. No drooling occurred.
	10:10 - 11:30AM	Wore mouthpiece - no drooling.
	11:30 - 12:00PM	Removed mouthpiece for lunch. No drooling occurred.
	12:00 - 2:30PM	Wore mouthpiece - no drooling.
	2:30 - 2:40PM	Removed mouthpiece - no drooling.
	2:40 - 4:30PM	Removed mouthpiece - no drooling.
12-13-77	The same as 12-12-77	
12-14-77	The same as 12-12-77	
12-15-77	8:00 - 10:00AM	Wore mouthpiece - no drooling.

From 12-15-77 to the time of this writing, subject has not worn the mouthpiece and no evidence of drooling has been observed since that time. 12-21-77

The following concepts are suggested as to why the appliance is successful. Upon close observation it was noted a great deal of added movement in the labial area. The individual apparently moves his lips because of the foreign material in that area and is much more sensitive. In any event he was exercising those muscles dealing with lip closure and swallowing. As stated above, the major theory of the appliance is that it creates a reservoir that will then trigger off the swallowing reflex mechanism. It is also believed there is both a positive and negative psychological effect. The positive effect is that an individual does not drool and is able to participate in activities that he had been unable to do in the past. The negative effect is that some clients are embarrassed with any type of appliance despite the control of drooling. So far we have noted positive effect on our clients. They have not objected to the device and have been happy with the results.

Fitting procedures

Often the individual who drools has oral hygiene problems, such as cavities, sore gums, halitosis and others. The first process is to make sure that the client's teeth and gums are healthy and clean and that proper dental care has been given. He should first be taken to the dentist and all other problems taken care of. The client can then be taken to the orthodontist, who takes impressions of both upper and lower dentures and gums as well as taking careful measurements of the parotid duct openings in relationship to the teeth. Once the mold is made the orthodontist will complete the appliance and insure proper fitting. The cost for the appliance is approximately $200.00.

Discussion

The appliance is made from a soft but firm polyethylene material that is comfortable to the gum ridges and does not create sores, irritation, etc. It can be made any color that the person may want. Suggested colors are pink or flesh-like color, clear or white. The clear material draws much less attention and looks better than other colors.

It must be considered that there is some disadvantage to the appliance. First, the person must breathe through his nose, therefore colds and congestions must be watched carefully. Secondly, the person cannot eat or talk while wearing the appliance. Thirdly, you must have the person's cooperation and understanding of the appliance and its uses.

The suggested approach is to have the client wear the appliance at two hour intervals, (usually two hours in the morning and two hours in the afternoon). Careful records should be maintained daily to note drooling with the appliance. If possible the amount of drool is important to document. It is, naturally, more difficult to keep exact swallowing data on the client in the work environment except noting the amount of drooling, if any.

Attention should also be given to the maintenance of the appliance. After each time it is worn, it should be scrubbed with hot water, toothpaste or a mouthwash. Most orthodontists will supply a carrying case for the appliance. It also must be washed thoroughly. Teeth and gums should also be inspected often to insure that no irritation or infection is taking place. Although the appliance has been subjected to limited research, it has been highly successful for our client population.

References

1. Bateson, Malcolm C.
Salivary Symptoms in Parkinson Disease by Malcolm C. Bateson, Frank B. Gibberd, and Robert S. E. Wilson. Archives of Neurology, Vol. 29, pp. 274-275, October 1973.

2. Robson, Martin C.
A Simple Technique to Treat Drooling: Lip Resection and Muscle Flaps by Martin C. Robson, William J. Hagstrom, Stuart J. F. Landa, and Lee E. Edstrom. British Journal of Plastic Surgery, Vol. 29, pp. 304-308, 1976.

3. Wilkie, Theodore F.
The Surgical Treatment of Drooling by Theodore F. Wilkie. Plastic & Reconstructive Surgery, Vol. 45, No. 6, pp. 549-554, June, 1970.

4. Garber, Norman B.
Operant Procedures to Eliminate Drooling Behavior in a Cerebral Palsied Adolescent by Norman B. Garber. Developmental Medicine and Child Neurology, Vol. 13, No. 5, pp. 641-644, October, 1971.

5. Haberfellner, H.
Zur Behandlung des Speicheltraufelns zerebral geschadigter Kinder by H. Haberfellner and B. Rossiwall. Munch. med. Wschr., Vol. 118, No. 27, pp. 879-882, 1976.
(Article in German, summary given in English.)

APPLICATIONS OF PREDETERMINED TIME STANDARDS IN WORKSHOP SETTINGS

Hal C. Todd

Emory University Regional Rehabilitation Research and Training Center

There is definite need for a simple, quickly applied tool which can correlate performance of the handicapped individual with that expected of the normal worker and still be easily introduced to lay personnel. Efforts at both the Cerebral Palsy and Rehabilitation Centers in Atlanta demonstrated that MTM-3 (Third Generation of Methods-Time Measurement) satisfies these criteria. As every motion involved in an operation is detailed and a corresponding time value applied, the overall result reflects a normal rate of accomplishment more accurately than the usual methods and is especially useful in bidding jobs for the workshop. MTM-3 also has a place in the evaluation section to verify or correct existing standards for work samples and to develop more meaningful distribution charts related to the specific population at a center. As regards the motor skills MTM-3 yields a more accurate determination of the actual degree of disability than the existing AMA estimated percentages.

CATEGORY: Device Development ☐ Research Study ☒	INTENDED USER GROUP: Evaluators and contract administrators in sheltered workshops. AVAILABILITY OF DEVICE: N.A.
STATE OF DEVELOPMENT: Prototype ☐ Clinical Testing ☐ Production ☒	AVAILABILITY OF CONSTRUCTIONAL DETAILS: N.A.
AVAILABLE FOR SALE: Yes ☐ No ☒ Price:	FOR FURTHER INFORMATION CONTACT: Hal C. Todd, P.E. Emory University Regional Rehabilitation Research & Training Ctr. Atlanta, Georgia 30322

Introduction

There is a definite need for a simple but effective tool which can compare the performance of handicapped individuals with that expected from normal workers. To be useful, such a tool must be capable of being understood by a variety of rehabilitation personnel. In earlier work, using industrial engineering methods, Chyatte and Birdsong (1972) applied a predetermined time system, Methods-Time Measurement (MTM), in various clinical and research settings to study motor performance. The MTM system applied was extremely detailed and examined "microscopic" motion units. The MTM system, being presented here, has the capacity to examine "macroscopic" motion units. It is thus easier to learn and much more rapid in application.

As background for those unfamiliar with the subject, MTM is the Industrial Engineering acronym for Methods-Time Measurement. It is a discipline developed in the forties to establish work standards in industry and measure rate of production. It has been concisely defined as a procedure which analyzes any manual operation or method into the basic motions required to perform it, and assigns to each motion a predetermined time standard whose duration stems from the nature of the motion and the conditions under which it is made. Over the years, it has been refined and broken down into such extreme detail that an experienced practitioner has only to analyze the motions involved in an operation to synthesize the time required for its performance. The standard time is expressed in TMU's, or Time Measurement Units, of which there are 100,000 in an hour, 1,666.7 in one minute and 27.8 in one second. It is readily apparent that MTM is much more sophisticated than a stop watch which measures time in seconds or .01 minutes. A standard of performance can be established more quickly using MTM because the multiple observations involved in a stop watch study are eliminated as well as the need to "level" the watch reading times to an estimate of normal performance which, of itself, requires a great deal of experience.

The MTM-3 approach

Realizing that all operations need not be analyzed in the detail possible with basic MTM, the originators developed from it an intermediate set of standards designated as MTM-2 and, in 1970, the Swedish MTM Association further simplified the system into MTM-3. In a sense, it uses paragraphs rather than letters of the alphabet. Thus, it can examine motor performance groups rather than the finely detailed elements of the original MTM. Analysis time using MTM-3 is seven times faster than MTM and three times faster than MTM-2. Consisting of only four types of motion and including only ten time values, MTM-3 is obviously simple and its application is rapid and easily learned. (See Figure 1)

Range	Code	HA	HB	TA	TB
Up to 6"	-6	18	34	7	21
Over 6"	-32	34	48	16	29
		SF	18	B	61

HA -- Handle without correction

HB -- Handle with correction

TB -- Transfer with correction

TA -- Transfer without correction

SF -- Step and foot motion

B -- Bend and arise

Figure 1. MTM-3

MTM-3 consists of four categories of motion: handle, transport, step or foot motion, bend and arise. Only the first two are variables. Handle is a motion sequence involved in getting control of an object with the hand or fingers and moving it to a new location. Transport is a motion of the hand or fingers if no control is involved or has been achieved in the previous operation. Selection of the proper number of TMU's requires consideration of only two variables: whether it is a case of handle or transport, and the distance the object is moved. Each category is composed of four values. The use of the two lower values (HA, TA) in each category is determined by the distance involved and is either over six inches (-32) or up to six inches (-6). The use of the larger values (HB,TB) requires a "yes" answer to only one question: are any corrections necessary? Thus despite the small number of categories and time values, the rules of application are precisely established. Some operations are performed simultaneously. In such cases, only the higher value is considered. Machine time is covered at 27.8 TMUs per second.

As an example, the determination of the standard time allowed to print "Merry Christmas" in gold on red cocktail napkins using a hand operated hot transfer press follows:

	CODE	TMU's
1. R.H. reach to stack of folded napkins 24"	~~TA-32~~ omit	~~16~~ simo #9
2. Separate one from stack and transfer to press platen 10", fumble correction	HB-32	48
3. L.H. locate in preset guide 1", alignment correction	HB-6	34
4. R.H. reach to operating lever 15", no correction	~~TA-32~~ omit	~~16~~ simo #3
5. Pull forward 12" to print and hold	TA-32	16
6. Machine transfer time 2 seconds	(2 x 27.8)	56
7. Return lever to stop 12", no correction	TA-32	16
8. L.H. reach to printed napkin 15", no correction	~~TA-32~~ omit	~~16~~ simo #7
9. Pick up printed napkin and transfer to finished stack 10"	HB-32	48
10. Place neatly on stack 1", alignment correction	TB-6	29
Total TMU's per napkin		247
Increase 15% to compensate for personal time, rest and delay		284
Allowed hours per 1,000 napkins (100,000 TMU per hour)		2.84
Standard napkins per hour @ 100% (.1704 min. each) is		352

Applications

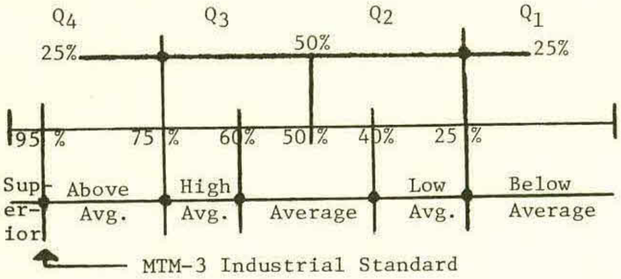
MTM-3 was applied to several practical situations to rate clients in the Work Activities Program of the Cerebral Palsy Center in Atlanta. Essentially, it was demonstrated that a comparison of client individual efficiency of performance, based on the several MTM-3 standards, provided a better index of disability than the AMA guide to impairment. The work potential of the clients for outside employment or for additional sheltered shop tasks was determined. A subsequent re-check this year, using evaluation work samples borrowed from the Atlanta Rehabilitation Center, confirmed the earlier conclusions.

Another use of predetermined time standards is in qualifying and quantifying abnormal, or subnormal, motor performance. Setting standards and timing or scoring task accomplishment quantifies individual ability. Such numbers are compared with the MTM-3 standard to arrive at a percentage (not percentile) thereof. Thus, scores near the 100% level signify performance comparable to persons with entry level skills in jobs requiring that activity. As an example, a 70% rating indicates that this person was functioning at a rate of accomplishment 70% of that expected on the job. However, a deeper analysis into performance on the detailed sub-units yields information as to which are being performed at an exceptionally slow pace. Certain poorly performed motions may thus be isolated and corrective treatment directed toward specific areas to improve overall performance.

MTM-3 is also useful in the establishment of standards for evaluation of work samples. This adjunct was clearly demonstrated in our work at the Atlanta Rehabilitation Center. Several work samples used there were from the Jewish Employment & Vocational Services (JEVS) System, with accompanying rating scales. However, the ratings supplied were based on a very limited number of clients at the JEVS facility and were not related to the population at large. Even a standardized dexterity test such as the Purdue Pegboard gives percentiles developed from eight groups of industrial and service workers and the clients passing through a rehabilitation center do not always fit neatly into such categories. Most evaluation work samples develop rating scales based on such either limited or specific populations. Percentile scales thus stem from an "after the fact" analysis of each category tested rather than from a comparison of a client's rate of accomplishment as a percentage of what should be expected from a normal individual working at a normal pace. Where possible, time limits should be established based on this industrial norm rather than on an overall completion time as this latter course only serves to distort the frequency distribution chart used to establish a rating system.

The application of MTM-3 to such work samples established an industrial standard and permitted the construction of a new six point rating system and frequency distribution charts directly related to the population at ARC. MTM-3 standards relate to the industrial population so that prediction of feasible outside employment is more accurate.

Within the rehabilitation process it is often useful to compare a client's performance with his peers. For convenience, a six point rating scale was adopted to show relative standing within that group. This scale uses the logically defensible quartile points as its foundation. Arbitrary levels assigned to the six categories are shown on the following chart:



Thus, 50% of the population rates in the "Average" category around the mean with 25% above and below the quartile cut-offs above and below this average. The High Average category isolates those slightly above the mean who may be helped to better performance. The bonus in this six point system is the "Superior" category, consisting of those people who attain or exceed the industrial standard established by MTM-3 analysis. Our findings indicate that generally, and with some practice, about 5% of our handicapped clients are initially capable of industrially competitive speed.

Conclusion

The proliferation of sheltered workshops and rehabilitation facilities now serving the disabled has expanded the competition for subcontracts from industry. It is extremely important, therefore, that the contract administrators of such workshops and facilities have some familiarity with the establishment of appropriate standards. Such information is especially useful during the contract bidding phase. Some contract administrators ask the industrial purchasing agent for information regarding the current cost of an item. They then proceed to submit a slightly lower bid for the production of the same item. Others follow the procedure of (a) securing a few sample items, (b) returning to their base, and (c) conducting relatively simple stopwatch studies to arrive at a bid price. Neither of these approaches presently meets CARF requirements. The use of the MTM-3 system would help to insure compliance with two CARF standards: (a) The use of "production rate norms based upon non-handicapped individuals" for contract bidding, and (b) the establishment of "competitive norms or industrial standards" for work samples in the evaluation area.

The more frequently this discipline is used, the easier it becomes to use it. Certain fringe benefits also accrue such as tabular standard data, development of a professional analysis sheet for reference, data for setting up balanced work stations on an assembly line, etc.

Acknowledgements

Sincere thanks are due Samuel B. Chyatte, M.D. and Stanley J. Smits, Ph.D. for their contributions to this paper and to the staff of the Cerebral Palsy and Rehabilitation Centers for their very kind cooperation.

References

1. Chyatte, S.B., and Birdsong, J.H., "Predetermined Motion Time Techniques as a Medical Measurement System," Industrial Engineering Research and Development, Reprinted from AIIE Transactions, 3, No. 3, September 1971.

2. Birdsong, J. H., and Chyatte, S.B., "Further Medical Applications of Methods-Time Measurement", The Journal of Methods-Time Measurement. Vol. XV, No. 2.

3. Antis, W., Honeycutt, J., & Koch, E., "The Basic Motions of MTM", The Maynard Foundation, 1973.

4. Todd, Hal C., & Chyatte, Samuel B., "Applications of Predetermined Time Standards in Sheltered Workshops", Numerous unpublished papers and presentations, 1975 through present.

5. Todd, Hal C., Lieffers, Rex C., "Methods-Time Measurement as Applied to the Purdue Pegboard", Vocational Evaluation and Work Adjustment Bulletin, 10, No. 2, June 1977

A SERVO-MECHANICAL STEERING CONTROL DEVICE FOR THE SEVERELY-HANDICAPPED DRIVER

Robert G. Wilson, M.S., M.A.*
Calman Gold, Ph.D. +

For the handicapped driver who cannot operate a conventional power steering wheel, a small circumferential servo-mechanical steering control has been designed to meet his remaining steering capability. The control, with its very low operatint force, provides precise steering similar to a standard steering wheel. By driving the servomotor with a pulse width modulation circuit, it is possible to achieve full torque at any rotational speed and to reduce both excessive thermal dissipation and inefficiencies in the system. Units of the control can be easily installed in any vehicle, i.e., vans and automobiles, and can be replaced with spare units by local labor in case of breakdowns or electrical failure.

CATEGORY: Device Development [X] Research Study [ ]	INTENDED USER GROUP: Drivers with weakness of the upper extremities; polio, spinal cord injury or Muscular Dystrophy cases.
STATE OF DEVELOPMENT: Prototype [X] Clinical Testing [X] Production [ ]	AVAILABILITY OF DEVICE: One year. AVAILABILITY OF CONSTRUCTIONAL DETAILS: Not at present.
AVAILABLE FOR SALE: Yes [ ] No [X] Price:	FOR FURTHER INFORMATION CONTACT: Robert G. Wilson, Jr. Institute of Rehabilitation Medicine New York University Medical Center 400 East 34th Street, N.Y., N.Y. 10016

Purpose

For more than ten years, we have been greatly concerned with the problem of providing a steering device for drivers with weakness of the upper extremities causing difficulty in rotating a conventional power steering wheel even with a very low effective valve at the base of its column.[1] At our Institute, several electrically-powered steering control devices have been fabricated and experimentally operated by our outpatients.

After an extensive evaluation of many different types of available steering controls created outside our Institute, we have agreed that a practical steering control should meet the following requirements: easy manipulation, precise steering, simple structure, ease of fabrication, low cost, simple installation in any vehicle, and ease of repairability by local mechanics.[2]

Description

To meet all the foregoing requirements, an I.R.M. Steering Control Device has been developed. It consists of two main parts: a) a mechanical control unit, and b) an electronic control unit. (Fig. I)

The mechanical control unit consists of a 2-potentiometer micro switch assembly, a gearmotor and its torque clutch, and a 3-gear and chain system in its own plastic housing mounted to the end of a steering column (it can permanently replace the standard steering wheel). On the front of the housing, there is a 6" handwheel with a small steering knob or a 3" crank handle. The handwheel is coupled to the potentiometer-switch assembly. (Fig. 2)

A mechanical feedback system is required. The system is composed of three gears and a looped chain. The first gear is attached to the end of the steering

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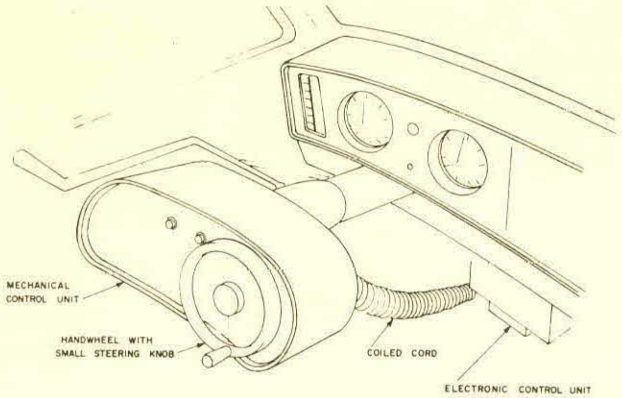

Figure 1. Perspective View of Servo-Mechanical Steering Control Device.

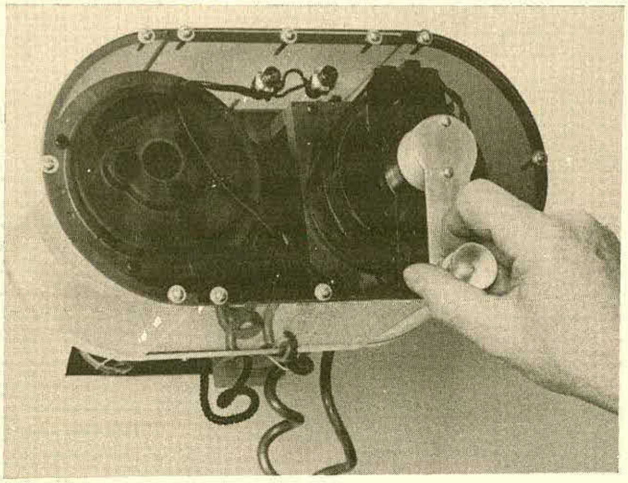

Figure 2. Driver's view of the I.R.M.Steering Control Device.

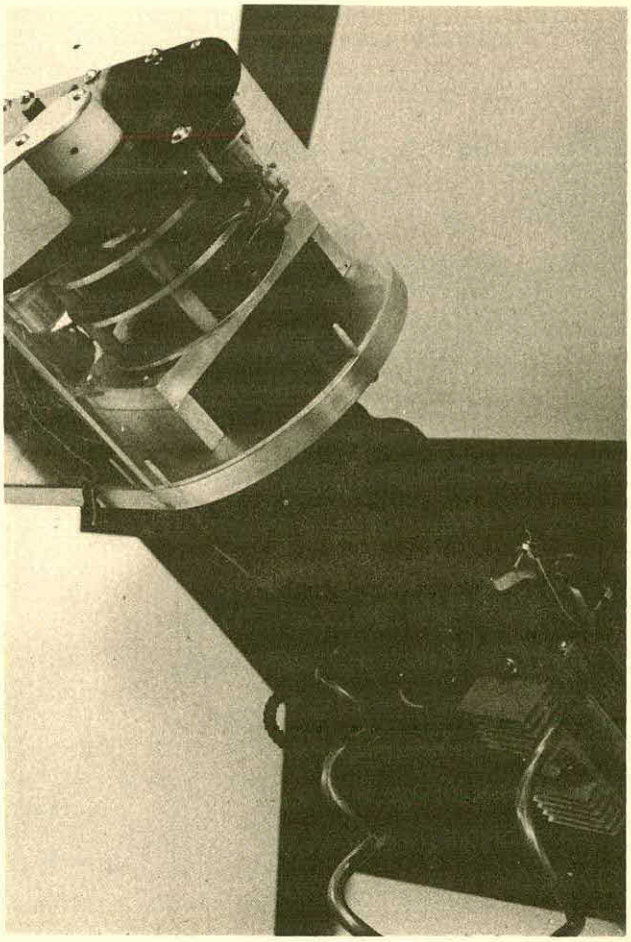

Figure 3. View of the Mechanical Control Unit and the Electronic Control Unit.

shaft in place of the removed steering wheel. The second gear is attached to the gearmotor (there is a torque clutch between the gear and the motor). The third gear is attached to the potentiometer-switch control. The movement of the steering control mechanism is thus synchronized with the motor and the steering shaft, thereby providing position feedback to the driver. (Fig. 6)

The electronic motor control circuitry operates from the 12 volt d.c. automobile electrical system, and is contained in a small box which can be located anywhere under the dashboard. The potentiometer-switch assembly, housed in the mechanical control, transmits input signals for the electronic control unit which determine both the direction and speed of rotation of the servomotor. The sense of potentiometer rotation from a "center-off" position determines the sense of steering rotation, while the angular excursion of the active potentiometer controls the speed of the servomotor.

The potentiometer voltage modulates the pulse width of a fixed frequency pulse train. The effective motor armature voltage, hence the speed, is governed by the pulse train duty cycle. The pulse train is applied to the servomotor by a Darlington power transistor switch. Because the transistor can provide any current required by the torque load on the motor, irrespective of the duty cycle, full torque is achieved at all motor speeds. Since the transistor is either fully on (saturated) or cut off, it dissipates very little power. (Fig. 3)

The circuitry is completely solid-state, and consists of two integrated circuits, a few transistors and a minimal number of passive components. The finalized design will be suitable for operation over the entire military temperature range of 55°C to + 125°C. The d.c. gearmotor is a pancake armature printed motor, thus providing rapid direction reversal, negligible inductive load on the switching transistors, and negligible contribution to the system inertia. (Fig. 4)

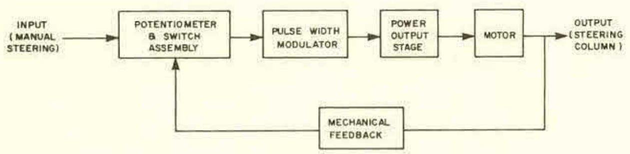

Figure 4. Schematic Diagram of Servo-Mechanical Control.

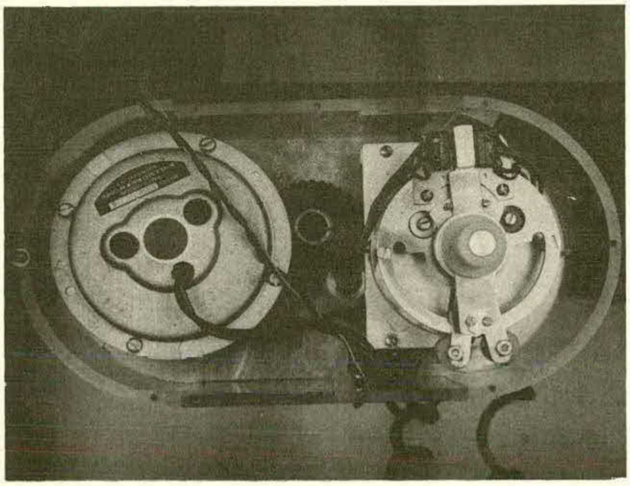

Figure 5. Front View of the Mechanical Control Unit with its crane handle and cover removed.

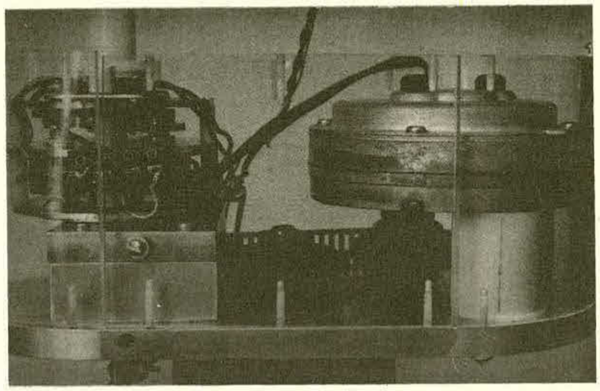

Figure 6. Top view of the Mechanical Control Unit showing a mechanical feedback - 3 gears and a looped chain with a Torque clutch.

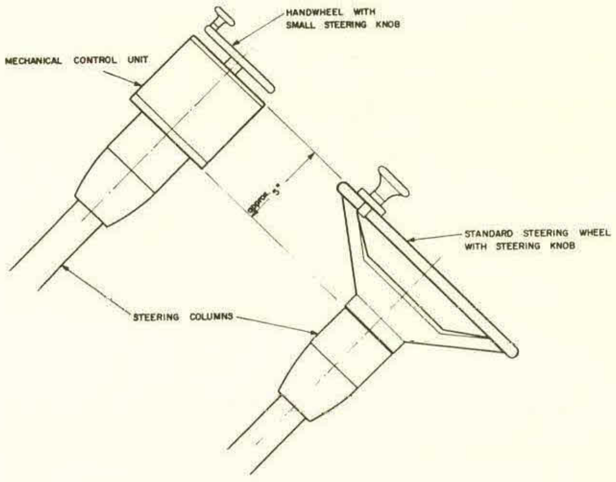

Figure 7. Side view of Mechanical Control Unit and standard steering wheel.

Operation

When a driver wishes to steer clockwise (or counter-clockwise), he moves the small steering knob. This causes a lever to make contact with one of two micro double-pole, single-throw switches and simultaneously rotates one of two potentiometers. This action turns on the motor to rotate the front tires clockwise (or counter-clockwise). When the driver ceases steering pressure on the knob, the steering knob is released from the switch and the potentiometer by means of a neg'ator extension spring. This causes the 2-potentiometer, 2-switch control to return automatically to its "center-off" position, thushalting steering wheel rotation. If the driver wishes to steer at a higher angular velocity, he simply turns the steering knob at his desired speed in order to accelerate the gearmotor. Only a 4-ounce force is needed to move the steering knob. (Fig. 5)

The ratio of revolutions of the steering shaft and the steering knob is 3-1/2:6. In many vehicles, it takes approximately 3-1/2 revolutions of the steering wheel to make a complete 80-degree turn of the front wheels. The diameter of the present standrad steering wheel is approximately 15 inches. That means a wheel circumference of 47.1 inches. Therefore, it takes a total of 164.85 inches to make the complete turn of the front wheels. To make a one-degree turn of the front wheels, a driver needs to rotate the steering wheel 15.75 degrees or 2.06 inches of the arc of the wheel's rim.

A driver needs to make six revolutions of the steering knob of the I.R.M. Steering Control Device in order to make a complete turn of the front wheels. The radius of the steering knob is 3 inches, which makes a circumference of 18.84 inches. Therefore, it takes a total of 113.04 inches for a complete turn of the front tires. The driver needs to make a 27 degree or 1.413 inch arc with the steering knob to make a one-degree turn of the tront tires.

The I.R.M. Steering Control Device requires a torque clutch to prevent stalling of its gearmotor when a driver makes a full right or left turn of the front tires. (Fig. 6)

The depth from the small steering knob to the base of the plastic housing and from the rim to the hub of the conventional steering wheel is approximately the same. [3] (Fig.7) A handicapped driver can easily reach the knob on the front of the plastic housing mounted on the distant end of the steering column in place of the removed conventional steering wheel. The handwheel can be located separately from the potentiometer-switch control and plastic housing by means of a flexible shaft in order to meet a severely-handicapped driver's need for remote-control manipulation from his best position. [4] (Fig.8) If a driver has only limited movements remaining of wrist and hand, he can still steer as if making a circle with a pencil. In this case, the steering knob can be moved closer to the center of the handwheel as much as 1" - 1-1/2", but the force of circumflexion would have to be a little higher - approximately 7 ounces more.

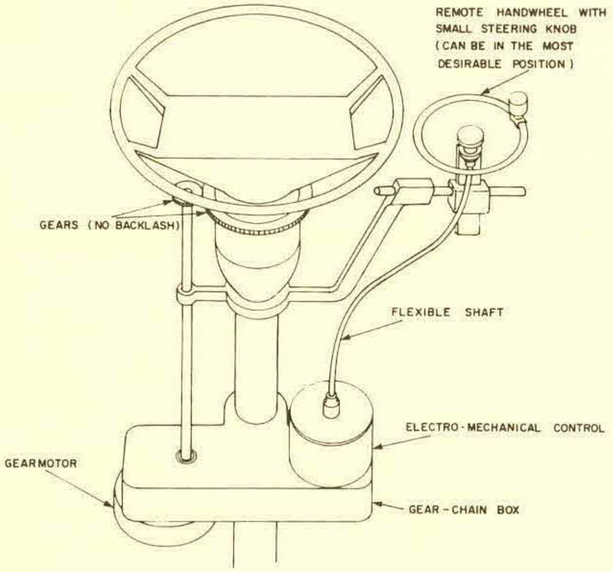

Figure 8. Handwheel with small steering knob can be in the most desirable position (with conventional steering wheel on).

Advantages

This I.R.M. Steering Control Device overcomes the disadvantages of earlier steering controls. The advantages are:

1. Easy Fabrication. Most required parts can be purchased off-the-shelf, i.e. gearmotor, gears, looped chain, electrical components and structural parts.
2. Low Cost. About $250 for all parts total. Also, only about 10-20 hours to build.
3. Easy Installation. The I.R.M. Steering Control Device can be installed in vehicles (vans and automobiles) in one hour.
4. Precise Steering. Already described.
5. Safety. The mechanism is completely [illegible]ded from unwanted substances, i.e.dirt, etc. Sa[illegible] operation over a wide range of environmental temperatures. Low thermal dissipation reduces probability of electrical failure.
6. Remote Handwheel with Steering Knob. Can be located in the position best meeting the handicapped driver's manipulative ability.
7. Fail-Safe Control. In case of electrical failure, the I R.M. Steering Control Device can function manually.
8. Repair by Local Mechanics. If an electronic control unit or an electromechanical control unit breaks down, it can be quickly replaced by local mechanics with a spare unit.

Evaluation and Future Design

This I.R.M. Steering Control Device was evaluated in the I.R.M. Laboratory and is being tested in a "Sportvan" by our I.R.M. Driving Instructor, in cooperation with our staff. After thorough testing, it will probably be marketed by an independent manufacturer and distributor.

An annoyance noted during our testing was the number of revolutions (6) required to turn the handwheel. A variable-ratio range gear may be used to reduce input turns, thus lessening both time and effort required for maneuvering the vehicle while providing a higher speed for the central range of steering, e.g., for straight-road steering corrections.

Acknowledgements

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Also, we wish to thank Mario Montreuil and Vincent Oberwiler of the Institute of Rehabilitation Medicine staff for their indispensable help in development and fabrication of the I.R.M.Steering Control Device.

References

[1] Lehneis, Hans R.; Hofkosh, Jack M.; Sapajlo, Jiri; Wilson, R.G.Jr. "Driving Aids: Design and Development," The Medical Clinics of North America, Vol. LII, No.3 May 1969. 689-692.

[2] Kope, David - Interview (Design Engineer & Manufacturer, Reedley, California) 1975

[3] Zegner, LeRoy - Personal communication (Consulting Engineer, Tannberg Building, Wayne N.J., 1976

[4] Scott, Charles M. "Driver Safety in Modified Vans" Bulletin of Prosthesis Research, Fall 1974, 377-387.

EFFECTS OF SPINAL CORD STIMULATION ON MODIFICATION OF MOTOR DISABILITY IN PATIENTS WITH UPPER MOTOR NEURONE DISORDERS

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Chronic, continuous electrical stimulation of the spinal cord of patients with upper motor neurone disorders has been successfully used to modify the motor performance of a group of 13 patients with multiple sclerosis, spinal cord injury and degenerative disorders. Principal motor effects observed over the period of observation (approximately one year for the longest duration stimulation) were the increased endurance of the patients, improved coordination, and decreased spasticity. The method appears to be effective if the patients have partial preservation of voluntary and reflex motor control.

CATEGORY:
- Device Development ☐
- Research Study ☒

STATE OF DEVELOPMENT:
- Prototype ☐
- Clinical Testing ☐
- Production ☒

AVAILABLE FOR SALE:
- Yes ☐ No ☐
- Price: N/A

INTENDED USER GROUP:
Paraparetics/quadriparetics with upper motor neurone lesions

AVAILABILITY OF DEVICE:
(commercial)

AVAILABILITY OF CONSTRUCTIONAL DETAILS:
N/A

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Introduction

We are all familiar with people who suffer from minor to major motor disorders due to upper motor neurone disorders such as patients with stroke, head trauma, Parkinsonism, cerebral palsy and spinal cord injury. These patients may have the common denominator of malfunction of the motor system, but underlying mechanisms are often quite different and complicated.

In this presentation we shall discuss the effects of spinal cord stimulation in patients with motor disorders related to demyelinating diseases, specifically, multiple sclerosis, injury to the spinal cord at multiple levels as a result of trauma, and degenerative disorders of the nervous system.

The application of epidural electrodes to certain sites in the spinal canal for the treatment of motor disorders was not its original objective, but rather to find a simpler means of estimating the effectiveness of the surgically placed dorsal column stimulator for the treatment of pain (1). Observation of other unexpected nervous system effects during these evaluations lead to new aveneues of research and treatment. The devices and techniques for spinal cord stimulation that have been used to treat the patients in this paper are reviewed elsewhere (2) . Briefly the system consists of electrodes in the epidural space of the thoracic spinal canal attached to a subcutaneous implanted receiver energized via an external apparatus consisting of a transmitter and an antenna. This basic system has been used with all of these patients.

Chronic spinal cord stimulation has been applied in 13 patients with multiple sclerosis, spinal cord injury, and degenerative disorders of the nervous system.

Patients

Multiple sclerosis: This group consists of 5 patients whose diseases had its onset from 1956 to as recently as 1971.

These patients all had considerable impairment of motor function from wheelchair-bound to walking with support aided by a cane or another individual (Table 1). Their ages varied from 28 to 55 years. The leading electrode placements (2 in each patient) varied from T-2 to T-4 and the trailing electrodes from T-3 to T-7 with the interelectrode distance ranging from segment up to 3 segments.

Spinal cord injury: There are 6 patients in this group but only 5 in whom the system was implanted. One patient (H.F.) was not implanted because of some loss of function during the period of trial stimulation. The onset of their injuries ranged from 1969 to 1975 and the levels of injury from C2-3 to T7-8. The motor impairment was considerable, varying from wheel chair bound with trace movement to walking with crutches or the aid of a walker (Table 2). Their ages ranged from 25 to 55 years. Placement of the leading electrode in this group ranged from T-2 to T-7 with trailing electrodes from T-4 to T-7 with the electrode distances varying from 1 segment up to 4 segments (most were 1 - 2 segments).

Degenerative disorders of the nervous system: There are 2 patients in this group, one is a 20 year old college student with Friedreich's ataxia clinically evident since 1965. He had his electrodes placed at T-1 and T-2. The other patient is a 65 year old female with familial spastic paraplegia clinically evident since 1954. Her electrodes were placed at T-2 and T-3 (Table 3).

Results

The effects of spinal cord stimulation are seen not only on the motor system, but also on bladder function, circulation, the sensory system and in some patients control of pain. All of the patients with multiple sclerosis showed some improvement in motor function including coordination, standing and gait. Consistently, they all emphasized a significant increase in endurance. The end point on the degree of these improvements is not seen for several months. One patient (T.G.M.) had so much improvement in endurance of his gait that he is subsequently planning to return to his former occupation as a chef. One patient (T.M.) has experienced a considerable increase in standing endurance and although using wheelchair support, she has been able to continue full time teaching. The patient with the most widespread nervous system involvement (F.W.) also experienced rather widespread motor improvement in that her gait and walking endurance improved significantly. She also had some improvement in her upper extremity dystaxia. She is also one of the 2 patients who experienced improvement in speech (improved articulation). One patient R.B. (M.S.) became depressed after implantation and complained that the system was unhelpful. His external stimulation was stopped and his depression treated successfully. The system has again been activated and he now has improved endurance and walking ability (Table 4).

All of the treated patients with spinal cord injury who had spasms and clonus were improved. The one patient who was included in this group but was not implanted (H.F.) did not have spasticity but hypertonia. He found that the stimulation modified the hypertonia. This reduced the load-bearing capability of his weak leg and deteriorated his gait pattern. In all others, significant improvement in endurance with a decrease in spasms (the diffuse long duration type) were seen. As a result of spasm control, patient B.B. has returned to school. In one patient (E.H.) some bilateral voluntary extension of his knees was observed that had been hidden by his spasms. An unanticipated problem was noted in one patient (K.C.). He had marked release of his spasms and clonus involving all extremities which allowed him a better gait, but he noted that during stimulation he could not carry out transfer activities (Table 5).

Both patients with degenerative disorders of the nervous system realized increased endurance and improved gait associated with decrease in spasms. The patient with Friedreich's ataxia also showed marked improvement in speech articulation. He also had improved hand coordination and cessation of nystagmus during stimulation (Table 6).

Conclusions

In conclusion, epidural stimulation has proved to be an effective non-destructive method to modify motor disorders. In all groups of patients treated, increased endurance has been a consistently reported and observed finding. This has usually been associated with the diffuse, long duration type of spasm. Additionally hand and arm incoordination and speech (clarity of articulation) have been improved by the procedure. The method is effective only in patients with predominantly symmetrical involvement of the extremities and only if the patients have partial preservation of voluntary and reflex motor control. Under these circumstances, spinal cord stimulation will augment motor functions.

TABLE 1

MULTIPLE SCLEROSIS

INITIALS	SEX	AGE	ONSET	MOBILITY	ELECTRODE PLACEMENT	SYSTEM IMPLANT	ELECTRODE LOCATION
T.G.M.	M	55	1971	walking with support	6-7-77	6-10-77	T2 - T4
F.W.	F	40	1967	walking with support	6-7-77	6-10-77	T3 - T4
R.B.	M	51	1956	walking with cane	7-11-77	6-10-77	T4 - T7
M.P.	F	26	1971	wheelchair bound - standing	7-27-77	8-1-77	T3 - T6
T.M.	F	28	1967	walking with support	8-2-77	8-5-77	T2 - T3

TABLE 2

SPINAL CORD INJURY PATIENTS WITH EPIDURAL STIMULATION

INITIALS	SEX	AGE	ONSET	MOBILITY	ELECTRODE PLACEMENT	SYSTEM IMPLANT	ELECTRODE LOCATION
R.T.	M	29	1969	incomplete, walking with walker, short distances, sens. part. pres.	7-27-77	8-1-77	T2,3 - T7
B.B.	M	20	1975	incomplete, wheelchair bound, sens. part. pres..	8-19-77	8-23-77	T2 - T4
H.F.	M	55	1971	incomplete, walking with crutches, sens. part. pres.	8-22-77	0	T2,3 - T4
E.H.	M	47	1975	incomplete, pain, spast., trace movement, sens. part. pres., clonus	1-24-78	1-27-78	T2 - T4
R.C.	M	45	1974	incomplete, pain, spast. walking with walker, sens. pres.	1-24-78	1-27-78	T4 - T5
K.C.	M	25	1969	spasticity, sens. pres. walking with walker, clonus	2-10-78	2-16-78	T4 - T5

TABLE 3

DEGENERATIVE DISORDERS OF THE NERVOUS SYSTEM

INITIALS	SEX	AGE	ONSET	MOBILITY	ELECTRODE PLACEMENT	SYSTEM IMPLANT	ELECTRODE LOCATION
S.L.	M	20	1965	unsteady walking with walker	8-17-77	8-22-77	T1 - T2
C.C.	F.	65	1954	spastic gait, poor endurance	3-14-77	3-20-77	T2 - T3

TABLE 4

EFFECT OF EPIDURAL STIMULATION ON PATIENTS WITH MULTIPLE SCLEROSIS

INITIALS	COORDINATION	STANDING	BLADDER	SPEECH	WRITING
T.G.M.	+	++	+	X	+
F.W.	++	++	+	+	+
R.B.	+	0	+	X	+
M.P.	+	+	+	X	+
T.M.	+	++	+	X	+

TABLE 5

EFFECT OF EPIDURAL STIMULATION ON SPINAL CORD INJURY PATIENTS

INITIALS	SPASTICITY	CLONUS	MOTOR COORDINATION AND VOLITIONAL CONTROL	PERIPHERAL CIRCULATION	BLADDER FUNCTION	PAIN MODIFICATION
R.T.	+	+	+	+	+	X
B.B.	++	+	++	+	++	X
H.F.	0	X	0	+	-	0
E.H.	+	+	+	++	+	0
R.C.	++	+	+	+	+	+
C.C.	++	+	+	+	+	X

TABLE 6

EFFECTS OF EPIDURAL STIMULATION ON PATIENTS WITH DEGENERATIVE DISORDERS

INITIALS	COORDINATION	STANDING	BLADDER	SPEECH	WRITING
S.L.	++	++	X	++	+
C.C.	+	++	0	0	0

WORSE: - NO CHANGE: 0 IMPROVED: + REMARKABLE IMPROVEMENT: ++

NOT INVOLVED: X

References

1. North, Richard B., Fischell, Timothy A, and Long, Donlin. M.,"Chronic Stimulation via Percutaneously Inserted Epidural Electrodes," Neurosurgery, 1:215-218, 1977.

2. Sherwood, A. M., Sharkey, P. C., and Dimitrijevic, M.R., " Techniques for Epidural Spinal Cord Stimulation," (proceedings this conference).

TECHNIQUES FOR EPIDURAL SPINAL CORD STIMULATION

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The application of chronic, continuous electrical stimulation to the spinal cord of patients with upper motor neurone disorders is described. The technique is based on the placement of small electrodes in the spinal canal outside the dura, using a spinal tap needle. Once the electrodes are in place, the effectiveness of the stimulation is evaluated prior to the implantation of the entire system. The permanent systems in wide use employ RF coupling of energy through the skin to power a passive implanted device.

CATEGORY: Device Development ☐ Research Study ☒	INTENDED USER GROUP: Paraparetics with upper motor neurone lesions AVAILABILITY OF DEVICE: (commercial)
STATE OF DEVELOPMENT: Prototype ☐ Clinical Testing ☐ Production ☒	AVAILABILITY OF CONSTRUCTIONAL DETAILS: N/A
AVAILABLE FOR SALE: Yes ☐ No ☐ Price: N/A	FOR FURTHER INFORMATION CONTACT: Arthur M. Sherwood, P.E., Ph.D. T.I.R.R., P.O. Box 20095 Houston, Texas 77025 (713) 797-1440

Introduction

Electrical stimulation has a long history of use in modifying pain and muscular paralysis, primarily through application to peripheral nerves. In more recent times, the application of electrical stimulation has been extended to neural structures such as the spinal cord, cerebellum, and internal capsule of the brain. Spinal cord stimulation as a means of alleviating pain has been used for more than a decade (1). More recently, it was discovered that such stimulation could also have a beneficial effect in motor disorders as well (2,3). The use of such spinal cord stimulation has been greatly facilitated by the discontinuance of the previously used laminectomy approach, instead effecting electrode placement using a Touhy needle inserted into the spinal canal, allowing the electrode to be passed up the canal outside the dura to an appropriate stimulating location. This paper presents the techniques for epidural spinal cord stimulation and a description of devices used for this approach.

Electrodes

The electrodes must pass through the shank of a 16 gauge Touhy, Hustead, or other spinal tap needle. A large electrode area is contra-indicated, both for ease of placement and to achieve the high current density required for effective stimulation. The typical electrode active elements are 0.5 mm diameter and approximately 5 mm long. The electrode must be non-reactive with the tissue, with and without the presence of the stimulating current. Thus, the material must approximate to the maximum possible extent the characteristics of an ideal, non-polarizable electrode. Platinum is the material of choice at the present time. Since the electrode lead must pass from the electrode location (typically at the second or third thoracic vertebra, centered over the spinal cord) down the spinal canal and out through the intraspinous ligament, it is very important that a strong, durable, and flexible lead be used. The Davis-Geck electrode, which has a platinum tip, uses stranded stainless steel wire for the lead (Figure 1).

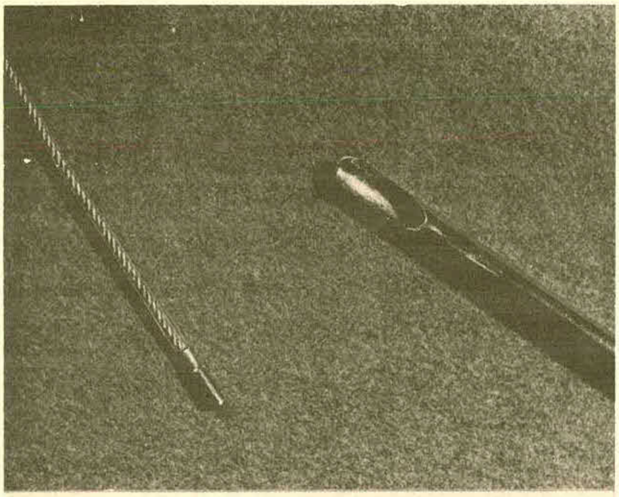

Figure 1. Davis Geck Electrode with 16 Gauge Touhy Needle Tip.

However, almost all other electrodes employ as leads a helix of platinum or other material, similar to those commonly used in cardiac pacemaker electrodes, to achieve the required degree of durability and flexibility.

A somewhat more difficult task is to join the electrode to the stimulation source. This is frequently done in two stages, in order to minimize trauma to those patients who do not receive a beneficial effect from the stimulation. In the first stage, the electrodes are directly connected to an external stimulator (typically battery powered, and perhaps quite similar or identical to the units which are to be used permanently). The electrode leads must be brought through the skin for the trial period, without providing a route for infection during this time and without compromising the sterility of the electrode lead for later implantation. A crimp connection can be made at any point along the Davis-Geck electrodes. Later, the leads can simply be brought out through the skin, and resected just below the skin surface, if suitable means of protecting the entry point are provided. On the other hand, no means currenly exist to reliably connect to the mid-point of a severed heilcal lead while working in a surgical sterile field. Thus, it is necessary to provide an extension lead set of some sort for the period of percutaneous testing when using this type of lead.

The second, or permanent implantation, stage of stimulation requires the connection of the electrode lead to the implanted stimulus source. The stimulus source is implanted under the skin away from the spinal cord, frequently in a subcutaneous pocket designed for the purpose just below the ribs over the abdomen. The leads are tunneled under the skin from there to the point where they connect to the electrode leads. The means of connection must be useable in the sterile field, allow the entire electrode-lead assembly to pass through the barrel of a 16 gauge thin wall needle, and provide a secure, permanent electrical contact, with no significant electrical leakage.

Stimulators

As described elsewhere (3), in order to have the desired effect on motor performance, we have used chronic stimulation with a continuous pulse train varying in frequency from 10 to 100 Hz, in pulse width from 50 to 400 microseconds, and in amplitude from 1 to 10 ma. The stimulating current is capacitatively coupled, to provide no-net-DC stimulation and to thereby attempt to minimize the deleterious tissue reactions to the stimulation. In some instances, symmetrical biphasic waveforms have been proposed for use. However, no clinical cases have come to light where the stimulation caused clinically relevant pathological changes. Furthermore, it is not clear how, if at all, the symmetrical waveform alleviates any problems. The level of stimulation currently employed, a 200 microsecond pulse of 10 ma delivered through an electrode area of 0.08 sq. cm, results in a current density of approximately 25 mocrocoulombs per square centimeter applied outside the dura, i.e, not in contact with the spinal cord itself. This is well within the allowable limit according to the assumed damage mechanisms discussed by Brummer and Turner (4). However, this is greater than the 0.45 microcoulombs per phase reported to cause damage when directly applied to brain tissue (5). Of course, the electrodes in this case are not in direct contact with nervous tissue at all, thus greatly lessening the probability of damage.

Two different systems have been developed to provide the appropriate stimulation. The most common is based on the use of a passive implanted receiver as the stimulus source. The receiver is energized by an antenna placed on the skin just above it, inductively coupling the necessary power and control information to the buried unit. The second approach is to provide the power source in the implanted unit, together with the controls necessary to adjust the stimulus parameters. External, battery powered stimulus control/transmitter units are currently available from several manufacturers, including Avery

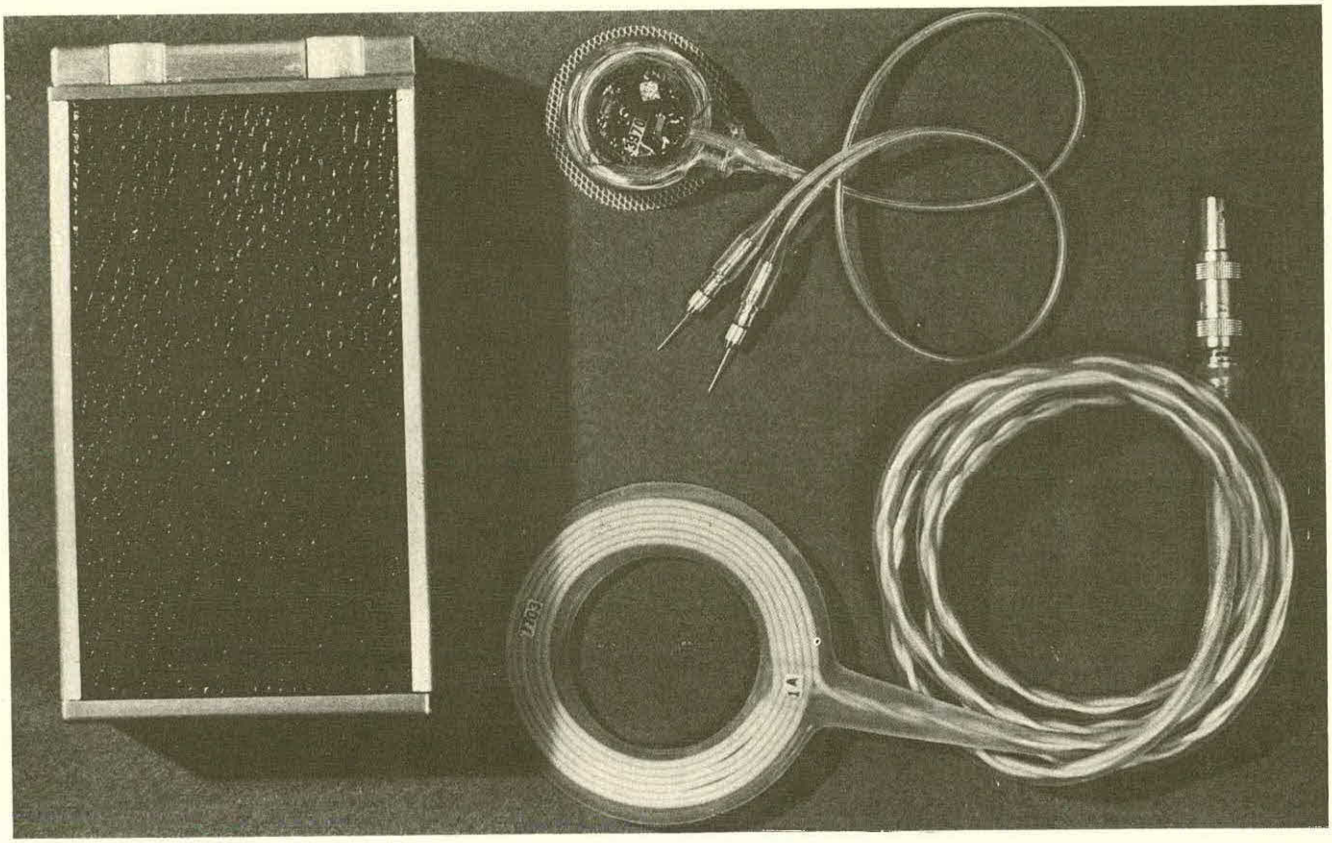

Figure 2. Typical stimulation system showing the power supply/transmitter unit , implanted receiver/stimulator and coupling antenna. These particular units are made by Avery Laboratories.

Laboratories and Medtronic Inc. Neurological Division. The units with which we have had experience are the Avery Model S-205 transmitter (with special x3 voltage modification), and the Medtronics PISCES (TM).

The Avery S-205 transmitter unit, shown in Figure 2 along with the antenna and implantable receiver, utilizes two 9-volt alkaline batteries to achieve a typical life expectancy of four days, and contains the necessary controls for adjusting pulse width, rate, and amplitude over the ranges 50 to 400 microseconds, 6 to 200 Hertz, and 0 to 45 volts (with the maximum mutual inductance, i.e., antenna directly on the receiving coil). It also has a very convenient self-check feature for assessing proper operation of the external system, including the antenna. It is housed in an aluminum case, with the battery compartment in the bottom. The methods of installing the batteries leads to some difficulty for the patient when changing the batteries, and consequently to frequently broken battery leads. The controls for rate and amplitude are on the top of the unit and are easily moved, unless they are secured with a piece of tape or other means.

The Medtronic PISCES , Model 3522, utilizes one 9-volt mercury or alkaline battery, providing about 2 days service. The PISCES unit is specified to produce stimulating pulses with adjustments over the ranges 100 to 1000 microseconds, 1 to 120 Hz,and 0 to 10 ma current. It uses a different energy coupling design, which requires a larger antenna, but produces optimum coupling with a vertical coil separation of 1 cm, producing near specification performance when implanted. The case is plastic, with partially shielded knobs not susceptible to accidental movement, but more difficult for the motor-impaired patient to operate. The battery compartment is easily accessable, with a snap-in connection, eliminating the problem of broken battery leads. The test features of this unit, however, are not completely self-contained.

The alternate approach, which packages the entire power supply and control circuitry in the implanted unit, is still in the evaluation phase but may soon be available from Cordis. These units have been used in human patients (6). They provide an anticipated life expectancy of approximately 18 months to three years.

Electrode placement and implant techniques

A primary requirement in placing epidural electrodes is to provide good visual control so that the surgeon will know precisely where they are located. This is accomplished by using a high-quality flouroscope with image intensification, to insure that the needle through which the electrode is passed is correctly positioned, as well as to observe the passage of the electrode up the spinal canal. Unless there is significant assymetry in the patient's motor defects, the cathode is usually centered over the spinal cord at approximately the T1 to T3 vertebral level, with the anode approximately one vertebral body lower (unless monopolar stimulation is used, in which case, the anode is located in the pocket with the stimulation source).

The effectiveness of the electrode locations chosen can be tested at any point by providing a sterile set of alligator clip leads for temporarily connecting the cathode to the electrode, using either the needle or the second electrode as the anode. Such testing is of particular value when the electrodes cannot be placed precisely in the anticipated positions due to obstructions in the spinal canal. Changes in motor performance may be of as much as three or four months in appearance, so the patient's sensation is used in evaluating the electrode location. Since the chronic stimulation level may be at or below the threshold of sensation, a higher level can be used for evaluating the electrode positions. Typically, the patient first reports a tingle or shock sensation localized near the area of the electrodes and extending around the trunk as a result of direct stimulation of nerve roots at the spinal cord. This sensation is felt as a result of the higher levels utilized initially to evaluate the stimulus effects, although chronic stimulation used later normally requires much lower intensities which depolarize only the immediately adjacent spinal cord structures, particularly the dorsal columns. It is typically desired to achieve paresthesia in both legs, and possibly the arms as well.

Once the proper stimulation has been achieved, the electrodes must be fixed in place by suturing to the skin. If the system is to be evaluated with a period of percutaneous stimulation first, the electrode leads must be extended through the skin which has been surgically prepared with betadine in such a manner as not to compromise the sterility of the portion which is to be permanently implanted. If the electrode lead cannot be cut and subsequently reconnected in the sterile field, as is the case with currently available leads of the helical type, provision must be made for implanting the whole lead length after attaching an extension at the time of electrodes placement, unless the electrodes are removed and later replaced when the system is implanted. This requires that a cut-down be made at the initial placement, and in fact, if manufacturer's recommended procedures are followed, that at least two cutdowns be made and the leads tunneled away from the spinal cord. The electrode is secured in position using a sleeve placed around the lead at the point it exits from the intraspinous ligament, sutured to the underlying tissue, after which the incision is closed. If the electrodes are to be later replaced or are of the type which can be cut and reconnected, then the position is stabilized by two external sutures on each electrode. To complete this portion of the procedure, a sterile dressing is applied, with the lead extensions to the external system brought out from under the dressing.

During the period of time while the electrode leads are externalized, it is important to measure the current and voltage levels required to produce physiological effects, such as threshold of sensation, motor effects (if any), and maximum tolerable levels. In addition, the electrode impedance should be calculated. These values are useful for determining the nature of the tissue in which the electrodes lie, the adequacy of stimulation, and for estimating the power levels required from the permanently implanted stimulation system. In our experience with dual electrode systems, the system impedances have ranged from about 800 to 2000 ohms, with no observable dependance on the polarity of stimulation. Since the electrodes are the same size in this system, it is therefore anticipated that each contributes equally to the observed impedance. This is borne out by the experience with monopolar stimulation systems, in which approximately half this range of impedances were observed (7), and by intraoperative measurements using a large indifferent electrode as the anode.

At the time of total system implant, a tunnel is made from the free electrode ends to the pocket into which the stimulus source will be placed. Connection of the electrodes to the stimulator and securing into place completes the procedure. If the unit is a totally implantable system, it must be preset to the parameters appropriate for that patient. If an implanted receiver is used, it must be placed so that proper inductive coupling to the external transmitter and antenna can be effected.

Conclusions and recommendations

Devices and techniques for effective stimulation of the spinal cord using an epidural approach are available and apparently safe. There are some problems which can be resolved by further engineering design and surgical technique technique development, particularly in the area of electrode connection, as well as electrode fixation.

Future developments in the area of totally implanted systems with adequate controllability will undoubtedly further enhance the appeal of this approach to the management of problems of motor disability. Accomplishment of this will depend on a number of factors, including better techniques for patient selection, electrode location, better implant designs, and proven long-life batteries.

References and Footnotes

1. Shealy, C. N., Mortimer, J.T., and Reswick, J.B., "Electrical Inhibition of Pain by Dorsal Column Stimulation: Preliminary Clinical Report,"Anesth. Analg. (Cleve.), 46: 489-491, 1967.

2. Cook , Albert W. and Weinstein, S., "Chronic Dorsal Column Stimulation in Multiple Sclerosis. Preliminary Report," N. Y. State J. Med., 73; 2868-2872,1973

3. Sharkey, Paul C., Meta M. Dimitrijevic, and Robert J. Campos. " Effects of Spinal Cord Stimulation on Modification of Motor Disability in Patients with Upper Motor Neurone Disorders," (this proceeding).

4. Brummer, S. B. and Turner, M. J., "Electrochemical Considerations for Safe Electrical Stimulation of the Nervous System with Platinum Electrodes," IEEE Trans. Biomed. Eng., BME-24:59-63,1977.

5. Pudenz, Robert H., "Adverse Effects of Electrical Energy Applied to the Nervous System," Neurosurgery, 1; 190-191, 1977.

6. Davis, Ross M., "Control of Spasticity and Involuntary Movement," Lecture at Texas Institute for Rehabilitation and Research, Houston, November 15, 1977. (Videotape available).

7. Personal communication with Dr. Seligman of Cordis Laboratories.

FUNCTIONAL ELECTRICAL STIMULATION FOR MODIFICATION OF WRIST DROP IN HEMIPARETIC PATIENTS AFTER STROKE

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One of the most debilitating results of injury to the upper motor neuron system as seen in hemiplegia secondary to stroke or traumatic head injury is that of chronic wrist drop. The wrist flexor hypertonia and extensor hypotonia can be subclinically improved with no functional improvement of control through alternate electrical stimulation of these two muscle groups in the well stabilized hemiparetic patient.

CATEGORY: Device Development ☐ Research Study ☒	INTENDED USER GROUP: P.T., O.T., Clinics
STATE OF DEVELOPMENT: Prototype ☐ Clinical Testing ☒ Production ☐	AVAILABILITY OF DEVICE: commercial AVAILABILITY OF CONSTRUCTIONAL DETAILS: Biomedical Engineering, T.I.R.R.
AVAILABLE FOR SALE: Yes ☒ No ☐ Price: ?	FOR FURTHER INFORMATION CONTACT: W. Barry McKay, R.EEG.T T.I.R.R., P.O. Box 20095 Houston, Texas 77025 (713) 797-1440

Introduction

Vascular diseases of the brain and head injury result in damage to the upper motor neuron system with a frequent consequence being hemiparesis. Recovery from the insult usually occurs within a few weeks, at which time any significant motor recovery which will occur will be seen. At this point, an active rehabilitation program should be started in an effort to make use of whatever functional abilities remain in the altered motor system.

There is a deficiency in evaluation as measured by clinical usefulness of the extremities. Gait re-education utilizing passive devices to assist the short swing phase of the leg has been reasonably successful in improving ambulation. This is usually not the case with the upper extremities, where some voluntary shoulder movements may remain and rapid flexion deformities of the wrist, hand and fingers develop. This results from the imbalance of extensor hypotonia and flexor hypertonia. efforts to deal with this have largely consisted of passive devices to support the hand in different positions or by a number of surgical approaches. Generally little significant change has resulted from these efforts.

Levine, Knott and Kabat (1) suggested that by stimulation of antagonist muscle groups it would be possible to suppress hypertonia in the agonist muscles. Liberson (2) showed that in the normal hand by the use of electrical stimulation of the extensor muscles he could achieve reciprocal inhibition of the finger flexors.

For a number of years we have had the opportunity to utilize functional electrical stimulation (FES) to peripheral nerves to gain functional movements in synergistic muscle groups. Our early work was largely directed toward improved hip function, ankle dorsal flexion and inversion for achievement of foot dorsiflexion and slight eversion during the swing phase of gait. As a result of this work it was decided to explore the usefulness of FES to modify the muscle tone disbalance resulting in wrist drop as a result of the chronic upper motor neuron lesion.

Material and Methods

Twenty-five patients were screened for some evidence of volitional control of the flexors of the wrist and fingers supported by sensory preservation (touch, temperature, position, two point stereognosis). From this group 19 patients (14 male, 5 female, 17 left hemiplegic, 2 right hemiplegic) were selected. Each patient used as his own control comparing abnormal arm to normal arm. In addition goniometric measurements of passive and active wrist flexion were made comparing the two extremities.

Twelve channel EMG data was recorded through Beckman (silver silver chloride) surface electrodes from the deltoid, rhomboid, biceps brachii, triceps brachii, wrist extensors and wrist flexor muscle groups from affected and non-affected extremities. Simultaneous electrogoniometric data from both wrists and elbows were amplified and displayed along with the EMG on a 16 channel Elema Schonander EEG device. The skin resistance for all EMG electrodes was reduced to below 5 kilohms. The patients were then provided with an ENA-2 stimulator and switch device which alternately delivered a 1 s train of 1 ms pulses at 33 Hz rate to the wrist extensors and wrist flexors through saline soaked gauze electrodes placed over the muscle bodies. Daily visits for 2 weeks were used to train the patient in the use of the equipment. The patient was instructed to continue stimulation for as long as tolerable each day. The PEMG and clinical reevaluation were carried out at 3, 6 and 12 month intervals. Efforts were made to have the patient keep a daily log showing the total stimulation time each day. Unfortunately, this was unsuccessful.

Results

During the period of evaluation there was no significant change in the basic clinical findings of any of the patients considered to be fixed in their neurological injury. This group comprised 16 of the 19 patients. It was interesting that 3 of these patients showed on follow up PEMG study some volitional extensor control of the wrist not previously seen along with some decrease in wrist flexor spasticity (Figure 1). This finding was strictly at a subclinical level since no clinical improvement in wrist control was reported by any observer.

The 3 remaining patients were still early in their potential recovery period (1 - 3 months) after injury. Two of

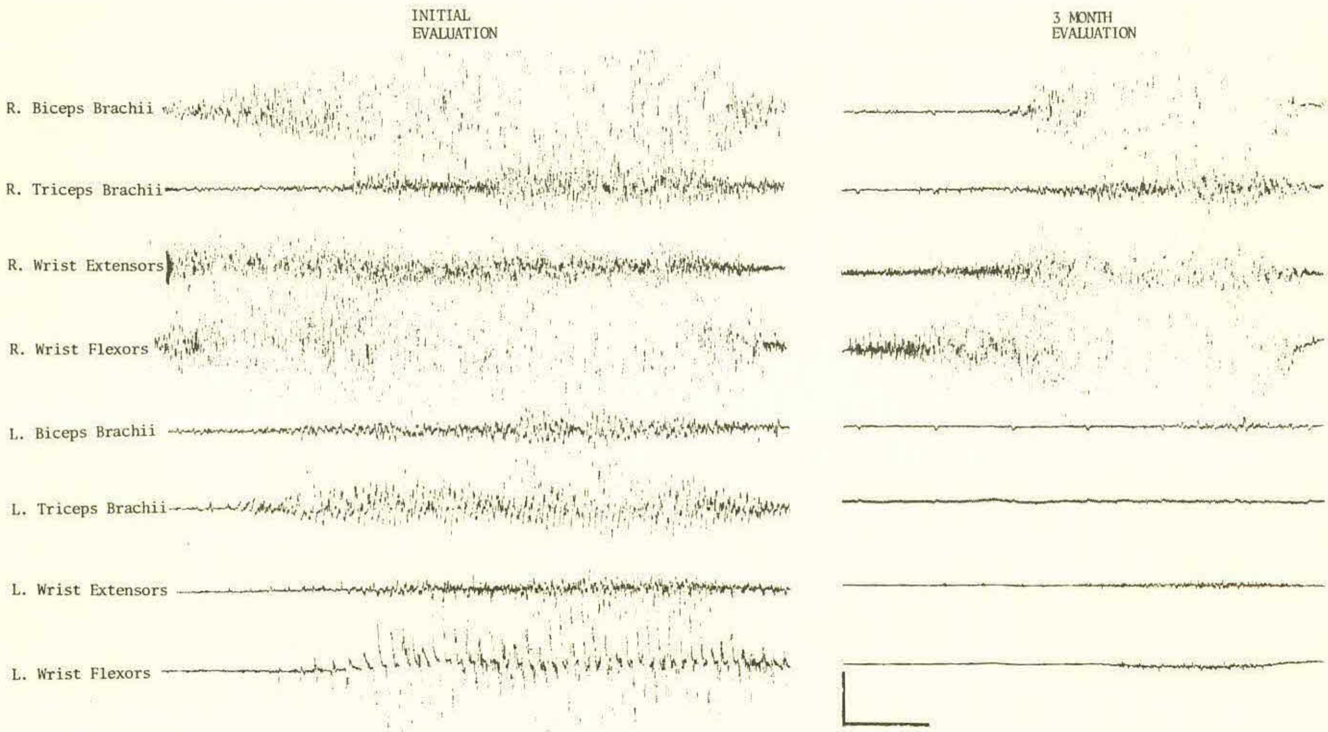

Figure 1. Polyelectromyographic record of left hemiplegic patient during right wrist flexion movement before and after functional electrical stimulation treatment. (Scale: 1 mv, 1 sec per division.)

these patients had improvement in wrist extension with decreased flexor spasms and some recovery of fine motor control of the wrist and fingers. These were the youngest patients (ages 13 and 21 years) in the entire group.

Although stimulation did show definite subclinical evidence of reduction in flexor hypertonia by a reduction of synergist coactivation on muscles bilaterally in the performance of unilateral maneuvers no clinical evidence could be found to support any modification of the , existing motor deficit at a functional level. The findings would support that FES does have a short segmental effect on the reciprocal relationship between the antagonistic and excitatory relation of motor cells but not on suprasegmental and segmental motor integration levels for volitional control.

It was noted that in the younger patients whose recovery had not yet stabilized that they showed the most pronounced subclinical effect with FES as shown on serial polyelectromyographic studies. This leaves the still not completely resolved question as to whether the procedure facilitates spontaneous recovery or that results are entirely independent of recovery.

References

1. Levine, M. G., Knott, M. and Kabat, H., "Relaxation of Spasticity by Electrical Stimulation of Anatgonist Muscles," Archives of Physical Medicine, 1952, 33: 668-673.

2. Liberson, W. T., "Experiment Concerning Reciprocal Inhibiton of Antagonists Elicited by Electrical Stimulation of Agonists in a Normal Individual," 1965, 36: 306-308.

THE DESIGN AND EVALUATION OF AN OPTICAL POINTER

Ronald Levy* and Keila Waksvik**

The objective of this paper is to describe the design, development and clinical evaluation of an optical pointer which was designed as a communication aid for the severely disabled non-verbal individual who lacks functional use of the upper limbs. The head-mounted device allows head movement to control the direction of a light beam, permitting direct selection of characters on a communication board. The light can be detached from the headgear and replaced by a rod, which permits typing on an electric typewriter. A felt pen, can also be attached to the rod to allow participation in graphic activities.

The basic concern of the evaluation procedure is to establish a precise description of the abilities and disabilities of the user, and to assess the device in terms of this base-line data. This specific evaluation is part of an ongoing study into evaluation techniques in relation to special equipment for the disabled.

CATEGORY: Device Development ☒ Research Study ☐	INTENDED USER GROUP: Non-verbal cerebral palsied children or adults
	AVAILABILITY OF DEVICE: Not Available
STATE OF DEVELOPMENT: Prototype ☐ Clinical Testing ☒ Production ☐	AVAILABILITY OF CONSTRUCTIONAL DETAILS: Available
AVAILABLE FOR SALE: Yes ☐ No ☒ Price:	FOR FURTHER INFORMATION CONTACT: The authors

Introduction

The Optical Pointer, with accessories, was designed as a communication aid for the severely disabled non-verbal individual who lacks functional use of the upper limbs. The head-mounted device allows head movement to control the direction of a light beam, permitting direct selection of characters on a communication board. The light, or optical pointer, can be detached from the headgear and replaced by a rod, which permits typing on an electric typewriter. A felt pen or paint brush, can also be attached to the rod to allow participation in graphic activities.

The optical pointer was originally developed for a young girl of 14 suffering from severe spastic quadriplegia. Prior to using the optical pointer, the vocabulary on her communication board was manually scanned for her, until she indicated that the desired character (word, letter, or Blissymbol) had been reached. This was a slow method, which did not encourage communication, particularly with the uninitiated. The high cost and limited availability of sophisticated electronic communication aids pointed to the need for a simple and direct means of access to her communication board. A headstick was not considered an optimal solution due to the effort required to point accurately, and spatial limitations. The concept of a head-mounted light is not new, and was considered to be worthy of further investigation. The first prototype proved successful in providing independent access to the vocabulary available on her communication board. Both on/off switch and call buzzer were actuated unassisted. The headgear proved to be very stable, despite poor grading of head movement. Increased spontaneous communication and more complete sentence structure were noted. The first prototype was

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also assessed with several severe athetoid quadriplegics with associated spasticity. A very cursory trial period indicated relevance with this cerebral palsy group. The first prototype did not include a typing rod.

Initial clinical testing of the first prototype led to subsequent redesign. Ten second-generation prototypes were then constructed and have been distributed to eight institutions in Canada, the United States, and Great Britain, for clinical evaluation with cerebral palsied children and youth.

I Design of the Optical Pointer

1. Objectives

The final design objectives for the optical pointer can be divided into ergonomic, technical, operational, aesthetic, economic and therapeutic considerations. One of the primary ergonomic objectives was to ensure that the pressure applied to the head by the head set would be minimal. Other identified goals related to such things as ensuring easy access to controls by the various users, the maximizing of safety considerations, high comfort criteria and minimum weight of headgear and attachments (i.e. below 100 grams). The technical objectives were oriented towards the use of simple materials, viability of manufacture and ease of maintenance and repairs. The operational objectives were primarily concerned with achieving ease of handling the device in terms of the initial fitting procedure and in every-day use. Non-complicated mechanisms and procedures were the goals here. The aesthetic objectives were concerned with developing a device which would be acceptable to both sexes, taking into account body image concepts. The economic goals were simply to ensure that the device would be economically accessible to the individual. Other objectives of the design were concerned with the device being sufficiently adaptive to the needs of the therapy programme and that it provide a reliable tool to facilitate independent communication for the disabled individual.

2. Description

2.1 The Headgear

The headgear consists of low density polyethylene tubing made up in two parts, or sidepieces. Each sidepiece is in the form of a large circle, containing within it a smaller circle designed to go around the ears. The two circles are connected via metal 'T'-junctions (Fig. 1).

Each sidepiece is fitted to the head and held together by three metal spacers. To obtain fine adjustment of the headgear, the metal spacers may be moved to increase or decrease pressure over the forehead and back of head.

2.2 The Light

The light is clipped into a clamp which attaches to the front spacer (Fig. 2). A v-filament high intensity bulb is used to provide a sharp image. The trailing electrical wire is clipped into the keyed grooves in the other two spacers. The wire is then threaded around the back of the wheelchair and connected to the switch box.

To avoid eye fatigue, it was suggested to users that the light beam be adjusted so that the light image is at eye level when focused on an upright communication board. For individuals with strong extensor spasticity, preference for the light to be directed slightly higher might minimize backward head movement, and subsequent increase in extensor spasticity. Direction of the beam is controlled via a ball-joint mechanism.

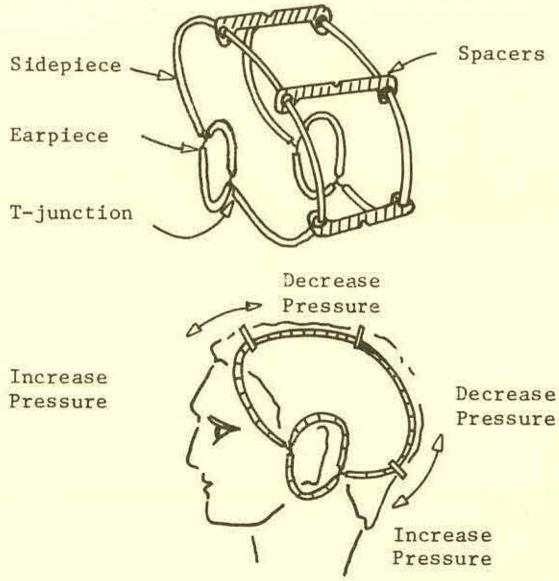

Figure 1

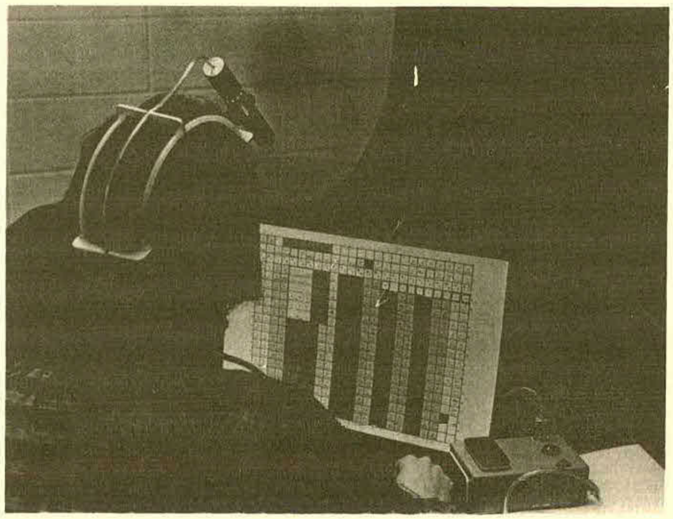

Figure 2

2.3 The Switch Box

The switch box which operates in conjunction with the light contains a number of elements.

- A master on/off switch to ensure that the battery is not in use during storage or transportation.
- An on/off switch for use by the disabled user to allow for independent control of the light.
- A buzzer to allow the disabled user to call for attention.
- An input/output jack, for recharging the battery and as the output source for the light itself (using a single jack for these two functions ensures that the device cannot be used while being plugged into a 110 voltage source).
- A battery voltage indicator. The battery can operate continuously for 6-8 hours with a recharging time of about 12 hours.
- A battery charger which corresponds to the particular specifications of the battery.

The switch box is positioned on the wheelchair tray in such a way as to facilitate the most effective and effortless use by the particular user.

2.4 The Typing Rod

The typing rod attachment is also fixed to the headgear using the spring spacer (Fig. 3). The position of the typing rod housing can be adjusted in the vertical direction by sliding the housing up or down the vertical bar. The thumbscrew on the housing releases or tightens the grip of the housing on the vertical bar and the typing rod itself. The housing is positioned above the eyebrows.

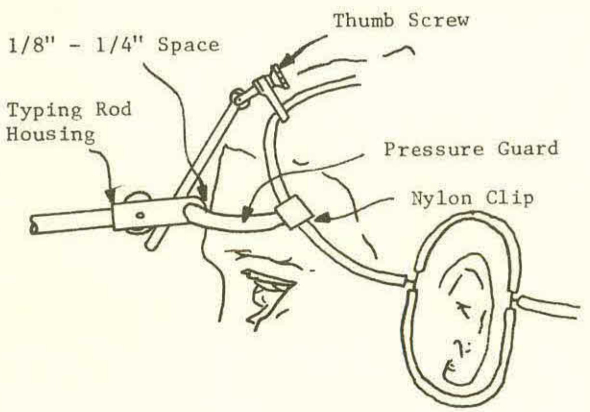

Figure 3

The pressure guard which retains the typing rod housing and prevents it from coming into contach with the user's forehead is made from the same material as the headgear. The guard passes through the housing, curves over the front of the forehead and is clipped onto the sidepieces of the headgear.

The typing rod is an aluminum tube which can easily be bent by hand. The length of the rod may be customized by cutting the tip-end with a tube cutter. A plastic cover is supplied for the tip. The tip should be positioned in such a way as to avoid upward or downward strain of the eyes. The disabled user provides important input here, regarding the best position for the tip and the length of the rod (Fig. 4).

Figure 4

2.5 Drawing Accessory

To provide an opportunity for the disabled user to use the typing rod as a means to draw, an accessory is provided that allows a felt pen or paint brush to be clipped onto the end of the typing rod (Fig. 5).

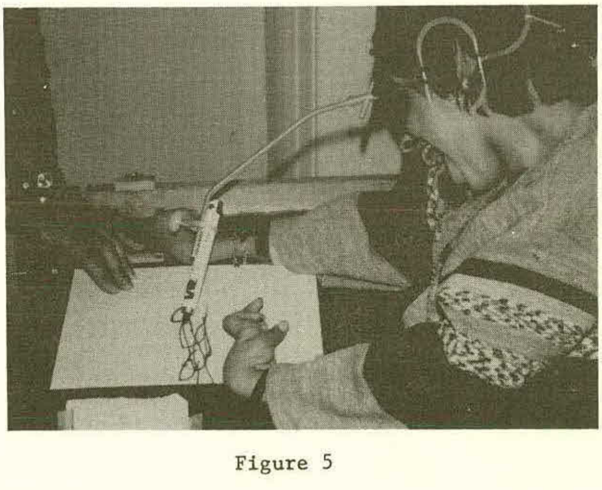

Figure 5

2.6 The Carrying Case

A canvas carrying case was designed for the protection and transportation of the device (Fig. 6). The case contains a sturdy wire frame to support the various components of the device. It may either be carried over the shoulder or hung over the back of the wheelchair. Certain spare parts are provided in the case such as a fuse for the charger, thumb screws, and extra lengths of plastic tubing.

Figure 6

2.7 Accompanying Documentation

A brief document, including a description of the device, technical specifications, fitting instructions with illustrative photographs, and initial training considerations, accompanies the Optical Pointer.

II The Evaluation Procedure

1. General Considerations

All devices designed for the disabled should undergo a thorough developmental process in order to ensure that they meet high standards of performance and are safe and reliable for use by the disabled population. In addition to this, economic viability must be demonstrated if the device is to be effectively distributed. A coherent and comprehensive evaluation process must therefore be part of the research and development program. When a device reaches the stage where functional, reliable, practical, safe and economical prototypes exist in small numbers, then serious field tests must be undertaken to show clinical feasibility.

It is suggested that the evaluation of a device for the disabled should include behavioural, operational, technical, and comparative aspects. The most fundamental issue to be ascertained in this process is the contribution that the device makes to the user's performance in a designated activity. It is therefore important to establish a coherent body of reference or base-line data against which performance may be measured. For example, it is important to establish:

(i) a clinical description of the disabled user, i.e. physical and behavioural attributes;
(ii) a description of the user's performance in the designated activity, carried out without, and with, the new device;
(iii) a description of the technical specifications of the device

The subsequent evaluation process, should allow further clarification of the needs the device can fulfill, make comparative evaluations with existing devices, and identify those segments of the disabled population that will find the device most useful.

In any evaluation procedure, those persons directly involved in the use of the device must be identified and taken into consideration. These include:

(i) the primary user, i.e. the disabled user;
(ii) the secondary users, i.e. non-professional people directly involved with the disabled user, such as parents, family members, or ward personnel in institutional settings; as well as the professional, medical or paramedical person(s) most involved with the disabled user and the activity associated with the device, such as therapists, teachers, psychologists. They are considered to be 'users' because they must perform activities with and on the device to ensure its proper functioning. At all stages of the evaluation procedure, input from both primary and secondary users must be obtained in appropriate area.

2. The Evaluation of the Optical Pointer

The major concern of the evaluation of the Optical Pointer is to assess how it a) functions as an assistive device, b) improves or facilitates communication, c) affects the rehabilitation programme developed by the professional team, d) affects the non-professional people interacting with the disabled person, and e) performs in relation to the technical goals identified by the designer. In the light of the General Considerations outlined in 1. above, the evaluation form has been divided into five sections:

i Initial and Final Description of Primary User
ii Operational Evaluation
iii Technical Evaluation
iv Comparative Evaluation
v Evaluation of Initial Fitting of the Device

The total evaluation is to be carried out over a period of twelve months from February 1978 to February 1979. In most cases, questions have been formulated in such a way as to be answered by a simple checking response. Space is generally provided for comments. Where this is not sufficient, the reverse side of the evaluation sheets can be used. It is considered that the total time required to fill out the evaluation form should not exceed twelve-fifteen hours.

In order to accommodate responses from both primary and secondary users, a standardized form of response has been developed for many of the questions asked. Each question is accompanied by a matrix within which the response from each of the persons involved in the assessment is recorded, e.g.:

How do you rate accessing the communication board with the light beam?	very difficult 1	difficult 2	satisfactory 3	easy 4	very easy 5
a. Disabled user					
e.g. occupational b. .... therapist					
c. .... teacher					
d. .... parent					

or

Do you find the thumb screws on the accessories easy to manipulate?	Yes	No	Remarks . .
a. Disabled user			.
b. ...			.
c. ...			.
d. ...			. . . . . .

The secondary users involved in the evaluation should be identified at the outset by the evaluating centre, and should retain the same letter code throughout the evaluation period. Their function must be noted in the space provided in the response matrix (i.e. b., c., d.). It is understood that not all centres will be able to provide more than one secondary user. However, input from a variety of secondary users would be benefitical to the evaluation process, even though in some instances questions cannot be answered by all participants - e.g. evaluation of the initial fitting process.

i <u>Initial and Final Description of Primary User</u>

The initial and final description provides the base-line data on the primary (disabled) user and also gives an indication of changes that may occur in the user, at various levels, over the test period. It should also provide the social and behavioural information, and the information pertaining to the physical abilities of the disabled user, necessary to assess the success achieved with the device or parts of the device, and assist in the development of future selection criteria of candidates for this type of device. This section, and particularly subsection (iv), has been developed keeping in mind the pathological movement patterns associated with cerebral palsy, as this population appeared to be the most likely user of this type of device. It is filled out at the beginning and the end of the evaluation procedure, and is subdivided as follows:

(i) general
(ii) family
(iii) psychological
(iv) physical
(v) speech and language
(vi) communication.

It is felt that this section should be the responsibility of the para-medical team member (i.e. therapist) most familiar with the primary user. Some of the information requested would be available in the primary user's medical file. However, direct input from teachers and other team members, as well as specific clinical observation by an experienced therapist, is required in order to complete this section.

The following is a brief selection of the types of questions asked in this section.

3.2 Check child'd general Level of Alertness (as often demonstrated by sense of humour):	initial description	final description
No interest in surroundings		
Little interest in surroundings		
Sometimes observant, sometimes sees humour in situations		

4.2.2 Visual Attention (check ability to attend to visual stimuli) stimuli)	initial	final
Excellent		
Good		
Fair		
Poor		

4.7.2 Check range of arm movement	initial	final
Full range of movement		
Minimally restricted range		
Moderately restricted range		
Severely restricted range		

4.7.3 Check quality of arm movement	initial	final
Adequate		
Slow and laboured		
Rapid, lacks stability		

4.5.1 Check ability to control head movement in sitting position

	initial	final
Able to control head movement in all parts of the available range of movement		
Able to assume and maintain upright head position, eyes foreward. Difficulty maintaining stable head position with head movement		
Able to assume upright head position eyes foreward. Difficulty maintaining this position. Unable to maintain stable head position with head movement		
Unable to assume or maintain upright head position, eyes foreward		

4.5.2 Check quality of head movement in sitting position

	initial	final
Adequate		
Slow and laboured		
Rapid, lacks stability		

6.1.3 Rate degree of frustration resulting from difficulty in communication (as often demonstrated by aggression, apathy, or other behavioural traits); i.e. frustration on the part of the disabled person (a) as well as the persons with whom he interacts (b,c,d).

	initial			
(please check)	no apparent display of frustration	mild frustration	moderate frustration	severe frustration
a. Disabled user				
b. ...				
c. ...				
d. ...				

ii <u>Operational Evaluation</u>

This section is concerned with the performance of the device during use by the primary user and/or secondary users. It provides baseline data regarding use of the device during the first week, and gives an indication of the progress which may occur over the evaluation period. It is filled out at the beginning, in the middle, and at the end of the evaluation process. The types of questions asked in this section relate to the activities associated with the everyday use of the device. In other words, verbs such as "connecting", "adjusting", "changing", "operating", "accessing", "handling", etc., form the major thrust of the questions. Many are aimed specifically at the disabled user, while in other cases the responses can only be given by the secondary user. The following is a brief selection of the types of questions asked in this section:

2.1 How do you rate connecting the light to the headgear?

	initial evaluation					mid-term evaluation					final evaluation				
	very difficult	difficult	satisfactory	easy	very easy	very difficult	difficult	satisfactory	easy	very easy	very difficult	difficult	satisfactory	easy	very easy
a. Disabled user															
b. ...															
c. ...															
d. ...															

2.4 How do you rate accessing the communication board with the light beam?

	initial evaluation					mid-term evaluation					final evaluation				
	very difficult	difficult	satisfactory	easy	very easy	very difficult	difficult	satisfactory	easy	very easy	very difficult	difficult	satisfactory	easy	very easy
a. Disabled user															
b. ...															
c. ...															
d. ...															

3.1 How do you rate operating the on/off switch for the light?

	initial evaluation					mid-term evaluation					final evaluation				
	very difficult	difficult	satisfactory	easy	very easy	very difficult	difficult	satisfactory	easy	very easy	very difficult	difficult	satisfactory	easy	very easy
a. Disabled user															
b. ...															
c. ...															
d. ...															

4.3 How do you rate accessing the keyboard of the typewriter with the typing rod?

	initial evaluation					mid-term evaluation					final evaluation				
	very difficult	difficult	satisfactory	easy	very easy	very difficult	difficult	satisfactory	easy	very easy	very difficult	difficult	satisfactory	easy	very easy
a. Disabled user															
b. ...															
c. ...															
d. ...															

iii Technical Evaluation

This section is concerned with an evaluation of the technical specifications of the device and its component parts. Each major component of the device is assessed in terms of "safety", "appearance", "comfort", "reliability", "durability", etc. This technical evaluation is completed only once, at the end of the entire test period. The following are examples of the kinds of questions asked in this section:

1.2 Do you find the headgear to be stable during independent use with the light?	Yes	No	Remarks:
a. Disabled user			.
b. ...			.
c. ...			.
d. ...			. . . . . .

3.2 Does the buzzer work reliably?	Yes	No	Remarks:
a. Disabled user			.
b. ...			.
c. ...			.
d. ...			. . . . . .

5.5 Do you like the appearance of the typing rod accessory?	Yes	No	Remarks:
a. Disabled user			.
b. ...			.
c. ...			.
d. ...			. . . . . .

iv Comparative Evaluation

This section allows comparison of the device with other devices or parts of devices which are used in similar situations. It is completed at the end of the evlauation period. The following is an example of the kind of question asked in this section:

3. If it is possible to compare the switch with existing equipment, how would you rate it?	much worse	worse	comparable	better	much better
a. Disabled user					
b. ...					
c. ...					
d. ...					

v Evaluation of the Initial Fitting Process

This evaluation is carried out in three parts. Like the overall evaluation, it too is concerned with operation, technical and comparative aspects. It is completed immediately following the fitting of the device and its accessories, at the beginning of the evaluation period.

The first part is concerned with the operational aspects of the fitting procedure, i.e. the activities performed with or on the device.

Example:

1.3 How do you rate the activity of measuring the tubing to achieve the correct size?	very difficult	difficult	satisfactory	easy	very easy
a. Disabled user					
b. ...					
c. ...					
d. ...					

The second part is concerned with an evaluation of the technical aspects of the device during fitting.

Example:

2.2 Do you find it easy to cut the plastic tubing?	Yes	No	Remarks:
a. Disabled user			.
b. ...			.
c. ...			.
d. ...			. . . . .

The third part is concerned with a comparative evaluation with other similar fitting processes.

Example:

If it is possible to compare the fitting process of the headgear with existing equipment, how would you rate it?	much worse	worse	comparable	better	much better
a. Disabled user					
b. ...					
c. ...					
d. ..					

Conclusion

At the time of writing the status of the evaluation of the optical pointer is such that no conclusions, however initial, can be drawn. The only statement that can be made is that no major problems have yet shown up and that the evaluation procedure is progressing smoothly.

It may be said that the character of the evaluation procedure is one which shows a strong orientation towards a qualitative form of evaluation. Only a very minimal use of statistical or quantitative analysis is foreseen.

In evaluating the optical pointer, we have made a concerted effort to take into consideration the most significant users of the device, i.e. both "primary" and "secondary" users. This aspect is considered to be essential in any evaluation of special equipment for the severely disabled. Ease of handling and use by secondary users is just as vital to the successful use of a device as the primary user's direct success with the device. Only by taking both into account, will the evaluation provide the information necessary to realistically improve the usefulness of the device.

The interest shown in the optical pointer to date, indicates the validity of the work undertaken in the development of this low-cost, intermediate technology, direct selection communication aid. The field of communication aids, or special devices in general, should not necessarily be weighted in favour of sophisticated, high technology equipment. There is a great need for simple aids, which meet specific aesthetic and technical criteria, and which can be made easily accessible to users in terms of cost. In the field of non-vocal communication, the development of eye-coding techniques is an example of a simple approach to providing a means of access to a communication board, with minimal technical assistance. Where direct selection is required or preferred, the optical pointer, we think, will provide a viable alternative.

Results of the evaluation should be compiled by the fall of 1979. These results, and future plans with regard to redesign and commercial availability of the Optical Pointer will be communicated in due course.

Bibliography

1. Bobath, K. and Bobath, B. (1972), "Cerebral Palsy", in Physical Therapy Services in the Development Disabilities, Paul H. Pearson and Carol Ethun Williams, Editors, Charles C. Thomas, Springfield, Illinois.

2. Bigge, June L. (1976), Teaching Individuals with Physical and Multiple Disabilities, Charles E. Merrill Publishing Company, Agincourt, Ontario.

3. Kirk, N.S. and Ridgway, S. (1970), "Ergonomic Testing of Consumer Products", in Applied Ergonomics, No. 1, Vol. 5, pp. 295-300, and 1971, No. 2, Vol. 1, pp. 12-18.

4. Wachsler, R.A. and Randall, P. (1960), "An Analysis of Some Factors Influencing Seat Comfort", in Ergonomics, No. 3, pp. 316-320.

5. __________ (1976), Science and Technology in the Service of the Physically Handicapped, Vol. 1, National Research Council, Washington, D.C.

6. __________ (1975), Electronics Controls Program, Kinsman Rehabilitation Foundation of British Columbia, Canada.

7. __________ (1976), Initial Assessment Recording Forms, Symbol Communication Research Study, Ontario Crippled Children's Centre, Toronto, Ontario.

8. Levy, R., Waksvik, K. (1977), Simple Equipment for the Handicapped, Proceedings of the 4th Annual Conference on Systems and Devices for the Disabled, Seattle, Washington.

9. Levy, R., Waksvik, K. (1978), Design for the Disabled: Towards Enhancing Independence Through Design of Special Devices, Proceedings of the 9th Environmental Design Research Association Conference, Tucson, Arizona.

THE VISUAL EAR* AND COMMUNICATIONS FOR THE HANDICAPPED IN CANADA

George S. Turnbull
Canadian Telecommunications Carriers Association

The telecommunications carriers in Canada have become involved with making telecommunications services more accessible to the handicapped over the past two years. Their involvement with the development of the Visual Ear, a telecommunications device for the deaf and speech impaired is described in some detail. A conclusion is drawn that those working in rehabilitation should attempt to involve industry more in the rehabilitation process.

CATEGORY: Device Development ☒ Research Study ☐	INTENDED USER GROUP:
	AVAILABILITY OF DEVICE: 1st Quarter 1979
STATE OF DEVELOPMENT: Prototype ☒ Clinical Testing ☐ Production ☐	AVAILABILITY OF CONSTRUCTIONAL DETAILS: Not available
AVAILABLE FOR SALE: Yes ☐ No ☒ Price:	FOR FURTHER INFORMATION CONTACT: Rentronics Inc. 2395 Bayview Avenue Willowdale, Ontario M2L 1A2 447-5391

Introduction

The Canadian Telecommunications Carriers Association (CTCA) is the association representing the telecommunications industry in Canada. Its twenty one members include all the major telephone companies, the two telex/telegraph companies, Telesat - the domestic satellite corporation and Teleglobe - the corporation that owns all overseas circuits.

More that 3 years ago the directors of the Association thought that it would be appropriate, on the centennial of the invention of the telephone, for the Association to do something for the deaf. Although Alexander Graham Bell may be best known for the invention that plays such an integral part of our lives, he did actually devote a large portion of his life to working with persons with communications difficulties - the deaf, blind and speech impaired.

* Visual Ear, registered trade mark of the Ontario Mission of the Deaf.

After the idea had passed around for several months between the directors and other standing committees of the Association, it fell to the author to develop a suitable program. The program which was developed was designed to help the profoundly deaf gain access to telecommunications services. It proposed three major activities to achieve its objective:

1. <u>Establish contact with the Deaf</u>

   Each company offering telephone service appointed a Coordinator to provide liaison with all deaf organizations in its operating territory and learn their communications problems.

2. <u>Contribute to their communications efforts</u>

   All companies owning teletypewriter equipment agreed to give right of first refusal on all equipment which becomes surplus to organizations for the deaf free of charge.

3. <u>Seek ways of improving communications for the Deaf</u>

   The Association formed a National Committee, made up of the Company Coordinators, to study what further devices or services might be provided now and in the future.

The "Visual Ear" Appears

While the CTCA program for the deaf was being prepared, a press release in a Toronto news paper described a new device for the deaf which was designed to use a pushbutton telephone as a transmitter and had an 8 character LED display to read out received messages. The main design objective was portability to facilitate mobility among the deaf and it could be used in normal two way communication or in special one way communication.

The device which was called a Visual Ear was designed to permit communication between two deaf or between a deaf and a hearing person in the following manner:-

Normal Situation	Both parties equipped with Visual Ear and pushbutton phone. Establish a connection, then, using a code, send a message from one end. Message appears on both Visual Ears. Response from other end appears on both Visual Ears. Etc., etc.
Special Situation	Deaf person establishes call from pushbutton phone to other party equipped with Visual Ear. One way message is sent by deaf person and received on Visual Ear.

CTCA was interested in the device as it proposed to use the telephone in an unconventional manner and arranged to speak to the inventor who was acting on behalf of the Ontario Mission of the Deaf. The main reason for contacting the inventor was to ensure that he had an appreciation of the intricacies of the telephone network. A secondary reason is that the pushbutton telephone signalling frequencies and format are governed by international standards and there were possibly violations of these standards taking place. In addition, telephone companies are sensitive in this area because, when a device that uses the telephone malfunctions, they are in line for criticism - whether they merit it or not.

Closer investigation showed that the device would be acoustically or inductively coupled to the receiver of the telephone and that a code would be used to allow the 12 buttons on the telephone to represent a complete alpha-numeric set. It was also discovered that the device was at a rather rudimentary breadboard stage and was experiencing some operational problems. CTCA enlisted the assistance of Bell Northern Research (BNR) Limited to advise the inventor and eventually, BNR proposed to the Ontario Mission that it take over development of the device. This was agreed to and to pay for the development BNR submitted a proposal to the Federal Government. After negotiations and the passage of considerable time, the Government approved the funding and development was started.

Limited Design

BNR's first task was to do a thorough analysis of the existing design. While some obvious technical shortcomings were evident, the devices appeared to be practical ones. BNR therefore suggested that a built in pushbutton pad would greatly increase its utility and flexibility. It would be even better if a standard alpha-numeric keyboard could be incorporated which would electronically send the necessary tone combinations for each character. These improvements, it was reasoned, would get around the drawbacks of using the pushbutton phone as a transmitter. For one thing, the deaf person would not have to depend on finding pushbutton phones which are relatively sparse.

Design Limitation

An important finding of the analysis however, was that when the standard pushbutton tones are fed through the transmitter of a telephone, the resulting distortion can result in difference tones of sufficiently high level to cause an unacceptable error rate. This factor plus the devices incompatibility with the existing deaf teletypewriter network led to a decision to drop the pushbutton tone approach and go to the more conventional FSK (Frequency Shift Keying) signalling method. Starting from this basis BNR designed a new Visual Ear which would fulfil the design objectives of the original device and also be compatible with the deaf TTY network. BNR's approach looked in depth into both physical/mechancial and electrical considerations.

Physical/Mechanical Considerations

On the physical/mechanical side a human factors study was done to come up with the best possible design from a users viewpoint. The main constraints on physical dimensions were the size of the standard telephone handset, the battery pack and a keyboard. The areas to be optimized were keyboard size and layout, display size and position and the shape of the device. These together with size, weight and ability to operate without AC contributed to the portability. In looking at keyboards, BNR examined various layouts, including calculator type, compact keys but settled on a standard QWERTY layout with normal spacing. On the display question the subjective choice was for 24 characters while objectively 16 were adequate and with cost constraints a 16 character, expandable to 24, layout was chosen. This was positioned above the keyboard and angled for best viewing. With these components fixed, the choice of shape was between a flat 7"x9" device with the telephone handset placed on top at the rear and a hinged version where the device is layed out the same way but hinged between the display and the acoustic coupler to make it more compact for carrying. The latter idea was dropped due to the possible mechanical weak point in the hinge - reliability being one of the foremost requirements.

Electrical Considerations

With regard to the electrical/electronic design, BNR used the latest LSI techniques and incorporated a microprocessor to simplify operation as much as possible for the user. Among its capabilities the Visual Ear, in its standby mode will be able to detect and display ringing if placed near a telephone. In this mode the keyboard and display will be operational and it will be able to output to an auxiliary printer or tape recorder or receive from a hard wired computer. In the normal operational mode it will perform the foregoing operations plus receive from a remote unit or a teletypewriter. It has one further operational mode that permits replay of tape recorded FSK messages.

Transmission Capabilities

The deaf teletypewriter network with which the Visual Ear is compatible uses Baudot (5 level) code and non standard signalling frequencies and a speed of 45.45 Baud. In addition to this capability, the Visual Ear is capable of sending and receiving ASC11 (8 level) code using standard data transmission signalling at 110 Baud. This makes it capable of being a simple computer terminal or of operating with other devices that use the same code and signalling mode.

Cost to User

Perhaps the overriding objective in all the foregoing has been to make the device available to its intended users at the absolute minimum cost. With Government paying all development costs the Ontario Mission of the Deaf is arranging for manufacturing that will be done at cost and for waiving of manufacturing taxes by employing deaf persons in the assembly operation. The original cost objective of $200 to user which was set 2 years ago will not be met but the cost should be about ½ to 2/3 that of other currently available devices with similar features.

Involvement of CTCA

The author has maintained a keen interest in the development of the Visual Ear and sits on a review committee that oversees BNR's work. In addition he is Telecommunications Industry Advisor to the Ontario Mission of the Deaf. From his position as Chairman of the CTCA National Committee on Communications for the Handicapped he has viewed the Visual Ear as a "telephone" for the hearing and voice impaired and has influenced the telecommunications industry in Canada to market and distribute it. This will be done at a minimal cost by the telephone companies in keeping with the objective of keeping costs down.

Other CTCA Activities

The involvement of CTCA with the Visual Ear is an example of the corporative efforts that are possible in making telecommunications more accessible to all handicapped persons. Although CTCA efforts were initially concentrated on helping the deaf, a policy statement by the Association in July 1977 broadened the scope to include all handicapped. The National Committee is now examining the communications needs of the handicapped and is looking for means of satisfying them. A possible R&D project being examined now is a modification of telephone operator switchboards to convert visual cues on incoming calls to computer generated voice to enable blind persons to become operators. The Committee is happy to entertain other ideas which have communications or telecommunications aspects in them.

Conclusion

The author is convinced that there is great potential for the telecommunications industry to be involved in rehabilitation of the handicapped. He has observed and participated in expanded involvement in Canada over the past 2½ years. There is a basic level of participation by most telecommunications companies in North America but it could be greatly expanded. There could be much more liaison between those in universities and institutions primarily involved in work with the handicapped and the telecommunications and other industries. From this liaison might flow help in financial matters, technical expertise and coordination of effort. That type of help could ensure that more devices reach completion and get to the people who need them. While these conclusions may not prove strictly accurate, the author feels the expanded liaison is a worthwhile effort if it results in better service for the handicapped.

UNICOM: A UNIVERSAL COMMUNICATION AND CONTROL SYSTEM FOR THE NON-VERBAL MOTOR IMPAIRED

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Massachusetts Institute of Technology

The UNICOM is a communicator for the non-vocal severely motor impaired which is based upon a microprocessor-controlled video display and printer. Its fundamental concept is that it is a single device which can be adapted by simple plug-in man/machine interfaces to operate in any of several control strategies: scanning, encoding, or direct selection. Input interface devices, ranging from a single switch to a full keyboard, are selected according to the residual motor capabilities of the user. The input device determines the control strategy.

CATEGORY: Device Development ■ Research Study □	INTENDED USER GROUP: Non-vocal severely motor impaired.
STATE OF DEVELOPMENT: Prototype □ Clinical Testing ■ Production □	AVAILABILITY OF DEVICE: Small number available for clinical evaluation. AVAILABILITY OF CONSTRUCTIONAL DETAILS: Not presently available.
AVAILABLE FOR SALE: Yes □ No ■ Price:	FOR FURTHER INFORMATION CONTACT: Prof. Derek Rowell Mech. Engin. Dept. M.I.T., Building 1-112 Cambridge, MA. 02139

Introduction

The development of the Universal Communicator (UNICOM) was undertaken after a survey of existing electronic communication aids for the non-verbal motor-impaired had led us to the conclusion that the advent of microprocessor technology provided a new opportunity to considerably enhance the functions and power of known techniques, while at the same time offering the potential of considerable price reductions.

While many electronic communication aids have been proposed and evaluated on a small scale[1], few have been taken beyond the point of limited deployment on an experimental basis. The need for enhanced communication for the non-verbal is well recognized[2,3]; the inability to communicate effectively with others limits the degree of functional independence and generally compounds the social and emotional development of the speech impaired person. Many of the existing communication aids have been developed in response to the needs of a particular individual, without thought to the generality of the approach to the population at large. An engineer or researcher responding to such an immediate need in a domestic, clinical, or educational setting is often geographically and intellectually isolated from other workers, with the result that there has been much duplication of prior effort and a tendency toward simple devices.

The UNICOM design project is an attempt to define a universal modular hardware system that will meet the needs of as wide a range of the target population as is practicable, and at the same time will perform as many additional functions as is possible. The approach has been to use a low-cost microcomputer as the heart of the system, and to endow the device with multiple "personalities" and intelligence through a resident library of programs that control the mode of operation, the message display, and the interaction between the user and the system. Care was taken to make the system convenient to use for users and therapists, and to design a flexible interface system so that user input devices could be fabricated as cheaply as possible.

The microcomputer approach allows complex electronic hardware design to be replaced with software design. By taking this approach, extensions and modifications to the system can be made by simply adding or changing programs stored in the permanent library. This allows fast implementation of custom system to meet the requirements of a given individual user.

The UNICOM design concept

The initial objectives of the UNICOM project were to provide users with a single device that would:

1. Act as a communication system with many control strategies available and with message display, both on a temporary video display and a line printer.

2. Allow communication between non-verbal patients in a residential setting. To achieve this, the communicator must be capable of receiving messages from other devices and displaying these messages to the user.

3. Be capable of being connected to a remote computer, so as to allow physically handicapped people access to computers in vocational and educational settings.

4. Act as an intelligent environmental control system through special interfaces to lamps, TV sets, radios, etc.

All of the above functions have been implemented on the current UNICOM devices, and now efforts are being directed toward including new features, such as video games and self-paced teaching machines.

The major elements of the UNICOM system are shown in Figures 1 and 2. The choice of a video monitor (or TV set) as the primary message display was based on many factors. Our previous experience in the field of non-verbal communication had convinced us of the importance of text editing and error correction in communicators for use in educational settings[4]. The video monitor display and the UNICOM software allows the user to edit and correct each line before it is sent to the line printer for a permanent message. A further advantage is that the video display provides a legible multiline message area that can be read from a distance.

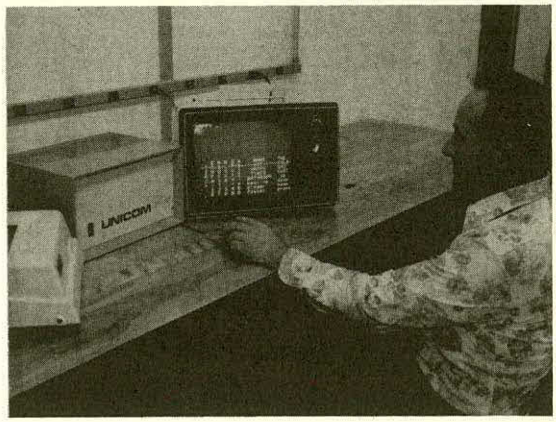

Figure 1. UNICOM system, with printer, processor and video display.

An essential feature of the UNICOM concept was that the video monitor should perform a dual function. In many of the operating modes, the lower half of the screen is used to display a matrix of characters, words, and commands that the user can access through the input device to create and edit the message text. For example, when the device is configured as a row-column scan system, the matrix is displayed with stepping horizontal and vertical cursors, as shown in Figure 3.

The present system uses a video display with a capacity of 16 lines of 32 characters as a compromise between legibility and line length. Although only upper case letters have been implemented in the current systems, the capability exists to use both upper and lower case, as well as special symbols such as Greek letters and math symbols.

The output to the external printer is through a standard RS232-C or 20 ma current-loop serial interface and has adjustable baud rate. The serial format was chosen to provide compatability with

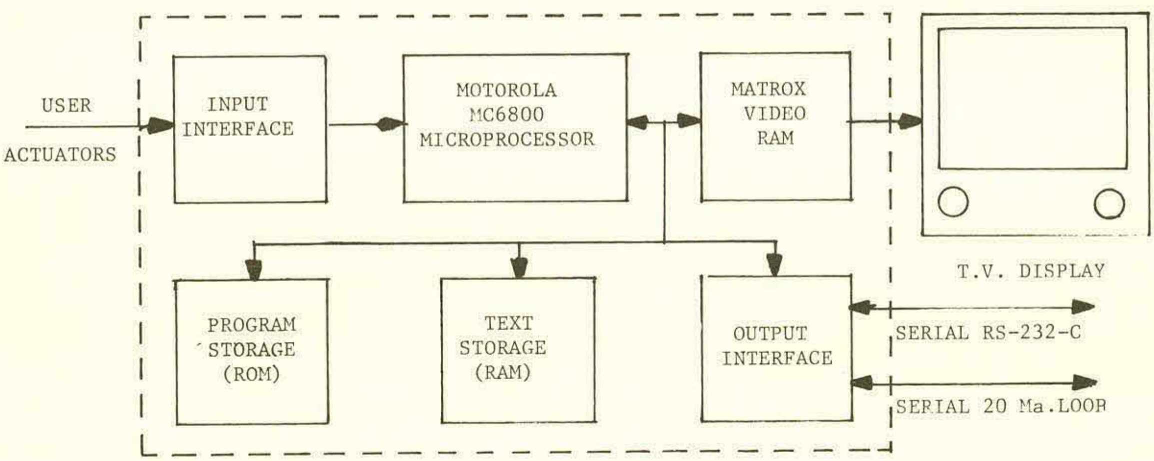

Figure 2. UNICOM Block Diagram.

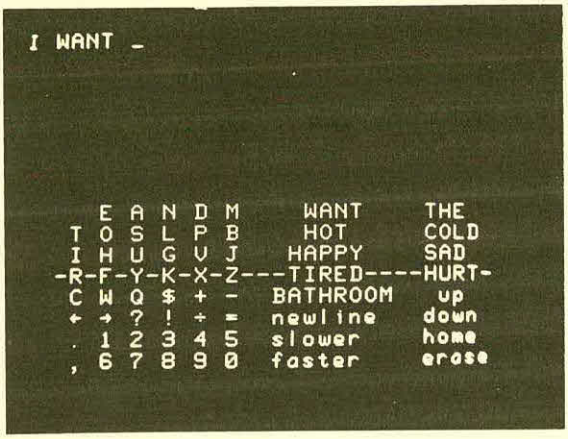

Figure 3a. UNICOM screen while operating as a row-column scanning mode, i.e. TIC style. The message space is the top 7 lines, the input matrix the bottom 8 lines. The horizontal row of dashes is the row cursor.

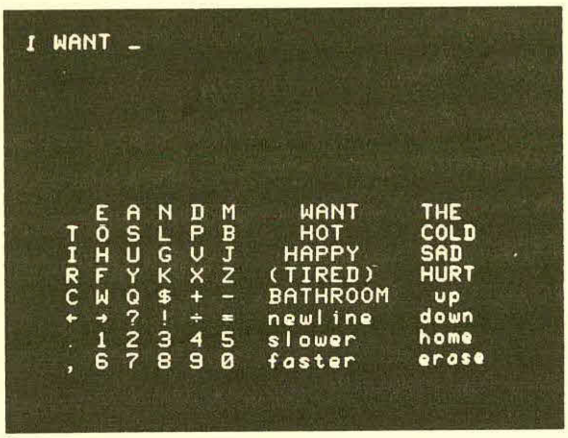

Figure 3b. Same as Figure 3a, except 4th row has been selected by switch closure. The cursor, a set of parentheses, is moving across the matrix. If the switch were closed at this time the word "TIRED" would be transferred to the message space starting at the location where the underscore is positioned.

as wide a range of low-cost printers as possible. A serial input interface is also provided, and upon reception of a line of text from an external device (for example, another UNICOM, or a remote computer) the received message is displayed above the current line. These two serial line interfaces provide the UNICOM with the capability of bi-directional communication. In a residential setting, with multiple users, it is planned that a central exchange unit be designed and used to stream messages between users. In this configuration, users will be able to "dial" and converse with any other user connected to the exchange.

The user-device interface is a set of programmable input/out lines. Although all interface lines are digital, analog signals can be used to drive the UNICOM through simple a/d converters or

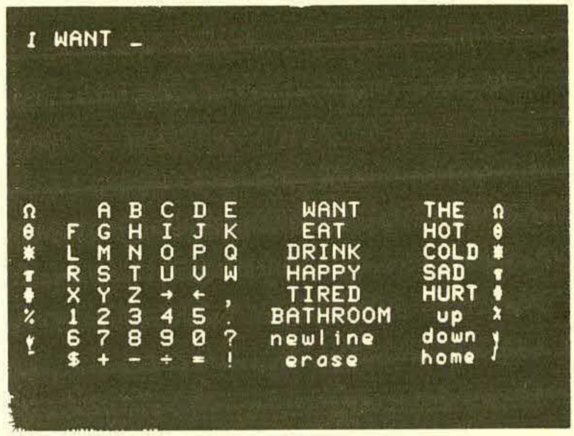

Figure 4a. UNICOM screen while operating in a 9-key encoding mode (8 select and a clear key). Each key selects a row if used now. The symbols on the sides of the matrix are marked on their respective keys.

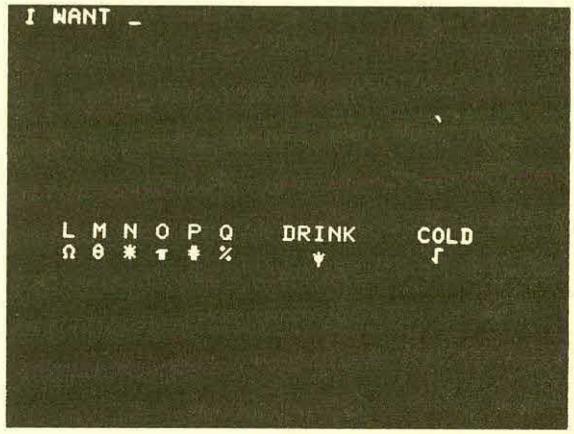

Figure 4b. Same as Figure 3a, except key "*" has been pressed. Pressing "ψ" will cause the word "DRINK" to be transferred to the message space starting at the underscore cursor location.

pulse-width modulators. The design philosophy has been to minimize the need for external circuitry in the input activating devices by performing all functions in software. This approach was taken so as to allow clinical personnel to develop simple custom input devices tailored to the vestigal motor-functions of the individual patients.

The environmental control features of the device are implemented by using two or three of the interface lines as encoded control signals to an external unit containing solid-state a.c. relays.

Operating modes

The operating mode of the system is selected automatically by the system by recognizing interconnections on the user interface plug. When any input device is plugged into the connector its code is interrogated by the microcomputer and the operating mode is adjusted to match the characteristics of the device:

a. Row-column scan: This mode, which requires a single momentary closure switch for an input device, is similar to the Tufts Interactive Communicator (TIC)[5], but uses the video screen for the display of the character matrix and cursor. The operation is illustrated in Figure 3. A horizontal line cursor steps cyclically through the matrix until a switch closure is detected, indicating the desired row. A second cursor, constructed from parentheses, then steps through the row until a second switch closure is detected. At that point the appropriate character or word is displayed, or the selected command is executed.

The system allows full editing of a line of text before printing, and allows the user to adjust the scan rate.

b. Multiple-switch encoded input: The encoded mode allows users with greater motor ability to communicate faster than the scan mode. The present implementation requires eight momentary contact switches to select from an 8 x 8 matrix. Two switch closures are required, the first to select one of the eight rows, the second to select the character from that row. Figure 4 shows the video screen at the two stages.

c. Keyboard input: The UNICOM will act as a keyboard terminal with special features for those users capable of using a head-stick or other means of accessing the keys. A special key is used to indicate that the next character will require a SHIFT (upper case) so that the user can have full access to the keyboard with a single actuator.

d. Direct selection using a joy-stick or X-Y input tablet: In this mode an 8 x 8 matrix is displayed on the video screen and a cursor is moved about by operating a joy-stick or other analog two dimensional input device. Characters are selected either by exceeding a preset dwell-time or by activation of an external switch.

e. Directed scan: In this mode the user is provided with a paddle that can be moved in four directions. Activation of the paddle will cause the cursor on the displayed matrix to move at a constant stepping rate in the appropriate direction. As in the joy-stick mode, the selection of a character is based upon dwell on a character or by activation of a selection switch built into the paddle.

Project status and conclusions

Seven UNICOM systems have been recently completed and are now undergoing initial field evaluation. Although it is too early to make definitive conclusions as to the acceptability, it can be said at this time that the devices have been received enthusiastically by users and clinical staff. The unit longest in the field has been used daily for over four months by a quadriplegic using an array of puff-sip switches in the encoding mode. This user is planning to enroll in college and use the device as her primary mode of communication. Other units are being used by multiple users in classroom situations using various input devices. The flexibility of the system in accommodating the requirements of many children has been noted by the teachers.

In this initial study no attempt has been made to miniaturize the system, or to design them at minimum cost. The objective has been to demonstrate the concept of the universal hardware by purchasing commercially available microcomputers so as to minimize construction time. Future work will be directed toward increasing the number of operating modes available, evaluating these modes, and redesigning the system packaging.

Acknowledgments

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References

1. Luster, M.J. and Vanderheiden, G.C., Preliminary Annotated Bibliography of Communication Aids, Trace Center, University of Wisconsin-Madison, 1974.

2. Lloyd, L.L. (editor), Communication Assessment and Intervention Strategies, University Park Press, Baltimore, 1976.

3. Vanderheiden, G.C. and Grilley, K. (editors), Non-Vocal Communication Techniques and Aids for the Severely Physically Handicapped, University Park Press, Baltimore, 1976.

4. Bullock, A., Dalrymple, G.F. and Danca, J.M., "The Auto-Com at Kennedy Memorial Hospital: rapid and accurate communication by a non-verbal multi-handicapped student", American J. of Occupational Therapy, Vol. 29, No. 3, pp. 150-152, March 1975.

5. Foulds, R.A., "Tufts Interactive Communicator: A Communicative Assist for the Non-Verbal Severely Handicapped", Biomedical Engineering Center, Tufts-New England Medical Center, Boston, MA. Sept. 1973.

AN ASSESSMENT SYSTEM AND RELATED MODULAR COMPONENTS FOR SEATING HANDICAPPED CHILDREN

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The limitations of previously-reported assessment equipment and the foam-in-place custom fabrication technique are presented. Suitable anatomical shape-sensing was obtained by the implementation of shadow Moire technology. Recently-developed modular components are described, as well as experience to date in their clinical application.

CATEGORY: Device Development ☒ Research Study ☐	INTENDED USER GROUP: Handicapped Children
STATE OF DEVELOPMENT: Prototype ☐ Clinical Testing ☒ Production ☐	AVAILABILITY OF DEVICE: Neckrests and headrests only are commercially available. Contact Engineered Therapeutic Systems, Box 39, Transcona, Manitoba, Canada AVAILABILITY OF CONSTRUCTIONAL DETAILS: Most blueprints are available
AVAILABLE FOR SALE: Yes ☐ No ☐ Price:	FOR FURTHER INFORMATION CONTACT: R. N. Holte Rehabilitation Centre for Children 633 Wellington Crescent WINNIPEG, Manitoba, Canada R3M OA8

Introduction

Correct seating is a basic prerequisite to any program for the handicapped. Previous experience has shown that the most accurate way of determining the synergistic effects of multiple component seating supplements is by mocking up the desired seating configuration and measuring essentially the finished product. This has been accomplished for the more difficult cases by positioning the child on a multiply adjustable chair to which modular bolsters, head supports, etc. could be added, and then manipulating the chair to fit the child.

While this approach yielded satisfactory basic data, it gave little information which would be required for fabricating the more complex and intricatley-fitting shapes, such as lordotic pads for muscular dystrophy patients (1). As reported at previous conferences (2,3,4), these type of back supports have been fabricated by foaming against the patients while they were supported in the desired position. Although this system produced generally satisfactory results, it had several drawbacks. It was difficult to modify the end-product shape. No shape-defining data was realized. Patient movement during foam set-up might cause the cushion to collapse. As the children aged, their backs became less flexible, and the foam product deviated increasingly from the symmetric lordotic shape desired. This, coupled with the observation that the foam end-products all had the same basic shape, led to the conclusion that prefabricated modular foam cushions would be a superior solution.

Shape Definition

Defining the shape of these lumbar supports is the first consideration. The shadow Moire technique offers a simple, elegant solution. This method was pioneered by Takasaki (5,6), and further applied by Foort and associates (7,8) at UBC and by Armstrong and colleagues in Ottawa(9). Point source light shone through a grid onto the patient's back forms an interference pattern contour map when viewed through the grid. Recorded photographically and entered into a computer, the resultant data can be smoothed and modified to guide fabrication of a single supportive cushion. Alternatively, a number of data sets may be averaged for a modular shape definition.

Accordingly, the shape definition capabilities of the shadow Moire technique have been combined with the advantages of the earlier fitting chair. All required assessment data can be gathered using the one piece of equipment. This approach has been applied successfully in the seating clinic. When more data has been acquired, modular back cushions will be defined by mathematical splining. Models will be shaped on an NC milling machine, and moulds for foam end-products made by traditional methods.

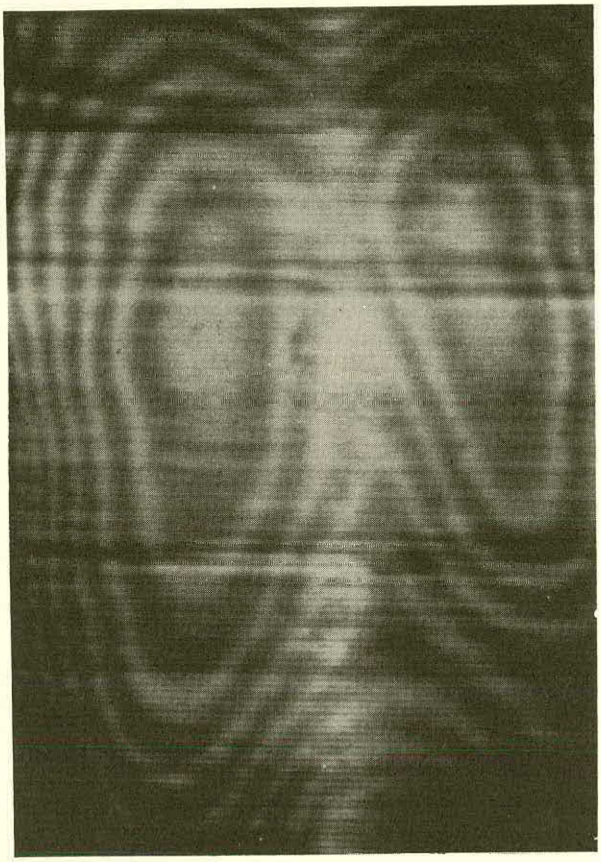


Photo 1 Topographic contours of patient's back produced by application of shadow Moire technique.

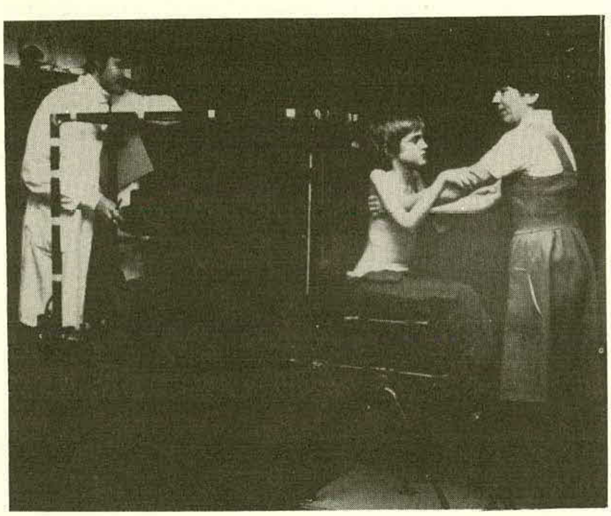
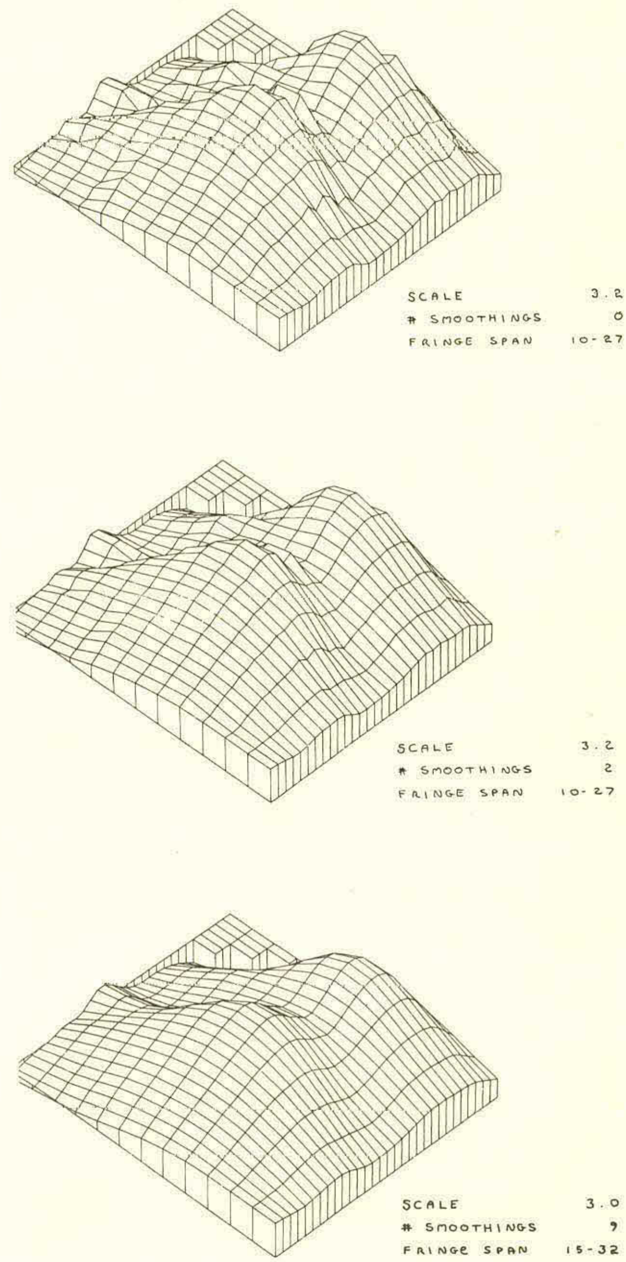


Photo 2 Therapist supporting patient in front of shadow Moire grid, while technician readies camera.



Photos 3,4&5 Progressive computer smoothing of digitized shadow Moire data.

Modular Components

Some modular components have already progressed to the application stage. Foam neck and head rests have been made in several incremental sizes and shapes, and used routinely in the seating program.

A special frame which interfaces with a wheelchair and supports the basic insert software has been developed, and reported at a previous conference (3). This frame offers the advantages of ready adjustments of seat/back and seat/shank angles by aluminum ratchets, and selection of leg length and footrest angles. The entire insert reclines in the wheelchair by sliding over a bar fixed to the seat support tubes, the position regulated by clamping the insert back crossbar against slotted brackets attached to the wheelchair handle uprights. The footrest flips up for transferring, and the entire insert folds. It can be removed from the wheelchair simply by disengaging the back crossbar from the slotted brackets.

Over the past year, the frame design has undergone several changes to improve function. Two chief advantages in using this frame are noteworthy: virtually any configuration of traditional insert software can be mounted; and modification to an insert to accomodate changes in patient size, prognosis, or lifestyle are facilitated by the adjustments incorporated into the frame design. Assessment is likewise simplified. An application where the insert and frame have met with limited success is with muscular dystrophy patients beginning wheelchair use. In addition to supplying good trunk support, particularly in the lumbar region, the insert should allow the child to put his feet on the floor and hands on the wheels to encourage arm and leg powered mobility as long as possible. Unfortunately, these basic criteria seem to be mutually exclusive, particularly with standard wheelchairs used by children in this age group. We will attempt to solve this problem by building special wheelchair bases.

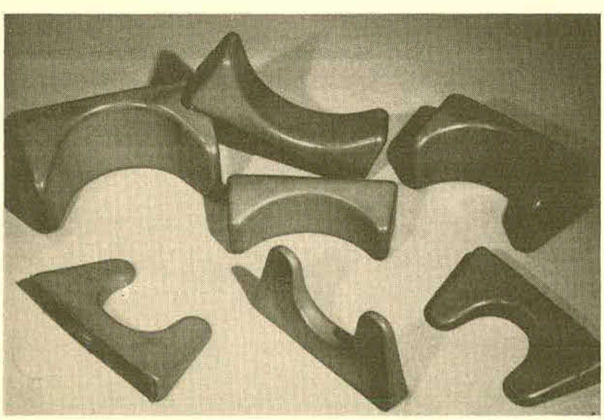


Photo 6 Modular neckrests (bottom) and headrests (top) of CPR Upjohn 1951N flexible polyurethane foam.

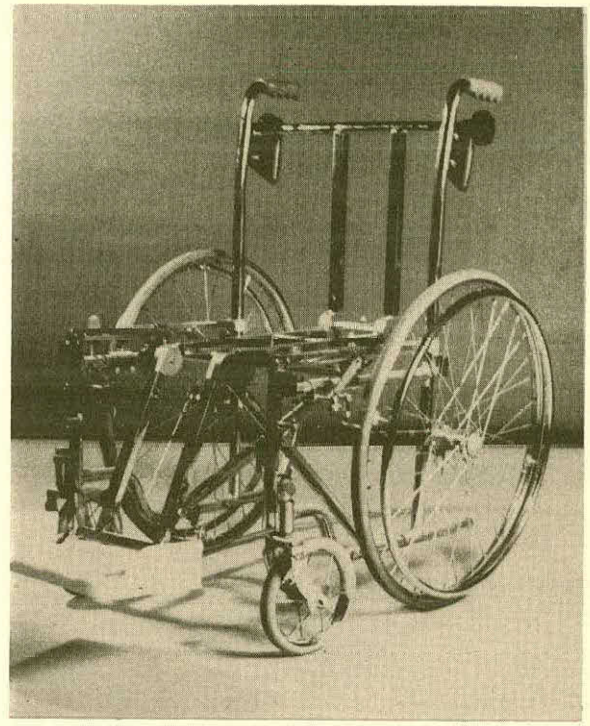


Photo 7 Adjustable insert frame on 18" E & J wheelchair.

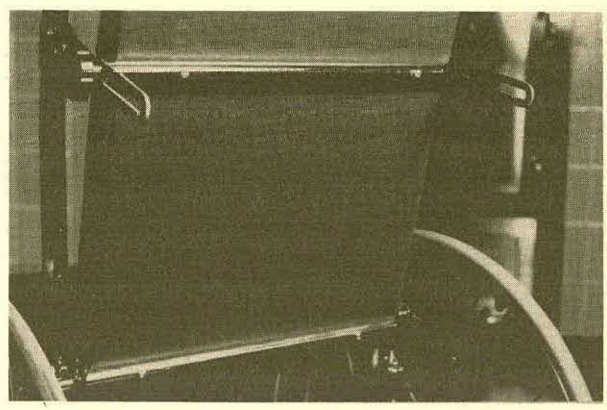


Photo 8 Simple insert hardware. Top, crosstube and pivotting slotted brackets. Bottom, crosstube and open clips.

Simpler interfacing hardware has also been designed. If an insert back alone is required, it may be held in place by lower and upper crosstubes, respectively dropping into open clips and bolting to brackets mounted to the wheelchair handle uprights. Slotted, pivotting brackets would allow slight reclining of the insert back. An insert consisting of a seat and back can be held in place by an upper back crosstube and brackets, as before, in combination with a seat crossbar sliding under clips mounted on the wheelchair seat tubes.

An interface especially for infants has been designed. It is suitable for use in a stroller, wheelchair, highchair, car seat, or on the floor. It is lightweight and easily cleaned. The infant seat kit includes a removable two-position tray, and an adjustable, removable footrest.

Not at the modular stage, but nonetheless worthy of mention, is a very effective thoracic bolstering system which has evolved over the past year. The bolsters may be applied in lateral pairs to correct moderate mid-line deviation as typically exhibited by athetoid children, or in a three-point configuration to support a scoliotic back. A sheet metal core is contoured to the lateral curvature of the patient's thorax, padded, and upholstered. By varying the gauge and width of metal core, the rigidity of support can be suited to a particular application. The resulting bolster is comfortable because of its shape and padding, and thin enough to be used in the sub-axillary region without detrimental effects on arm function or patient comfort. These bolsters are flexible, allowing patient movement under active resistance. They may easily be bent wider to accomodate change in patient size or amount of clothing worn.

Concluding Remarks

Experience in providing inserts for handicapped children has brought the development of thorough assessment equipment, modular foam products, and wheelchair interfaces. Development of modular back cushions and other accessories to replace traditional upholstery methods will follow.

Photo 9 Attaching modular neckrest to infant seat bucket. Note offset bolsters, and tray (upside down) in foreground.

Acknowledgements

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Bibliography

1. J. Koreska, A.M. Albisser, D.A. Gibson, S. Wilkins. A Novel Support System for Unstable Spines. Proceedings, 1975 Conference on Devices and Systems for the Disabled, Philadelphia.

2. R.L. Daher, R.N. Holte, I.T. Paul. A Complete System for Meeting the Seating Requirements for the Multiply Handicapped. Proceedings of 1976 Conference on Systems and Devices for the Disabled, Boston.

3. R.L. Daher, R.N. Holte, I.T. Paul. Progress Report: A Complete System for Meeting the Seating REquirements for the Multiply Handicapped. Proceedings of 1977 Conference on Systems and Devices for the Disabled, Seattle.

4. R.L. Daher, R.N. Holte, I.T. Paul, E. von Kampen. Practical Devices for the Disabled. Presented at 1977 CMBES Conference, Montreal.

5. H. Takasaki. Simultaneous All-Around Measurement of a Living Body by Moire Topography. J. American Society of Photogrammetry, Volume XLI, Number 12.

6. Y. Yashino, M. Tsukiji, H. Takasaki. Moire Topography by Means of a Grating Hologram. Applied Optics, Volume 15, Number 10, October, 1976.

7. D.G. Forsyth, G.W. Vickers, J.P. Duncan. Replication of Anatomical and Other Irregular Surfaces. 1976 Proceedings, Fourth North American Metalworking Research Conference.

8. D. Forsyth. Instructions in the Use of Shadow Moire Repercating System. Department of Mechanical Engineering, University of British Columbia, September, 1975.

9. I.V. Adair, M.C. van Wijk, G.W.D. Armstrong. Moire Topography in Scoliosis Screening. Clinical Orthopedics and Related Research, Volume 129, November - December, 1977.

A NONDISTORTING TRANSDUCER FOR MEASURING PRESSURE UNDER LOAD-BEARING TISSUE.

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A device has been developed to determine the pressure distribution under a seated or reclining subject. An array of small slack closed air pockets is inflated one at a time by means of a syringe and fine tubing. By recording the volume and pressure changes in the inflating system, the pressure at which the pocket begins to inflate can be determined. The system has been calibrated against known pressure conditions and has proven to be accurate within two millimeters of mercury. Further work is planned in automating the process.

CATEGORY:	INTENDED USER GROUP:
Device Development ☒ Research Study ☐	Researchers, Clinicians.
STATE OF DEVELOPMENT:	AVAILABILITY OF DEVICE: Not yet available.
Prototype ☒ Clinical Testing ☐ Production ☐	AVAILABILITY OF CONSTRUCTIONAL DETAILS: Yes.
AVAILABLE FOR SALE:	FOR FURTHER INFORMATION CONTACT:
Yes ☐ No ☒ Price:	J. P. O'Leary

It is generally accepted that local pressure is the major contributing element to the formation of decubitus ulcers (1). Much of the current effort at reducing the ulcer problem seeks to improve the pressure distribution. The most common method is to use pads or cushions which alter the spatial distribution of pressure supporting the patient. Other methods use active systems to change, over time, the pressure at significant locations (2). It would seem obvious that the effectiveness of these approaches can be at least partially evaluated by measuring the pressure distribution at the skin cushion interface. This paper describes a device developed for that purpose.

The problem of measuring pressure at this interface is particularly difficult compared to other situations where force or pressure measurements are required. The pressure transducer deforms the tissue, and usually the cushion. This results in a pressure distribution which may be significantly different than that which would occur if the transducer were not present. An ideal transducer would have no volume and offer no resistance in conforming to whatever shape the cushion-tissue interface adapted.

A number of recent pressure measuring devices have used a slack membrane, inflated as a balloon (3). The balloon is inflated until separation occurs in electrical contacts positioned on facing sides of the balloon wall. The pressure at which this occurs is assumed to be the interface pressure. For a value to be observed, the balloon must be inflated to a significant volume.

The work described in this paper was begun with the objective of detecting the pressure at which inflation of the balloon begins. This would be a more valid measure of pressure at the undisturbed tissue interface.

Theory

A slack membrane is closed to form a sealed container. A tube connects that container to an air source or reservoir. If the container is placed in an environment which is at a higher pressure than the reservoir, the pressure of the environment will force all air out of the container and back to the reservoir. If the pressure in the reservoir is increased there will be no flow of air into the slack container (balloon) until the pressure of the reservoir reaches that of the environment surrounding the container. At that point the container will start to fill, and if time is sufficient the pressure inside the container will equal that in the reservoir. Because the container is a slack membrane, the pressure inside the container must equal that of its environment until the container reaches its full volume. Then the membrane becomes taut and the pressure within the container can exceed that of the environment. In short, as the reservoir pressure increases the container goes through three distinct conditions: first, it is empty while the pressure of the reservoir is below that of the environment; next, it is partially full or filling while the two pressures are the same; and last, it is full when the container pressure is higher.

While the second stage condition is that the pressures are equal it does not follow that they are constant. The growth in volume may cause these pressures to increase as the container is inflated. This is the case if the "environment" is the tissue-cushion interface, where both tissue and cushion are being distorted and are resisting this distortion. This system is usable as an instrument to measure the pressure only if the pressure at which the container starts to fill can be determined.

The method used to determine the point at which this transition occurs is based on the behavior of the air in the system. Figure 1 shows the system and Figure 2 is a system which is thermodynamically equivalent. The container is modeled as a piston being held by a spring. The plunger on the reservoir side is slowly moved to decrease the volume of the reservoir and thus increase the pressure. As long as the piston does not move, the air is being compressed in an isothermal gas process, resulting in the pressure changing according to Boyle's Law. Change in volume of the reservoir will be the same as the change in volume of the gas as long as the container (balloon) does not start to fill. When the system pressure reaches the level at which the container begins to fill a deviation in the pressure vs. reservoir-volume relationship will occur. The pressure at which this deviation appears will be the interface pressure.

To predict the behavior of the system as the balloon inflates, the volume of the balloon must be known. Using spring-loaded piston as a model, at a pressure above the preload value the piston will move until the force in the spring equals the force on the piston (pressure times area). The change in spring force equals the piston motion (ℓ) times the spring rate (K). Denoting the area of the piston as A and the pressure change as Δp,

$$\ell \cdot K = A \cdot \Delta p$$

or:

$$\ell = \frac{A \cdot \Delta p}{K}$$

The change in volume (ΔV) will equal the area times the piston motion:

$$\Delta V = A \cdot \ell$$

or:

$$\Delta V = \frac{A^2 \Delta p}{K}$$

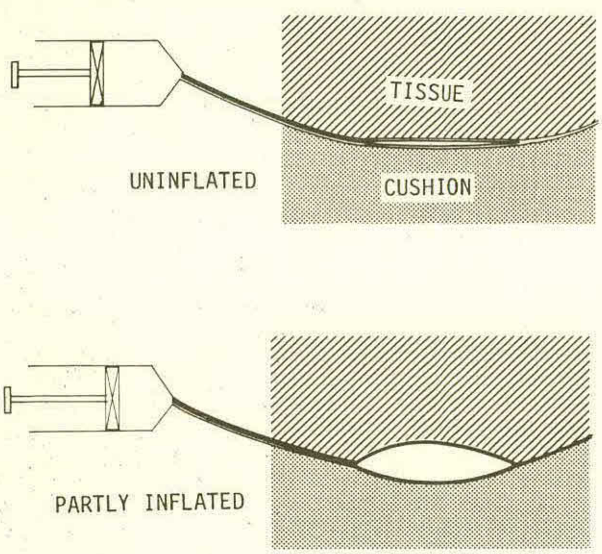

Figure 1. Measuring System.

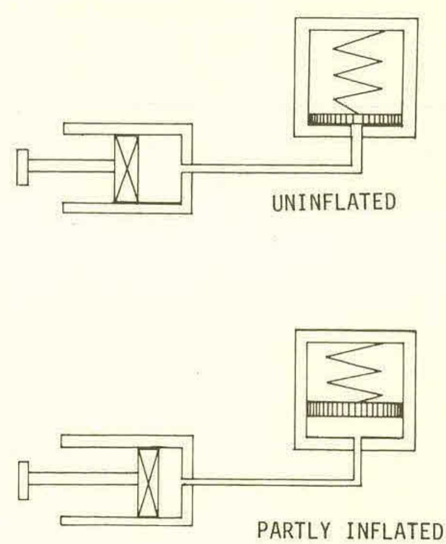

Figure 2. Idealized Model.

The resulting increase in the system volume is proportional to the amount the system pressure exceeds the environment pressure when that amount is positive.

The air in the system is a fixed amount governed by Boyle's Law, which at constant temperature states:

$$P \cdot V = \text{Constant}$$

where P is pressure and V is volume. Figure 3 shows a plot of the pressure which this relationship predicts as the volume is reduced.

The volume will be the original system volume less that swept by the plunger, as long as the balloon has not begun to inflate. The volume the balloon inflates will be offset by the plunger displacing an equal additional volume. This inflated volume was shown earlier to be proportional to the amount the pressure exceeds the environment. Figure 4 shows a plot of the pressure vs. the plunger displacement where the environmental pressure equals 60 mm Hg, and the piston has an area of .5 sq. inches and K equals 12.0 lb./inch.

Test Model

In order to determine the practicability of this concept in measuring pressure, an experimental model was constructed using a section of Polyethylene "Bubble Pack" material with approximately one inch diameter bubbles. An array of nine bubbles was used with a six cubic centimeter syringe, and an aneroid pressure gage. Connections were made with "Tygon Microbore" tubing with an internal diameter of 0.020 inches. Figure 5 is a photo of this device.

Tests were made first to determine the sensitivity of this system. Figure 6 is a typical plot showing the pressure as a function of the syringe displacement. These tests indicated that an accurate determination of the pressure at which inflation began could be made.

In order to be certain that there were no artifacts affecting the system, a calibration scheme was devised. The transducer was placed on the bottom of a trash container which was then lined with a plastic bag and filled with water. The instrument was used to measure the pressure between the bag and the container wall. The results obtained were within 2mm Hg. of that which was indicated by the water depth.

Future Work

The concept described here has been shown to be an accurate, workable way to ascertain the pressure under a seated or reclining patient or in a similar static environment. The process is, however, somewhat slow and tedious, involving the plotting of data and the determination of the curve break-point for each location at which pressure is desired. It is expected that this problem can be overcome with the addition of some control hardware and either a microprocessor to determine breakpoints, or a data channel to record the data for later automated handling. With this additional development, and a bubble array manufactured for this purpose, a set of values of pressure should be obtainable in two or three minutes.

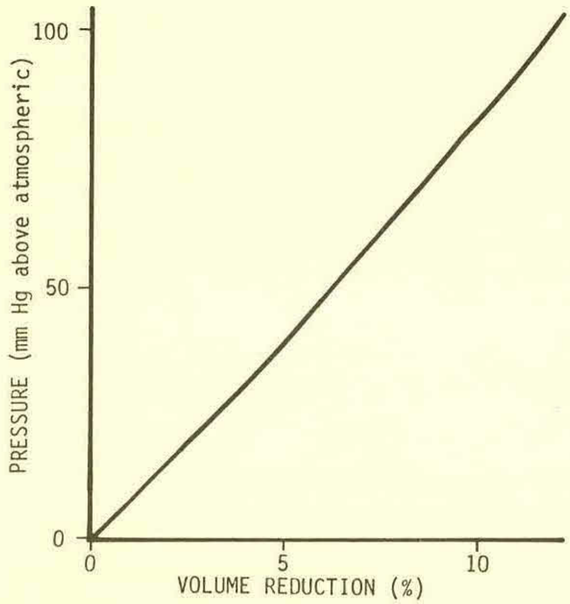

Figure 3. Air Volume vs Pressure at Constant Temperature.

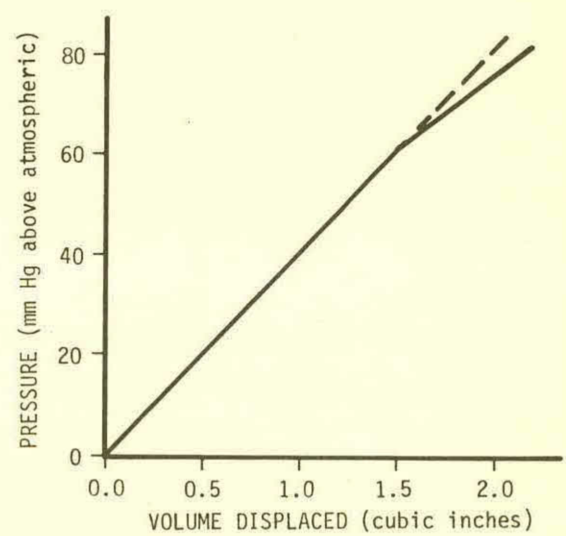

Figure 4. Idealized Model Behavior.

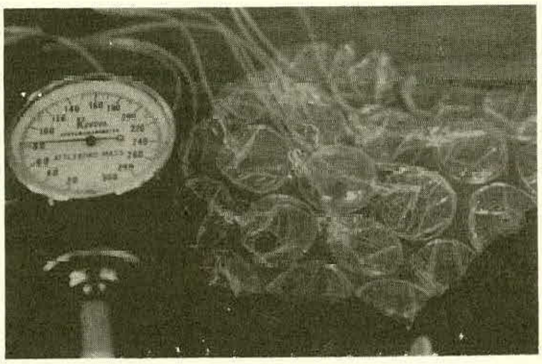

Figure 5. Prototype System

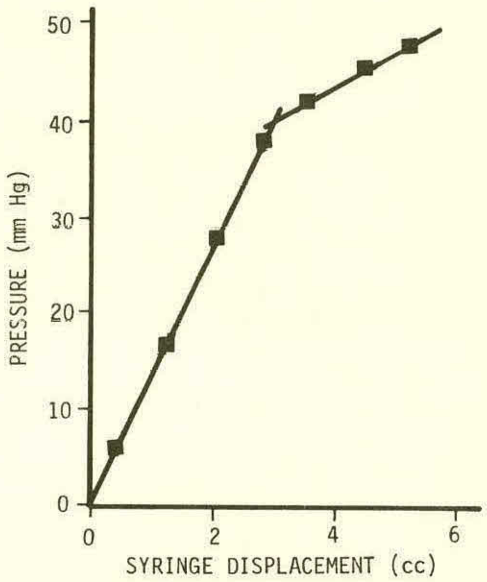

Figure 6. Prototype System Response.

References

1. Kosiak, M., Kubicek, W. G., Olson, M., et al: "Evaluation of pressure as a factor in the production of ischial ulcers." Arch. Phys. Med. Rehabil. 39:623-629, 1958.

2. Kosiak, M., "The motorized wheelchair seat, a new concept in resting support." Fourth Annual Conference on Systems and Devices for the Disabled, Seattle, Washington, June 1-3, 1977

3. Krouskop, T. A., Harrison, J. M. et al, "Effects of Posture on Pressure Distribution under Wheelchair-Bound Patients." Fourth Annual Conference on Systems and Devices for the Disabled, Seattle, June 1-3, 1977.

CLINICAL SELECTION OF CUSHIONS BASED ON A PROPOSED SOFT TISSUE DEFORMATION INDEX

Robert H. Graebe, President
ROHO Research and Development, Inc.

A clinical assessment technique is proposed based on establishment of a soft tissue deformation index. The index would establish a most allowable interference criteria so that ischemic ulcers would not be induced when sitting or using a bio-suspension device. A deformation gauge using differential temperature readings is also proposed as a clinical tool to obtain individual quantitative measurements.

CATEGORY: Device Development ☐ Research Study ☒	INTENDED USER GROUP: Clinical personnel involved in wheelchair cushion selection AVAILABILITY OF DEVICE:
STATE OF DEVELOPMENT: Prototype ☐ Clinical Testing ☐ Production ☐	AVAILABILITY OF CONSTRUCTIONAL DETAILS:
AVAILABLE FOR SALE: Yes ☐ No ☒ Price:	FOR FURTHER INFORMATION CONTACT: Robert H. Graebe ROHO Research & Development P.O. Box 866 E. St. Louis, Ill. 62203

Introduction

The complexity of the bio-suspension problem, when considering long-term maintenance of soft tissue health, has been over simplified. At the clinical level, where the cushion selection decision is made, no standard method or tools are available.

When pressure evaluations are used many test procedures require that the pressure under only one boney prominence be measured. One such data point can not allow for an optimum selection or fit.

A bio-suspension device such as a wheelchair cushion must provide two important long-term functions; maintenance of soft tissue health and overall comfort. It is the purpose of this paper to discuss how distortion of soft tissue may serve as a better means of understanding the mechanics of bio-suspension and how distortion measurements may be applied to matching cushions capabilities to the needs of the individuals.

Discussion

Cushions, mattresses, or any other type of bio-suspension device, which are used to interface between skeletal components and a supportive surface, i.e. a wheelchair seat, ideally should not be able to induce cell necrosis.

Studies have been performed (1), (2), (3), which show that small amounts of mechanical pressure are one cause of cell necrosis in soft tissue. Other studies have been performed wich show that the soft tissues of the human body are incompressible and can withstand very high pressure loading (4), without damage. These studies are supported in that aquanauts and scuba divers do not develop pressure sores (5), (6).

Both of the above conditions are true. Low amounts of mechanical pressure over a small area even for brief periods of time will cause a pressure sore. Very high hydrostatic pressure uniformly applied over large areas will not induce a pressure sore no matter how long they are applied (at least on normal skin for scuba divers in a total immersion environment).

These two extremes in bio-suspension domains leads to the conclusion that pressure measurements made only under a boney prominence is not necessarily valid. A more valid approach may be in assessing the differential pressures that exist within all areas of contact with a bio-suspension media. This approach then would recognize that distortion of soft tissue is the real villain in the cause of a pressure sore. The more accepted criteria of a not to exceed pressure level (measured under a boney prominence) would be replaced with a new set of criteria based on a not to exceed deformation limit. Such deformation limits may possibly be estimated by comparing peak to average pressures. Such criteria may offer a better set of guide lines in judging how well a cushion or mattress is satisfying the overall needs of its user. It should be noted that making many pressure measurements with accuracy and then analyzing the data is time consuming and therefore not a practical clinical method.

The cushion needs of the user goes beyond just the prevention of a pressure sore. He is faced with the every day responsibilities and obligations of his life. He or she should have the opportunity to develop his full potential and therefore not be inhibited by a sitting time limit either from threat of skin breakdown or reduced endurance for sitting long periods of time (the 18 hour day).

It is the opinion of this author that a deformation index may provide a better and more comprehensive guide line to selecting a proper fitting cushion or mattress in that it inherently includes a means of ascertaining maintenance of soft tissue health as well as offering a means of allowing for comfort. It would also facilitate research into a better understanding of suspension force effects on wound healing.

In the selection and fitting of a wheelchair cushion, pressure sore prevention is of paramount importance but not without considering the comfort offered to the user or the practical aspects of having a device which is lightweight, impervious to moisture or urine, readily cleaned, durable and reliable.

Current clinical criteria

In many clinical settings there is a lack of good instrumentation, procedures or criteria to aid in making a good cushioning selection. When the concept of differential pressure measurements are considered there hasn't been any studies identified by the author which relates the amount of distortion (shear) which can be present and not induce ischemia or to studies on the disabled to ascertain their comfort needs and fatigue factors. Distortion of soft tissue can be expected to affect discomfort and the onset of fatigue.

A study by Rancho Los Amigos Hospital (7) showed that the posterior thighs of the legs could be loaded to 80+mmHg. the trochanters to 60mmHg. the coccyx to 14mmHg. and under the ischii 40mmHg. These were considered safe not to exceed load limits. These load limits would appear to be related to how much tissue distance was present from the skeletal part in question and that scar tissue or other trauma was not present. These conclusions for pressure limits are somewhat supported by M. Sachs and M. Miller (8) where their test established (on normals) that blanching pressures at the sacrum averaged in the 60 to 88mmHg. range. These observations indicate that the 32mmHg. criterion is not necessarily valid.

Hydrostatic pressure produces a non-distorting effect on the soft tissues of the body especially with total immersion. Hydrostatic pressure occurs only in a zero shear environment which only exist in fluids. A no shear environment, especially for wheelchair users, is not practical or desirable since a wheelchair user must have purchase as well as security from sliding off from his seat.

Soft tissue deformation evaluation

The maintenance of soft tissue health can be considered from the view point of most allowable interference with natural fluid flows and exchanges in an area of contact. Most allowable interference may possibly be evaluated if deformation limits for an individual could be quantitatively measured.

Deformation of soft tissue brings about consideration of those components which affect the overall mechanical properties of tissue to resist inward deformation.

Human soft tissue is constructed, of several major components generally identified as skin, fat, muscle and a well distributed vascular and lymph system. Each of these components will make a mechanical contribution to resisting externally applied forces which tend to deform the soft tissue. How much deformation must occur, to diminish the nutritional processes by collapsing the vascular bed (ischemia) and therefore bring on the onset of necrosis, appears to be a very individualized event modified by current or past traumas.

Skin Characteristics

The condition of skin for each individual when it is tight, loose or elastic must be considered. Moist macerated skin can be expected to offer lower resistance to deformation. Scar tissue would be expected to exhibit low tolerance to deformation.

Amount of flesh available

The amount of flesh (fat) available provides a means of increasing the thickness of flesh which covers a boney prominance and therefore would permit excursion of penetration before exceeding a most allowable interference level.

Muscle characteristics

Absence of muscle bulk or tone will reduce resistance to deformation. The degree of atrophy of muscles is therefore of prime concern for each individual. Deformation resistance during a spasm or as a result of spasticity becomes an interesting factor which needs further study.

Capillary pressures

Most studies have investigated what amount of externally applied pressure will cause the capillaries to collapse and therefore produce ischemia. These studies (1), (2), (3) did not consider what effect pressure generally applied to the tissue surrounding the point of the applied pressure would cause. These studies worked only in the domain of point contact. Husain (4) recognized that a pressure difference of less than 50mmHg. will "alter the shape" of tissues and induce pathological change.

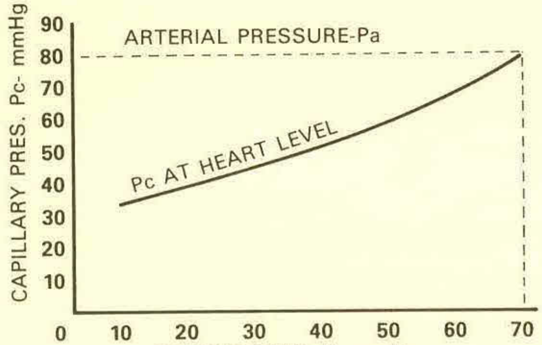

FIG. 1 VENOUS PRES. vs. CAPILLARY PRES. AT HEART LEVEL

The effect on capillary pressure with increases of venous pressure induced by a pressure plethysmograph.

McLennan, McLennan & Landis

A study by McLeannan, McLeannan, and Landis (9) showed (fig. 1) that occlusion of the venules increases the capillary pressure. Landis also showed in an earlier study (10) that the pressure inside a capillary increased as a function of blood column height (hydralic head effect) from approximately 32mmHg. to 50mmHg. when the hand is lowered from heart to hip level. Hydrostatic capillary pressure is therefore a factor in developing a variable component of resistance to deformation. Hydralic head pressures are independent of the pressure differential required, across a capillary, to maintain flow through that capillary.

Cushion selection

When considering a bio-suspension structure and how well it will accommodate the individual, a slightly different point of view can be taken. The types of cushioning available goes from high distortion short exposure time (bare seat or alternating pressure) to medium distortion (sculptured or cut-out techniques) or very low distortion (full floatation or total contact structures) which provide longer and more continuous exposure time to suspension forces.

Cushioning devices inherently present a means of supplying suspension forces through the soft tissue media to the skeletal parts which carry the weight of the body. They, therefore, can be evaluated as to how small or great their differential pressures are when engaging and supporting an individual.

The efficiency of coupling for a cushion can be measured approximately by the ratio of average pressure Pa to peak pressure Pp (see ref. 11).

$$\text{Coupling efficiency} = \frac{Pa}{Pp} \times 100$$

The match of bio-suspension needs of the individual and available cushions is void of adequate instrumentation, procedures and especially knowledge of physiological limits.

The problem therefore leads to recognizing that a deformation gauge may be useful as a clinical tool to evaluate each individual. This deformation gauge would need to have a fairly large weighted contact pad (to load the venous side of the vascular system) surrounding an adjustable deforming probe. Two (2) temperature sensors could be employed to give a relative comparison between the deformed skin and non-deformed skin (under the contact pad). Increases in probe force and displacement would be compared to the temperature differential to determine a most allowable interference level for the individual being evaluated. This assumes that as the deformation probe intruded to the point of interference with blood flow a cooling of the skin would occur. How much of a reduction in temperature can be allowed needs to be determined by additional research. If a deformation index can be established then a corresponding efficiency of coupling rating for bio-suspension structures can be used to make a selection of a cushion or mattress best suited for the individual.

Conclusion

If by no other means a visual observation can show that skin is being pushed into unusual positions or flattened out. Such distortions serve to indicate that high shear loads are in effect. Posture deformation can also serve to indicate that the user just doesn't look like he could be comfortable. Early fatigue while sitting or lack of endurance to extended sitting times may also serve as an indicator that his cushioning system is not correct even if the skin is not showing evidence of trauma. Expanded use of pressure evaluators to look at differential pressures or comparison of peak pressure to average pressure can aid in the cushion selection process.

Having a means of assessing the mechanical deformation properties of soft tissue to establish a pressure tolerance for each individual would allow for involving all of the major components of soft tissue (skin, fat, muscle and vascular system) in the determination of a pressure tolerance. The study of deformation characteristics of soft tissue may also permit a means of understanding better how an allowable mechanical force profile can be utilized to offer the least interference with wound healing.

A wide range of critical bio-suspension applications could be better served, including non-uniform pressures for therapeutic positioning, if better quantitative methods are developed to aid the clinical decision making process in cushion/mattress/prosthetics/orthotics (bio-suspension interface) selections.

References

1. Kosiak, M. Etiology of Decubitus Ulcers; "Archives of Physical Medicine and Rehabilitation" Jan. 1961 pp. 19-29

2. Dinsdale, S.M., "Decubitus Ulcers in Swine: Light and Electron Microscope Study of Pathogenesis", Archives of Physical Medicine and Rehabilitation, Vol. 54, Feb. 1973, pp. 51-56

3. Lindan, O., "Etiology of Decubitus Ulcers; An Experimental Study" Archives of Physical Medicine and Rehabilitation Nov. 1961, pp. 774-783

4. Husaine, T., "An Experimental Study of Some Pressure Effects on Tissues; with Reference to the Bed-Sore Problem" J. Path and Bact., Vol. 66, Oct. 1953, pp. 347-358

5. Underseas Habitat, "The New Encyclopedia Britannica" Macropedia Volume 10, p. 926, 1973

6. Lanphier, Edward H., "Man in High Pressures" Handbook of Physiology Vol III Chapt. 58, pp. 893-906, 1965

7. Edberg, E., and Hervey, N., "Cushion and Pad Fitting Procedure for the Wheelchair Confined Person" pp. 25-31 Rogers, J., Annual Reports of Progress Dec. 1974-Nov. 1975, Rehabilitation Engineering Center at Rancho Los Amigos Hospital, County of Los Angeles

8. Sachs, M.L. and Miller, Marian, "Circulatory and Postural Factors in Pressure Sores" USPHS Research Grant NU 00146 Date of Report 1967

9. McLeannan, Charles E., McLeannan, Margaret, and Landis, Eugene M., "The Effect of External Pressure and Its Relation to Capillary Blood Pressure and Venous Pressure", Journal Clinical Investigation 21; 319, May 1942

10. Landis, Eugene M., "Micro Injection Studies of Capillary Blood Pressure in Human Skin", Heart 15, pp. 209-228, 1930

11. Graebe, Robert H., "A Proposed Evaluation Method for Bio-Suspension Devices Using a Decubitus Threshold Pressure Concept", Proceedings Fourth Annual Conference on Systems and Devices for the Disabled pp. 199-204

"MICRO-ED" AN EDUCATIONAL SUPPORT SYSTEM FOR THE DISABLED CHILD

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A major characteristic of any support equipment for the young developing child should be flexibility, particularly in the educational sphere where the needs of a given child are constantly changing as his intellect develops. The MicroEd system described creates such flexibility by exploiting the microprocessor as a control unit. An infinitely expandable library of user programmes is made accessible, via a common transmission line, to a variety of displays and switch inputs situated around the school. A prototype display unit consisting of a matrix of lamps so controlled has just begun clinical use and applications to the areas of communication, assessment, education and recreation are immediately apparent.

CATEGORY: Device Development ☒ Research Study ☐	INTENDED USER GROUP: Severely physically disabled children from early school age onwards AVAILABILITY OF DEVICE: Not yet
STATE OF DEVELOPMENT: Prototype ☒ Clinical Testing ☒ just starting Production ☐	AVAILABILITY OF CONSTRUCTIONAL DETAILS: Refer to contact person
AVAILABLE FOR SALE: Yes ☐ No ☐ Not yet Price:	FOR FURTHER INFORMATION CONTACT: A.G. Cartwright, Department of Mechanical Engineering, University of Surrey, Guildford GU2 5XH

Introduction

The lack of flexibility in much of the currently available equipment designed to support communication, education and leisure activities in the non-vocal, physically handicapped child places a severe limitation on its effectiveness. With the advent of the microprocessor, current technology provides the possibility of greatly enhancing that support through the use of this device as a control element. Appropriately programmed, the microprocessor is capable of controlling a wide range of input and output devices.

Input devices typically include child or teacher-operated switches ranging from single mechanical or pressure switches to full typewriter keyboards. The flexibility of the microprocessor permits not only the function of the switches to be modified, but also their effect on the output device which they control. More specialised inputs like remote switches (as used on some television sets for remotely changing the channel) and audio inputs which respond to particular sound could easily be catered for. The audio input has implications in stimulating sound or word production in the child by causing the output device to respond to the child's sound.

Output devices encompass all the various means of displaying material either to the child or to the teacher and include matrices of lights, television monitors, typewriters, music synthesizers, etc. The reinforcement of visual displays with sound, ranging from a simple bell or buzzer to a recognizable voice, is eminently feasible by virtue of the microprocessor's inherent flexibility.

The exceptional degree of flexibility afforded by the microprocessor not only extends the range and degree of handicap to which machine support may be given, but also enhances the effectiveness of that support through tailoring programmes to meet not only the *current* but also the *future* needs of a particular child.

The system

In collaboration with the Child Psychology Unit of the University's Department of Psychology, the Area Education Authority's Psychology Unit, the Education and Psychology Department of The Spastics Society, who are in fact financing the project, together with two UK centres for the treatment and education of the physically and mentally handicapped child, a microprocessor based educational support system known as MicroEd is under development. The overall system consists of an expanding range of display units and interchangeable switches located in various parts of the centre, eg: the class room, the speech therapy department, the assessment unit, etc. Initially two types of display are under development. The first utilises a matrix of lamps and has just begun its field trials, whilst the second concentrates on the domestic television set as the display medium. Future displays will include music and speech synthesizers. Individual display units, each supported by an internal Intel 8080 microprocessor(1), are connected to a central, master microprocessor via a common transmission line running around the centre, see Figure 1.

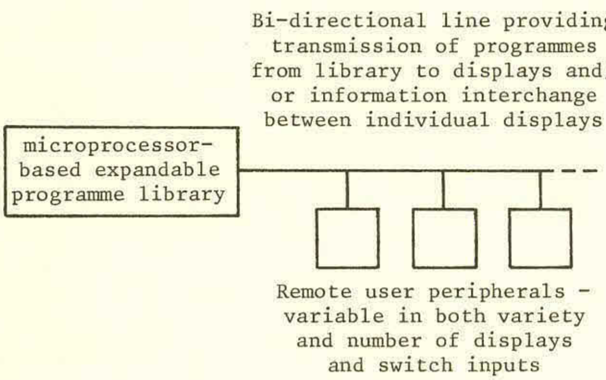

Fig. 1 A schematic illustration of the MicroEd system See text for description

The function of the central processor is two-fold: firstly to maintain an infinitely expandable library of user programmes which it transmits to the particular display when requested by a supervisor or child; secondly to provide a common link between individual displays required for example in many classroom situations.

Operation of the system is simple. Individual displays have only a programme selection dial and a number of sockets for the various input switches used by the child. Having dialed the programme, the in-built microprocessor requests the selected programme from the central library, which it then subsequently runs on its display. Should the currently running programme so require, then this processor also exchanges information with other display units via the common transmission line.

A low power standby facility permits any display to be pre-loaded with a library programme and then used remotely - in the child's home for example. In the case of the television display, the home set may be used as the display itself.

Application

Contributions to initially four major areas have become immediately feasible with this system. These are: communication, education, assessment (in particular that of intellectual ability) and game-playing. For example, methods of communication are very much a function of both intellectual and physical ability. For the young (pre-school), non-vocal child the medium of pictures seems to be a commonly used format in which the child is required to select an appropriate picture from a series. By simply sticking the pictures on to a transparent backing sheet, slotting it into the front of the light matrix display (see Figure 2) and selecting the appropriate programme number, a frame of light appears as a border around one picture. Under the control of the child this frame may be moved from one picture to another, so enabling the child to objectively 'point' to any desired picture. Variations in the number of pictures, their size or arrangement is easily accommodated via different programme numbers which generate any desired arrangement and subsequent movement of the lamps.

Fig. 2 The illustration shows a child challenging the light matrix display to a gam of Nim - illustrating just one of the possibilities afforded by a microprocessor control. Typewriter and other typical masks covering further examples of its use are also shown. Programmes stored in the central library's virtually unlimited memory are simply selected by dialling. All display units may be pre-loaded with a library programme and used remotely if required.

As age and ability increases, the addition of a typewriter and mask of typewriter symbols for the display allows the whole range of functions and modes of operation for the typewriter-assisted communication devices currently available(2) to be mimiced - simply by dialling the relevant programme number on the display. For the classroom situation the television display might be more appropriate, displaying the current page with editing facilities on the television screen (using a standard, un-modified domestic set), storing the previous pages in memory and finally producing a hard copy via a typewriter for filing.

Since the television is able to display any shape or combination of shapes, its usefulness in terms of displaying the characters used in symbolic languages such as BLISS(3) is immediately apparent.

Through the various display media a great variety of teaching and assessment programmes including matching, spelling, arithmetic, skill training, etc., are possible. Individual programmes may be modified, not only to suit the *current* needs of a particular child, but also with respect to the degree of teacher participation they involve. Objective recordings of a child's progress through automatic scoring is another easily arranged facility, if required.

But perhaps the most exciting prospect for this equipment lies in its application to leisure activities. Severe disability inevitably results in considerable periods being given to self-amusement which often means stagnation on the part of the child, since he is unable to play many of the games available to his able-bodied counterpart.

The light matrix display unit enables games such as Snakes and Ladders, Noughts and Crosses, etc., to be played with a handicapped or able-bodied partner, or independently against the machine. Games requiring secrecy, like 'Battleships', are easily arranged using two displays interacting through the central control unit. Rules may be changed if so desired by simply selecting a different version of the same programme. By means of the television display more advanced games like Lexicon and Draughts become feasible.

Evaluation

As mentioned previously the first display unit, namely the light matrix shown in Figure 2, has just begun its clinical trials and at this stage it is too early to be anything more than subjective in terms of evaluation. Being confined to this level then, indications of the relevance of this system are provided by two examples:

A disabled child's progression through the educational system is very much a function of his or her intellectual ability which is conventionally assessed utilising 'eye-pointing' as the communicative pathway. Recently assessment of a five year old very severely athetoid boy at White Lodge Centre[4] was required in preparation for his move to another school. Using 'eye-pointing' his mental age was assessed to be only 11 weeks. However, during a further assessment in which he used the light matrix as a simple pointer to objectively indicate his answers, his assessed age was shown to match his physical age - a significant result in terms of his impending move.

The second example makes reference to a small group, who have been somewhat sceptical about the use of machines in an educational support role. Suffice it to say that the demand for programmes from this group is rapidly increasing. Their changing attitudes may be embodied in the words of a therapist who summed up the potential of the system by saying, "At last we can adapt the machine to suit the needs of the child, rather than the other way round."

Acknowledgements

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The Spastics Society, 12 Park Crescent, London W1N 4EQ, England.

The Research Committee of University of Surrey, Guildford GU2 5XH, England.

References

1. Intel Corporation, 3065 Bowers Avenue, Santa Clara, California 95051.

2. Possum Controls Ltd., 63 Manderville Road, Aylesbury, Buckinghamshire, England.

3. Bliss, C.K. Semantography-Blissymbolics, Sydney, Australia. Semantography Publications, 1965

4. White Lodge Centre for the Treatment and Education of Spastic Children, Chertsey, Surrey, England.

SENSORY AIDS FOR BLIND & VISUALLY IMPAIRED EMPLOYEES

Improving Employment Opportunities Through Application of Technical Devices

Marjorie Linvill, Jerry Kuns, Susan Phillips

Sensory Aids Foundation*

Through the application of sensory aids, blind persons can overcome obstacles to employment, such as accessing visual materials and displays. Many areas of employment are open when data is changed to a form that can be interpreted by the blind or visually impaired person. This paper will describe the use of sensory aids in varied employment situations where blind or visually impaired people are now competitively employed.

CATEGORY:	INTENDED USER GROUP: Blind/visually impaired
Device Development ☐ Research Study ☐	AVAILABILITY OF DEVICE: Query vendors
STATE OF DEVELOPMENT:	
Prototype ☐ Clinical Testing ☐ Production ☐	AVAILABILITY OF CONSTRUCTIONAL DETAILS:
AVAILABLE FOR SALE:	FOR FURTHER INFORMATION CONTACT:
Yes ☐ No ☐ Price:	Sensory Aids Foundation 399 Sherman Ave., Suite 4 Palo Alto, California 94306

An area which poses serious problems for many blind persons is employment. Blind people in the United States have a significantly higher unemployment rate than their sighted counterparts. Among the employed blind there is marked underemployment.

This paper will address the role of sensory aids in solving employment problems for blind and visually impaired people. Sensory aids are instruments which can augment the vision which a partially sighted person has or provide alternative forms of information for totally blind individuals.

Much of the difficulty in obtaining suitable employment for the blind is the concern of the potential employer about the ability of a blind person to perform. Through the application of sensory aids, blind persons can overcome obstacles to employment, such as accessing visual materials and displays. Utilizing appropriate adaptive devices, a blind person on the job demonstrates improved productivity, decreased dependence on sighted intervention, and an ability to accomplish a wider range of job-related activities.

Sensory Aids Foundation, Palo Alto, California, has been operating a vocational program, An Expanded and Technically Innovative Vocational Development Program for the Blind, for over two years. Our initial and continuing problem in developing employment opportunities through this program is to find ways to interpret or access information that cannot be seen but must be converted so that the information can be interpreted by the blind person. The use of a wide range of sensory aids in varied employment situations has resulted in the placement of over 80 blind people in competitive positions. In this program the expertise of the technologist and the skills of the rehabilitation placement specialist are combined with the existing Rehabilitation System to generate these employment opportunities, which range from professional to assembly line jobs.

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In these placements many sensory aids are used. Sometimes it has been necessary to develop new devices or to adapt existing equipment to meet the needs of the blind employee. Some examples will best demonstrate how we solve the problems of changing data to a form that can be interpreted by the blind or visually impaired person.

A totally blind machinist fills commercial orders from his home shop. To fill these orders he has special equipment which allows him to complete work tasks. In the machinist trade a visual readout dial indicator is commonly used for precision measurements. With the indicator, the sighted machinist can center his lathe, checking to see if the work is rotating true with no wobble. He can also perform dimensional checks on parts he or someone else made. In addition, he can set up tools and jigs to be used in machine work.

The blind machinist has a substitute for the visual readout dial indicator. It is an electronic gauge built in cooperation with San Francisco Rehabilitation Engineering Center. The gauge has audio and tactile readout which provides information on mechanical or linear displacement to 1/1000 of an inch. The gauge utilizes a linear variable differential transformer (LVDT) as a sensing probe.

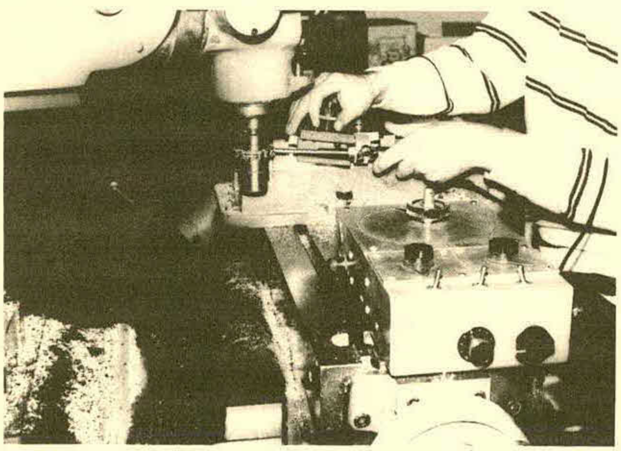

Figure A-1 Machinist Setting Up Mill With Electronic Gauge

This substitute electronic gauge is important in that it is an example of a portable component for existing machinery in industry which can be carried on and off the work site by blind employees. This substitute electronic gauge does not need to be permanently attached to machine tools.

The substitute electronic gauge is vital equipment for the blind machinist but it also has applications in the field of auto mechanics. The dial indicator measures the amount of the axial or radial play, information needed for checking bearings. The free play of the shafts can also be indicated with this device.

Another piece of equipment used by the blind machinist in his shop is an adapted dial gauge. The San Francisco Rehabilitation Engineering Center adapted a commercially available electronic dial gauge with analog readout to include auditory output and tactile readout. With this equipment, the machinist can complete his inspection work, such as identifying gauge blocks (normally done visually), testing parts for length and height, and measuring the distance between holes.

Figure A-2 Machinist Taking Precision Measurements With Adapted Dial Gauge

In our program a second blind machinist, off the job for 1½ years due to his blindness, has been hired to rebuild refrigeration compressors for airplanes. One of the requirements of his job is to check the refrigeration system for gas leaks after the repairs have been completed. Air is forced into the system until it reaches a pressure of 300 psi. It is then necessary to monitor the pressure inside the system. Sighted machinists do this by watching a large gauge with a needle pointer. Since this needle is too delicate to be touched by the blind machinist, an alternative was developed. Working in close cooperation with the San Francisco Rehabilitation Engineering Center, a new device was developed to accomplish the monitoring task. An Auditory Electronic Pressure Gauge was produced.

The gauge measures 5"x7"x3". A hose connects it to the refrigeration system. On top of this box is a crank knob with a pointer. Braille markings for the pressure levels surround the pointer. As long as the pointer is not on the correct value of pressure, the unit produces a tone. When the pointer is adjusted to the correct pressure setting, the tone disappears.

Because the output is audible, the machinist can be working on another project in a different area of the shop. Also, this technology can be used in other pressure measurement tools, in laboratory instruments that require vacuum readings, and in auto vacuum gauges.

A wide variety of aids are currently available for the visually impaired. The one using the most advanced technology is the CCTV, closed circuit television. This device utilizes a television camera and monitor screen which produces enlarged and enhanced images. It can enlarge documents placed under the camera up to 60X the normal size based upon individual needs. In this employment program a Claims Examiner for a Life Insurance Company uses such a device to access written material. Also the same type of equipment is used by a Deputy Court Clerk, a college level Coordinator for Blind and Partially Sighted Students, a Systems Analyst, a Medical Center Supervisor, and a PBX Receptionist. A Telephone Service Representative had her job expanded through the use of a new CCTV system with microfiche viewer. This device permits the representative to read microfiche records not accessible to her previously. She now has more immediate access to accounts and stored information.

A new device, a CCTV Selectric System, has been developed in this employment program. This system allows partially sighted individuals to efficiently use Selectric-style typewriters. The camera may be moved across the page of type so that one can view the last several letters of typing. This CCTV system permits form completion, proofreading and error correction with a Selectric-style typewriter. Also, it may be adapted for word processing equipment and hard copy computer printers. The CCTV system is now utilized by a legally blind secretary in a large electronics company. Some of her job duties include: typing memos, letters, status reports and charts; taking messages from a call director system for seven people; and taking minutes at department business meetings utilizing low vision aids.

Figure A-3 Employee Typing Document From Copy With Aid of CCTV Selectric System

In our program, totally blind people are using the Optacon, a machine which converts ink print into tactile information which can be read by the user.

A totally blind college graduate is now working as a Human Services Aide in the City of La Mirada, California. An information and referral service is being established to provide general, social, and public service information to local residents. This individual has been one of the principals in creating the service and organizing the information. He assesses all social and public service agencies and updates the readily available format of information, so that either he or a sighted individual may access the information. The formated material was specially designed to be rapidly Optacon-readable. Material is housed in a catalog rack with braille and print tab dividers for easy referencing.

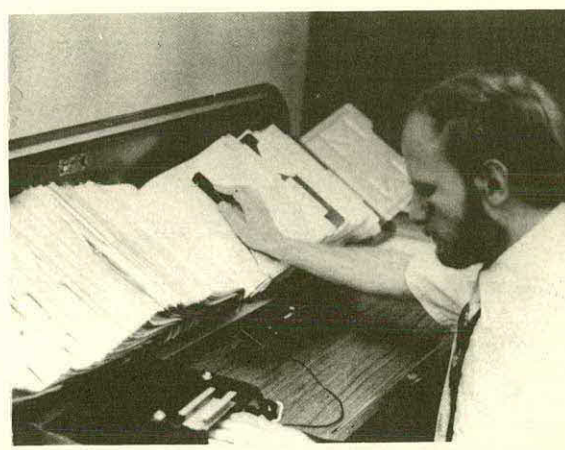

Figure A-4 Human Services Aide Reviewing Cataloged Information With Optacon

In addition to the Optacon with typewriter attachment for reading and form completion, the individual uses a light probe for answering a multi-line telephone. He responds to information requests by referencing the stored materials and providing immediate feedback to the calling party.

Additionally, word processing operators, medical transcribers, and secretaries use the Optacon to proofread their work and to correct their typing errors. A library assistant uses the Optacon to read processing slips for new books as they arrive. In order to review these processing slips quickly a special template was designed which increases the speed of camera positioning and information spotting. A music therapist in a State Hospital uses the Optacon to read residents' charts, memos, and other printed materials. A radio archivist utilizes the Optacon to retrieve typed data from labels on discs, tapes and other documents. Computer programmers use CRT lens attachments for viewing data on CRT displays and Optacon tracking guides for more rapid scanning of computer printouts. In our program, people in positions such as physical science technician, bank loan officer, elementary school teacher, engineer, and job information specialist use the Optacon for reading educational, scientific and business manuals.

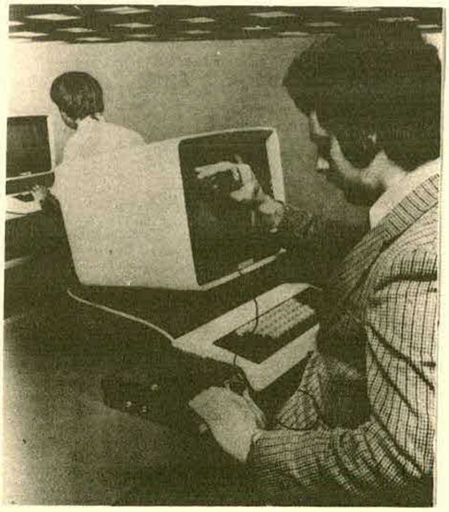

Figure A-5 Computer Programmer Examining CRT Display With Optacon and Special Lens

These employment situations are successful because the job matches the talents of the employee and because sensory aids and adaptive equipment have been appropriately utilized to significantly reduce the effects of a handicap. Through the application of sensory aids, it is clear that the effects of a handicap in employment settings are significantly reduced. The end result of selective placement with necessary adaptation or support equipment is that blind employees are competitive with their sighted contemporaries.

Acknowledgements

We would like to thank the Foundations, the Companies, the individuals, and the California Department of Rehabilitation for their contributions to this program. We appreciate their financial support and encouragement.

References

1. Sensory Aids Foundation, Quarterly Reports, Volumes 1-7.

AN ELECTRONIC GAMES CENTER FOR THE BLIND

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The first sophisticated electronic game for the blind was developed with the aid of keyboard, microcomputer, and speech synthesis technologies. All game cues and results are provided audibly. Eight different games are built into a single unit. A ball game, "Paddleball", played using stereo earphones, is an audio version of video ball and paddle games. "Craps", "Blackjack", and "Tic-Tac-Toe" closely follow well-known rules. "Skeet Shoot" simulates various bird "flight paths" across the nine-digit keyboard. The "Chain Game" requires unerring recall of an ever-increasing sequence of digits. "Number Run" is a race against time to correctly press a fixed number of keys. "Tug-o-War" is a reaction-time match between two players. They are educational and recreational.

CATEGORY: Device Development ☒ Research Study ☐	INTENDED USER GROUP: The Blind AVAILABILITY OF DEVICE: Contact Manufacturer
STATE OF DEVELOPMENT: Prototype ☐ Clinical Testing ☐ Production ☒	AVAILABILITY OF CONSTRUCTIONAL DETAILS: Not Available
AVAILABLE FOR SALE: Yes ☒ No ☐ Price: $895.00	FOR FURTHER INFORMATION CONTACT: Vladimir Walko Telesensory Systems, Inc., 3408 Hillview Ave., P.O. Box 10099, Palo Alto, Ca 94304 Telephone 415/493-2626

Commercial video games are currently very popular but cannot be played by the blind. Development of keyboard, speech, and microcomputer technology gave us at Telesensory Systems the tools to consider special electronic games for the blind. Blind people can successfully use keyboards for input, as proven by the acceptance of our SPEECH+ talking calculator. Speech provides a natural output medium requiring no learning. Microcomputer technology gives the ability to readily program and try alternate possibilities, as well as to achieve a relatively low cost implementation of sophisticated and varied games.

To test the idea of games for the blind, we built two breadboard game units. The first utilized a keyboard input, speech output, and microcomputer control to implement a number of games that we either invented or adapted. The second breadboard used analog and discrete logic circuitry to create an audio version of the ubiquitous TV-display ball and paddle game. The acid test, of course, was whether the games were fun to play. We informally tested them with blind students from our periodic Optacon training classes. It was quickly evident, from the spirited play, that the games were indeed enjoyable and welcome. It was therefore determined to clean up the software and package the hardware into a single Games Center for the Blind.

The final unit contains eight games housed in a single package and microcomputer controlled. Figure 1 is a photograph of the unit. It is small enough to be easily transportable, measuring 16" x 14" x 4". The games are played either on the keyboard or with the two slide potentiometer controls. The built-in loudspeaker or headphones provide the audio cues. The particular game desired is chosen by pressing its number on the keyboard.

We call the audio ball and paddle game "Paddleball". The "ball" in Paddleball is created by a time-varying audio tone heard via stereo headphones by each of the two players. Up-down ball motion is indicated by increasing and decreasing pitch. Left-right motion is indicated by relative intensity of the ball signal in each ear. Fish (1975) showed that a display of this sort, using pitch for vertical localization and stereo separation for horizontal localization, was effective for audibly creating a virtual spatial image.

Like its video counterpart, the Paddleball "ball" is simultaneously moving back and forth, up and down, driven by asynchronous oscillators. Each player has a slide potentiometer paddle, with which he tries to "hit" the ball at either the left or right "wall". The paddle moves vertically with its vertical position represented by the pitch of a chopped tone. The goal is for the "left" player to match steady ball and chopped paddle tones at the instant of time when the ball tone is strongest in the left ear, thereby making a "hit". Similarly, the right player tries to match his paddle and ball at the right "wall". Using synthetic speech, the computer registers hits and keeps a running total of the score. The first player to achieve ten hits and lead by two is declared the winner. In case of ties, play continues until either player leads by two.

Paddleball is harder to describe than to play, and is usually learned quickly. As an added challenge, the paddle "width" (i.e., how close the pitch of paddle and ball tones must be matched to declare a hit) can be narrowed for expert players. Also, the game can be played using any stereo system, rather than headphones, allowing for group participation and "kibitzing".

The keyboard games utilize a modified SPEECH+ calculator keyboard and words chosen from the SPEECH+ vocabulary. The speech synthesizer is also used to create special tones for prompting and "sound effects".

Three of the keyboard games are versions of well-known pastimes. In "Craps" and "Blackjack" the player matches his skill against the computer. The computer plays the role of the "house" or dealer, following the rules and statistics of each game. In "Tic-Tac-Toe", two players play using the matrix of the keys defined by keyboard number positions one through nine. Instead of the traditional "X" and "O", "plus" and "minus" define each player's positioning on the matrix.

We invented the remaining four games, using traditional principles. "Skeet-Shoot" again uses the one-through-nine matrix, this time to define three digit, linear "flight paths" of the bird ("one-two-three", "three-six-nine", etc.). The player scores a hit by pressing any key of the sequence as its number is announced. A game consists of sixteen trys, with the speed of "flight" increasing as the game progresses. The "Chain Game" is a short-term memory game where the player tries to repeat an ever-increasing string of digits. At each subsequent trial, another randomly chosen digit is appended. The game continues until the player is unable to correctly repeat the sequence. In "Number Run" the player tries to race the clock in entering a sequence of digits. Each correct entry triggers another random digit. Finally, "Tug-o-War" is a reaction-time game between two players. Whoever presses his key first after a random "beep" is rewarded, and the first player whose total "wins" exceeds the opponent's total "wins" by five is the winner. If a player cheats by pressing the key before the beep, a two-point penalty is assessed.

The hardware needed to construct the Game Center is depicted in block diagram form by Figure 2. Game control signals are input from the keyboard (which contains the "hard/easy" paddleball switch), the potentiometers, and the audio volume control. Audio output signals are generated by a small loudspeaker and (for Paddleball) two headphones. The electronics consists of three printed circuit boards -- a 6800 microcomputer, an analog board, and a speech synthesizer board.

The microcomputer was designed by us especially for the Game Center, using a MC6800 microprocessor. It is programmed using 2048 bytes of read-only memory and requires 256 bytes of random-access memory. It communicates with the keyboard, analog board, and speech board via two parallel interfaces. The computer is designed for easy troubleshooting and service using the signature analysis technique.

The speech synthesizer utilizes technology described elsewhere (Savoie, et al, 1976) whereby highly encoded speech waveforms are stored in read-only memory and then decoded by a custom LSI circuit. This technique enables a limited set of words to be generated inexpensively. To save vocabulary generation and read-only memory mask expense, the SPEECH+ vocabulary is used.

The analog board is composed of quad operational amplifiers and CMOS gates. It generates, using voltage-controlled oscillator circuitry, the "ball" and "paddle" for Paddleball. The analog board also contains comparator circuitry, controlled by each player's potentiometer "paddle", which determines whether a "hit" is made.

The keyboard, microcomputer, speech synthesizer and speaker are used for the seven keyboard games. The computer's stored programs operate the various games. The computer scans the keyboard and determines what key is pressed. In accordance with the logic of the particular game chosen, the appropriate speech codes are then sent to the synthesizer.

For Paddleball, the three voltage-controlled oscillator signals (ball, left paddle, right paddle) generated by the analog board are sent to the headphones. The left and right paddle control signals determine the pitch of the paddle tone. Digital signals that indicate hits and ball direction are sent to the microcomputer. With these signals, the computer does the necessary bookkeeping, and drives the speech synthesizer which announces the score.

An additional important capability made

FIG. 1 PHOTOGRAPH OF THE GAME CENTER

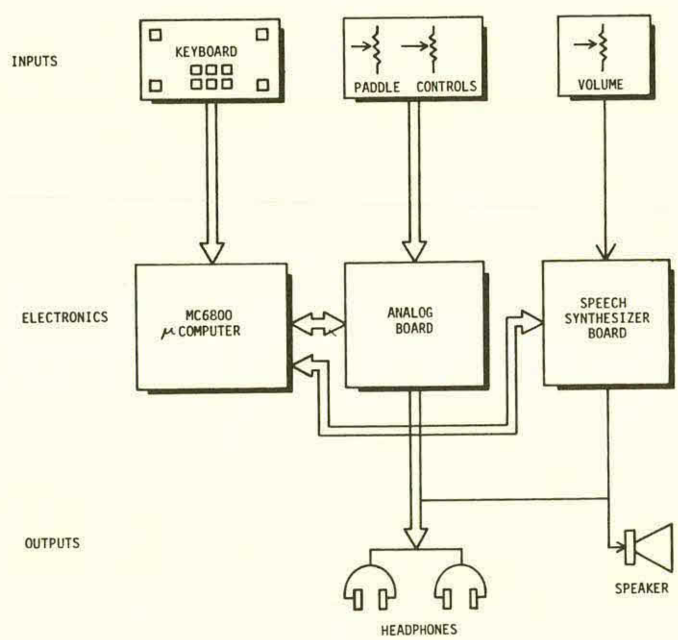

FIG. 2 BLOCK DIAGRAM OF ELECTRONIC GAMES CENTER

possible by the use of a computer is self-checking. When the unit is turned on, startup routines spend several seconds checking most of the computer circuitry, and then the speech synthesizer announces that play can commence.

In summary, we have utilized up-to-date digital and analog circuitry, keyboard, and speech technology to create the first sophisticated electronic game ever developed for the blind population. User tests verified that the games are fun, and user feedback helped determine the final specifications. We tried to mix the choices to provide single and two-player games, and to provide mental and physical challenges. Another important feature is that sighted and blind players can compete on an equal basis. We speculate that at least some of the games may have educational and/or motor training value. However, we feel that purely recreational devices for the handicapped have been neglected, so the games need no further justification beyond enjoyment.

References

1. Fish, Raymond M., "An Audio Display for the Blind", IEEE Trans. on Biomedical Engineering, Vol. BME-23, No. 2, March 1976, pp 144-154.

2. Savoie, R.E., J.S. Brugler, and J.C. Bliss, "Development of a Hand-Held Talking Calculator for the Blind", AFIPS Conference Proceedings, Vol. 45, June 1976, pp 221-225.

AUTHOR INDEX

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