Proceedings of the Fifth Annual Conference on Rehabilitation Engineering

Houston, Texas, USA
August 22-26, 1982

**1982—
THE NATIONAL
YEAR OF
DISABLED
PERSONS**

Technology Utilization
The Key to Independence

Proceedings of the Fifth Annual Conference on Rehabilitation Engineering

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Thomas A. Krouskop, Ph.D.
Conference General Chairman

The Conference Committee endeavored to build on the strengths of previous meetings and to plan educational, scientific, and social events that would stimulate interdisciplinary discussions on some very timely topics in rehabilitation engineering. This year a series of formal instructional courses was added as a pre-conference activity and a poster session incorporated into the exhibit hall to provide a forum for new ideas for technical aids.

The theme of the conference, Technology Utilization: The Key to Independence, was selected to help us demonstrate how the results of rehabilitation engineering activities have increased the independence of handicapped people and enabled them to more easily integrate their lives into the mainstream of society.

This document contains abstracts of all contributed papers for presentation at the Fifth Annual Conference on Rehabilitation Engineering. The abstracts were prepared by the authors and have not been edited. The papers from the student design competition have been edited so that all could be included in this volume. The role of these abstracts is to permit work to be shared with other fellow workers while the ideas are timely and moldable so that the interchange can play a significant role in formulating final ideas and developments. The abstracts are arranged in schedule order of presentation and can be used in conjunction with the program to schedule the most effective use of your time during the conference.

These proceedings are a continuation of publications begun in 1974 by the Conference on Systems and Devices for the Disabled. Documents from those conferences, along with proceedings of the Second Interagency Conference on Rehabilitation Engineering in 1979, the International Conference on Rehabilitation Engineering in 1980, and the Fourth Annual Conference on Rehabilitation Engineering in Washington, D.C., in 1981 form an almost unbroken record of activities in rehabilitation engineering from the time this field began its rapid growth.

The conference committee believes that this compilation is particularly important to workers in the field of rehabilitation engineering since it provides a means of accessing earlier or more comprehensive work on a particular subject that has been published in one of the broad ranging journals that serve the many disciplines involved in applying technology to solve problems of the handicapped community.

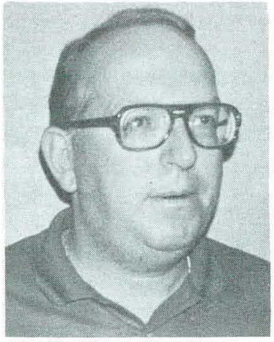
Thanks must be extended to my colleagues on the Conference Committee for their time and efforts on behalf of RESNA and this conference, and to the staff of TIRR, particularly Barbara Crisp.

The Fifth Annual Conference on Rehabilitation Engineering is sponsored by the Rehabilitation Engineering Society of North America (RESNA) for the second time. This Conference is one of a growing number of activities in which RESNA is involved. Other projects include publishing a quarterly newsletter and providing much of the technical input necessary for establishing voluntary standards for wheelchair manufacturers. We have a national headquarters and an Executive Director, Pat Horner. Our most valuable asset is a growing number of enthusiastic members! All in all, we have made a good beginning for a society in its third year.

I would like to take this opportunity to invite any of you who are not presently members to consider the benefits of membership in RESNA. Our society is open to all persons who are interested and involved in the development and delivery of functional aids and other equipment for disabled persons. If this describes your interest, please join with us as we continue to develop activities and programs to promote the application of appropriate technology for the benefit of those who are disabled.

Special recognition is due the Conference Chairman, Tom Krouskop, and his committees. We extend our appreciation and thanks to them and their institutions which so generously supported the Committee's efforts.

Donald R. McNeal, Ph.D.
President, RESNA



James P. O'Leary
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Scientific Papers

This is the second year that the Annual Conference on Rehabilitation Engineering is being conducted by the Rehabilitation Engineering Society of North America. These proceedings attest to the continued health and growth of our very young organization, as well as documenting the breadth of interest represented by those involved in technology utilization for disabled individuals.

Sections of this publication deal with communication, mobility, service delivery, and a variety of other problem areas. They are dealt with in theory and in clinical practice, in the present and even in the future. (There is little here which notes the past.) The diversity of topics is most gratifying and it is hoped that it will continue to be a hallmark of this meeting.

A seemingly thin area is the reporting of clinical trials and hard data on the successful implementation of technology in the community. Perhaps the format used in this volume made that difficult, or perhaps the lead times were too constraining. We must start to document this aspect of our efforts, to provide better information (and perhaps arguments) to those who would use the results of these innovations. With next year's meeting scheduled for June, it isn't too soon to begin to think about those kinds of papers for the proceedings. Work on it, please.

This volume records some diverse work and achievements in the area of Rehabilitation Engineering. No book with as many authors as this one can be expected to tell a coherent story, but if these proceedings are examined closely, an interesting and very coherent picture may become apparent.

Recorded here are the efforts of a number of individuals representing a large number of professions, a variety of types of organizations, wide ranging amounts of experience, and dealing in various aspects of many distinct problem areas. For many reasons, Rehabilitation Engineering is a multidisciplinary field, and these proceedings reflect that, as have previous volumes. The underlying story is that the problems are everywhere, at all levels, and so are the individuals willing and able to tackle them.

It is this group of individuals who are responsible for this publication. This is a record of their work, written in their words. It is they most of all who need to be thanked for their efforts.

Thanks must be extended to some people for other contributions, to Rick Foulds and Bill Crochetiere who helped review papers and gave valuable counsel, to Tom Krouskop who, as meeting chairman, was most patient, asking little and always answering on the positive, to Margaret Vilaine in my office, and to Pat Horner and Susie Fletcher of the RESNA office, who did all of the real work, always cheerful even when the rest of the world was putting them further behind schedule. A sincere thanks to all of you who made my task easy.

August 1982

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A DATA-BASED APPROACH TO CHARACTER/SYLLABLE/WORD SETS

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One of the principal methods of accelerating a non-speaking individual's rate of communication is to eliminate the need for the individual to spell out words letter by letter. Originally, this was done by including words and phrases along with the alphabet on communication boards. In addition, endings such as "-ed" and "-ing" were often included. Choice of a particular set of words for the communication board, however, was usually done based upon little or no hard data, and often did not represent the optimal set based upon the person's actual usage.

More recently, studies such as that done by Cheryl Goodenough-Trepagnier[1] have taken a more quantitative look at wordsets to try to optimize them. The WRITE system, for example, is a carefully selected set of letters, groups of letters, and words which has been optimized based upon existing word frequency studies. Several versions of WRITE are available depending upon the number of squares to which the client is able to point. These studies, however, are limited to a single level, direct selection communication aid. Adding levels to the system, using a scanning technique, using an encoding technique, or employing any other strategies which make selection of some items easier than others, would result in an entirely different character/unit/word/phrase (CUWP) set. In addition, changing the word usage study used as the basis for the analysis will change the CUWP set. Since the word frequency pattern for physically handicapped individuals is likely to differ from that of non-handicapped individuals, some systematic means for recalculating the optimal CUWP set needs to be generated.

Character/Unit/Word/Phrase (CUWP) Analysis Program

In order to provide a mechanism for analysis of the effect of different word usage patterns and selection algorithms on the optimum CUWP set, a series of programs has been developed and implemented on an IBM Personal Computer. These programs allow the researcher to simulate any selection algorithm, and to determine the optimum CUWP set and physical configuration of vocabulary items on the communication aid being modeled. The programs then automatically calculate an efficiency score showing the increase in communication rate which would be achieved using this set over straight spelling.

The programs allow the user to rearrange the items, change the words, or in any way desired modify the CUWP set and its arrangement. The computer will then recalculate the efficiency, and present the efficiency score of this new system both as it compares to spelling, and as it compares to the original computer optimized wordset and arrangement. In the same manner, the programs allow any arbitrary vocabulary and arrangement to be tested on any communication aid model. They will provide both an overall efficiency score and a comparison of said vocabulary against the computer optimized vocabulary for that aid.

Clinical Use

Although the programs are designed to make modeling of the aids and vocabulary systems possible, they will generally be too detailed to be easily clinically applicable. Major techniques and aids will therefore be pre-modeled and vocabularies analyzed for them. These example vocabularies can be used as starting points in generating custom vocabularies without needing to go through extensive calculation or effort. Emphasis will be placed upon practical discussions of how to use the information provided, and not just upon presentation of pages of data, with little insight as to how it can be used clinically. The manual will be set up in such a way that:

1) clinicians will be able to see the general form and content of optimized vocabulary sets for these aids
2) clinicians will be able to see the effect of various aid parameters on the overall efficiency of wordsets and arrangements
3) clinicians will be provided with rules-of-thumb in vocabulary selection and layout
4) clinicians will be able to judge the direct impact of adding or deleting specific words from an individual's vocabulary and will be able to determine the relative efficiency of the word when placed in different locations or different levels in the system.

The overall effect will be the provision both on a research and on a clinical level of systematic methods for selection and analysis of the efficacy of specific CUWP sets, allowing the user to tap the results in both simple and advanced forms.

Funding: National Institute for Handicapped Research

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OPTIMAL LANGUAGE MENU FOR A ONE-SWITCH NONVOCAL COMMUNICATION DEVICE

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One of the primary interface strategies for nonvocal communication aids is the use of a single switch, adapted to conform to the residual motor ability of the most severely impaired patients. Row-column scanning, and the arrangement of the alphabet placing letters with highest frequency of occurrence in positions requiring fewest steps are traditional menu selection strategies. Another approach (1) used a data base of quadgram frequencies to offer predictions of upcoming characters based on the last 3 characters entered. This technique resulted in a 23% improvement in rate. Larger inventories of language units, when appropriately chosen, may greatly reduce the average number of such units the user needs to put together to produce each word. Data from a subject using an alphabet and a 400-unit system, both via direct selection, showed a 30% communication rate advantage for the larger system, attributable to its units-per-word "cost" C=1.5 (compared to C=3.9 for the alphabet) (2). Extrapolation from this data to an encoded system with the 26 key interface of the alphabet device, but a 400-unit inventory with C=1.5, predicts an even greater rate improvement (3). Similarly, calculations for a hypothetical direct selection system based on a linear array of keys and assumptions derived from Fitts' Law predict continuous improvement in rate for increases in size for inventories of this type over a range of 64 to 512 (4). Given these indications of rate enhancement with large inventories for direct selection and encoding, it is of interest to question the traditional practice of using only alphabet plus short word list menus with scanning devices.

The technique used to derive the low C unit inventories referred to above assumes equal access time for each unit. While this assumption is necessary in deriving unit lists for direct selection and encoding, actual access times depend on the particular motor abilities of each patient, and the input interface configuration and coding system (3 ,4). In the case of scanning devices, however, relative access times for units are determined entirely by their position in the scan sequence. Only the dwell interval is adjusted for the individual user. Furthermore, there is considerable difference in access time between the most and least rapidly accessible units.

On this basis, a modification of the procedure used to derive SPEEC and WRITE is proposed, in order to minimize steps per word on a scan interface:

i) A representative text is decomposed into a list of all units of lengths ranging from single letters to whole words.

ii) Redundant units are deleted. For example, NESDAY is omitted while WEDNESDAY is retained since the former only appears as a subset of the latter.

iii) The truncated unit list is used to resynthesize the original text, using fewer, longer units to build words where possible. A count of total uses is obtained for each unit and units are listed in order of descending frequency.

iv) Assuming a hypothetical scanning array large enough to accept the truncated unit list, units are mapped onto locations so that greater frequency of occurrence is associated with shorter access time.

v) Average word access time is calculated from the sum of the products of unit use counts with their associated access times.

vi) Practical-sized inventories are derived by further truncation. Units are chosen for deletion by determining which can be replaced by sequences of shorter units with the least increment in average access time.

Steps iii) through vi) are then repeated.

Further refinement and testing of the derivation technique are in progress.

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TEN-BRANCH ABBREVIATION EXPANSION FOR GREATER EFFICIENCY IN AUGMENTATIVE COMMUNICATION SYSTEMS

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At the present time, one of the primary barriers to the effective use of augmentative communication systems is the rate of information transfer. Whereas normal speech rates are about 200 words per minute, and normal writing rates are about 35-40 words per minute, the usual rate of character input by physically handicapped individuals is .5 to 3.0 words per minute. Because of this, a number of specific approaches have been developed to try to accelerate the rate at which an individual can feed information to a writing system in order to increase his effective rate.

Most acceleration techniques involve the use of full word or phrases to supplement spelling. For the individual who can point to a large number of squares (or keys) (approximately 200-300), the words or phrases can be directly displayed. Levels can be used to allow more than one word or phrase per square (or key). Both of these techniques, however, have limitations in the size of the vocabulary which can be supported (usually 1,000 words or less). When one considers that the normal five year old child operates with a vocabulary of 2,500 words, and the adult with a vocabulary of 10,000 words, the extent of this limitation can easily be seen. It is also difficult to display longer phrases or sentences which cannot be written on a portion of the square (or key).

One solution that has been tried is the use of number codes to access the vocabulary items. For smaller vocabularies, this is a powerful and useful technique. As the vocabulary gets larger, however, it gets increasingly difficult for the individual to remember the number code for each of the words.

Abbreviation Expansion: In an effort to circumvent the problems associated with memorizing number codes, researchers and clinicians have tried using letter codes or abbreviations for words. This technique has the advantage that letter sequences which have an orthographic or phonetic relationship to the desired word can be used, making memorization of the codes easier.

In some cases, abbreviations are selected on an idiosyncratic basis; in others, they are made up in some systematic fashion, using a set of rules. With the latter approach, an individual would generate the same abbreviation for the same word over multiple trials. If this approach is taken, one would not need to remember the abbreviation for each word explicitly, since it is easy to reconstruct (for this method, it is beneficial to have some type of display of the word which has been indicated before entering it into the text in order to check accuracy of recall.

A Means for Implementing Abbreviation Expansion Routines: Initial abbreviation expansion routines looked for strings of characters followed by a period. Whenever this occurred, the aid would look up that string in the dictionary to see if it was an abbreviation on record. If it was, the aid removed the abbreviation and replaced it with the proper word or phrase. This approach could result in problems, however, if letter/period combinations were used in text and at the end of sentences.

Use of a special terminator, rather than a period, solves this problem. Whenever the expansion program encountered this special terminator, it would look up the character string immediately preceding the terminator. The special terminator might be implemented using a key labeled "EXPAND".

This technique would allow abbreviations of any length to be used. As a result, it is possible to have 26 two-keystroke 676 three-keystroke and 17,576 four-keystroke abbreviations (remembering that it takes a keystroke to hit the terminator or EXPAND key). Many of these keystroke combinations, however, do not yield useful letter sequences (in terms of mnemonic characteristics) and would generally not be used. Also, it is generally not very effective to use four-keystroke sequences to encode five-letter words. Finally, many of the codes (such as those starting with the letter "S") are used up quickly, while others (such as those starting with the letter "Q") would go unused.

TenBranch Abbreviation Expansion Approach: In the above abbreviation expansion routines, it can be noted that one keystroke is required at the end of every abbreviation expansion routine, in order to activate the look-up system. With the ten-branch abbreviation expansion routine, any sequence of alphanumeric characters which ends with a number (e.g., "A1", "TH3", "5") is taken to be an abbreviation. This results in 10 1key, 260 2key, 6760 3key, and 17,560 4key codes.)

If all words were used with equal frequency, with a 10,000 word vocabulary, this approach results in an additional increase in efficiency of approximately 25%. Since the frequency with which words are used is very non-linear, the increase in efficiency is considerably larger. (Computations to determine the exact efficiency difference require the simulation of the different techniques, and the use of a complex program; these computations were still underway at the time of publication for this abstract.)

This technique can be easily implemented on a standard keyboard without the addition of extra keys, legends, etc. This implementation provides for completely user definable abbreviation vocabularies. In addition, it provides constant cuing to the user of the abbreviations as s/he is typing in order to facilitate his/her memory.

Funding: National Institute for Handicapped Res.

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THE INFLUENCE OF SCAN DIMENSIONALITY ON NON-VOCAL COMMUNICATION RATE

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Among commercially available non-vocal communication systems, scanning aids are particularly prevalent. This reflects the minimal demand scanners make on the residual motor ability of users. From a marketing standpoint, it makes sense to offer a system likely to be usable by a large portion of potential consumers. In contrast with the ease of the use of scanning systems, however, is the relatively limited benefit they offer. While it is unarguable that some communication is better than none, the tediously slow communication permitted by present scanning aids may be almost intolerable to receivers in face-to-face communication.

The clinical literature offers examples of non-vocal individuals whose impaired motor control is better exploited via encoded systems, e.g. 16 words/minute with a UNICOM controlled through a "harmonica" of puff-sip tubes (1). For those users who are in fact restricted to scanning, however, strategies for enhancing communication rate are critically important. The companion to this (2) treats language inventories which should offer dramatically shortened average access time. This article considers the dependence of rate on the "dimensionality" of a scanned array.

Most present scanning communicators offer users a sequence of language units via a two-dimensional scan. In other words two switch closures are necessary, typically, to halt a scan of rows followed by a scan of columns of a matrix display. It is commonly recognized that the average access time is greatly reduced with respect to linear, i.e., one-dimensional scanning of the same array. It may be demonstrated, as shown below, that this improvement may be extended by further increasing the scan dimensionality.

Define N = Number of units in inventory;
D = Dimensionality of scan;
$X + 1$ = "Size" of array; i.e. number of scan steps per dimension.

It may be seen that the average time measured in scan steps, T, to access a unit, assuming equiprobable units for simplicity, is just the time needed to get to the "middle" unit, i.e. --

$$T = D\frac{X}{2} = D\frac{[N^{1/D} - 1]}{2}$$

For the convenient example of a 64-unit array, D influences T as follows:

$D = 1;\ X + 1 = 64;\ T = 31.5$
$D = 2;\ X + 1 = 8;\ T = 7$
$D = 3;\ X + 1 = 4;\ T = 4.5$
$D = 6;\ X + 1 = 2;\ T = 3$

More generally, units are not equally likely. While a rigorous treatment of T vs D is mathematically complex, the decrease of T with D is easily demonstrated:

All scanned arrays have "ranks" of equal access time, e.g., the diagonals of a row-column array which can be reached in zero steps, 1 step, 2 steps etc. If f_j is defined as the frequency of use of unit j, and $f_1 \geq f_2 \geq f_3 \ldots$, then the average access times for two- and three-dimensional scanning of 64 items may be calculated --

$$\text{for } D = 2 \text{ as } T_2 = 0(f_1) + 1(f_2 + f_3) + 2(f_4 + f_5 + f_6) + \ldots + 14(f_{64})$$

$$\text{and for } D = 3 \text{ as } T_3 = 0(f_1) + 1(f_2 + f_3 + f_4) + 2(f_5 + \ldots + f_{10}) + \ldots + 9(f_{64}).$$

Even without knowing actual values of unit frequency, T is clearly lower for the higher dimension scan. This is true since each value of f_j is multiplied by the same or a smaller number when D is increased.

It is important to notice an important functional tradeoff. The discussion above is concerned only with the access time required by the device to reach an item. For each switch closure, however, a human reaction and activation time is required to respond to the arrival of the scan at a desired point. Increasing dimensionality requires increasing the number of switch closures and therefore increased total response time, probably proportional to D. Experiments are planned to determine the net effect of decreased access time and increased response time. It is hoped that general guidelines may be found for choosing the scan dimension which maximizes communication rate.

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DEVELOPMENT AND EVALUATION OF VOICE OUTPUT COMMUNICATION AID SIMULATOR

Jeffrey J. Moyer

Telesensory Systems, Incorporated

The National Science Foundation funded a project at Telesensory Systems, Inc. (TSI) entitled "A Research Project on Needs and Design Concepts for Voice Output Communication Aids." The project was to develop a design simulator of a voice output communication aid, or VOCA, with extensive involvement of vocally handicapped consumers. Existing VOCAs were evaluated, a conference was held concerning state-of-the-art of VOCA research, design, and use, and a simulator was developed and evaluated.

SIMULATOR DESIGN AND EVALUATION

The simulator provides considerable flexibility of input, manipulation of data and output of messages. The VOCA simulator was evaluated by a variety of vocally handicapped individuals. A detailed account of feedback on simulator features is not possible here, but a brief summary of incorporated (and unincorporated) features and feedback follows.

Input

The simulator may be accessed through three different systems: a computer keyboard, the Autocom, or the Express. (The latter two are commercially available communication aids from Prentke Romich Company). This range of input devices can accommodate a broad spectrum of motoric capabilities of VOCA users. Speed of input still presents difficulty for users with all input systems. Since the simulator is based on text-to-speech, ordinary English text is input. This was appreciated and increased communication speed. Desired input features not implemented were: word spoken after entry, announce text with automatic clear, volume control from input device, and direct telephone interface.

Controller

The controller, or custom software at the "heart" of the system, enables the user to prepare messages for announcement and monitor construction on a visual display. Messages can be rehearsed through a headphone, cleared, spelled, or announced in segments of words, sentences, whole messages, or from user-set marker. Preprepared messages can be stored in a phrase buffer and recalled through short codes. This compression of input during message construction can be a great time saver.

Response to system software was favorable, with requests for more editing capability. A strongly supported feature was the interrupt command, which interjects, "Excuse me, I would like to say something," with a single keystroke or input command. User-programmable interrupt message capability was also suggested. The rehearse feature was used by all and appreciated as a desirable feature for avoiding mispronunciations. The marker, which enables the user to bracket text within the message for announcement and/or clearing, was recognized as a valuable feature for interjecting comments during longer phrase construction. The escape feature, which cuts off message announcement instantaneously, was appreciated as a good one for correcting inadvertent message announcements. Desired but not included features were: volume control set by ambient noise level, and real time and text-embedded expressiveness.

Output

Messages are spoken through either the Votrax Type and Talk, or the TSI TTSC speech synthesizer. The highly intelligible TTSX speech provided many user requirements, including speech rate and amplitude control, and automatic prosodic control. Users reported virtually no difficulty concerning intelligibility from interlocutors. Users also desired voice to match sex and age, non-speech sounds, and emotional expressiveness.

Other Factors

Other desired characteristics, such as waterproofness, attractiveness, impact resistance, light weight, modularity, and portability, pertain to actual product design and could not be implemented in the simulator.

SUMMARY

The VOCA project identified critical design factors which should be well considered by researchers, developers, and manufacturers in the field of augmentative communication. The simulator achieved implementation of certain characteristics, but of lasting value is the summary statement made by the vocally handicapped consumer evaluators concerning VOCAs of the future. A detailed report is available.

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DEVELOPMENT OF AN EFFICIENT AND VERSATILE SPEECH PROSTHESIS

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INTRODUCTION

An evaluation by Tobias of two models of a commercially available speech prosthesis reveals that -- despite generally positive acceptance -- the devices are still typically adjudged to require improvement, particularly in regard to efficiency and versatility (1). Here we understand an efficient speech prosthesis to be one that permits maximally rapid generation of unrestricted utterances, effecting economies wherever possible in traversing the thought-to-speech chain. A versatile prosthesis is one amenable to tailoring, in order to be consistent with and provide clues to the speaker's age, sex, dialect type, etc., and which additionally can provide the speaker with a degree of control over such speech characteristics as pitch, intonational contour, and emphasis; in normal speech these latter, suprasegmental features provide information necessary for proper interpretation of sentences. At the Palo Alto RERanD Center, two types of user interfaces for an efficient and versatile speech prosthesis are currently under development.

TWO APPROACHES

Vocally disabled individuals may or may not have other physical disabilities, which can influence the design of speech prosthesis interfaces. From a practical standpoint, a disabled person's manual dexterity is of especial importance: individuals with full manual dexterity may be able to use the very rapid, two-handed, chord-style keyboard found on stenotype machines (used by court reporters); those with impaired manual dexterity will require other interface devices, such as head- or eye-movement sensors, one-handed keyboards (as developed by IBM), or joysticks. In our current work, we are are incorporating the results of linguistic analyses and interface design analyses to develop efficient interfaces for both types of non-vocal users.

The two-handed chord keyboard

The stenotype-style keyboard allows one to strike between 1 and 22 different keys simultaneously, yielding 2**22 distinct single-stroke "chords" for "translation" into speech. These "chords" are used in a hybrid recording system, which employs a mixture of phonemic notation and arbitrary abbreviations. Individual syllables may be spelled out phonemically, at one stroke, syllable-initial consonants being recorded by the small- through index-fingers of the left hand, syllable-final consonants by the small- through index-fingers of the right hand, and intervening vowels by the thumbs of both hands. Common polysyllabic words (e.g. 'today', 'also', 'December') and expressions (e.g. 'will you', 'can he') are given mnemonic, monosyllabic masks, to reduce their recording to a single-stroke chord. Polysyllabic words may be "spelled out" syllabically, at one stroke per syllable. On the keyboard itself, commonest letters are assigned their own keys; less common letters are recorded by assigning their values to impossible letter combinations (e.g. 'TK' at the beginning of a word represents the letter d).

Initial results in developing a chord keyboard interface are encouraging. The tasks of adapting such a keyboard to the purposes of real-time generation of synthesized speech appear soluble; in important respects, in fact, it is actually easier with such a system to generate speech than printed text (prior intended usage), since arbitrary spelling conventions may be ignored. As to efficiency, the configuration promises to yield speeds far closer to normal conversational tempo than those now attainable.

Joystick input configurations

For non-vocal persons with impaired manual dexterity, an alternative input configuration is being developed: this latter currently employs a joystick to position a cursor on a video screen, but the system could be modified to allow control by head- or eye-movement sensors. As currently implemented, the video screen displays the 26 letters of the alphabet, the digits 0 through 9, and the major punctuation marks, along with a list of control commands, such as 'READ', and 'ERASE'; layout of these elements is formatted for selection efficiency. The user manipulates the joystick to position the cursor, in turn, at succeeding letters of a word or designated abbreviation; pushing the joystick's 'fire' button enters the current selection. When the word or abbreviation is fully entered, the user activates the 'READ' command in the same manner, producing an utterance.

Research is under way to determine the best way of gaining efficiencies with such an input system. One possible avenue is to allow a microprocessor to analyze the content of strings already entered -- at the orthographic, morphological, and syntactic levels, and additionally at the lexical level, taking discourse context into account -- in order to present the user at each point with the most probable candidates for next letter, morpheme or word position. If any of the possibilities is the correct one, the user can select it directly, bypassing letter-by-letter spelling. Attempts to implement such choices at the orthographic level are currently under way in this project.

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THE USE OF DIPHONES IN SPEECH SYNTHESIS

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INTRODUCTION

Non-vocal communication aids employing speech synthesis have traditionally been limited by either the quality of the speech output or by the size of the vocabulary. For example, a formant synthesizer, by concatenating phonemes to form a word, provides an unlimited vocabulary, but at the cost of natural sounding speech.

A synthesizer using elements extracted from continuous speech offers a more intelligible output by retaining the human characteristics of the original speaker. The most important of these is the preservation of the formant transitions between each phoneme in an utterance. These transitions are the result of the effects of coarticulation. Even as one sound is being emmited, the vocal apparatus is changing its configuration to form the next, producing this smoothing of the formant frequencies. The importance of the formant transitions to the perception and intelligibility of speech has been demonstrated on a number of occasions (1).

Speech synthesis with elements extracted from natural speech has a major drawback in that the length of each element is great and this permits only a few to be stored in a reasonable amount of memory space.

To achieve an unlimited vocabulary, (as in the formant synthesizer), one might consider the use of shorter, transition preserving elements that could be concatenated to form any word. Such a set of elements was introduced by Peterson et al (2). In their work, the authors presented the concept of the diphone, a transition preserving, concatenatable element extracted from continuous speech. A diphone begins and ends at the most acoustically stable point of each of the two component phonemes. Diphones are joined at phoneme steady states, thus eliminating formant discontinuities at the junctions. In a subsequent work, the authors described a complete inventory of diphones to synthesize American English (3).

THE DIPHONE INVENTORY

The diphone inventory used in our experiments is a modified version of the Peterson and Wang inventory. Units longer than the two member diphones have been added to the set. These are units where one of the component phonemes lacks a steady state of a minimum duration (i.e., stop consonants, and diphthongs). In addition to these units, a group of the most frequently occuring syllables (4) in English has also been added. All of the elements begin and end at the appropriate phoneme steady states.

LOCATION AND EXTRACTION OF DIPHONES

The location and extraction of the diphone inventory from continuous speech is carried out with the aid of the Interactive Laboratory System (Signal Technology, Inc.). The ILS is a set of integrated Fortran programs designed to do spectral analysis, Linear Predictive Coding (LPC) analysis and synthesis of speech and is installed on a PDP-11/34 computer.

Continuous speech is recorded and converted to a digital representation, and spectral analysis of the speech signal is then performed. A diphone is located by examining the time domain signal and the frequency spectrum, including a computer generated spectrogram. Once the diphone is located it may be extracted and LPC analyzed to derive parameters for later synthesis into messages.

EXPERIMENTAL RESULTS

Recent attempts to synthesize words with diphones have proven successful. For example, the spectrogram of a word made with two diphones was compared with the spectrograms of the word spoken as a whole, and spoken by the Votrax "Type 'n' Talk" speech synthesizer. The first two spectrograms were identical, whereas the spectrogram of the Votrax lacked any transitions between phonemes.

FUTURE PLANS

Once the LPC parameters have been derived, they may be transferred to an Echo II speech synthesizer (Street Electronics) installed on an Apple computer. LPC parameters are used to drive the Echo's voice synthesis processor (T.I. TMS 5220). With the diphone inventory implemented on the Apple, a communication aid with high quality speech, and an unlimited vocabulary may be obtained.

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ASSESSING THE IMPACT OF TECHNOLOGICAL INNOVATIONS ON THE DAILY LIFE OF PERSONS WITH DISABILITIES

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A key concern that should be addressed with respect to technological innovations is the measurement of their impact on users. What difference does a device, technique or adaptation make in the consumer's life? Such impact can be measured from multiple stances (e.g., improved health, decrease in pain, changed feelings about self); however, assessing the relevance of innovations to patterns of activity in day-to-day life provides information necessary to an adequate evaluation of the benefits associated with new technologies.

In this presentation, data will be presented that describe the impact of environmental control units in the daily lives of 20 high-level quadriplegics. In the study, users of ECU's were compared to a similar sample of non-users, to define the effects of ECU adoption on how the person engaged in activity--at home and in the community.

Using Activity Pattern Indicators, a method for systematically describing time usage, developed by the Rehabilitation Indicators Project[1] of New York University Medical Center, daily life of users and non-users was compared: users more frequently participated in educational activities, in travel and phone calls and spent more time in school activities. The non-users more frequently engaged in and spent more hours in passive recreation at home (e.g., television watching). Also, users performed more activities independently than non-users and made greater use of adaptive devices in addition to the ECU. These results were attributable neither to participants' having third party sponsorship nor to the individual's being in student status. Interestingly, in the study, ECU use/non-use was associated only with differences in daily behavior, not in measures of affect and adjustment (i.e., Bell Adjustment Inventory, TAT, MAACL, and Locus of Control).

These data are used to illustrate a general approach to evaluating the real-life benefits of technological innovations on individuals who have opted to use them. A major thrust of the presentation is that appropriate utilization--both the initial adoption and continuation of use--depends on consumers who are provided sufficient information as to the likely impact of innovations before they commit themselves to purchase and/or adopt new technologies. In the presentation, a model that depicts the relationships between behavioral, environmental and intra-person (e.g., affective, cognitive) variables will be introduced--providing a taxonomy of the targets for measuring impacts of interventions.

FOOTNOTE

1. R & D Grant No. G008003039, National Institute of Handicapped Research, U.S. Department of Education.

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Alternatives to Hand Function Enhanced by Technology

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It is the experience of Project Threshold that rather unconventional techniques are often used to replace hand function. Individuals with such diagnoses as upper extremity amputations, arthrogryposis, cerebral palsy and polio whose disabilities have severely affected upper extremity use have learned alternative means of performing daily activities. These individuals often demonstrate an amazing ability to use other parts of their bodies, such as mouths or feet, in ingenious ways for performance of a wide variety of tasks. Despite these unique capabilities, the functioning of such persons has been enhanced by the appropriate application of technology.

Over the past four years, Project Threshold has seen a number of clients who have compensated for lack of hand function with other body parts. In most instances they had lived with their physical disabilities for many years and had been long removed from or never involved in a rehabilitation program. It was the task of the Project Threshold program, as with all cases, to evaluate functioning, determine problem areas and devise solutions. Such solutions generally include recommendations for adaptive behavior, commercially available assistive devices and/or custom designed equipment. In this population, however, the area of adaptive behavior was generally highly developed. For this reason they often had not been exposed to available technology or the possibility of custom equipment. With the use of appropriately selected technical aids however, the client's unique adaptive behaviors were expanded and functional abilities were enhanced.

Project Threshold found that this particular population of clients had a wealth of creative ideas and provided valuable input both in problem solving and actual devices. In some cases homemade equipment was used as a prototype for the development of refined designs. In all cases, the client was an integral part of the team in exploring solutions.

The focus of the presentation will be a description of cases which illustrate the application of technology to this population. Examples will demonstrate how assistive devices were used to improve efficiency, avoid or minimize secondary complications such as wear on the teeth from mouth activities and broaden the spectrum of tasks performed with an improvement in quality of performance. For example, a dressing tree with a button hook and a quick release clamp incorporated into the design allows client to independently don and button shirt (Figure 1). Equipment highlighted will include general use products designed for the able-bodied population as convenience items commercial products developed specifically for persons with disabilities, equipment from both of these categories which was modified and devices which were custom designed and fabricated by rehabilitation engineering personnel. Many of these equipment items provided inexpensive solutions. Custom devices which were fabricated are of fairly simple design and could be duplicated quite easily.

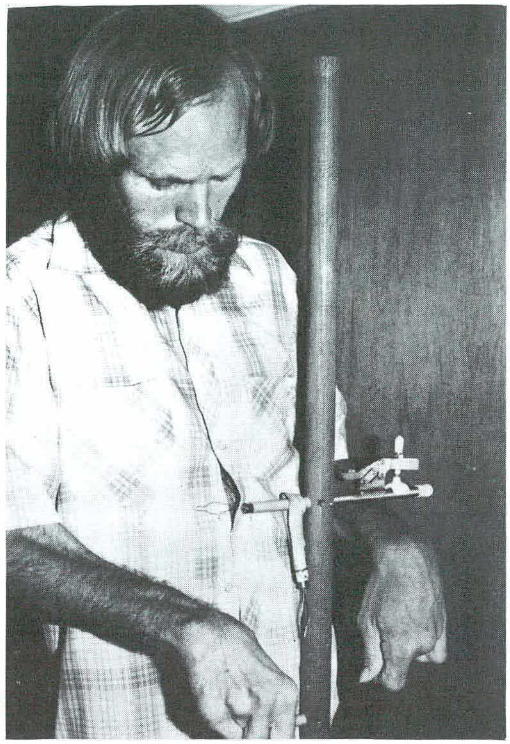

Figure 1 - Custom designed dressing tree allows client to independently don and button shirt. A commercially available button hook and clamp are utilized in the design.

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A WRITING DEVICE FOR PEOPLE WITH HIGH LEVEL SPINAL CORD INJURIES

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THE NEED

People who have lost the use of their hands and arms through spinal cord injuries must use a mouthstick to write script. While this method does allow the person to write, it has certain drawbacks. First, mouthstick writing requires the user to hold the pen firmly with his mouth which hinders breathing, wears the teeth and causes fatigue. Secondly, the required gripping force and control necessary by the mouth prevent some people from using mouthsticks. Thirdly the method has poor accuracy and slow speed. Generally, if one has any arm function at all, he prefers an orthotic device to a mouthstick. A further point is that mouthsticks use neck rotation and neck flexion but fail to use either mandible rotation or scapula elevation. These various drawbacks suggest that mouthstick users need an improved writing device.

New writing devices should include the desireable features of a mouthstick. Mouthsticks are adaptable and people use them to write draw and paint. Additionally, mouthsticks portability allows one to write with them independently in a variety of situations. The low cost and simplicity of mouthsticks make them available to everyone.

APPROACH

In order to design a more efficient writing device, we researched past work in this area and sought advice from Occupational Therapists. The most advanced mouthstick design we found was developed by Heyer (1) in 1980. This mouthstick allows its user to talk while writing. A work station which enables the user to change pens and load paper complements the design. Other communication devices allow people with spinal cord injuries to type and operate computers with input signals from: 1) head movement, 2) eye movement, 3) breath signals or 4) myo-electric signals. Occupational Therapists advised that most people use less sophisticated mouthsticks, and further, that a person only uses a mouthstick if his capability restricts him from using an orthosis to write. This suggested that further work is needed even though several communication devices exist.

Next, we asked a number of mouthstick users at the VA Medical Center what features they would like in new writing devices. They said that they wanted a writing device which would allow them to: 1) set up quickly, 2) breathe easily and 3) write rapidly. Additionally, mouthstick users wanted a writing device which required less effort to operate than a mouthstick. Most mouthstick users said that they would prefer to control writing devices with their mouths for one or more of the following reasons: 1) previous experience with mouth controlled devices 2) ability to grip firmly with the mouth and 3) fine sensory discrimination of the mouth.

At this point, research on handwriting helped solve the dilemma of whether to retain the mouth control feature along with its disadvantages or eliminate it against popular demand. The work by Hollerbach (2) states that four degrees of freedom underlie handwriting control: 1) horizontal constant sweep, large amplitude; 2) horizontal oscillating, small amplitude; 3) vertical oscillating, small amplitude and 4) contact. In handwriting, a separate body motion controls each of these degrees of freedom. According to Hollerbach, this optimizes the writing process because the separate motions superimpose into one pen movement without the writer taking the time to add the motions in his brain. This suggests that one could write better with a device which has more input degrees of freedom than a mouthstick. Thus, Hollerbach's work underscored the disadvantage of a mouthstick using only two input motions. Therefore, we eliminated mouth control from the design of the new writing device.

DESIGNING A "CHIN" WRITING DEVICE

A writing device controlled by the chin could incorporate the attractive features of a mouthstick, but overcome its drawbacks. In addition, it would provide other features asked for by mouthstick users. We hypothesized that the performance gained from the extra control motion (mandible rotation) would more than compensate for performance lost because of leaving out mouth control. Mouth control has the disadvantage of requiring something in the mouth. Chin control overcomes this disadvantage. Also, a well-fitting connection at the chin gives the user tactile information and allow him to firmly control the pen movement. Thus, chin control offers little disadvantage in sensing or gripping capability.

The chin writing device mechanically transfers the user's chin (i.e. jaw and head) motion in any direction to pen movement in the same direction. The device follows Heyer's work by incorporating a writing surface with rollers to hold the paper. An adjustable linkage can change the ratio of input to output magnitudes so that small chin motions can produce large writing or vice versa. Other adjustments and the size of the device (20" X 16" X 18", 20 lbs.) allow one to use it either while seated or lying down. As shown in Figure 1, a bedside table supports the device while in use. The device sets up easily. After an able-bodied person adjusts the device to a user's individual needs, the user can drive his wheelchair up to the device on the bedside table and begin writing. The device is anticipated to cost less than $100.

The device transfers chin motion with a linkage consisting of two rods. One rod holds a chin cup and the other rod holds a pen. The linkage, shown in Figure 2, supports each rod on a spherical bearing and connects the rods with an in-line ball joint. Collars keep the rod with the chin cup from sliding through its support bearing. The rod with the pen can slide through its support bearing, however, and does so as the user moves the chin cup. When the user moves the chin cup downwards, the in-line ball joint moves upwards. This slides the rod holding the pen through its support bearing and moves the pen downwards. Thus the user moves the pen downwards by moving the chin cup downwards. Likewise, the user can move the pen in any direction by moving the chin cup in that direction because the support bearings and connecting ball joint have spherical races.

As shown in Figure 3, the pen moves away from the writing surface as the connecting joint flexes. To keep the pen in contact with the paper, the user maintains a small forwards force on the chin cup. This moves the entire linkage towards the writing surface because the linkage rests on a track which can slide relative to the writing surface. To move the pen out of contact with the paper, the user pulls the chin cup towards himself. A light spring then slides the linkage away from the writing surface.

TESTING THE FEASIBILITY OF THE CHIN WRITING METHOD AND EVALUATING THE DEVICE

We then tested the ability of mouthstick users to control the size, shape and spacing of letters while writing with the device. Hollerbach's research on handwriting served as the basis for these tests shown in Figure 4. Other tests, shown in Figure 5, had one follow paths between guidelines and draw smooth connected shapes.

Two experienced mouthstick users took the tests with the device. The results confirmed the feasibility of the chin writing method. Both learned to use the device in less than twenty minutes. Figure 6 shows an alphabet written during the training period. The tests showed that mouthstick users could write better with the device. The users also discovered that they could draw with the device and enjoyed drawing objects in the room. Both users showed an interest in obtaining a chin writing device of their own.

The device has two shortcomings: 1) jagged output lines and 2) limited writing speed. The jagged output lines result from the characteristic of the linkage which continuously slide the linkage along its track while writing. We are developing a linkage which uncouples pen contact and pen movement. This linkage should eliminate the awkward operation and yield a smoother output line. One's writing speed with the device is faster than with a mouthstick, but is limited because neck rotation controls two horizontal pen movements (constant sweep, large amplitude and oscillating, small amplitude). In handwriting, separate body motions control each of these pen movements. Thus, the writing speed is limited by the rate at which one can superimpose the two movements in the brain and send the result to the muscles which rotate the neck. We are working at improving the writing speed by using separate motions to control the two pen movements.

Hollerbach's work has suggested matching body motions with pen movements that they control best. In order to do this, we are measuring people's motion control ability. These experiments have a person with a spinal cord injury use a body motion to control an oscillating display on a video screen. An Apple computer then assists in the frequency, amplitude and varience analysis of the motion. Findings will point the way for future designs.

CONCLUSION

The chin writing device offers three major advantages over mouthsticks: 1) it frees the user from having to hold anything in his mouth, 2) it uses one more control motion (mandible rotation) and 3) it allows one to write faster. Additionally the device's adjustments, built in writing surface and low cost make it attractive to mouthstick users. The prototype device proves the feasibility of a writing method which uses chin rather than mouth control. Mouthstick users's rapid learning, performance on writing tests and enthusiasm with the device all point out that further development of chin writing devices is worthwhile.

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ACKNOWLEDGEMENTS

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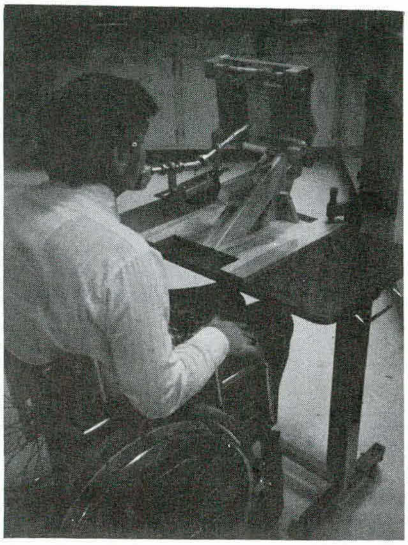

Fig. 1 Chin Writing Device In Use

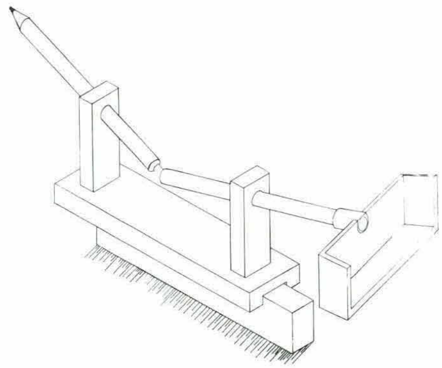

Fig. 2 Transfer Linkage

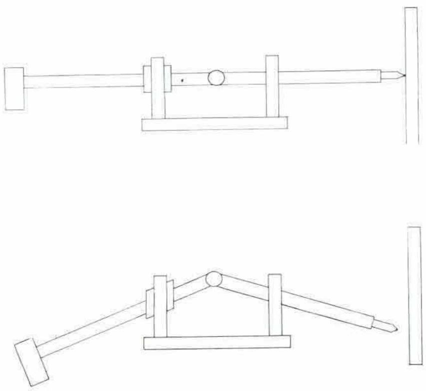

Fig. 3 Connecting Joint Flexing

Fig. 4 Writing Test Strings

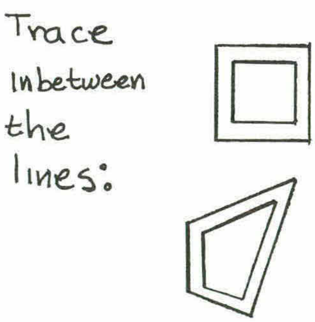

Fig. 5 Tracing Test Sample

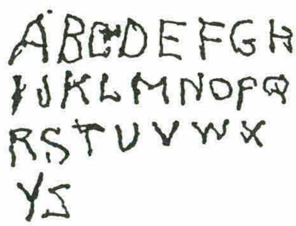

Fig 6. Alphabet Written With The Device

THE ADAPTABLE KITCHEN

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The kitchen is among the greatest obstacles that disabled persons must overcome; counters are too high; cabinets block access for people in wheelchairs; cupboards are out of reach; faucets are beyond reach; the conveniences of doors and controls of the major appliances are too often inconveniences for the handicapped user; and so on. The rapidly increasing financial and social costs of remodeling or moving to gain a more accessible and usable kitchen are making these traditional alternatives almost impossible for the general population, let alone handicapped individuals.

The Adaptable Kitchen is a project to develop and test a kitchen system that may be constructed and installed in the same manner as conventional kitchens, but whose work surfaces, storage elements, and appliances may be arranged in a variety of configurations to meet specal needs. The system uses an adjustable structural frame to support all of the kitchen components. Counters and storage cabinets may be raised or lowered to fit the height and reach of the user, appliances and storage units may be interchanged or relocated for added convenience; and appliances may be easily removed for repair or replaced with new or different models when needed.

The kitchen meets equally the requirements of both disabled and able bodied persons. It uses conventional appliances and materials and may be readily produced by existing kitchen builders. It is a generic product fitting into any home decor, but one that has the advantage of being tailored to its user. It provides extra convenience for the average house-wife, essential service and accessibility to disabled persons, and is capable of being modified at any time after it is installed to fit persons who may become disabled, or who merely desire other features. This adaptability gives the consumer an economical means to maintain the kitchen in an always modern, up-to-date condition, adding to the value and enjoyment of the home, and reducing the expense of remodeling or the trauma of having to move from the home and neighborhood, or being forced to endure, when the kitchen becomes obsolete.

The Adaptable Kitchen project is being undertaken by the Center for Rehabilitation Technology in a program involving appliance manufacturers and other suppliers to the building industry. There are obviously other versions of adaptable kitchen cabinetry and appliances that have been developed and are available for custom installation and the project will make use of this technology. The focus of the project, however, is not so much on the development of specific new devices as it is on the development and introduction of a commercially acceptable kitchen system that will enter the mainstream of housing construction and renovation. The focus of the project is thus so that a kitchen as an adaptive device is available to the public and in place in the home whenever a person may become disabled. After a disabling injury is not the time nor economic position to consider remodeling the kitchen or moving away. To achieve this it is necessary to involve the housing producer and to meet his economic and functional requirements (whether he is interested in rehabilitation or not) as well as the needs of the disabled. Conducting the project at Georgia Tech provides an objective research and development framework necessary for the introduction of the innovations required for adaptive equipment of the magnitude of kitchens and houses.

A MODULAR MOUTHSTICK SYSTEM

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A mouthstick system has been designed and developed by NUREP and the RIC Occupational Therapy Department which incorporates a combination of desirable features based on a review of existing literature and examination of commercial systems. Existing design has evolved from clinical experience and mouthstick user input based on the refinement of twenty prototype modular mouthstick systems. A very important feature includes the capability of the user to independently change a variety of appliance tips (e.g. pen; rubber tip for turning pages, pushing buttons; etc.) and also to adjust shaft length. Longer length is necessary to enable some individuals to turn pages, type and engage in other desk top activities. Shorter length provides stability and improved control for activities such as writing and drawing. A holder was required which mounted to a desk or wheelchair to support the appliances and connected mouthstick. The user has freedom to initiate, complete or change activities without assistance. The diverse range of interests and functional capabilities of mouthstick users dictated a system that was easily modified, light weight and durable. A custom fabricated mouthpiece was recommended be ause the need to maintain dental integrity under the stress of mouthstick usage was widely recognized in the dental literature.

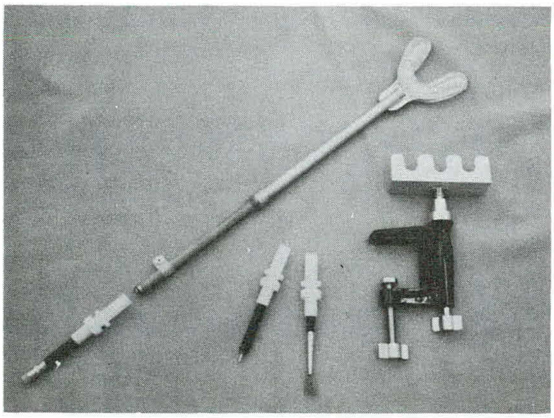

Fig. 1. Components of Modular Mouthstick System

Components of this modular mouthstick system to be manufactured in kit form include: 1) custom mouthpiece (to be fabricated by dentist), 2) telescoping shaft consisting of a fiberglass arrowshaft which can be slid in/out of an aluminum tube by the user; friction necessary to maintain desired shaft length is provided by a vinyl coupling (Tygon tubing). To extend the shaft, the user pulls it out like a telescope by a tab on the distal end. The shaft is shortened by pressing the distal end against a fixed object. 3) shaft/appliance holder tube latching mechanism consisting of a round head screw which holds a rubber "O" ring against a threaded insert; the insert is bonded into the distal end of the arrowshaft, 4) three appliance holder tubes fabricated from Delrin plastic; appliances are secured into the holder tube with a set screw (allen wrench included), 5) mounting system consisting of an aluminum bracket (which positions the appliance holder tubes) attached to an adjustable camera clamp.

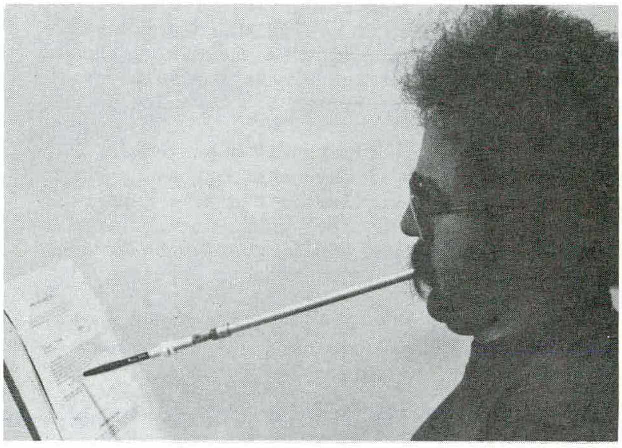

Fig. 2. Writing with Modular Mouthstick

The modular mouthstick system enables users to independently participate in a wide variety of activities - from academic/vocational involvement to avocational pursuits. Tasks which can be accomplished independently may include operation of desk top devices such as telephone, electric typewriter, tape recorder, dictaphone, calculator, computer terminal, environmental control unit, and communication aids. In addition, the user could learn to write and turn pages. A wide range of avocational interests can be pursued including painting, drawing table games, cards, puzzles - the list is limited only by one's imagination.

One problem still remaining is the development of a custom-fit mouthpiece to be included in the kit. A team consisting of dentist, occupational therapist and rehabilitation engineer is currently developing a fabrication technique for this mouthpiece.

A future goal is to adapt this modular system for utilization with head and/or chin pointers.

ACKNOWLEDGEMENT

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MATCH: MANIPULATION OF ADAPTED TOYS BY CHILDREN WITH HANDICAPS

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PURPOSE:

Project MATCH tested the effectiveness of specially adapted toys with severely multi-handicapped students within Houston Independent School District in conjunction with the Rehabilitation Engineering Center at The Institute of Rehabilitation and Research, Houston, Texas. The importance of play in developmental learning has been increasingly realized in recent years. The remote control mechanism on commercially available toys is unsuited to children who lack adequate fine motor control and strength(1). These control switches can be adapted using external switches so that the child independently operates the toy. It was proposed that if the students could independently operate selected toys, thus gaining important learning experiences, their developmental skills would be enhanced.

PROGRAM:

Approximately 14 to 20 students, ranging in age from 3 to 21 who were enrolled at T.H.Rogers/Grady Special School, participated in the program. All students were enrolled in Special Education classes, were pre-academic, and over 90% were non-speaking and had diagnoses of cerebral palsy, mental retardation and/or conditions causing motor impairment. This project assessed individual students, matched the most appropriate control switch to each student, electronically/mechanically adapted 10 toys and provided the opportunity to utilize the toys within the classroom setting. Pre-and post-testing using a Communication Skills Checklist developed by the project director documented changes in motor, cognitive and language skills. Using a Piagetian model, in the realm of sensori-motor intelligence schema, cognitive skills such as cause-effect and remote control were emphasized(2). Improved social response, increased range of motion and communication skills were additional goals.

TEAM:

Speech/Language Pathologist, Rehabilitation Engineer, Occupational and/or Physical Therapist and classroom teachers comprised the project team. Based on the motor abilities and positioning available for each student in the group, a series of control interfaces were selected. The toys were then modified to be controlled remotely through the use of momentary contact switches. The switches represent a graded set of activities that could be interchanged to teach and reinforce motor control. Each of the switches could be interfaced with a relay box that converted momentary closures to controlled time latched response. This feature permits the child to learn to sustain the action required to activate the toy in a manner controlled by a teacher.

IMPACT:

By utilizing the expertise of a Rehabilitation Engineer, Project MATCH allowed severely multi-handicapped children the opportunity to play with battery operated toys independently. This was the first time that these children have experienced this activity. Students' reactions thus far have been positive and have provided the staff with increased motivation to explore innovative teaching strategies with multi-handicapped children. Activating toy switches served as practice for future use with electronic communication devices. Data from post-testing on the Communication Skills Checklist and toy/interfacing strategies were presented.

ACKNOWLEDGEMENT:

This pilot project was funded by the General Superintendent's Office of Houston Independent School District.

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"THE HUMAN BODY IN THE DESIGN OF EQUIPMENT, PRODUCTS AND BUILDINGS" A MODEL COURSE

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Winter Quarter the Center for Rehabilitation Technology sponsored a course offered through the Industrial Design Department of the College of Architecture at Georgia Tech.

The class was structured around the use of the team project approach. Each team consisted of allied health professionals and technically oriented students (engineers, ID's, Arch). By requiring the class projects to be done in teams we hoped that the interaction between the two groups would provide a stimulating awareness into the differing and similar aspects of their approach towards a given problem.

The general field of rehabilitative technology provides a broad umbrella for the inclusion of a variety of fields in the process of designing for the disabled. The basis for this inclusion lies in the proposition that all person's are faced with situations and conditions which may be disabling. The skills and technologies to overcome these are therefore not exclusive to the handicapped.

The class was structured as a one hour lecture followed by a laboratory session. The principle difficulty of bringing together two groups with divergent background and orientations was the lack of a common basis for communication. The early class sessions were devoted to the development of such a base of understanding between the groups and particularly within the team units.

In preparing the class outline we requested several instructors and professionals to share their expertise with us and if possible to participate in the class. Soliciting this input allowed us to develop an outline suited to the requirements within our particular locale and succeeded in generating community support.

Course Outline

Meeting	Topic
1	Introduction to course, introduction to shop
2	Anthropometrics/Gross Anatomy
3	Ergonomics/Physiology
4	The Psychology of Disabilities
5	Simple Industrial Practices
6	Designed items for Industry
7	Starting a small Industry
8	Selection of Projects
9	In class Design Lab
10	In class Design Lab
11	Critique and Project Evaluation to Date
12-15	Shop Work
16	Group Critique
17	Group Critique
18	Course Evaluation and Summary

The last 11 classes were devoted entirely to lab sessions, where each team of students focused on the development of a single project. Sample projects are outlined below:

- a shopping cart designed for the wheelchair user;
- a device to make the rear seat loading of a wheelchair easier;
- a device for maintaining proper upper body attitude for individual with little or no upper body strength;
- the evaluation tool and adaptation of a building for a wheelchair bound user.

The class is currently undergoing evaluation by the students, professors, guest lecturers, and college administrators who participated. After 6 months there will be a second evaluation to determine what impact the course may have had on the work of the allied health professionals and that of the technically oriented students.

Benefits of the course are not restricted to the direct participants. By introducing the needs of a special population to the technical community here at Georgia Tech, we have noticed an increased awareness of rehabilitation and the role that designers of an environment can play to either enhance or detract from an individuals opportunity to live a full life.

The class is tentatively scheduled to be offered fall quarter, as a result of requests from Georgia Tech students and allied health professionals who have heard of our pilot class. Modifications to the course will be determined by the feedback received from the participants with pilot course.

A PSYCHOLOGICAL ISSUE IN REHABILITATION ENGINEERING

Jim Tobias
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When we as engineers perform a rehabilitation role, what are we actually doing? From our point of view we are selecting and combining hardware and possibly software in an effort to substitute a device's abilities for our client's deficits. In this effort we are called upon to match physical and cognitive skills available to the user with a particular function to be performed by the user. As this is an especially sensitive integration of human factors, engineering, and needs identification, we are forced to focus intensely on our devices and their development from a physical point of view, how they work.

But we may be missing the boat somewhat. Looking at our role from the other end, the user's point of view, reveals that our devices, generally speaking, offer control, which is primarily a psychological entity. This is especially true when our clients are congenitally disabled children, but runs across the whole spectrum of disabled people. We are replacing inabilities with abilities, and the physical manifestations, important as they are, may be accompanied by vast psychological transformations.

The issue of where actions originate is known in psychology as locus of control. Rotter (1) states that:

> "When a reinforcement is perceived by the subject as following some action of his own but not being entirely contingent upon his action, then, in our culture, it is typically perceived as the result of others, or as unpredictable because of the great complexity of the forces surrounding him. When the event is interpreted in this way by an individual, we have labeled this a belief in external control. If the person perceives that the event is contingent upon his own behavior or his own relatively permanent characteristics, we have termed this a belief in internal control."

So internal control is a belief that we ourselves originate actions, and external control is a belief that others, or fate originate them.

It can be assumed that especially disabled children, and disabled people in general, have a more external locus of control belief than others. Is this a mistake? Bad judgement? Probably not. After all, to someone who is moved around passively, often ignored communicatively, or whose thoughts are guessed at, who is fed, dressed and toileted by others, actions look and indeed are orginating elsewhere.

The point is not to condemn as weak anyone who has an external locus of control. The point is to offer means of internalizing control. This is part of normal personality development; non-disabled children are constantly being offered new challenges to their autonomy and escalated rewards for believing in their own power. Rehabilitation engineers can help offer the same challenges and rewards.

Our work in this field began with an informal collection of anecdotes pertinent to new users of equipment and any ripple effects observed. Typical of these stories concerns a seven year old boy with cerebral palsy, non-speaking, who recently acquired an electric wheelchair. After one day of mastering the joystick, he was observed tooling down our hallways, stopping every ten feet or so, as if he were at an art museum. Indeed, we do have art on our walls, as well as poems, letters, etc., posted there for all to see. All except someone being pushed down the hall from room to class to therapy to lunch and back again at fast walking speed. Now our subject was making up for lost time by acquainting himself with our displays, one by one, at his own pace. Over the next few weeks we noticed other changes. For instance, he was now initiating conversations far more often than before, and indeed communicating more. If he wants to talk with you, he drives up in his chair until you recognize him, even if it means cornering you, which he has gotten quite good at.

After a few more weeks of this, we began bemoaning the fact that we had no way of documenting these changes, no records at all of something everyone has been noticing. His wheelchair had become more than a mobility aid, it was also his environmental control and communication aid. His teacher noticed increased social involvement, as the student can now go on errands to help his classmates.

We began looking for ways to measure these effects. We hit on locus of control scales as a way to measure generally what was going on psychologically. We selected several standard scales (2,3,4) and modified some questions. We added some of our own to test the subject's attribution of control to disability itself; these questions were based on a scale originally designed for black student's feelings about race discrimination.

We have collected some baseline data on students who will be getting adaptive equipment soon, and we hope to add other semi-objective measures as well as continue to collect anecdotes.

This kind of research may aid in constructing integrated programs for our students by keeping the focus on a concept proven to predict academic success (5). Locus of control may also be of interest to funding sources looking for reasons to pay for equipment, and we hope to use it in our general fund-raising as well as for specific projects.

We believe that rehabilitation engineers would do well to keep this concept in mind as they plan their technical interventions. If we keep in mind the psychological impact of our devices, we can't help but attune them better to our users as people seeking power in their lives.

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REPORT ON A PROPOSED TELIDON BASED FACILITY FOR DISABLED PERSONS

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INTRODUCTION

This paper describes the findings of a feasibility study funded by the Canadian Federal Department of Communications in September 1981, to determine the viability of establishing a communication system based on Telidon videotex technology for disabled users. Telidon is the interactive text and graphics videotex protocol developed at the Communication Research Centre of the Canadian Federal Government which is rapidly gaining acceptance as a de facto communications protocol across North America.

PROJECT HISTORY AND SCOPE

The study describes the initial application of Telidon technology for speech impaired Blissymbol users in 1977 and the development and testing of a prototypic text and graphics display terminal called the "Blissterm" (developed by the Canadian National Research Council and Norpak Ltd.) in 1980. Based on this experience and the current state-of-the-art of communications technology two important issues are underlined:

1. That the Telidon/microcomputer field is in a state of rapid development at the present time, and that in two to four years not only will there be more stability but there will be available public Telidon based networks and systems, allowing access to a very large and wide variety of data and services.
2. That these powerful communication systems will be inaccessible to a large number of disabled persons if there is no 'universal' interface system available to help adapt the Telidon networks to the needs of the individual, i.e. by augmenting where required, their linguistic, cognitive and physical abilities.

In order for the appropriate development to take place, a demonstration project is proposed in order to assess the viability, usefulness, impacts, required resources, etc., of a Telidon based service for the disabled population. As a first step, certain fundamental systems relevant to accessing Telidon services require research and development since they are not commercially available. These are: 1. An interface system comprising an input level, an information amplification/expansion level and a program selection multi-tasking control.
2. Workstation configuration.
3. Special program content and data base structuring.

The development of these key elements are given the highest priority and form the basis for the first trial of the proposed demonstration project.

Once the overall interface system has been developed, then and only then can the viability of a Telidon based communication facility be reasonably and objectively demonstrated. As part of the demonstration project the potential advantages for a specific user group, ex.: the speech impaired, in the role of information provider and information user on public or commercial Telidon networks will be assessed. The extent of the network capabilities and the quality of the content of the programs offered would also be evaluated in combination with the technical performance of the entire facility.

CONCLUSION

It is recognized that Telidon technology is presently in a rapid state of development. The required "interactive" characteristics necessary for a viable communication facility for the disabled is some years in the future. The strategy proposed in the two stage demonstration project, allows for the development of the interactive capabilities of the public Telidon networks to take place. This provides the time to develop the specialized systems that would allow 'universal' access to these Telidon services. In other words the goal of the demonstration project is to ensure that the disabled can unconditionally access the Telidon phenomenon and then once this is achieved, evaluate the full impact of this technology on the users. The potential of being able to access a wide range of goods and services across Canada and the United States is of significant importance to everyone. It is therefore imperitive that all members of our society have equal means to access these services and share in the benefits.

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THE DEVELOPMENT OF COMMUNICATION DEVICES BASED ON THE PANASONIC HAND HELD COMPUTER

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INTRODUCTION

The development of communication aids for the non-vocal has been advanced though the utilization of available technologies. The Tufts Interactive Communicator was the first device that employed discrete digital circuitry (1). Later incarnations of the TIC utilized microprocessor design to decrease size and price as well as increase available functions and flexibility (2). The advent of personal computers has represented another advance in making such devices available. A personal computer such as the Apple II utilized as a communication aid offers many advantages over previous custom designs. The Apple II is a mass produced device. Mass production offers substantially reduced costs to the user as well as greater reliability. If the unit does fail, an extensive dealer network usually results in efficient service. Most importantly, the availability of commercial hardware allows the rehabilitation engineer to direct his efforts to the design of creative implementations of the device. The Apple II has been demonstrated as a communication system in a number of papers (3). Until recently all personal computers have had restriction in their application to rehabilitation aids. The major limitation is a lack of portability due to size and power requirements. This limitaion has been overcome by the introduction of the Panasonic Hand Held Computer. The HHC offers a battery powered microprocessor in a 9x4x1 inch package and a host of peripherals that connect through its own bus structure. The Rehabilitation Engineering Center has been involved in applying the HHC to the development of Communication aids. This paper discusses two such implementations.

SCANNING COMMUNICATOR

Configuration

The current configuration utilizes the HHC main unit as the scanning matrix display and the single switch input. Message output is accomplished on the main unit display and through a Votrax Type'n'Talk. The Votrax is connected via the Panasonic RS-232 peripheral. A printer has recently become available and will be included in future versions.

Operation

The 8x7 matrix of the scanner appears one row at a time on the LCD display of the main unit. When the desired row is displayed the user presses any charcter on the keyboard and that row is selected. Each element of that row is then displayed sequentially. The user again depresses the keyboard when the desired element appears. In the case of a character selection, the composite message is displayed on the LCD. In the case of a control selection the command is executed (e.g. the message will be spoken if the "speak" selection is made).

DIRECT SELECTION COMMUNICATOR

Configuration

A digitizing tablet manufactured by Houston Instruments was chosen as the user input for a direct selection scheme. It has an 11x11 inch active area, an RS-232 interface and can be battery operated. It is connected to the main unit through the RS-232 peripheral. The Votrax Type'n'Talk is connected for speech output (a printer is also planned in future versions).

Operation

The digitizer has an 11x11 matrix overlay that incorporates a preprogrammed user vocabulary. The user positions the cursor over the desired selection and then presses either the button on the top of the cursor or an external switch more conveniently located. The selection is displayed on the LCD display along with the rest of the message. Certain squares on the tablet are dedicated to control functions such as clear or speak.

CONCLUSION

The above mentioned projects were written in Microsoft Basic (the resident user software). The HHC has the capability to run SNAP (a derivative of Forth) programs that are created and debugged on an Apple based development system. SNAP programs will not only run faster but will also allow the programmer greater access to many of the HHC's unique features.

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ACKNOWLEDGEMENT

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ADDRESS

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Extremely Low Cost Computer Based Portable Communication Aid

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We are all aware of computer based portable communication aids, such as Autocom and Express. These aids are flexible, user-programmable, applicable to users with a wide range of physical and cognitive skills, and extremely effective. Perhaps their main drawback is their expense, several thousand dollars, plus inevitable maintenance costs. Prices are high because the hardware is customized and the volume is small, necessitating a high profit margin per unit. Funding agencies and insurance companies are reluctant to pay for these devices because communication is a subtle and non-medical need. It is hard to justify them under the guidelines most of these institutions use, so they languish on catalog pages as examples of what applied research could provide disabled consumers. It is my guess that 90% of these circulated devices serve as evaluation and training tools, not primarily as communication aids.

In an effort to remedy this, some researchers have turned to off-the-shelf personal computers, and have written communication software. Some of the results of the Johns Hopkins First National Search for Applications of Personal Computing to Aid the Handicapped (1) show this strategy.

However, personal computers are not made to be portable, and although their prices are lower, systems based on them founder on the inability of the user to have the device travel as widely as he or she does.

We have combined the lowest-priced personal computer, the Sinclair ZX-81, with a low cost television as a display to create a portable aid for under $500. With a variety of keyguards and software written for each user, we are now experimenting with a highly flexible aid.

The software now available for it enables direct selection from any page of a multi-page lexicon, automatic page-flipping based on a Fitzgerald key, alphabet page with symbols, or any of several scanning schemes. These are all stored on tape, which is easily loaded into the computer by an attendant.

Keyguards permit control of a range of scanning and special commands, tailored to the abilities of each user. At present we are setting up each aid differently, but we plan on systematizing our aid for dissemination. Hopefully we will come up with a device which can be easily assembled from readily-available, non-intimidating parts, with full documentation and suggestions for on-site customization.

Other future plans include experimenting with liquid crystal displays (LCD) and flat-screen TV (also being developed by Sinclair) as it becomes available. The advantages here would be that one could embed a dynamic display in the user's laptray, making the device less intrusive. In software, we will be looking to store the user's complete daily output and accessing time information. This could prove valuable in suggesting changes in the lexicon and access scheme.

We would hope that all researchers and clinicians who recognize the present dismal funding realities would put some effort into exploring similar low-cost options. We look forward to seeing future developments as the mass market continues to offer us cheaper building blocks to work with.

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THE TALKING BLISSAPPLE: A USER PROGRAMMABLE PICTOGRAPHIC COMMUNICATION/ WRITING PROGRAM FOR SEVERELY HANDICAPPED INDIVIDUALS

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Discussion: Without effective communication and language skills, meaningful education is impossible. For this reason, special communication and language learning systems have had to be developed for non-vocal severely physically handicapped children. For younger children or for mentally retarded children, these systems usually take the form of some type of pictographic system. These systems, although easy to learn, are by their nature very difficult to incorporate into any self-practice or computer aided learning programs.

One very popular and effective approach is the use of Blissymbols. These symbols are both pictographic and ideographic. The effort needed to compress the approximately 1,500-plus vocabulary into a small, fast-running package was, however, beyond the means of any single center. A number of centers therefore pooled their resources to develop an aid which is capable of both displaying and printing Blissymbol messages for their children.

Description: The BLISSAPPLE is a software program contained on a single disk, intended for use with any standard Apple II computer (Apple II or Apple II Plus) with 48K of memory and one disk drive. The BLISSAPPLE turns the Apple computer into a self-contained talking Blissymbol displaying/ printing aid. It can also be used as a talking Blissymbol display/printer for another communication aid.

The objective in developing the BLISSAPPLE was to provide a means to write with Blissymbols which was:

- low-cost
- easily duplicated
- commonly available
- easily updated
- easy to custom-fit for specific users
- modifiable by the user for specific vocabulary

The program which was developed is trimodal in that it can function as 1) a Blissymbol display/ printer for other aids (even very simple electronic scanners); 2) a communication aid with special input keyboards; or 3) a completely self-contained communication aid using the keyboard, game paddle, or game pushbutton (or other switches) for input.

The vocabulary of the BLISSAPPLE is completely user-determined. A library of over 1,400 pre-programmed symbols is available, which can be specifically selected and put into the user's vocabulary. In addition, Blissymbol creation/ revision commands allow the user to create new Blissymbols or modify existing symbols to meet his specific needs.

Program Information and Availability: The BLISSAPPLE program is written in a language called FORTH. Use of this fast and efficient language, combined with special data compression techniques developed at the Trace Center, allows both the BLISSAPPLE program and a 1,400 symbol vocabulary to fit into the core memory of a 48K Apple computer. (Non-compressed storage of the words and symbols would require the memory of ten Apples for the symbols alone. The compressed storage of the symbols takes only about one-half of one Apple's memory.)

Storing both the program and the BLISSAPPLE vocabulary directly in the Apple is important, since continuous access to the disk drive to retrieve symbols would quickly wear out the disk drive (and the disk), and slow the program down considerably.

The BLISSAPPLE program is compiled from source code which occupies five disks (three for the program source code, and two for the symbol segment source code). Once compiled, the program and library fit on one disk, with room for the user's vocabulary as well.

Equipment Required: The basic BLISSAPPLE system is composed of:

- Apple II or Apple II Plus, with 48K of memory
- Disk drive (3.2 or 3.3)
- TV display (black and white)

Optional items for the BLISSAPPLE include:

- Vodex speech synthesizer (for speech output)
- Silentype printer (for printed output)
- Joystick, paddle, or switch (for built-in scanning and one-dimension joystick modes)
- AIO serial/parallel interface card (only needed if BLISSAPPLE is to be used as an output display/printer for another communication aid)

Dissemination of the resulting instructional programs has been initiated through the clinical Blissymbol dissemination centers participating in this cooperative project, the national Blissymbol distributor, and through the Trace Center.

Funding: The development of this software was made possible through a consortium of funding efforts, including (in alphabetical order) Apple Computer Corporation, Cupertino, California; Blissymbolics Communication Institute, Toronto, Canada; Cerebral Palsy, Inc., Green Bay, Wisconsin; David P. Kelso, Madison, Wisconsin; Ted Perry, the Kydetyme Project, San Juan, California; San Luis Valley BOCES, Alamosa, Colorado; Trace Research and Development Center, Madison, Wisonsin; and Gregg C. Vanderheiden, Madison, Wisconsin

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EXPANDED KEYBOARDS FOR ELECTRONIC LEARNING AIDS

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INTRODUCTION

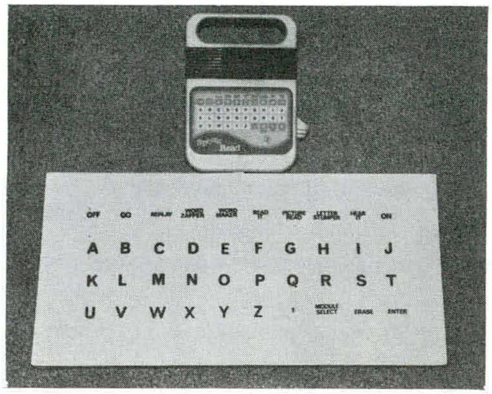
British Columbia is Canada's most western province with a population of 2.5 million, with 75% living in urban centers. A survey of the disabled population yielded a minimum figure of more than twelve thousand severely physically disabled persons, with the largest group being that of 2800 Infantile Cerebral Palsied individuals, 45% of whom are of school age. There are at present a number of special schools for these persons and the province is introducing a mainstreaming program this year for these and other disabled children. In 1981 Rehabilitation Engineering in the School of Rehabilitation Medicine at the University of British Columbia developed a number of speciallizwd interfaces for the disabled. Among these were expanded keyboards specifically created for use with the Speak & Spell , Speak & Read and Speak & Math electronic learning aids, and designed to accomodate students with a variety of physical disabilities.

EXPANDED KEYBOARDS

Although designed mainly with cerebral palsied children in mind, the expanded keyboards may be used to accomodate children with other forms of motor or limb dysfunction, as well as those with visual impairment or learning difficulties. Measuring 12" x 24" (approx. 30 x 60 cm.), and only 3/4" (2 cm.) thick, the expanded keyboards provide a welcome option to the small keyboards on the original consumer versions of the learning aids. Individual keys are located 2 inches (5 cm.) apart on a flat surface of durable plastic. The entire unit is waterproof, and easily cleaned. The keyboards are solidly constructed to withstand heavy classroom use, yet are easy to transport. To use the keyboard, students merely press the appropriate letter firmly. The units are designed so that unintentional movements, often the result of involuntary tremor, will not register an unnecessary entry.

FIELD TESTS

These units have been tested in the field at Queen Elizabeth Annex School in Surrey, B.C. for a period of six months, and no major design problems have yet been encountered. It was discovered that the silkscreened keyboard panels should be protected by a Varathane-type material and, in severe cases, a mylar cover; these adjustments have since been made. Some



EXPANDED KEYBOARD FOR
SPEAK AND READ

children with muscle weakness were having difficulty with the regular firm expanded keyboards. A softer version was developed for this type of student and this is now offered as an option.

CONCLUSION

Students up to twenty years of age have since benefitted from this assortment of learning aids.These expanded keyboards, which are now commercially available from Contemporary Artistic Technology(CATCO), will prove to be valuable tools in almost any special education situation!

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ACKNOWLEDGEMENT

Funding for the development of these keyboards was provided by a grant from the B.C. Health Care Research Foundation to Dr. Graystone, Rehabilitation Engineering, U.B.C..

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PROPORTIONAL CONTROL FOR FASTER NON-VOCAL COMMUNICATION

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Researchers at the Tufts REC have found evidence of surprisingly good hand control in a number of people with athetoid CP whose poor arm control makes letterboard use very slow and prevents effective use of keyboards or joysticks (1). Yet scanning or encoding aids that are controlled by surface-mounted switches are too slow, and ignore the user's fine-movement capability.

We developed a simple aid in which small proportional movements of a hand-mounted control (2) move a pointer across a row of letters at variable speed -- skipping quickly over unwanted areas, and slowing down for final positioning. An athetoid user averaged 28 selections/minute after a few minutes of practice, compared to 10-11 items/minute with his fastest existing aids (letterboard and TIC) which he had used for years.

To test the hypothesis that proportional control permits faster communication for some severely disabled people than can be obtained from existing aids, we have developed a Proportionally Actuated Communication Evaluator (PACE). Based on an Apple II, this system presents a video display of either a large or a small "letterboard" on which the experimenter can display a target at any location. By manipulating a proportional interface, the subject controls the movement of a marker across the screen -- steering it with any desired speed and direction until it comes to rest on the target.

PACE makes a continuous record of input and output signals, measuring target acquisition time for comparison with that for scanning and direct selection techniques. Errors, movement patterns, and learning curves can be analyzed. PACE can also be operated as a total proportionally-controlled communication system with printed output, for studies of text transmission rate.

A Remote Pointer, controlled by the user via the Apple, positions a beam of laser light on any desired location on a laptray letterboard, projected slide, or other communication array. This allows rapid direct selection in response to very small control movements and permits immediate comparison of communication rate for whole-arm pointing vs. finger-operated remote pointing with any letterboard the subject is accustomed to using.

The PACE system can operate in either position- or rate-mode; control signals can be single or dual channel, uni- or bi-directional, depending on the user's capabilities. Operating modes include:

Direct X-Y. Two independent input signals control vertical and horizontal position of the marker, allowing movement along any path at any speed.

Alternate X/Y. A single control signal moves the marker up or down until the desired row is reached; then the same signal is reconnected so that it produces side-to-side movement for selecting the desired location on the row. Alternation is controlled by either a switch closure or a pause of adjustable duration. When one coordinate has been set, it is protected from accidental change while the other is being varied, making this mode potentially more efficient than Direct X-Y for some people with athetoid movements.

Raster Scan. A single control signal moves the marker back and forth along a row. When moved past the end of a row, it jumps to the beginning of the next row and continues along it. A strong signal causes the moving light to sweep rapidly along one row after another, giving a visual effect like row-column scanning as each row lights up in turn. Reducing the input signal immediately slows down the marker to allow careful final positioning.

Auto Reverse. With no control signal present, the marker moves slowly backward in Raster Scan mode (rate is adjustable). An input signal produces a variable-speed forward movement that overcomes the backwards drift--allowing the user to move rapidly to the target and slightly beyond it, then release the control and let the marker drift back to the target at a slow and predictable rate. This mode makes bidirectional movement possible for a person who can only control a unidirectional signal.

Alternate Forward/Reverse. This mode also allows a unidirectional signal to produce bidirectional movement. It works like Raster Scan during rapid search and slow positioning; but if the marker overshoots, touching a switch provides direction reversal -- so that the user's control now moves the marker backwards at any desired speed to reach the target. Reversals may be repeated as needed.

Severely disabled athetoid users of scanning and direct-selection aids are currently being tested with the PACE unit; data will be presented.

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HYBRID OPTICAL HEADPOINTING TECHNIQUE

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For many severely physically handicapped individuals, the use of a head or mouthstick has proven to be an effective mechanism for pointing or operating typewriter keyboards. More recently, the lightbeam headpointer has been introduced.[1,2] results with the lightbeam headpointers showed that they not only were easier to use for many headstick pointers, but that they could also be used by a large number of clients who were previously unable to use headpointing at all. Many individuals who were able to point with their hands were also found to be much faster and more accurate pointers using the lightbeam headpointer.

Because of this increase in communication speed and accuracy, as well as the accompanying improvement in body tone and positioning noted for many individuals, the lightbeam headpointer is quickly becoming a major technique for communication. Unlike the headstick, however, it cannot be directly used to manipulate objects or activate keyboards. To overcome this problem, several research teams developed lightspot sensitive selection panels; these include the PILOT from England, the LOT from Holland, and the OCCUR from Canada[3]. Because of the high power of the lightbeam required, and the expense for the circuitry associated with each of the analog sensors, all of these systems were very expensive and received relatively little clinical application.

An Alternate Approach: An alternate approach to sensing headpointing was developed at the Rehabilitation Engineering Center in Memphis[4]. This technique used a matrix of discrete LEDs and a tunnel vision sensor attached to the user's head. As the individual pointed, the LEDs nearest to the target center on the display board would light. This approach provided a low-cost and fairly ambient light insensitive technique for detecting head pointing, and was quickly picked up and made commercially available by Prentke Romich in their ProScan, Express I, and Express III communication aids.

Although this provided a low-cost headpointing technique, it offered only discrete feedback to the user as to his current head position. As he moved off of the desired target, there was no feedback until the LED suddenly jumped to the next character position. The individual then had to try to compensate for his error, causing the LED to jump back and the countdown to square selection to reset to zero and begin anew. It was found that only about 2 out of 10 individuals who could use the lightbeam (which provides continuous head position feedback) for pointing were able to use the reverse optical headstick (with discrete feedback). Consequently, its application was limited to a small percentage of potential headpointers.

The Hybrid Optical Headpointer: To combine the best features of both approaches, a hybrid technique was tried at the Trace Center and the Communication Aids and Systems Clinic at the University of Wisconsin. This combined a continuous lightbeam with the Memphis Optical Headstick. The result was a system which was highly immune to ambient light and provided continuous head position feedback. In addition, the discrete LEDs gave an added measure of feedback, confirming the aid's interpretation of the target. Using this hybrid technique, the user sees a spot of light which he directs around the selection panel. When he is trying to point to a square, he simply tries to hold the spot of light (which is usually constantly moving due to the client's erratic motions) so that its motions are centered over the desired square. As his headpointing deviates in any direction from the target center, he can see this deviation and move to correct it before he leaves the target area. At the same time, the user will observe the LED in the center of the target area, which will remain lit as long as his excursions stay within allowable bounds. If he momentarily leaves the allowable bounds, he will be able to easily detect this, since the LED will flick to a neighboring square and back again. This additional feedback can be very important, since hysteresis can be built into the system to allow an individual to have stray motions which actually leave the target square by small amounts but which are not counted as being "off target".

Clinical Results and Preliminary Conclusions: Results to date have found that none of the individuals who have been able to use a lightbeam headpointer have been unable to use the hybrid approach (using the same size selection squares). In addition, individuals who were able to use the optical headstick without the lightbeam reported that the combination (hybrid) was less strenous. Their rate and accuracy for selections also increased. More extensive studies are planned.

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Funding: Cerebral Palsy, Inc., of Green Bay

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DESIGN OF A NEW COMMUNICATION AID: SPA-SYN-COM

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INTRODUCTION

Since its conceptualization in 1978, the Polhemus Navigation Sciences, Inc. SPA-SYN-COM communication and control aid has evolved to the prototype stage based on Polhemus' military electromagnetic head tracker. The SPA-SYN-COM concept was first presented to the rehabilitative community at the 3rd Annual Conference on Rehabilitative Engineering in August 1979. A follow up paper in September 1981 detailed the initial results from the first working demonstration model SPA-SYN-COM utilizing our military system and a microcomputer. Presently, the SPA-SYN-COM has been scaled down to a semiportable, independent, direct selection aid. The design philosophy behind SPA-SYN-COM was to produce a standard interface between the handicapped individual and his environment while being versatile enough to grow with the individual. The prototype design takes into account the ideas of portability, operational simplicity, versatility, speed, permanent copy and maintainability. The RS-232 serial communication protocol used throughout the electronics industry was chosen as the standard interface between the aid and all other electronic devices.

PROTOTYPE CONFIGURATION

The prototype SPA-SYN-COM consists of an electronics unit, an electromagnetic source and sensor, a symbol/character (target) board, a printer and a sighting device. The electronics unit contains two printed circuit boards and a linear power supply. One printed circuit board (Analog Board) contains all the circuitry necessary to generate, sense and digitize the electromagnetic dipole field used by the system. The other printed circuit board (CPU Board) is an 8086 based Multibus compatible single board computer. It controls the Analog Board, does all the required computations and communicates with the outside world.

The source and sensor each consist of three mutually orthogonal loops (three axis). The source produces a 10.286 kHz electromagnetic field when driven from the Analog Board. This field induces voltages across the sensor which are then processed by the Analog Board.

The symbol/character (target) board is a passive board made of clear plexiglas with symbols and/or characters on it. The source is also mounted on the target board. The target board is similar to commercially available letter or Bliss symbol boards in that its symbology is partitioned in a matrix format with lesser used symbols lying on the periphery of the boards. The printer is a lightweight, thermal dot-matrix printer with an RS-232 interface.

The sighting device employed on the prototype instrument is a virtual image device. It clips on to a pair of eyeglasses and also provides a mounting surface for the sensor. The actual sighting reticle is a single red dot generated by an LED and projected onto a dichroic mirror.

SYSTEM OPERATION

Upon power up the SPA-SYN-COM performs a self test and flags failure by printing appropriate error messages. If no failures are detected a "Request Alignment" message is printed followed by three carriage returns spaced one second apart. The third carriage return indicates system alignment and requires the user to be sighting on the source cross hair on the letterboard at this time. SPA-SYN-COM is now aligned and sighting on a specific symbol or character for a user adjustable period of time will cause that symbol to be printed on the terminal. Two of the symbol board blocks allow user adjustment of the dwell time required for signifying a successful symbol selection.

WHAT'S NEXT

Numerous possibilities exist for expansion of the SPA-SYN-COM usefulness as an aid for the handicapped person. The immediate goal is to reduce SPA-SYN-COM to a user affordable, fully portable, battery-powered aid. Once this is accomplished and dependent upon a positive clinical evaluation, SPA-SYN-COM's universal RS-232 interface can be put to good use. Word processing with the help of a personal microcomputer, voice synthesis and long range communication via modems all become possible. Looking further ahead, the control of environmental and household appliances as well as menu driven projected letterboards optimized for particular situations, become feasible.

There is also no reason why sighting on a target board is the only operational scenario. With the appropriate type of feedback, communication and control could be achieved by measuring the position and orientation of other well controlled parts of the body other than the head. A sensor mounted on the foot accompanied by voice synthesis feedback and the appropriate training program might be a very effective aid.

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THE DESIGN OF AN OCULAR CONTROLLED COMMUNICATION SYSTEM FOR CLINICAL IMPLEMENTATION

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INTRODUCTION

Although the concept of ocular controlled communication has existed since 1976 (1), there is no commercial device yet available. Clinical testing of prototype devices has shown a great potential for successful use, but has also illustrated many of the problems in device implementation. Recently, efforts at Tufts have been aimed at understanding those design issues that will bring ocular controlled communication to clinical reality.

TUFTS LINE OF GAZE SYSTEM

The Line of Gaze system represents Tufts efforts in ocular controlled communication. The system is comprised of a CCD (Charge Coupled Device) video camera used as an oculometer and an ultrasonic ranging device manufactured by Science Accesories Corporation for head position measurement. The information provided by the hardware is used to compute the user's direction of gaze with respect to a display (2). Although this system is confined to a laboratory setting (due to the size of the ultarsonic ranging device), it has been extremely useful in understanding those issues critical to the succesful design of a clinical instrument.

RESEARCH TOOL VS. CLINICAL APPLICATION

The major effort has been in understanding how the task specifications of a clinical device differs from those of a research tool (the traditional implementation of oculometers). The following differences have been identified:

1. The clinical device will most likely have one user. The research device has many different users.
2. The clinical device will be operated by the single user for long periods of time. The research device will be used by the same person for the length of the particular experiment.
3. Because the clinical oculometer is a "Personal" device, user acceptance becomes a consideration (e.g. asthetic acceptance).

The difficulties in implementing eyeglass mounted oculometers in a clinical situation can be understood from an awareness of the above considerations. Because oculometers are mounted on a single ("One Size Fits All") pair of glasses, there is considerable slippage evident in long term use. Also, the oculometer is mounted on a mechanical stage; this allows for location of the corneal reflection in the imager's field. The adjustment procedure is extremely tedious and must be repeated if any slippage occurs.

DESIGN SOLUTION

The solution to the problem is not a product but rather a process. It consists of a custom fitting of the oculometer to the single intended user. In detail the process is as follows:

1. The user is fitted for a snug, but comfortable pair of eyeglasses. The style of eyeglass has been chosen to minimize slippage.
2. With the user wearing the glasses, the position of the eye with respect to the eyeglass frame is measured.
3. Based on the previous measurements, the oculometer is mounted on the eyeglass frame.

With this configuration, the initial adjustment procedure is unnecessary (as a matter of fact, mechanical adjustment is impossible. With a well fit eyeglass frame slippage is kept to a minimum (the corneal reflection is always in the field of view of the camera). A fixed mounting (as opposed to an adjustable mounting) will minimize the amount of hardware on the eyeglass frame and raise fewer asthetic objections.

FUTURE CONSIDERATIONS

We at Tufts are very optimistic about the future of ocular controlled communication. The dramatic decrease in price and size of computers is occurring in solid state imaging devices. It is predicted that imager prices will drop from $1000 down to the $20 to $40 range (3). What remains the challenge to the rehabilitation engineer is the successful interface of these technolgies to the disabled individual.

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EYETRACKER COMMUNICATION SYSTEM

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ABSTRACT

The EyeTracker Communication System is a device that allows those with severe physical handicaps to control high quality speech output with eye movements. The system is comprised of three main modules: a video based sensor module which determines the direction of the eye gaze, a dynamic display module that provides rapid access to a large data base and an output module offering language output in a sex and age identifiable voice or in hard copy form. The output includes not only letters and words but full phrases and sentences. Currently there is a table-top model in use as a teaching aid. A portable, personal communication system is also under development. The main features of the EyeTracker include ruggedness, convenience, safety, and portability.

INTRODUCTION

The EyeTracker Communication System has been designed to aid severely physically impaired children. A table-top model is being used as a teaching aid daily in a classroom at The Rehabilitation Institute of Pittsburgh (formerly The Pittsburgh Home For Crippled Children). We are developing a similar, more portable device that will be a personal communicator.

Safety, ruggedness, portability and convenience are all features of the EyeTracker System. Powered by low-voltage direct current, it is all solid-state. There are few moving parts or critical alignments and it requires no physical contact with the user. Supervision of the handicapped person using the system is not necessary.

Eye-movement based control of the communicator is significant for two reasons. Children who are severely spastic or paralytic have unreliable or, at best, slow voluntary control of body movements. For many of these children, eye movements are the only motions controlled enough to use for communication. Even for people able to control conventional communication aids, many find the use of our system more rapid and non-fatiguing. When the encoding of a message can be done quickly and with ease, a person is more likely to voluntarily use a communication aid.

MODULAR ORGANIZATION

Three related modules, all controlled by the same microprocessor, constitute the EyeTracker System. The sensor module remotely senses which of eight display areas a user is looking at. Incorporating a hierarchical data base, the display module serves as the user interface of the EyeTracker. Finally, the output module produces high quality speech and printed copy.

The remote sensor module uses an infra-red video camera and a digital preprocessor. Under most indoor lighting conditions, a sharp image of the user's eye may be maintained by an ultrasonic ranging and automatic focusing system. By calculating the relative positions of a corneal reflection and a pupil image, the direction of the gaze is computed.

The dynamic display module consists of eight displays arranged on the margin of a three by three matrix. Currently eight words or short phrases can be presented. By gazing at one of these areas, the user can select which word will be sent to the output module.

Nearing completion is a hierarchical data structure to allow access to data base of thousands of phrases. Initially, eight category headings will be displayed. Gazing at one of the headings will lead to the presentation of eight subject-related words or phrases. Successive passes leading to more specific information continues until the level of specificity desired is reached. A particular word or name, for example, can be inserted in a general phrase and the final sentence can then be sent to the output module.

The output module produces both printed copy and concatonated speech having the tonal quality of good telephone transmission. Compressed speech is encoded digitally and reproduced using a delta-modulation technique. The speech is age and sex identifiable. We have found that unlike many normal children who accept totally synthesized speech, speech-impaired handicapped children prefer speech communication that is sex and age specific. They want their communicator to sound like they think they should sound.

HARDWARE AND SOFTWARE

The present system is built around a 6502-microcomputer, the Rockwell Aim-65 single-board computer with built-in printer, with vocabulary stored in EPROM memory. The system now being developed utilizes magnetic bubble memory produced by Intel Corporation. Not only will the bubble memory greatly enhance the capabilities of the EyeTracker, it will enable us to produce a more compact communication device.

Entirely written in 6502 Assembly Language, the software for the EyeTracker System is modular in style. As a result, each hardware sub-system is associated with a software module containing a well-defined set of operations. This allows higher-level routines to be coded in a straightforward manner as though they were written in a high-level language. At the user interface level, the system presents reasonable error messages and also protects against data destruction.

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IMPART - RESULTS OF A FIVE-YEAR REHABILITATION TECHNOLOGY UTILIZATION PROGRAM

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ABSTRACT

The effectiveness of technology utilization was clearly demonstrated in numerous rehabilitation cases. But the most important accomplishments were direct and indirect effects of IMPART on establishment of ongoing rehabilitation engineering programs in some of the participating states.

Texas Rehabilitation Commission cross-trained a vocational rehabilitation counselor who acquired experience and demonstrated expertise as a practical rehabilitation engineer. Texas also developed a technical rehabilitation information specialist, a technical equipment specialist, an an extensive file of technical rehabilitation resources information. Funding and means for continuing these services are in development. Oklahoma permanently employed a rehabilitation engineer in their state-funded O'Donoghue Rehabilitation Center and sub-contracted with an ex-IMPART rehabilitation engineer at Tulsa Rehabilitation Center. Louisiana developed their own rehabilitation engineering program independent of IMPART.

GEOGRAPHIC AREA SERVED

The target area was RSA Region VI consisting of Texas, Oklahoma, New Mexico, Louisiana and Arkansas. Problems were also received from many other states even though they were not solicited outside Region VI. These extraregional problems were serviced in a manner similar to those originiated within the region. The general exception was that site visits were not made; however, workshops and presentations were made outside the region with some support from the host agencies.

ROLES OF PARTICIPATING STATES

Texas, as recipient of the grant, provided a Program Director, Program Coordinator, Secretary-Information-Specialist and Secretary-Equipment Demonstration Specialist. Extensive rehabilitation engineering support was provided by Southwest Research Institute (SWRI) under sub-contract. An SWRI rehabilitation engineer elected to become an employee of Tulsa Rehabilitation Center in order to establish a rehabilitation engineering department and to more efficiently deliver IMPART services to Oklahoma during the final year and one-half of the program. IMPART technology utilization services were supported by a contractual agreement between Oklahoma and SWRI. New Mexico supported the IMPART program by providing funds via a contract with Southwest Research Institute. Louisiana provided grant funds to the Biomedical Rehabilitation Engineering Department of Louisiana Tech University which provided rehabilitation engineering services. Arkansas did not develop a formal rehabilitation engineering service program.

MEASUREMENT OF EFFECTIVENESS

Direct indicators of the effectiveness of a rehabilitation technology utilization program are as follows:

- Amount of money spent by state agencies for technical rehabilitation devices - compared to money spent in prior periods.
- Number of client cases where technical devices played a major role in successful rehabilitation and case closure.

In the absence or unavailability of this information the following factors can be used as measures:

- Rehabilitation engineers and other technical personnel acquired or retained by the state agency.
- Number of problems received and solved by the program.
- Number of severely disabled clients vocationally rehabilitated.
- Technical information files developed.
- New services, training, teaching or therapeutic methods established as a result of technology utilization program.
- Numbers of presentations, workshops and special programs made to select groups.
- Numbers of publications.
- Development of extensive file of information on rehabilitative methods, devices and other resources.

CONCLUSION

Ideally, the five-year IMPART program would have caused each of the five primary states served to fund and operate ongoing rehabilitation engineering programs. It appears that three out of the five states have done so. There is no doubt that field counselors, therapists, teachers and consumers in this area are much more inclined to utilize technology as a result of the IMPART program.

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HUMAN FACTORS ENGINEERING IN SERVICE DELIVERY

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The Georgia Institute of Technology in cooperation with the Veterans Administration has an active engineering service program for providing adaptive devices and systems for the disabled veteran. This program is similar to many in the nation in that engineers work with an individual disabled user to engineer specific adaptive aids. The major difference in this service delivery is the amount of input and method of communication employed in working with the end user.

A team approach is utilized from the moment of referral. A research staff person who himself has a disability conducts the initial interview and obtains necessary records from the Prosthetics Division of the Veterans Administration Medical Center. The researcher works closely with graduate students and occasionally undergraduate student engineers in developing a design in conjunction with the disabled person who will utilize the system. When a design has been evolved that has apparent user acceptance, it is forwarded to the Veterans Administration staff for their review, input, modification, and funding.

When the project is established an iterative process of design, test, modify, and test is undertaken. Some of the systems have gone through three to four prototype stages before completion while others have worked upon completion of the first prototype.

Four specific examples are the Automatic Joystick Box Retractor for powered wheelchairs, an Automatic Leg Bag Evacuation System for quadriplegics, an Environmental Control System for severely disabled persons, and a Treadle Actuator for an engraving machine. Oddly enough the seemingly simpler projects often necessitated the greatest number of iterations as opposed to more complex designs. Ultimate user satisfaction and acceptance are guaranteed by the fact that the user must sign the release for payment of the purchase order.

We have found that involving student engineers with an experienced disabled staff member and the disabled user in a team approach provides a well engineered end product, useful to many disabled persons and often not far from manufacturing and distributing prototype stages. A student engineer is often more willing to accept the user's lack of understanding concerning elements of engineering design, and with the assistance of a researcher is quite able to communicate successfully and therefore seriously consider the suggestions and ideas of the user. The student, in our experience, has always had an enthusiastic and excited attitude often with an overly optimistic outlook that the user finds flattering and reassuring. Rapport is quickly established and the team sets out to solve the problem.

While the program is now only a year old, it has had a number of successes that have extended beyond provision of a system to a user. Commercial interest has been aroused concerning half of the designs and the contractor, the user, and the engineering student have all gained in the program.

It is the authors' opinion that this approach is probably initially more expensive. However, it does appear to assure a quality of engineering essential in meeting human needs and provide adaptive devices for many persons beyond thoses directly served. Also less tangible benefits such as the education of engineering students as Rehab Engineers, and the involvement of disabled persons directly in their own rehabilitation cannot be ignored. The long term impact of such a program may be difficult to assess, but the authors feel that the immediate benefits themselves justify the program.

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FROM RESEARCH TO SERVICE DELIVERY: A CASE STUDY IN QUEBEC

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INTRODUCTION

The use of technology to compensate for disability arising out of sensory and/or motor impairment, forces the research engineer or designer to determine needs and resources at two levels: those relating to the users, and those relating to the local service delivery system. A research project undertaken at the School of Industrial Design, University of Montréal, illustrates the problems which can arise when the interrelationships among these needs are not adequately studied from the outset. The objective of the research was to develop a commercially available seating system for non-ambulatory children with cerebral palsy, maintaining involvement with medical and paramedical professionals, as well as parents, children, teachers, and support personnel throughout.

USER NEEDS

Three "user groups" can be identified:

Primary users: the children whom the seating system is destined to serve.
Secondary users: the family and friends of the children, and/or certain support personnel.
Tertiary users: the professional people interacting with the children, such as therapists, teachers, and doctors.

Each user group has a variety of needs:

Therapeutic needs: e.g. normalization of tone, symmetrical posture, change of position...
Functional needs: e.g. stability and support, ease of use, adequate documentation...
Psychological needs: e.g. feeling of security, aesthetic appeal, personalisation, self-image...

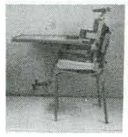
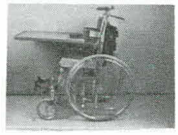
DESIGN SOLUTIONS

The main characteristics of the seating system are:

- It is an independant system, equipped with a set of optional accessories, including a work or play surface, footrests, a head rest, and lateral trunk supports.
- The seat fits into an "interface" which ensures stability when used on the floor or on a standard straight-backed chair, and is compatible with most wheelchairs.
- The seat can be reclined easily for rest by means of a small hand crank.
- An individualized seat can be built to meet the needs of children requiring more support by procuring only the interface with a simple "shell", and the desired accessories.

All adjustments have been highly simplified, and maintenance requirements have been reduced to a minimum.

Self-image can be positively or negatively affected by the use of a technical aid. Besides aesthetic considerations, a school bag, and a compartment in the tray surface, have been provided for practical purposes, and to enhance the user's appropriation of the system. The accompanying documentation includes a comic book for the primary user group, describing the capabilities of the system, and a manual for secondary and tertiary users (to be developed).


SERVICE DELIVERY SYSTEM NEEDS

The development of service delivery systems for technical aids has brought with it a plethora of intermediaries, each having different objectives and needs. One can, for example, identify specific needs at the levels of Research and Development, Manufacturing, Distribution and Service, Education/Information, Financial Coverage Schemes, etc. When initiating a research project, needs of other sectors are rarely identified, even though subsequent availability and coverage depends upon these sectors. In Québec, a developing government insurance scheme has enhanced universal availability of certain aids, but lacks a coherent plan for future growth. While seating has been identified as a definite service need, the process of transition from research to availability has proven to be extremely difficult. In order to remedy this situation, a process known as Delphi (1) has been initiated, allowing trans-disciplinary, anonymous, consultation among persons from the economic, service, government, and education sectors.

CURRENT STATUS OF RESEARCH

A number of Service Delivery System needs have been identified. It is hoped that the outcome of the consultative process will assist in making available the seating system developed, as well as the growing number of other aids designed to enhance the function of children and adults with disabilities.

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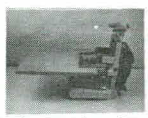


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A NETWORK APPROACH TO BUILDING A REHABILITATION TECHNOLOGY CENTER

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The Center for Rehabilitation Technology is a collaborative interdisciplinary activity of the University System of Georgia to develop equipment and procedures that help handicapped and disabled persons become important members of the national work force, and remove functional barriers in the workplace, home and community environment. The Center's goals are based on the postulate that all persons require some assistance in adapting to their surroundings.

The Center is administered by a small core staff consisting of a director, an administrative manager, technical services coordinators, an information specialist, a project development coordinator and editor, and a secretary. The core staff is responsible for the development and operation of the Information and Referral Service and the Center's laboratories, and provides technical services under contract to governmental and private institutions. In addition it initiates and coordinates projects providing assistance to individual faculty members, staff researchers, and departments of the University in developing research proposals, securing funding, preparing reports, and generally helping to expedite project development and ensure the quality of contracted work.

The core staff is funded through an administrative budget made up in part from information service and laboratory user fees. Administrative funding is separate from project funding and no administrative costs of the Center are charged to projects. This gives full use of all project funds to the research or instructional unit undertaking a project.

All projects of the Center are carried out under memoranda of understanding or formal contracts following usual University System contract procedures. Requests for projects are made to the Center by letter or simple form outlining a need or problem; the program area concerned; key individuals or agencies involved; and the estimated level of effort required. The core staff of the Center processes the request, assembles a research or technical assistance team from Georgia Tech and other units of the University System as appropriate; and prepares a proposal to the requesting agency for funding the project. The proposal is then reviewed and the project authorized according to established University procedures. All project results are evaluated and recorded by the Center for application to other projects.

The main challenge to the Center has been how to provide quick service delivery. Anyone who has been connected with a technical university knows that administratively they are not set-up to handle this "unique" approach. We are working closely with a few well placed individuals who have administrative positions in the University to develop the necessary procedures.

Responsibility for the Center's development and funding is carried out by an incorporated Board of Directors made up of University alumni and administrators, representatives of governmental and private agencies involved in rehabilitation services, and private individuals. The Board has a strong business orientation and plays a principal role in developing and responding to the interests of the business community in rehabilitation.

The Center's programs are also supported by two advisory groups. One is a network of individuals and agencies representing rehabilitation services consumers and providers. The other is a committee drawn from the various departments of the University that have existing or emerging interests in rehabilitation technology. These two groups assist the Center's administrative core staff and Board of Director's in developing program priorities and procedures that are reasonable and realistic in terms of their appropriateness to the University, and to the needs of consumers and the delivery of services. As you will note, these functions are beneficial to both parties which serves to further encourage participation. These groups, along with the administrative staff, provide the nucleus for the development of the Center. The primary challenge to the Center in the future is maintaining communication between these groups while keeping the individual goals of each group clearly in focus.

TECHNICAL AID TO THE DISABLED IN AUSTRALIA

George Winston B.E., M.I.E.E., Executive Engineer of Technical Aid to the Disabled in the State of New South Wales, Australia.

To move in the direction of equal opportunity, disabled people need attendant care, non-institutional accomodation, access, mobility, communication, assistive devices and work place modifications. There is,in Australia,a growing realisation that rehabilitation engineering services are essential to provide these needs but their growth is blocked by lack of funds.

In an attempt to remedy this situation, concerned technical people in five Australian states have formed voluntary associations called Technical Aid to the Disabled.

Working with little or no experience of rehabilitation, TAD volunteers work closely with rehabilitation professionals, solving practical problems presented by disabled people. The volunteers include engineers,architects, industrial designers,technicians,draftsmen, tradesmen and others with design or workshop skills.

TAD organisations are well suited to the solution of individual problems of daily living which require a great deal of personal attention.

Work in a TAD group offers technical people a unique opportunity to exploit their ingenuity, experience and creativity. Satisfaction stems from helping another person directly, from being in control of the whole project, from a short time scale and, hopefully, from client satisfaction.

The Australian activity is almost but not quite unique. Similar groups are operating in Great Britain under the name of REMAP and the Bell Pioneers are involved in the development of assistive devices in parts of North America.

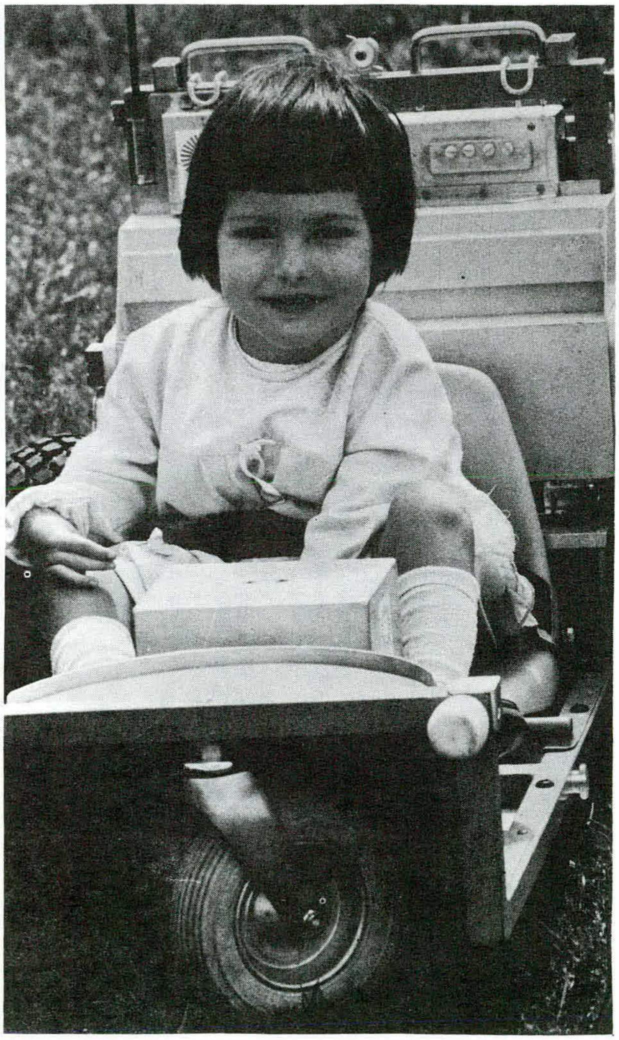
TAD groups are separate,independent,non-profit voluntary organisations with charitable status. Recently, a federation of these groups has been established to provide a forum and a united voice on federal and other general matters.

Between them, the five groups command the services of over 600 volunteers who complete approximately 1000 projects per year. Branches have been formed in some country centres where needs are even more urgent than in state capitals.

The scope of TAD activities is limited by such factors as the scarcity of people with biomedical knowledge and unavailability during working hours. Thus it is seldom possible to tackle complex problems involving prosthetic or orthotic engineering.

It is also seldom possible for volunteers to develop new products to be produced commercially. Nevertheless, some outstanding successes have been achieved in this field.

The rapid growth of the TAD movement is indicative of the complementary needs on which it is based: the need of disabled people for technology and special equipment and the need of technical people to contribute their special skills to the community.



A foot operated, proportionately controlled outdoor electric vehicle constructed by a volunteer of TAD (Victoria) for a 3 year old girl with arthrogryposis.(Herald & Weekly Times)

I thank the Board of TAD (NSW) for the opportunity to present this paper.
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New Technical Approach to Young Cerebral Palsied Children

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Conventional aids for the physically handicapped tend to be prostheses which replace a missing function by direct substitution, thus modifying the patient to give him a maximum of experience and interraction with environement. In the case of severe handicapped child, prostheses may be insufficient and a more workable approach is to provide a learning and experience environement closer and more accessible to the patient. An example of this approach is the one we use for cerebral palsy child, characterised by severe motor and perceptual impairment. Our children are rarely able to make a single reproducible volontary response (e.g. limb movement, utterance or facial expression). Provided training can be given to exicit a binary trigger these children could access the information, learning and expressive capacities of computer systems. Our program concerns cerebral palsied children without gestural or vocal expression. (6 to 13 years). A study of 3 of them, and videotapes shows that evident gestures are often complexed and secondary to the true voluntary gesture. Isolation of the true gesture and training using electromechanical triggers for toys lead to effective command of the triggers, allows computers access, and shows that these children are of considerable higher intellect than had been established. Piaget's theory allows an approach to program development and evaluation for the benefits of these children.

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A SERVICE DELIVERY MODEL - A SYSTEMIC APPROACH

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INTRODUCTION

This paper explores some of the critical issues to be considered in the adoption of a systemic approach to the service delivery of technical aids for and with disabled individuals in a clinical setting. A framework, in the form of a model, is proposed in which the field of technical aids is shown to be not just another isolated 'program' but one which cuts accross many facets of rehabilitation. In order to address the problems associated with the 'provision' of technical aids, some fundamental ideological principles have been identified on which the structure of the overall approach is based. Added to this are some important historical events which relate to the rise of technology in rehabilitation and which prescribe its present operational modalities. In the proposed model, technology is looked upon not simply as 'technique' but more in terms of the larger paradigmatic socio-technological imperatives. Rather than promoting a purely engineering approach, rehabilitation technology is advocated as a medium focused on achieving wider social, individual and technical objectives. Definitions of technical aids are also proposed in terms of the current trend towards developmental or global analysis of user needs.

A SERVICE DELIVERY MODEL

The proposed service delivery model is described as part of an overall user rehabilitation/education/vocation program, where the goals of the system are:

1. To develop a comprehensive global analysis of user needs in terms of his/her overall daily activities.
2. To optimize the matching of technical aids to the needs of the user, and to his/her goal oriented-activities.
3. To unite the user, family and professionals in a co-intentional, dialogical decision making process.
4. To establish the support mechanism required to set-up and maintain the operational procedure for service delivery.
5. To provide a process that can be understood administratively, and which identifies the professional and personal responsibilities of each actor in the process.

Through the mechanism of the model, objectives have been identified which concern the interdisciplinary activities required in the service delivery of technical aids, a check-list of issues to be considered when setting up such a program has been defined, and concepts assuring dialogical and co-intentional practices at all stages in the process have been developed. The model is divided into nine functional areas and form a set of procedural activities.

Definition of the Model Components

Research Function. Concerns documentation of the field, development of in-house information, in-service courses and includes the development of programs, plans, procedures and protocols for the service delivery system itself.

Problem Identifying Function. Relates to the initial identification of needs made by the disabled individual, family, teachers, doctors, therapists, etc., leading to initial referrals to the appropriate bodies.

Pre-Clinic Function. An in-depth analysis of user needs from a developmental or global point of view. It deals with user needs and wants, the ensuing goals and the activities that are necessary to achieve the goals.

Multi-Disciplinary Clinic. This is where the overall checks and balances of the system resides. It has the ultimate decision making responsibility and is the overall prescriptive body.

Specification Writing. Relates to the protocols which provide comprehensive data either to fabricate a required device (design specifications) or to purchase a device (purchase specifications).

Fabrication or Purchase Function. Implies all of the technical procedures required to develop and construct a technical aid or the approach required to analyse the documented technical specifications and user manuals of a commercially available device.

Clinical Evaluation Function. The evaluation that takes place in a clinical setting, in order to assess user behaviour changes, user/device functional operation and the technical performance of the device.

Delivery Function. Relates to the situation that once the device is pronounced 'user friendly' transfer or responsibility for the technical aid, from the service providers to the user, takes place. This implies appropriate instructions and documentation.

Follow-up Function. The monitoring of the user from a global point of view in order to assess the impact of the new device in a multi-factorial way over a long-term period.

CONCLUSION

This systemic approach challenges, in some ways, the entrenched disciplinary atomism found in the field of rehabilitation, where the true value of interdisciplinary cooperation has yet to be fully appreciated. The disciplinary roles formed by the now threatened medical model, requires urgent re-evaluation. Attention should be directed towards professional attitudes which must keep pace with the now fast-moving politicization and self-affirmation movements of the disabled people themselves. Administrative apathy, professional short sightedness and plain stubbornness to adjust to evolving frameworks is the most difficult factor to deal with, and is possibly the greatest hinorance to the general evolution of the rehabilitation field itself.

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RECOMMENDATIONS ON THE ESTABLISHMENT OF A REHABILITATION ENGINEERING SERVICE DELIVERY PROGRAM

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INTRODUCTION

Based on the results of a survey of rehabilitation engineering facilities and the ongoing experience of the University of Tennessee - Rehabilitation Engineering Center Service Delivery Program, established in 1974, guidelines for the establishment of new rehabilitation engineering service delivery efforts are presented.

SURVEY

The survey was initiated in the fall of 1980 to establish a baseline of information on delivery of rehabilitation engineering services. Responses to this survey were received from seven facilities in the United States, one in Canada, two in the United Kingdom and one in Australia. Seven of these service delivery programs are located in primarily in-patient/out-patient rehabilitation facilities, two function primarily as out-patient facilities, and two service delivery programs are located in in-patient/out-patient acute/rehabilitation care facilities. Of the responding facilities all report associated research activities such as seating and mobility (7), communication (3), gait studies (2), biomechanics and internal joint replacement (3), and orthotics (2).

The majority of the responding agencies have service delivery programs located in comprehensive rehabilitation facilities. In these settings they are able to draw upon the resources of the comprehensive facility to bolster a limited number of full time staff dedicated to the service delivery effort. The total personnel devoted to the service delivery effort range from the equivalent of one to eleven full time individuals (average 4 to 5). Eight facilities are operating under, or initiating, fee-for-service funding. Certain facilities have obtained a significant amount of grant support in establishing their serivce delivery operations. The cost of fee-for-service activities are generally based on an hourly rate according to the personnel required. The professional rate ranges from $25.00 to $80.00 per hour (average $50.00) and the technical rate ranges from $12.00 to $35.00 per hour (average $30.00). While by far the majority of service activity is funded by state Departments of Vocational Rehabilitation, significant third party support is provided by private insurance and state Crippled Children's Services.

RECOMMENDATIONS

A supportive environment is essential for the growth and viability of a fledgling Rehabilitation Engineering Service Program. As shown by this survey, traditionally rehabilitation engineering service delivery efforts have arisen in facilities that both provide in/out patient rehabilitation services and are also affiliated with related medical research activities. Such a facility provides depth of medical and scientific resources and a staff trained in the functional aspects of rehabilitation. Such a facility provides an umbrella organization which may assist in attracting grant funds to offset the cost of initiating a service program or at the very least provides an existing fee structure for medical services. In such a facility, the recognition of the need for additional technical services to facilitate the total rehabilitation of an individual may create an environment condusive to the introduction of rehabilitation engineering services. In such an in-patient/out-patient rehabilitation facility there is a continual flow of patients who are in need of such technical services. Although such an environment facilitates the establishment of a Rehabilitation Engineering Service Program it by no means assures its success.

Regardless of the context in which such a service delivery system is established the following guidelines are presented:

The establishment of a service delivery program is best initiated by a dedicated core group of professionals and consumers. Through a process of self education, they become aware of the range and character of the existing technical solutions that are products of the Rehabilitation Engineering research and service efforts. Further educational efforts are initiated to target professionals and consumers within the community at large to generate a recognition of local need and the potential solutions available through the application of established technology. Following these initial educational efforts, the careful introduction of technical solutions can demonstrate the potential effectiveness of this service delivery. At this stage it is important to avoid creating expectations that cannot be readily fulfilled. The service delivery effort must grow with the available technical and professional resources, utilizing some throttling valve to prevent overloading the system during its initial growth stage. Each locale will have its own unique local politics which must be dealt with in maximizing communication and the use of existing community resources.

Most service delivery programs exist within larger rehabilitation facilities. This environment provides them with many requisite basic needs. Establishment of a viable service effort involves community education, communication and mobilization of existing resources. With the support of an increasing body of knowledge and experience in the provision of rehabilitation engineering technology, the formation of viable autonomous programs will become a reality.

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FUNDAMENTALS OF A PRACTICAL REHABILITATION ENGINEERING SERVICE FOR NORTH AMERICA

Nigel Shapcott

Woodrow Wilson Rehabilitation Center

MAGNITUDE OF THE PROBLEM

Rehabilitation Engineering is specifically concerned with the development, provision, and maintenance of technical devices and services as part of the rehabilitation process. It has been estimated that approximately 3% of the U.S. population has a physical disability and could benefit from Rehabilitation Engineering Services (RES's) if they were available (1). For the U.S., that means approximately six million people. There are probably about 50 Rehabilitation Engineers actively involved in full time service delivery (2). 120,000 clients per rehabilitation engineer is quite a caseload!

METHODS OF DEALING WITH THE PROBLEM

Expansion

This is obviously required to deal with the magnitude of the problem, but in these times, the economic argument and basis for Rehabilitation Engineering is generally weak. One approach to this problem would be to encourage Universities, (with Economics Departments) associated with RES's to study the short, medium, and long term cost to society of RES. This would enable priorities to be drawn up which might stimulate third party payers and government at different levels to fund RES expansion.

Education

RES is a new field in comparison with most other health services and there appears to be a public and professional mental block applied to it - both health care professionals and the general public seem to lack the information and understanding to get the RES they need. Video tapes and tape/slide presentations funded by RESNA and professionally produced would be of great value here. Also, publishing costs are high for low volume pamphlets- if RESNA produced high volumes of a professionally made pamphlet onto which the address of the local RES could be stamped - these local RES's could purchase low quantities of pamphlets at substantial savings. These measures would considerably enhance the local educational efforts of RES personnel.

On Site Consultation and Treatment

One method of providing service to clients who otherwise would not get it is to take the service to them. This is particularly important in the case of work site modifications: an industrial environment is of necessity, a competitive one, and rarely can lengthy delays in service be tolerated a fact which is likely to be losing many disabled people jobs every day. A Mobile RES could provide on site modifications at fairly short notice with minimum disturbance of production. An MRES with a clinic as well as workshop facilities would have sufficient versatility to tackle a wide range of projects, visiting institutions such as schools, nursing homes, mental institutions, and hospitals to provide seating and other specialized services.

Staffing

Probably one of the most vital factors of the service is the quality of the staff. At this early stage in the development of RES, with the large caseload and the responsibilities this implies, it is very clear that well qualified, competent and self-motivating staff would be a great asset in tackling these problems. Unfortunately, there are barriers which discourage or prevent hiring people with the desired characteristics. Often hiring is done within existing State or University rules which do not have adequate job descriptions for the positions required. The immediate effect is most often non-competitive salaries which can lead to loss of self-esteem, poor motivation, and high staff turnover after a while.

Perhaps, RESNA should work with e.g. NIHR to establish new guidelines for grant applications giving freedom to employ qualified people at competitive rates.

Research and Development (R & D) Techniques

For solving individual problems it is important to consult with people who have or will have an active part in the client's rehabilitation and to agree on common objectives.

Design for simplicity, functionality, and reliability - where possible using standard equipment with simple modifications. This will in most cases give you the least expensive solution in the long and short term.

Repeat prescriptions or devices may indicate a development for production project the objectives of which would be to market a particular device through an outside manufacturer. This would result in many clients being served in an economical manner without tying up RES staff. This approach is very important at this stage in Rehabilitation Engineering because of the large caseloads existing at the present time.

In order to accomplish this R & D for production effort, RESNA should develop with NIHR guidelines for RES's and REC's that for the former allow 30-40% R & D time and for the latter 30-40% service time. This dual commitment at all staff levels should lead to the understanding and the resources to tackle priorities which will not go away - disabled people.

CONSLUSION

RESNA should encourage a forum for active RES providers to discuss problems and establish goals, and should follow this through with discussions with major RES resource providers in order to attain these goals.

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BRINGING REHABILITATION ENGINEERING BACK HOME
A TECHNOLOGY RESOURCE CENTER

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Technology has long been used to overcome human physical limitations. For people with physical disabilities, it has been an important means of entering and/or of rejoining the mainstream of life. In the last 10-15 years, there has been an explosion of technology for everyone, including disabled people. In addition, changing attitudes about disability and independence have raised expectations, and placed new demands on technology to keep pace with needs of integrated living in the mainstream of the community. Nowhere is this more true than the San Francisco Bay Area. This area brings together: 1) a large population of active, independent disabled people; 2) supported by more than half a dozen Independent Living Programs; 3) a general public and mass medica with increased public awareness of the potential of disabled people; and, 4) a large number of technology-rich resources, with an enormous range of service delivery and R&D capacities.

To take advantage of the trend setting nature of this area and to demonstrate a model that could be used across the country, the Rehabilitation Engineering Center at Children's Hospital at Stanford is developing a technology resource center for people with physical limitations. The resource center will be spun off from the REC. It will function as a totally independent community based operation. It will be consumer oriented. The focus will be community living aids, i.e., devices that enhance the ability to live in the community, that can help keep people out of institutions and help get people out of institutions. The ultimate goal is to improve the individual's ability to make the best choices about using technology. We are setting up a multi-level center with 1) a core exhibit area of hands-on displays that have an engaging, playful aspect to them; 2) poster-type exhibits showing the range of commercial and DIY devices and possibilities available 3) a redi-reference desk where people can get their information requests answered; 4) an equipment demonstration area where people can actually "try on" devices.

The resource center will look more like an exploratorium than either a museum or a medical equipment showroom. The integrating possibilities of this approach are very exciting. An exploratorium approach will attract people who don't label themselves as disabled, yet have a physical limitation that technology could aid, e.g. senior citizens and their families, people with mild to moderate arthritis, parents of children with limitations. We all know someone with arthritis or have an aging relative whose life could be made much easier by using a simple gadget here or there, but they don't know such a thing exists and/or who to ask, or even that they could ask. They just go on, sometimes until they really disable themselves and/or end up in a nursing home. Technology isn't the answer, but it surely is part of the solution. We hope to make the use of technology less frightening, and more available to the people who could benefit from it.

Several different models have been explored for such a center. Consensus is to first establish a fixed site operation, accessible to public transportation and centrally located to a large group of disabled people. After the initial site is running smoothly--programmatically and fiscally--satellite centers can be established in other communities. Some of these could be mobile vans where that type of service would most suitably meet the needs of the locale.

The Center will act as a networking resource, identify community resources and make them available by a manual then computerized data base. It will also act as a resource to help needed services develop within the community. The Center will not compete with any segment of the "market"-sell/rent/repair equipment, sell assessment training or therapy services, perform examinations, or write prescriptions, nor will it duplicate existing efforts or develop a service or expertise that could be encouraged to develop within the community. The Center will provide direct service in the form of information about products, hands-on experience, pictures, referrals, advice. But this "service" would be within the context of general public awareness in a model of integration. It will be exposing people to a broad range of possible solutions--so they would know that there are other ways of doing things if and when they need them. It will help translate the promises of Rehabilitation Engineering into tools for every-day living.

ACCESSORIES: Tools for Everyday Living

	Component	Objective	Staff Role
Play With Me	Hands-on exhibits	Inform about technology's: -availability -usefulness Demystify technology	Docent/Explainer
Show Me	Poster displays	Show pictures of applications in real environment Inform about: -availability -usefulness	Docent/Explainer
Tell Me	Information clearing house	Give specific product/service data Help clarify needs Make appropriate referrals	Information Broker I & R "Redi-Reference" Librarian
Try Me	Demonstration Unit (model kitchen, bath, bedroom, office)	Make individual comparison/ evaluation See which devices work	Occupational Therapist/ Peer Counselor
Read Me	Library/small bookstore	Referral source for more information Central place to obtain non mass market books	Librarian/bookseller

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DEVELOPMENT OF COMMUNITY RESOURCES FOR REHABILITATION - A SOLUTION TO MONEY PROBLEMS ?

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ABSTRACT

Fund-raising for rehabilitation of severely disabled clients has been suggested as a means for acquiring community support. Fund-raising for cute, pitiful, and popular clients can work. But if we examine the true costs of multiple fund-raisings and delays imposed on the rehabilitation process, we may decide that we cannot afford this prejudicial and "apanaceic" activity.

SUCCESSFUL AND UNSUCCESSFUL FUND-RAISING EXPERIENCES

Client A

Friends raised $21,000 in a matter of hours for a Tulsa quadriplegic who had been bedbound and on a respirator for eleven years. This man had been a very popular college athlete and had been injured in a sporting event. He had many friends and fraternity brothers who eagerly helped once they learned that technological intervention would be effective. As a result, environmental control equipment, a special "puff-sip" operated wheelchair, a computer and other equipment was acquired for this deserving man. Acquisition of sophisticated equipment provided employment potential and legally qualified him for services by the state vocational rehabilitation agency. Donors and all involved were justifiably proud.

Client B

In another case, a young quadriplegic was discharged from a rehabilitation center manifesting inability to shift his weight while sitting. The attending staff had clearly recommended that an electric powered back-recline feature be installed on the wheelchair - cost $1500. No funding source was available. Before a fund raising program could be organized the patient returned for a $15,000 hospital stay for treatment of decubitus ulcers.

Client C

An individual who failed in a suicide attempt became a mute tetraplegic. Intense effort by therapists resulted in development of communication capability with the use of a $1,000 electronic communication aid. There was no source of funds to purchase this device so the man was committed to a nursing home, with no means of communication whatsoever. Needless to say, deep depression occurred and four months later the patient returned for surgical treatment of decubitus ulcers. The state vocational rehabilitation agency could not legally accept this man as a client because he had no "reasonable degree of vocational potential".

Client D

This client was committed to a state school for the mentally retarded because she was a severe tetraplegic with very severe cerebral palsy. She drooled and could not talk and was not pleasing to the view of most people. Nevertheless, dedicated therapists and engineers devised and demonstrated an effective communication method for this young lady. Ability to communicate, purportedly, would qualify the client for residence in a nursing home. No source of $2,600, cost of the communication aid, was available.

No one is interested in a fund-drive for this unpopular, unattractive lady so she remains in a facility for retarded people even though she is not retarded.

Client E

This client is a deaf quadriplegic. He is full-time employed as an assembler in an electronics assembly plant. He ekes out a living with some governmental subsidy. His meager earnings are consumed by costs of special equipment and supplies for personal care and cost of a care-provider and other usual medically-related and every day living costs. He needs communication and environmental control equipment and a van equipped with a lift. A fund raiser may work.

DISCUSSION

Client A

The fund drive worked very well for this popular and deserving man.

Client B

Delays in the rehabilitative process were costly and painful.

Client C

No one was interested in organizing a fund drive because the client was not popular. Even if compassion is totally disregarded, society would have saved considerable money by purchasing a communication aid when it was needed.

Clients D & E

Deaf, retarded and cerebral palsied people are poor subjects for fund drives.

CONCLUSION

Acquisition of resources via community fund drives for individual disabled persons is seldom productive. True cost accounting, including loss of time of professional people, media expense, transportation etc, and delays in the rehabilitation process will prove this approach is not cost-effective.

The ugly, ignorant, and socially unimportant are inherently discriminated against by voluntary programs. Theft would probably be a more productive alternative.

Society must be made to understand that rehabilitation will be better, quicker and less expensive when adequate funds are budgeted and made available when rehabilitation professionals, not administrators, say they are needed.

CUSTOMIZED SOFTWARE APPROACH TO REHABILITATION ENGINEERING

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INTRODUCTION

Many researchers including the authors have recently devoted their research efforts to developing customized software for off-the-shelf microcomputers. Software may be loosely defined as the programs that tell the computer how to behave in a given application. The properly used microcomputer can solve some problems of cost, availability, and serviceability in rehabilitation engineering.

Three computer programs developed at Indiana University-Purdue University at Fort Wayne (IPFW) enable a microcomputer to serve as the hardware in rehabilitation applications.

THE HARDWARE SYSTEM

The three rehabilitation devices developed and currently in use at IPFW share the same hardware: The Apple II microcomputer with one disk drive, selected primarily because of widespread availability, popularity, low cost, and adaptability to plug-in modules.

One such module, the ECHO II voice synthesizer (Street Electronics), allows computers to imitate human speech. The ECHO II is designed to speak a limited number of whole English words. Since the limit was unsatisfactory for the intended applications, software was developed to translate English words into phonemes. Storing phonemes rather than words makes possible the ECHO II's synthesis of all English words, since the number of distinct phonemes in English is less than the number of words the ECHO II can reproduce.

The voice synthesizer determines which phonemes to pronounce by analyzing spellings. The analysis is simplified by an algorithm, a formula which tells the synthesizer whether, for example, a C is pronounced as a K or an S. Any algorithm dictates imprecision. For instance, English contains heteronyms such as "tear," words spelled the same way but pronounced differently. People know how to pronounce such words from context, but the algorithm is not as clever.

The algorithm used produces comprehensible speech approximately 95% of the time, and most users judge the synthesized voice quality satisfactory. The low cost of the device (about $200) makes the ECHO II an excellent compromise.

THE SOFTWARE PACKAGES

Three programs have been developed at IPFW for use with the above hardware system.

The Talking Typewriter

Developing the talking typewriter for the blind and visually impaired involved writing programs that make the microcomputer behave like an ordinary electronic typewriter with a TV-like display, except that users can listen to a line of text before sending it to the printer. Keyboard commands make the computer speak a line; perform a word-by-word search; speak, spell, or delete a word; and insert text. Printing or diskette storage begins when the carriage return is pressed.

Visually impaired users who touch-type can use the talking typewriter for letters, articles, or books. Users can also learn touch-typing without having a sighted reader constantly on hand, if the software is revised to permit echoing each character as it is typed in a spell mode: Lines of text made up only of "fjfjfjfj" would be more than a little difficult to pronounce as words.

The Talking Computer

The talking computer enables blind and visually impaired students to study various technical curricula without having sighted readers. Experience shows that blind students tend to become too dependent upon their readers and that readers will not be furnished in the workplace.

The talking computer extends the talking typewriter described above by audibly echoing not only characters typed by the user, but also those characters generated by the computer itself.

The first steps in developing the necessary software were to modify the disk operating system (DOS) and to develop a patch. For the Apple II, these tasks proved straightforward, since Apple DOS routinely intercepts all input and output (I/O) before sending it on. A software modification intercepted the DOS interceptors, so that each character typed on the keyboard or generated for display was duplicated in a separate text buffer. Speaking is activated by entering a blank character (space) or carriage return. Since the patch uses a text buffer separate from the normal video portion of the microcomputer, the talking computer retains its normal video output.

The Talking Communicator

Applying the hardware of the talking typewriter to the talking communicator for the severely physically handicapped required substituting a puff-sip switch (Prentke-Romich) for the keyboard character selectors. The monitor of the talking communicator displays one character at a time as stepped by the user puffing on the tube. Each character is about one-fourth the TV screen. A menu in another quadrant enables users to step characters forward or backward, place a character in the message part of the screen in smaller type, delete a character, and insert a space. The menu also allows users to have the computer speak, print, store, or delete a message, and to call up messages stored on disk. This last feature provides access to a large library of routine messages which need not be spelled out one letter at a time.

Different software would permit automatic scanning of the characters or other scanning methods. The talking feature of this communicator, although perhaps inessential, provides significant reinforcement even to vocal users.

INTERFACING COMPUTERS FOR THE DISABLED

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COMPUTERS AND THE DISABLED

Computers are playing an increasingly important role in our daily lives. The lowering of costs and reduction in size have made computers readily available for use in the work-place, home, office and even in liesure time activities. In fact, skills in computer related tasks are providing a gateway to opportunities in a computer oriented but cronically short supplied job market. Unfortunetely, this demand has bypassed the disabled person. Rectifying this means providing the disabled with a convenient and compatable interfacing devise which can be optimally utilized to circumvent their physical restrictions. It is in this area that human factors engineers have provided a solution.

HUMAN FACTORS APPROACH

Many past attempts to utilize a human factors approach in opening up jobs for the disabled were only partially successful. Often, even with economic incentives and subsidies, the direct cost of adaptation, and indirect loss of production have seriously hindered progress. In addition, by being costly, difficult to implement and usually inflexible, such endeavors solved a problem for an extremely small number of persons.

ALTERNATIVE SOLUTION

Given this background, an extensive R&D program was conducted to design and produce an instrument which would be convenient, mobile and flexible for rapid communications with a computer. The result was a unique keyboard interfacing unit. A pilot project involving a number of severely disabled persons confirmed its ability to meet all these requirements. Not only did it prove suitable for persons with disabilities, but the simple "plug-in" procedure into exisiting computer related facilities meant that adoption by employers would be of little inconvenience and at a modest extra cost.

KEYBOARD INTERFACING

The keyboard, invented and internationally patented by a team of Israeli scientists, provides a means of circumventing the problems that a standard keyboard presents to the disabled. It is designed to be easily operable by persons with a wide range of physical restrictions including visual impairment and motor disabilities. The physical design is highly flexible allowing a match with the specific physical abilities of each person. And, it allows rapid communications through a simplified and easily learnable instruction code.

The keyboard is a small, inexpensive key operated chordic devise having between 3-8 keys. It provides a full set of symbols (128 or 64 ASCII) with learning time for the entire symbol set taking between 10-20 minutes. Laboratory and field tests on free text employing a variety of sample populations indicate that any person, even with below average intelligence, can master the complete code within an hour. Proficiency of up to 200 characters per minute are attained within 35 hours of use.

TRAINING PROGRAM

It is our contention that many persons with disabilities, given an appropriate keyboard interfacing unit, have the capacity to successfully interact with a computer. This could mean an expanding number of job opportunities (which were previously not available to them). However, the keyboard only bridges the physical gap created by the disability. Only in combination with a specially designed training program can the ability to utilize computer communications be effective.

Such a program is now in its initial stages of development in Israel. Its aim is to graduate trainees with appropriate knowledge and skill to make them competitive in the job market. In addition, it should increase their independence and improve the quality of their lives. Unlike other programs based on a closed work-shop or 'make-work' schemes, the objective of the program is skill attainment. Involved is a R & D unit and technical workshop designed to utilize the results to improve both the keyboard and the training schedule.

Initial results of a pilot project were extremely encouraging. The staged expansion of the program combines the 'input' of rehabilitation professionals, including educators and human factors engineers. A 'skill attainment' schedule in the form of a training manual has evolved. Evaluation and monitoring procedures, including a follow-up of the graduates, allows rapid changes in the training process to meet the realities of the market place.

Overall, the combination of a keyboard interfacing unit allowing the disabled to communicate rapidly and a skill attainment program geared to job market needs should bring about a rapid reevaluation of the disabled in our society.

We would like to express our gratitude to the Rehabilitation Departments' of the National Insurance Institute and Ministry of Defence as well as the Chief Scientist of the Ministry of Commerce and Industry of Israel. Send inquiries to Box 83, Tivon 36100, ISRAEL

COMPUTER COMMUNICATION, ACESS AND PROGRAMMING BY SEVERELY HANDICAPPED CHILDREN

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Computer Communication, Access, and Programming by Severely Handicapped Children is a beacon project conducted at the Yooralla Special School, Glenroy, Melbourne, Australia, with the support of the Australian School's Commission. This project is concerned immediately with the educational communication needs of a group of nine non-vocal cerebal palsy students aged 7 to 16. One of these children can only operate a single key, while the most mechanically capable can effectively use a five key interface.

The project is concerned to provide personal computing facility adapted to the physical handicap of the user which better equip the user to participate in education. Firstly, it has aimed to provide a Conversation program in which the non-vocal communicator can prepare statements for sending but which can be readily guessed by the receiver before completion. In such conversation the sender requires the 100% attention of the receiver. Secondly, it aims to provide written and spoken communication, with statements prepared in advance being readily voiced by a few keystrokes. Thus in an ordinary class room situation the non-vocal sender can prepare answers to questions etc and then voice these at the appropriate instant. The system incorporates a text to speech phoneme translator so that all words in a prepared statement will be spoken rather than spelt out. Thirdly, the project is concerned to provide programming experiences for these children, particularly those involving the development of geometrical and spatial capabilities.

During 1981 a prototype system, based on a commercial microcomputer was developed. This prototype offered the user capable of using five keys a means of building up statements by "zapping" words and letters from menus. Subsequently the method of scanning menus was drastically revised to improve selection rate while remaining simple to learn to use. During 1982 a single board computer version is being developed which is portable, using a 5 inch TV for video output, and can be run off a chair battery. In order for the word menus offered to be readily altered to meet the needs of the individual much of the program menus and prepared statements is stored in CMOS RAMS, rather than in non-volatile but unalterable ROM. In the portable unit the CMOS memory is battery backed, so that at all times the unit is in stand-by mode holding program, menus, and prepared statements.

Associated with the above project is the OZNAKI educational project. This project is concerned with a family of robotics languages which were conceived to promote the learning of mathematical ideas. Of particular interest is OZ, a simple language for programming an Australian version of the LOGO "Turtle" robot, and WHAM, a simple TV graphics language offering coarse grained but rather effective picture drawing and movie-making capabilities. During early 1982 versions of OZ and WHAM were implemented for both cassette based TRS-80 and disc based Apple II microcomputers. By July 1982 one-key versions of OZ and WHAM for the two school microcomputers mentioned will be available for use by handicapped children. In these one-key versions the immediacy of control is only marginally slower than that offered by use of a full (ASCII) keyboard.

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VOCATIONAL REHABILITATION OF HIGH LEVEL QUADRIPLEGICS BY MEANS OF THE APPLE II COMPUTER

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INTRODUCTION

In British Columbia, Canada, with a population of 2.5 million, there are an estimated 500 quadriplegics with normal intelligence. Many of the high level quadriplegics are either in government financed institutions or receive government support because they are unemployed. Little attempt has been made to vocationally rehabilitate these persons in the past, and they were mainly considered unemployable.

The advent of the microcomputer has changed the picture. It is possible for a quadriplegic or any other severely disabled person to utilize the microcomputer as a work tool for a variety of purposes. Knowledge of programing is not necessary as there are a multitude of fully documented commercially available programs for everything from word processing and accounting to horse racing and stock market analysis. A high level quadriplegic actually has a reasonable selection of vocations from which to choose a career.

For those whose aptitude or intelligence is not high, a variety of programs exist which require little or no operating ability. These programs prompt the user at every step and check for errors at entry. An example is Apple Post, a mailing address and label mailing program, which is extremely easy to use and which can be used to set up mailing lists and label runs for small businesses. Data entry for a variety of uses could easily be arranged to be in a similar prompting format.

CASE HISTORIES

With the financial support of the Community Vocational Rehabilitation Service, part of the Ministry of Health, three high level quadriplegics have been vocationally rehabilitated in the past year and are now utilizing Apple II computers in their jobs.

No. 1 is a 33 year old accident C3 quadriplegic with no arm movement. He was formerly a financial analyst but with no previous experience with computers. He is now employed back at his old job, using Visicalc with an Apple computer by means of a headstick.

No. 2 is a 21 year old C1 accident quadriplegic permanently on a respirator. He successfully attended the Air Canada travel agents course and is able to operate a RESERVAC computer terminal with a mouthstick. He is presently using an Apple computer in a business application.

These first two persons are using a special remote keyboard developed in Rehab. engineering at the School of Rehabilitation Medicine at the University of British Columbia. This keyboard mounts in any position and has latching switches installed on SHIFT, CONTROL and REPEAT. It can be operated simply by means of a mouthstick, headstick or single stylus. The latching switches are necessary, of course, as only one switch closure movement is available to these persons. Both of these persons have an attendant who can change diskettes, ready the printer and do other tasks which cannot be done by the disabled person.

No. 3 is a 25 year old accident C4/5 quadriplegic with arm but no hand movement. He has not completed high school but has attended a vocational college where he took an introductory course in BASIC programming. His computer system had to be installed in such a way that he could reach the controls of the printer and the computer keyboard with his mouthstick. He soon devised a way of changing diskettes using his mouthstick and his teeth. He was until recently employed as office manager for an industral operation. He utilized an Apple II computer, for business accounting, payroll, inventory and quotations. He was fully employed and receiving a full salary. He is presently in the process of moving to a new job.

DISCUSSION

The cost of keeping a high level quadriplegic in an institution in British Columbia is Can$91,000 per year at present costs. For Can$6,000 for an Apple II computer system and printer plus approximately the same for modification of the work place, he can become a financially independent, taxpaying member of society.

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MECHANICAL FLOPPY DISK LOADER FOR COMPUTER DISK DRIVES

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INTRODUCTION

Everyone who has worked with computers utilizing floppy disks as storage devices should be able to visualize the problems encountered by people with physical handicaps involving their arms and hands when it comes to loading or unloading these disks. A person with cerebral palsy may have difficulty in lining up the disk with the narrow slot into which it needs to be inserted. (These disks are sensitive to excessive abuse and we have lost more than one as our users with cerebral palsy attempted to change disks.) Persons with a spinal cord injury at the C5 level or above are unable to change disks due to limited hand function.

We were acutely aware of this problem and it was only when the Control Data Corporation offered to support a project investigating the handling of disks by disabled users on their new Plato terminals that we were able to pursue a solution. The mechanical loader presented has been developed for their system but is able to operate on many stand-alone disk drive units.

OBJECTIVES

We set out with the objective of retrieving a single disk from a selection of disks previously placed in a storage rack. The assumption was made that, say at the beginning of the day, these user-selected disks would be placed in the rack by an able-bodied assistant. The mechanical loader would then have to accomplish the following:

1) retrieve the disk from the rack

2) insert the disk in the disk drive

3) close the door to complete the insertion process

4) open the door to retrieve the disk

5) return the disk to the rack.

In addition, we did not want to alter the disk drive mechanism in any way or interfere with normal operation of the drive by other users when the loader was positioned for use.

MECHANICAL LOADER

The mechanical loader is fairly simple in construction, consisting of a carrier to support the disk, a mechanism to grasp the disk for retrieval or insertion, and a mechanism to move the carrier from the storage rack to the drive itself.

It needs to be pointed out that these disks store information magnetically and for that reason are sensitive to magnetic fields or excessive pressure which may physically damage the disk or destroy information contained on the disk. For that reason, components of the loader generating magnetic fields are located at a safe distance from the disk carrier itself. And the gripper retrieving the disks exerts minimum pressure and grips the disk on the extreme edge of the casing only.

The components of the mechanical loader are a motor driving the carrier vertically, a motor driving the gripper for retrieving or inserting the disks, a solenoid activating the opening of the gripper, and infrared LED's/phototransistors used as controls to position the carrier at each station.

With an experienced user, the mechanical loader is able to change disks in the drive in 60-90 seconds. The device is currently being used by a Control Data Corporation employee who has a spinal cord injury at the C4-5 level and is a full-time programmer on the Plato system.

CONCLUSIONS

We have developed a mechanical loader (prototype) for floppy disks which operationally is able to be used on many stand-alone disk drive units. Although this is only a prototype, if manufacture of the item is ruled out, construction of the device is such that a person with access to a basically well-equipped mechanical shop could assemble one for individual use.

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DIGITAL ELECTRONIC INTERFACE - A NEW DESIGN IN LOW COST CONTROL

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The introduction of the Hewlett Packard bit series loop interface provides a new means of low cost digital control. The authors have taken advantage of this advance in digital electronics to develop a design for a digital electronic control system for powered wheelchairs.

The Georgia Institute of Technology with funding provided by the Veterans Administration has begun a program to develop an advanced control system for an improved power chassis that may well compose the base of tomorrow's powered wheelchair. The system began as a microprocessor based digital electronic control system driving a power amplifier of the SCR type. Efficiency of the power amplifier is high and the only control necessary is exerted through the timing pulses to the power amplifier. Inputs from the joystick are immediately encoded into a digital format through a simple analog to digital conversion scheme using an RC circuit with associated timer and counter. Optical encoders on each motor shaft provide a digital output also indexing counters which are "read" by the processor(1). The innovation came with the advent of the HP-IL interface.

The HP bit series interface loop allows the use of an HP-41CV as the heart of the system replacing the microprocessor. This versatile interface has sufficient speed to handle the 5000 bits per second that is the maximum operating rate of the HP-41CV. The calculator is programmable to 2000 program steps thus allowing ready manipulation of the readings from the joystick and the encoders to the control timed outputs to the power amplifier.

The interface is exciting and unique in that it allows communication with equipment that will for the first time provide the capability of having the controls based on hardware that is nationally distributed and serviced, provides for future modification and addition of accessories, and reduces the system design to a modular basis that can be self-diagnostic and user serviced.

Some of the additions expected later this year include a RS-232C serial interface to allow communication with printers and modem equipment. This provides for telephone diagnosis and interface for control of any additional communication aids or environmental control that may be necessary.

It should be noted that the HP-41CV provides for customized control with individual parameters as to integration schemes, acceleration curves, top speed, multiple operating ranges, alternate input devices such as puff and sip, chin switch, etc., and various warnings such as low battery, vehicle in reverse, and control defect or failure. The latter may be done by the ability of the HP-41CV to generate eight musical tones.

Perhaps the greatest benefit is the very fact that this control scheme can be obtained at a lower cost than any existing control system that is even slightly comparable which is now on the market.

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DESIGN OF UNIVERSAL KEYBOARD EMULATORS

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Individual modification of software systems to fit the needs of handicapped individuals is both makeshift and expensive, and is therefore of limited value. In addition, the technology of computer/information systems is growing at a tremendous rate, and software programs are therefore continually changing and evolving. Handicapped individuals cannot keep up if they must rely on only those systems and software versions which have been adapted for their use. Techniques must therefore be developed which allow a handicapped individual using a nonstandard input device to use standard software. Since most software is designed to use input from the keyboard, a device which precisely emulates the keyboard will be transparent to all software. To this end, the Trace Center is designing keyboard emulator(s) that will work with a variety of personal computers (and terminals*).

The major goals in our design are:

1) that the keyboard emulator mimic the actual keyboard so well that it is invisible to the system

2) that the keyboard emulator allow the actual keyboard to be used normally with the keyboard emulator installed

3) that the keyboard emulator accept input via standard serial data

4) that the keyboard emulator work with as many of the most popular personal computers as possible

5) that the keyboard emulator be affordable.

In order for the keyboard emulator to be invisible to the computer, it must exactly duplicate all of the normal responses of the keyboard, including any control line signals. To make the keyboard emulator as universal as possible, we have analyzed the keyboards of several computers, including the Atari 400 and 800, VIC, Pet, CPM, Apple II and III, Xerox, TRS-80 II, III, and Color, and the IBM Personal Computer. We found three main types of keyboards:

1) keyboards that output serial ASCII coded data

2) keyboards that output parallel ASCII coded data

3) keyboards that use the central processor to read the keyboard matrix directly.

The most demanding type of keyboard to emulate is the third type. The TRS-80 Model I is an example of a keyboard matrix type machine, where the CPU treats the keyboard as memory and directly reads the keys as bits. On the TRS-80, the keys are switches arrayed in an 8x8 matrix so that each key potentially connects one column to one row. In order to determine which key has been pressed, the computer addresses one row at a time, and examines the eight columns as an eight-bit byte of memory.

The reason that this type of keyboard is difficult to emulate is that the polling of rows is done very quickly (in the time of a single normal memory fetch). This leaves very little time for the keyboard emulator to put its simulated column signal on the bus when it determines that the CPU is polling the proper row. As a result, it is difficult to use a microprocessor-based keyboard emulator, since the microprocessor in the emulator cannot respond directly to the row polling strobes quickly enough. Therefore, it becomes necessary to use a more complicated strategy that can respond very quickly to the row polling strobes.

Two approaches can be used to handle this rapid access. The first is to load a block of RAM with the bit pattern corresponding to a single depressed key. The CPU would then read this block of RAM in the same fashion as it reads the keyboard. This approach requires bus separator circuitry in addition to the RAM block and the microprocessor.

The second approach uses a gate array or crosspoint switch array which is controlled by the microprocessor. To simulate a key closure, the gate array is enabled in such a way that a direct logical path is created beteeen the desired row and column.

In use, the keyboard emulator is plugs into the personal computer between the keyboard and the main CPU board. The handicapped person who desires to use the computer simply plugs his/her intelligent communication aid into the emulator. He/she then has control of the computer through the communication aid and is free to use the computer to run any standard software programs, and, because of the design of the emulator, the normal keyboard also continues to function in the normal manner.

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* The keyboard emulator will work with some terminals, but a simple solution is to use a "data stream routing module" that connects the communication aid to the line between the terminal and the computer. This device is also being developed at the Trace Center.

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DUAL AND NESTED COMPUTER APPROACH TO VOCATIONAL AND EDUCATIONAL COMPUTER SYSTEMS

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Computers are making rapid inroads into both the educational and work environments. As they do, they are beginning to reduce the amount of paper and physical manipulation required in favor of information manipulation. For physically handicapped individuals, this can represent a significant decrease in the impact of their handicap. Activities that would formerly require extensive physical manipulation of documents and writing instruments can all be carried out electronically.

In order to take advantage of this capability, however, the handicapped individual must be provided with a mechanism which will allow him/her to issue commands at a meaningful and productive rate. Many physically handicapped individuals are unable to effectively use a keyboard. Other individuals can use the keyboard, but their rate of input is four to ten times slower than even a slow normal typist. As a result, they would only be able to complete a day's work every ten days, or a night's homework every week or two. For these individuals, some type of alternate input modes and acceleration techniques are required if they are to be able to meaningfully access and use the microcomputers as aids to their education or employment.

Two Approaches to Computer Access: The traditional approach to providing access to computers has been to develop special software to either provide an alternate input other than the keyboard or to provide acceleration routines such as abbreviation expansion to increase the person's effective input rate. Since these routines will rarely coexist with standard, unmodified software, desired function routines (e.g., text editors, accounting packages, etc.) had to be custom written or specially adapted to work with the input routines. Although this approach works for very simple applications or demonstrations, it is generally not functional in real-life applications.

In many cases, the best packages are sealed in such a way that they cannot be entered, and source code is not available. In addition, new and better software packages are continually becoming available. To limit handicapped individuals to only those few (and older) programs which have been adapted would be a serious handicap in itself.

A Dual Nested Computer Approach: In order to overcome this problem, Trace Center has adopted a dual nested computer approach in the design of its vocational microcomputer systems. Although this was not the approach originally taken by the Center, it soon proved to be not only the most flexible, but also the least expensive approach to developing custom microcomputer systems.

With the dual nested approach, one computer is used to handle special interface and communication acceleration programs. The output of this computer is then fed into a second microcomputer through a keyboard emulator (or into a large computer through its normal terminal ports). Because the second computer is completely unburdened of any special input or acceleration adaptations, it is able to run at full speed, and use standard unmodified software. Because the first computer does not have to support the function software, the full resources of the computer are available to the handicapped individual to implement his special input and acceleration routines. As a result, large vocabularies and sophisticated assistance programs can be utilized. This freedom and access to the entire computer allows rehabilitation personnel to utilize more modular software and higher level languages. The result is a much lower cost to configure the system for the individual, and much higher performance.

Non-Matched Computers: Because the two computers are completely independent, it is also unnecessary to have both computers be the same model, make, size, or configuration. The second computer can be of whatever size and configuration is necessary to run the type of applications that the individual needs. By using a universal keyboard emulator, the computers presently on-site in the school or on the job site can be used running the same software programs used by the other students or employees. In this fashion, the handicapped individual's computer (the first computer) could be simply regarded as a "super keyboard".

Moreover, since the first computer will not be running standard software, it does not have to be either a standard computer or computer configuration. In many cases, a lower cost system can be used for this computer. In one application, an Atari 400 ($359) computer is being configured as the first computer, and interfaced to a $2,500 Apple II computer system which runs the individual's application programs. In this case, the first computer is less expensive than many of the plug-in modules for the second computer, and less expensive even than some of the software programs run on the second computer.

Conclusions: Where special software is required in order to enable an individual to access a computer system, it is often less expensive and more functional to actually use two microcomputers than to try to implement all of the functions within a single computer. This is especially true where standard software systems or existing software packages are used, as would be true in educational and vocational applications. In many cases, the second computer can be the computer or computers already on-site and being used by the non-handicapped persons, enabling the handicapped individual to parallel the educational or employment activities of his colleagues without requiring modification of the standard software systems.

Funding: Nat'l Institute for Handicapped Research

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AN ELBOW EXTENSION ORTHOSIS

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An orthosis has been developed to maintain the range of elbow extension achieved following a serial plaster casting program. The orthosis was designed and developed by Northwestern University Rehabilitation Engineering Program and the Occupational Therapy Department of the Rehabilitation Institute of Chicago. It serves as a maintenance orthosis to preserve the gains made by the plaster casting technique. A program of serial plaster casting was applied to six individuals with flexion contractures of the elbow, secondary to head injury, and one person with a C_5 spinal cord lesion. All had serious impairment of function in the upper limbs. Loss of elbow extension would severely limit capabilities to perform functional activities of daily living. A program of serial plaster casting was applied to these individuals to reduce the contractures, thus facilitating maximal functional use of the upper extremities.

When a conventional program of serial plaster casting is initiated, the plaster cast is changed at least weekly and the degree of increase in passive range of motion noted. Initial gains in passive range of motion were realized from the serial plaster casting program, however, after a time, range of motion plateaued. Instead of continued application of plaster casts, the elbow extension orthosis was applied to serve as a maintenance orthosis preserving the gains made by casting.

The major advantages of this elbow extension orthosis include the following: 1) the elbow extension orthosis could be specifically fitted to each client's involved limb; fabrication and fitting could be conducted by the occupational therapist or orthotist within the clinic setting, 2) passive range of motion could be maintained following serial plaster casting, 3) the orthosis was lightweight when compared with a plaster cast, 4) adjustments could easily be made to accommodate arm volume and degree of elbow extension, 5) the plastizote liner provided sufficient pressure relief to prevent skin breakdown, and 6) The orthosis could be donned and doffed easily to facilitate participation in a program of active/passive exercise. As with all orthoses, wearing tolerance must be monitored to prevent high localized pressure areas.

Disadvantages include difficulty fitting the orthosis when the arm is contracted eighty degrees or more, and also sliding the liner over a severely contracted hand or wrist. Some users reported their arm felt noticably warm when wearing the orthosis.

The elbow extension orthosis was designed to be fabricated by the occupational therapist or orthotist, using materials commonly found in most clinics. The elbow extension orthosis consists of two parts: a polyethylene foam liner (plastizote) and an assembly consisting of humeral and forearm orthoplast cuffs connected by an aluminum bar (2024-T4 alloy). A photograph of the orthosis is shown in Figure 1.

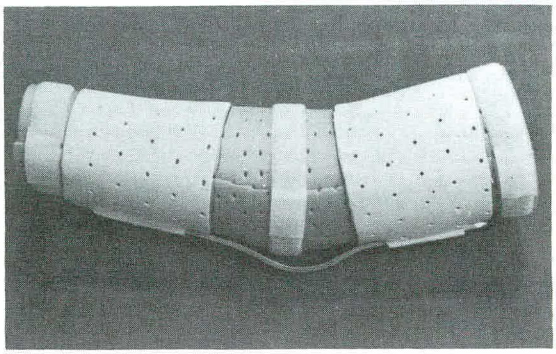

FIG. 1 - THE ELBOW EXTENSION ORTHOSIS

The foam liner is fitted directly on the client's prepared extremity. This technique involves covering the arm with three layers of cotton stockinette and then sliding a premeasured, preformed, heated plastizote tube over the arm. Once the foam is cooled, with the arm set in the required amount of extension, the liner is removed using bandage scissors by cutting along the medial-longitudinal axis. Three velcro closures are added to hold the liner in place. Low temperature orthoplast forearm and humeral cuffs are formed over the foam liner; velcro closures secure the cuffs. The aluminum bar is contoured to follow the dorsum of the liner and incorporates a relief over the olecranon. The bar slips into slots prepunched in the cuffs and is riveted in place.

The completed orthosis includes: 1) cotton stockinette (the user is given an extra stockinette so that one may be laundered while the other is worn), 2) plastizote liner with three velcro closures, 3) orthoplast cuffs with velcro closures and dorsal bar.

SUMMARY

This orthosis was designed to supplement serial plaster casting in a program for the management of elbow flexion contractures.

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TORSO ROTATOR

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INTRODUCTION

A torso rotator has been designed and built for the Remedial Gym Department at the G.F. Strong Rehabilitation Centre in Vancouver, B.C. The concept of the trunk rotator resulted from the problem of exercising the trunk rotation muscles of quadriplegics. The patient is in a safe position where the effects of gravity have been eliminated and the trunk can be rotated through a predetermined arc length against resistance or with assistance.

THERAPEUTIC OBJECTIVES

Quadriplegics

Quadriplegics who used the device showed an improvement in their physical ability which resulted in: better sitting; balance; improved "wheeling" ability; and improved roll-over ability in bed.

Head Injuries

The rotator allows a good range of rotation at the trunk and fixes the pelvis allowing a good stretch of the contracted soft tissues. Rotation is also thought to be instrumental in the breakup of spastic patterns and through the use of biofeedback, reinforces the feel and concept of cross facilitation.

Other Disabilities

It was observed that the rotational effort provided; a good thigh exercise and strengthened both adductor and abductor muscles on persons with a weak hip girdle, and an assist for breaking up spastic patterns in trunks, hips and arms.

DESCRIPTION

The device consists of two parts; the tail-piece which is stable and a head-piece which rotates about a horizontal axis. The tail-piece is a padded four legged table with a cut out for the knee adjustment mechanism that adjusts for various leg lengths and degrees of flexion. (The mechanism on the prototype if adapted from a hospital bed adjuster.) The pelvis and flexed legs are secured to the tail-piece by webbing straps that minimize skin trauma but still provide a firm hold to prevent rotation of the pelvis. The head-piece is attached to the tail-piece through a pivot joint, which permits rotation in the horizontal plane and maintains full body alignment. The head-piece consists of a tapered back portion, shoulder support, head support and arm extensions. The head-piece is supported by an end support that contains a bearing, a pulley for the weights, the mechanism to control angular rotation and the potentiometer for monitoring angular rotation.

The taper of the head-piece accommodates the actual motion that the spine moves through during rotation. The arm extensions permit different sizes of patients to use the rotator. The weight pulley has attachments to insure that the weights hang vertically. The mechanism that controls angular rotation is two semi-circular metal plates with holes cut at five degree intervals around the circumference of the plate. Another piece rotates between the two plates. A pin through the central part of the plates and the rotating piece insures that there is no rotation during transfer. A potentiometer has been included in the device for monitoring and evaluation of the device. The complete device is approximately seven feet long and five feet wide at the widest point. The frame of the torso rotator is made of structual steel, covered in foam and upholstered in naugahyde.

OPERATION DESCRIPTION

The torso rotator is used by the patient under the supervision of the Remedial Gymnast. The rotation stop is secured and the knee adjuster is put flush with the surface of the tail-piece. The wheelchair patient is transferred from the wheelchair to the tail-piece by first lifting the legs and then the hips onto the tail-piece. The feet, knees (the knee adjuster is adjusted) and hips are positioned in place and secured down with the webbing straps. The patient lies down on the head-piece where the arms may or may not be secured in place. The rotating stops and weights are applied as required and the centre stop is removed so that rotation may begin. The therapy session is monitored by a small electronic counter that counts the number of correct, erroneous and total rotations. At the end of therapy, the supervisor applies the rotation stop to stabilize the rotator. The webbing is removed and the knee adjuster is repositioned flush on the surface of the tail-piece. The patient is returned to the sitting position, then transferred off the apparatus to the wheelchair.

CONCLUSION

The torso rotator is used regularly for treatment of quadriplegic and head injured patients. The torso rotator device will also be evaluated to determine the necessary design modifications.

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A NOVEL ORTHOTIC DEVICE FOR HEAD-NECK TREMORS IN A PATIENT WITH CEREBELLAR DYSFUNCTION

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INTRODUCTION

This paper reports a new orthotic management approach to stabilize the head-neck tremors in a patient with cerebellar dysfunction due to multiple sclerosis. The symptoms of the cerebellar dysfunction were manifested by intention tremors in all rotational degrees of freedom of the head and both upper extremities with the involvement greatest proximally. This lack of functional control made the patient completely dependent upon another person for his activities of daily living (ADL). An initial examination revealed that passive stabilization of the head-neck tremors resulted in diminished tremors of the upper extremities. This led us to aim our intervention at stabilizing the patient's head-neck tremors utilizing a cervical spine orthosis.

A NOVEL APPROACH

The problem was approached as one of forced vibrations of the head-neck structure. A preliminary analysis of this problem using available data on the stiffness properties of the cervical spine revealed that the natural frequency of the head-neck structure in all rotational degrees of freedom (flexion-extension, lateral bending, and axial rotation) was on the order of 20 radians/sec (3 cycles/sec). The frequency of the patient's tremors was measured by video taping the patient and later visually analyzing the tape. Frequencies of the same order of magnitude were found. The objective of this project was to substantially reduce these tremors without severely restricting his head-neck mobility. It was hypothesized that rigid stabilization (fixation) of the head would be too restrictive from a patient mobility point of view and likely cause skin irritation at the orthotic pressure points. Thus, the basic concept chosen was to attenuate the tremors with viscous damping. Viscous damping was selected over coulomb damping because of its inherent velocity dependence, i.e., it allows slower velocity movements for basic mobility but impeds higher velocity, oscillations (uncontrolled tremors).

DESCRIPTION OF THE ORTHOSIS

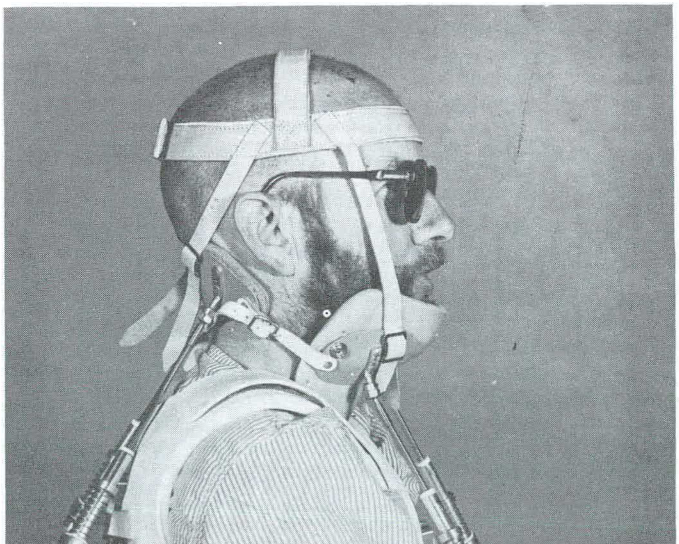
An existing four poster cervical orthosis was modified to suit the functional requirements and conceptual design described above-i.e., to function as a non-rigid orthosis. Each of the four rigid posts were replaced by a damped mechanical module. The module consisted of a piston moving in an oil-filled cylinder in series with a compression spring as shown in figure. The viscous damping was achieved via flow of the oil through capillaries in the moving piston. Two such modules were attached between the chest and chin pads via ball and socket joints. An identical mechanical system consisting of two modules was also mounted between the occipital pad and the posterior trunk pad (see Fig.). The four ball and socket joints at the chin and occipital pads were primarily for the purpose of alignment of the pads. The remaining 4 ball and socket joints were positioned to allow the necessary rotational degrees of freedom. The motion at the ball and socket joints at the trunk pads was restricted by a torsional spring. The torsional spring supplied added stabilization in axial rotation of the head. The existing mounting (anterior and posterior trunk pads) of four-poster orthosis was replaced by a custom molded polypropylene jacket extending to the waist. The occipital and chin pads were fastened to the head using straps to prevent the separation of the head from the pads and to trans- the oscillatory motion of the head to the mechanical modules.

RESULTS

A prototype of the "first-generation" design was designed and fabricated at the RER&D Center,Hines VA Hospital. A pre and post-orthosis evaluation of the patient using a video tape revealed a significant reduction of the head-neck tremors. This resulted in diminished intention tremors of the upper extremities thus allowing fair control over hand to mouth activities and some independence in simple ADL. Future design modification involve optimizing the design parameters to achieve even better functional performance at the same time making the design more cosmetically acceptable by the patient. The patient is currently using the first design and will provide the necessary feedback for future modification.

ACKNOWLEDGEMENT

The assistance of the Orthotics Lab in fabrication of the device is greatly acknowledged.



A DAMPING SYSTEM FOR IMPROVEMENT OF LIMB FUNCTION

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INTRODUCTION

Relatively uncoordinated upper limb function is quite common in a number of disease states, such as cerebral palsy, stroke and spinal injuries. Preliminary studies have shown that the provision of support and damping (controlled restraint) improves hand function.[1,2] Pursuit tracking tasks have been found to be useful in assessing the recovery of arm control.[3] This presentation describes a system for providing damping and pursuit tracking for assessment in improving two dimensional motion.

SYSTEM DESCRIPTION

The damping system is controlled by an APPLE II Plus computer. Since both damping and pursuit tracking and assessment are handled separately and concurrently by the computer, each one will be described on its own.

DAMPER

A geared permanent magnet motor is used as a driving force for the damper. The position of the motor's shaft is detected by a precision potentiometer. Angular position and velocity are converted to digital data for use in calculating the amount of torque to be applied by the motor. Pulse width modulation is the method of motor excitation. The damper algorithm, used to control the motor, attempts to minimize the magnitude of acceleration of the motor's shaft. In order to provide two dimensional motion of the limb being damped, two motors are used. The configuration is illustrated in Figure 1.

PURSUIT TRACKING

In order to assess the performance of an individual using this dampered arm support, a computer program has been developed to generate a moving target symbol on the computer's display screen. The subject attempts to track the target's motion using a second symbol that moves in accordance with the position of the arm support. The paths of both the target and pursuit symbols are stored on the display screen.

Once the subject has attempted to trace a pursuit path, the resulting data may be analyzed in a number of ways to provide some quantitative measure of the effect of the damper. The analysis techniques include Torque versus Velocity curve generation, measurement of the amount of work performed by the damper and signal-to-noise measurement.

APPLICATION

Although the direction application of the system is in the area of improving performance of children afflicted with cerebral palsy, the system may also be a useful learning aid. Since it is possible to have the target symbol trace out any pattern at all, the subject may be made to trace specific letters or shapes. The proprioceptive feedback of the damper and the pursuit task provide interest in learning the alphabet or simple shapes.

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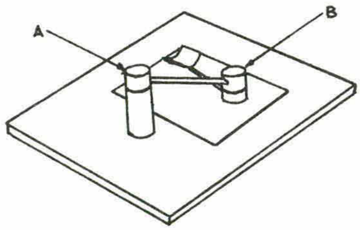

Fig. 1 Schematic diagram of the electrically damped arm support is illustrated here. Each joint, A and B,is comprised of a servo motor.

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EVALUATION OF THE RANCHO TRACKING TRAINER FOR THE TREATMENT OF THE HEMIPARETIC WRIST

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A new device proposed to be used in the treatment of hemiparetic patients was presented at the Fourth Annual Conference on Rehabilitation Engineering last year in Washington, D.C. That device is the Rancho Tracking Trainer, a microprocessor-based system which presents a visual target on an ordinary TV screen for a hemiparetic patient to track by controlling the reciprocating motion of a joint in the upper extremity. The Tracking Trainer is currently being evaluated in a formal study to determine its therapeutic benefit to the wrist on the Stroke Service of Rancho Los Amigos Hospital and results to this date are discussed below.

METHODS

Stroke patients from the patient population at Rancho are included in the study. Patients are evenly divided into control and study groups. In order to qualify for participation, patients must be able to demonstrate at least 15-20 degrees of selective wrist motion in extension and flexion and/or be able to obtain a 30% correct score on the Tracking Trainer with the easiest parameter settings. In addition, patients must have unilateral involvement with an onset of less than six months, and no serious wrist contractures.

All subjects are screened on a Thursday or Friday prior to starting the program. The screening process determines whether a patient can perform the tracking task adequately and it also determines parameter settings for the Tracking Trainer to be used in testing the progress of the patient. These parameters include target size and velocity, range of joint motion, and treatment time. On the following Monday, the subjects are tested using standard techniques for passive range, total active range and selective range of the affected wrist. Spasticity and proprioception are also assessed and a dot test is used to measure visual perception. In addition, a test intended to be independent of the Tracking Trainer in its ability to ascertain visual-motor function, called the cylinder turning test, designed explicitly for the wrist, is performed.

Following the preliminary evaluation above, study subjects train with the Tracking Trainer five days a week for three weeks in addition to receiving traditional therapy. Each subject first performs a test run using the parameters determined in the screening session and a known random tracking signal. Then the subject performs five more runs with a completely random tracking signal, and then again a test run using the screening parameters. These runs are all recorded on a separate form for each day. On the Friday of the third week a final evaluation is conducted covering all of the tests performed in the preliminary evaluation.

The control subjects receive traditional therapy five days per week for three weeks and are tested with the Tracking Trainer on the Monday of each week. The scores reported are ONTIME, the amount of time that the patient keeps his cursor within the bounds of the target, ERROR SCORE, an integral of the patient's deviation from ideal tracking performance, and CYLINDER TURNS, an independent test of a patients reciprocating motor ability as measured by counting the number of times a cylinder is turned in a 45 second period.

RESULTS

Thus far, data have been collected on four study and three control subjects and are summarized in Figure 1. There was an average improvement of 44% in ONTIME for the study patients and 6.5% for the control group and ERROR SCORE improved 37% for the study subjects and -4.2% for the controls. There was an average improvement in the CYLINDER TEST of 4.3 turns (in a 45 second period) for the study group as opposed to -0.08 turns for the controls.

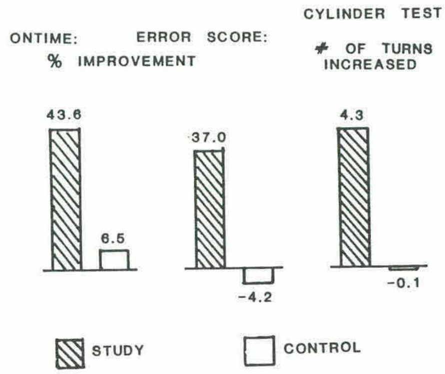

Figure 1. Improvement in tracking and functional ability for the study and control subjects.

Figure 2 shows typical progress in ONTIME for a study and a control subject. It can be seen that there is a trend towards the improvement in ONTIME for the study subject while the converse is true for the control subject.

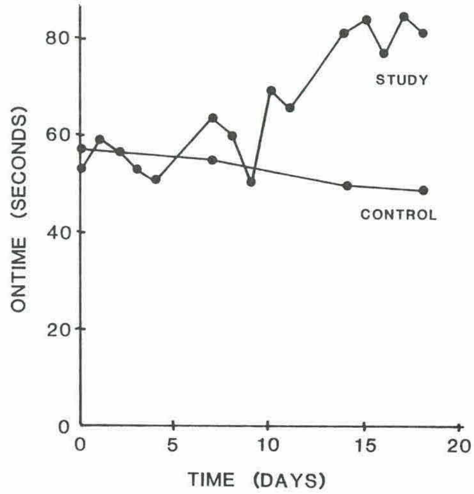

Figure 2. Comparison of ONTIME for a control and a study subject.

These results were typical for the four study and three control subjects evaluated, and although there are not sufficient data to draw any conclusions, the results thus far are encouraging.

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Introduction. A frequent method of treating cervical fractures or dislocations is by a halo-vest apparatus (1). The purpose is to immobilize spine and provide distraction. Comparing the halo-vest to various orthoses, the halo-vest was found to be far superior in restricting motion (2,3). However, where distraction forces and neck motions were measured in different activities, the forces oscillated and the spinal motions were considerable (4). In our study, we aimed to measure the forces and moments between the halo and the vest in different directions, and determine the cause of these forces.

Methods. The forces were at the connections between the upright bars and the halo are shown (fig. 1). Equations were written for the strains in vertical and horizontal bars. Four clip-on inductive strain transducers were attached, and their output fed to a mini-computer, programmed to compute the maximum forces and moments during that sequence. Continuous readings were obtained on a strip recorder. By making certain assumptions to solve the equations, Fx (horizontal), Fy (vertical) and Fz (sideways) were determined. The computer programs were adapted for different halo-vest-designs. Data was obtained from four normal volunteers (using rubber pads in place of pins), and from five different patients, as follows: Fx odontoid 8 weeks in halo-vest, C6-C7 4 weeks, C6-C7 6 weeks, FxC2 3 weeks, C6-C7 6 weeks.

Results. From the chart recordings, various features were notable. In bending to the floor from a standing or seated position, bending strains predominated in the upright bars. In getting on to a bed, the strain patterns were very erratic. Pushing up from a chair with the arms to relieve pressure produced sudden high strain peaks. Jogging on the spot, or lifting weights up and down gave oscillatory but smooth patterns.

The Fy force in normals ranged from 0.5 to 46 Newtons for one side, but a patient gave 43-93 for the same activities, the highest in lying from seated, or reaching with the arms across the chest. The Fz forces were only 0.9 - 23 per side, for all activities. The front-to-back forces, our main emphasis (fig. 2) averaged 25 per side for all activities, but many tests gave 2-3 times this. Bending to the floor, or lying from seated, produced forces consistent with the weight of the head. Reaching upwards, bending forwards, produced forces due to gravity and distortion of the vest. The latter was especially noticeable in reaching with the arms across the chest while lying. Jogging on the spot or jumping from a step produced comparatively low forces.

Conclusions

1. The front-to-back forces were comparable with the vertical, whereas side-to-side forces were much lower.
2. Forces were caused principally by gravity and by distortion of the vest.
3. The skull pin forces include shear in multiple directions, implying a crater-like loosening mechanism would occur.
4. The data is being applied to a new stabilization system to try to improve on the halo-vest.

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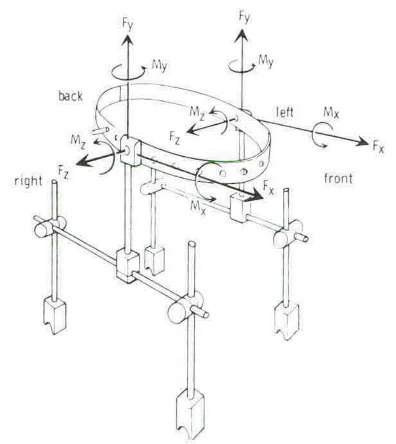

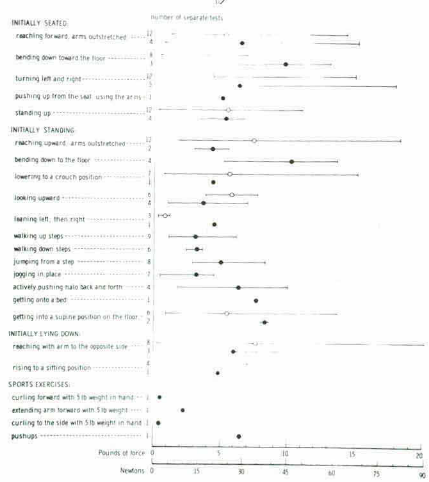

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ORTHOPAEDIC IMPLANT RETRIEVAL AND ANALYSIS: AN EVALUATION OF FAILED HARRINGTON RODS

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Six mechanically failed Harrington rods have been retrieved and examined. Diagnosis at insertion included scoliosis (two idiopathic, one post-paralytic, two congenital) and lumbar fracture (one). All rods were analyzed metallurgically for chemical composition, microstructure, hardness, and evidence of corrosion. Fracture surfaces were examined using optical and scanning electron microscopy.

Metallurgical examination showed that all implants conformed to ASTM standards for chemical composition, grain size and inclusion content. No evidence of fabrication flaws or corrosion was noted in all rods except one in which intergrannular corrosion was observed. Fracture surfaces demonstrated damage from in vivo motion prior to removal but still demonstrated fatigue as the mechanism of failure. Mechanical failures occurred at the ratchet-shaft junction except for one unusual case in which failure occurred in the mid-shaft at the site of a pseudoarthrosis. Pseudoarthorosis did not necessarily accompany failure, being evident in only three of six cases. Average time for implantation to failure exceeded 2 years.

These results indicate that manufacturing deficiency was not a primary factor in implant failure. Early failure is rarely reported and was not seen in this series. Rod failure occurs due to fatigue where the number of cycles at a relatively low stress exceeds the endurance limit of the material. Presence of excessive motion in the form of a pseudoarthrosis serves to increase the stress per cycle thus lowering the number of cycles to failure. The rod-ratchet junction presents an area of stress concentration predisposing to earlier failure at this site.

The success of the Harrington Rod system is unquestioned in the treatment of spinal deformity. However, in recent years increased usage and expanded indications have placed greater demands on the system. Based on the observed failures the following recommendations can be made. The first ratchet should be placed as close to the upper hook as possible to lessen the bending moment. Decreasing the number of ratchets and increasing the radius of curvature of the ratchet would serve to lower the stress concentration effect. Polishing in the area of the junction would further serve this goal. Finally, an alloy with a higher endurance limit might be used, although this must be balanced against the necessity for corrosion resistance and some degree of ductility to allow pre-bending when desirable.

Mechanical failure is not a devastating complication to be avoided at all costs. Aside from reoperation, which is often not necessary, patients rarely suffer serious consequences from this occurrence. In addition, failure often signifies some other deficiency in the system; often, but not always, failure of fusion. However, in more demanding applications such as adult deformities, particularly rigid or severe curves and heavy and/or active patients, application of recommendations based on biomechanical analysis may decrease the vulnerability of the implant. Implant retrieval allows for quality control and failure analysis. Application of the information learned can hopefully maintain the failure rate at the admirably low level inspite of increasing application.

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A NEW ANTERIOR-FIXATION DEVICE FOR BURST AND FRACTURE-DISLOCATION SPINAL INJURIES

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RATIONALE

In the case of dislocation injury and partial compression fracture of the vertebral body, the Harrington compression instrumentation (posteriorly attached to the lamina) is the rational method of choice for stabilising the injured spine. However, for the management of burst and fracture dislocation injury, the posterior mode of fixation of spinal injury (1) cannot increase the stiffness of the injured spine sufficiently, so as to minimise bending strains at the injured section of the spine to a level precluding posterior segments, and (2) cannot relieve pressure on the compressed cord from the anterior side, which is so essential to neurologic recovery and nerve tissue repair.

Therefore, a new device called the "Anterior Spinal Fixator" has been developed to enable (1) near-rigid fixation and immobilization of the injured spine in the cases of burst vertebral body and fracture-dislocation, and (2) anterior compression of the cord.

DESCRIPTION OF THE ANTERIOR SPINAL FIXATOR

The Anterior Spinal Stabilizing Fixator is a two-component device: (i) a compression bearing vertebral prop (Fig. 1) and (ii) a tension resisting staple. The former restores anatomical height and bears the compressive force induced by the anteriorly-acting torso weight vector, while the latter simulates the tensile-resisting role of the ligaments (Fig.1). A turnbuckle on the prop effects anatomical vertebral height restoration. The prop consists of a turnbuckle held between two plates (Fig. 2); the latter are made to rest on the intact end-plates of the proximal and distal vertebra; spikes are provided on each plate of the prop, to engage the vertebral plates and to get a good grip on the bone.

After reduction, the vertabrae adjacent to the fracture are stabilized by the vertebral staple.The bone fragments, ligaments and discs are removed. The cord is decompressed anteriorly, and the fractured body is replaced by the spinal stabilizing-fixator. After the spinal fixator is in place, the correct height of the broken vertebra is restored by turning the turnbuckle and the kyphotic deformity is corrected. The vertebral staple is designed to hold the adjacent vertebral bodies together when the spine is in flexion, and thereby fulfill the tension resisting role of the ruptured ligaments.

LABORATORY ASSESSMENT OF THE STIFFNESS OF THE FRACTURED SPINE BY THE ANTERIOR DEVICE

Intact cadaver spines were cleansed, mounted between rigid blocks, and loaded to fracture in an Instrom machine, in a mode simulating its physiological loading. Following fracture, the vertebral body at the injured section was removed, the spine was stabilized by the new Anterior Spinal Fixator, and again loaded. Typical load-deflection curves of the normal spine and of the fractured spine fixed by the Anterior Fixator are shown in Fig. 3, which demonstrates the significant stiffness imparted to the fractured spine by the new device, and its consequent capability to safely sustain high levels of compression and flexion loadings.

CLINICAL RESULTS

Twenty-one cases have been treated by this technique, with the use of the Anterior Spinal Stabilizing-Fixator. There were 6 females and 15 males with an age span of 14 to 56 years. There was complete paraplegia in 12 cases and incomplete in 9 cases. The fracture levels were between T5 and L4, all with neurological deficit. Minimum hospitalization was 14 days and maximum was 42. All were able to sit comfortably in one to three days and to stand (with or without braces) in 14 to 21 days post-operatively. Complications were rare. However, malposition of the fixator resulted in a second operation in one case.

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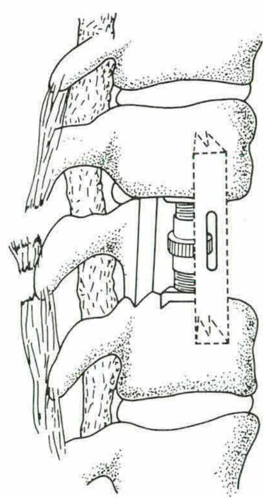

FIGURE 1

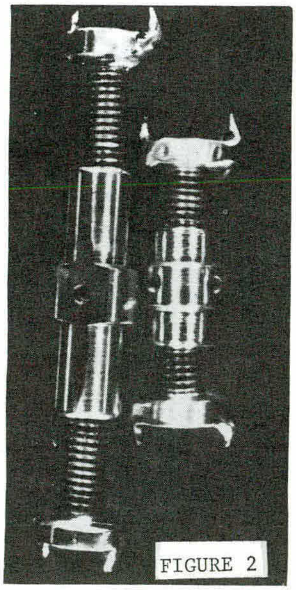

FIGURE 2

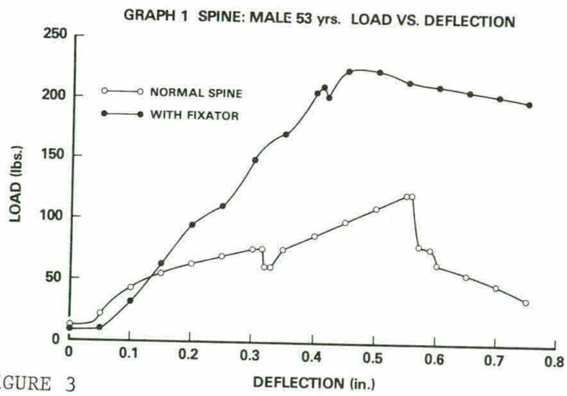

FIGURE 3

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FUNCTIONAL ELECTRICAL STIMULATION CHANGES JOINT COMPLIANCE

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INTRODUCTION

Functional Electrical Stimulation (FES) has been used for rehabilitative purposes to provide limited degrees of purposeful motor function in otherwise paralyzed muscles. In some cases, it is desirable to have FES utilize remaining involuntary motor function, for example by inducing a flexion reflex for swing phase of gait. In other cases, it is desirable to have FES overide phenomenon like clonus to produce a smooth, steady contraction. One of the problems in using FES which has not been fully explored is the changes induced in the underlying neuromuscular system by the electrical stimulation. Studies on FES induced changes in spasticity have shown a variety of effects (1). The purpose of this study was to assess the effects of FES on joint compliance in spinal cord injured patients and make comparisons with normals.

METHODS AND RESULTS

The laboratory apparatus used to apply known sinusoidal torques about the ankle joint has been previously described (2). Briefly, sinusoidal torques in the frequency range of 3 to 12 HZ were applied to the ankle and the resulting joint position was measured. The ratio of joint position to torque is a measure of joint compliance. This compliance may be plotted versus frequency and typically shows the characteristics of a second order system. The sinusoidal stretching also evokes electromyographic activity in ankle dorsiflexors and plantarflexors (2).

Joint compliance measurements were made on four spinal cord injured patients before and after 20 to 30 minute periods of flexion reflex stimulation at the peroneal nerve. The compliance curve changes as shown in Fig. 1. Plots of averaged torque, joint angle and EMGs are given for one such subject in Fig. 2. Note the drastic changes in TA stretch-evoked EMG.

Joint compliance measurements were also made on a normal individual before, during and after a period of ischemia in the leg. Compliance curves for before and during ischemia are given in Fig. 3. Plots of averaged torque, joint angle, and EMGs for this experiment are given in Fig. 4. Again note the drastic changes in stretch-evoked SOL EMG.

DISCUSSION

The experiments in this abstract show that significant changes in joint compliance may be obtained in spinal cord injured patients using FES. Similar changes were obtained in the ischemic normal subject. The most interesting finding is that upon abolition of stretch-evoked EMG, the joint becomes less compliant. This is the exact opposite of what would be expected, since excessive stretch reflexes have typically been thought to be the mechanism behind increased muscle stiffness. Such a mechanism does not appear to fit either experiment reported here, and an alternate mechanism has not yet been formulated.

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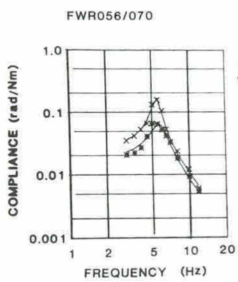

Fig. 1

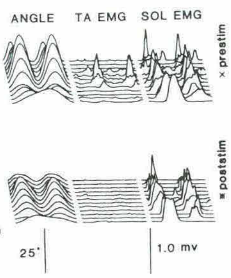

Fig. 2

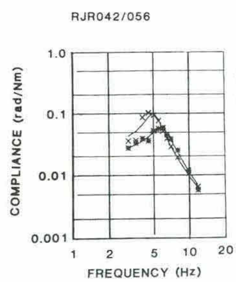

Fig. 3

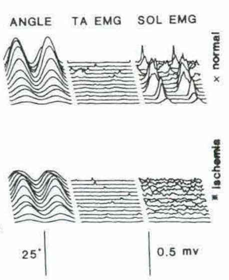

Fig. 4

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THE INFLUENCE OF ELECTRICAL STIMULATION AND PASSIVE MOVEMENTS ON SPASTIC ANKLE JOINT IN HEMIPLEGIA

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INTRODUCTION

There are many reports in the literature /1,2,3/ which attempt to document that electrical stimulation has an important influence on spasticity. All the data show that electrical stimulation either decreases spasticity or has no influence on it. Practically no data can be found which should document the increase of spasticity due to electrical stimulation. Although we believe that stimulation sometimes decreases spasticity, we do not understand completely the mechanisms involved in the effect of electrical stimulation on reorganisation of the central nervous system. In the studies of the influence of specific therapeutic treatments on spasticity it is very important how to measure different aspects of spasticity. It is believed namely, that measurement by itself modify the state of spasticity. In general the measurement methods can be divided in three groups: clinical, neurophysiological and biomechanical. The third one was used in our work.

EXPERIMENT

Three different kinds of therapy were used for each patient. First, tetanic electrical stimulation of muscles tibialis and soleus producing dorsal and plantar flexion of ankle joint. Second, passive movements of ankle joint produced by special electrohydraulic servosystem (Fig. 1), which were also used for the measurements of resistive torque due to passive movements. Third, combination of electrical stimulation and passive movements, so that electrical stimulation activated the contraction in the muscle streched by hydraulic system. Different therapy procedures were applied for 15 minutes each in time intervals of three days. For the evaluation of spasticity the resistive torque due to passive movements and EMG of both muscle groups were measured. This method is very similar to those used by Agarwal et al /4/. Each patient was measured every day, starting two days before the first therapy and closing two days after the last one. The same measurements were done also immediately and 20 minutes after the end of the therapy. All measurements were done at four different frequencies (0.5, 1, 1.5, 2 Hz) of sinusoidal passive movements.

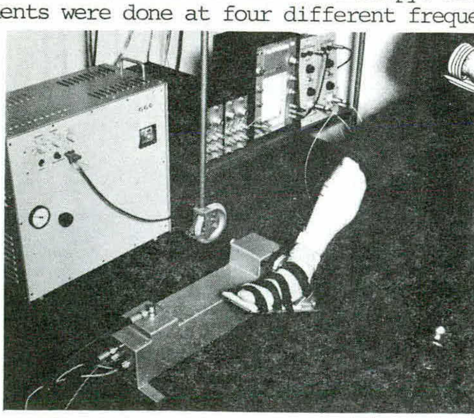

Fig. 1 : Electrohydraulic servo system

RESULTS

Ten hemiplegic patients were treated with described therapeutic program. In the present analysis only resistive torque is used. All collected data were statistically evaluated. For this evaluation "T" test with level of significance 0.05 was used. The results of "T" test are collected in table 1.

f (Hz)	STIMULATION		PASSIVE MOVEMENTS		COMBINATION	
	t_0	t_{20}	t_0	t_{20}	t_0	t_{20}
0.5	0	0	+	0	0	0
1	0	0	+	0	0	0
1.5	0	0	+	+	0	0
2	0	0	+	0	0	0

Table 1: Results of tested hypothesis that resistive torque after specific therapy is lower than average value of all other days. t_0 represents the measurements done immediatelly after therapy; t_{20} represents the measurement done 20 minutes after the end of the therapy; 0 - means no significant decrease of resistive torque; + - means significant decrease at level 0.05.

From table 1 can be concluded that neither stimulation nor combination had any significant influence on resistive torque, while the therapy with passive movements was much more effective.

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Acknowledgement: This investigation was supported in part by Research Grant 23-P-59231/F from the National Institute of Handicapped Research, Department of Education, Washington, D.C., and the Slovene Research Council, Ljubljana, Yugoslavia.

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MULTICENTER EVALUATION OF ELECTRICAL STIMULATION FOR CORRECTING WRIST FLEXION CONTRACTURES

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It is not uncommon for patients recovering from stroke or head injury to develop joint contractures due to lack of voluntary control of extensor musculature and spasticity of flexor musculature. Neuromuscular electrical stimulation has been used at the Rancho Los Amigos R.E.C. for preventing and correcting joint contractures for many years. The goal of this project was to verify at other rehabilitation centers, the results of a study carried out by this institution where cyclical electrical stimulation was used to decrease flexion contractures of the wrist, metacarpophalangeal and interphalangeal joints in sub-acute and chronic hemiplegic patients who displayed moderate wrist and finger spasticity (1).

METHODS

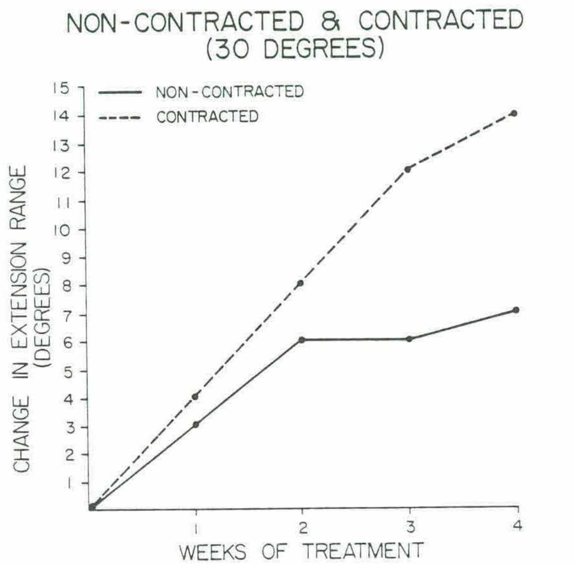
Hemiplegic stroke patients who had moderate spasticity of the wrist and/or finger flexors and whose stroke onset was less than four months received one to two stimulation sessions daily for maintenance of range of motion, while patients whose stroke onset was more than four months received from two to three sessions of electrical stimulation a day. All other treatment programs aimed directly at maintaining or gaining range of motion were discontinued. Both groups were treated for four weeks and passive wrist flexion and extension were monitored weekly with an electrical goniometer that read motion to the nearest one degree.

RESULTS

Five rehabilitation centers participated in this study. The number and type of patients treated and evaluated are shown in the Table below.

Hospital	Total No. of Patients	No. of Acute Patients <4 mo's.	No. of Chronic Patients >4 mo's.	No. of Patients Non-Contracted >30°	No. of Patients Contracted <30°
Moss Rehabilitation Hospital	35	19	16	33	2
Dallas Rehabilitation Institute	19	12	7	19	-
Providence Medical Center	17	3	14	13	4
Woodrow Wilson Rehabilitation Institute	11	--	11	2	9
Helen Hayes Hospital	3	2	1	2	1
TOTAL	85	36	48	69	16

In total, 85 patients completed the four week treatment program. Sixteen patients demonstrated extension range limited to 30 degrees or less and were classified as contracted. These patients had a mean time since onset of nearly four and one-half years. As can be seen in the dotted line of the figure below, on the average these patients made progress throughout the four week treatment program and were still improving at the termination of the formal study period. These patients started the program with just over 20 degrees of extension and finished with more than 35 degrees.



The remaining 68 patients had greater than 30 degrees passive extension range prior to the program and were considered non-contracted. As can be seen in the solid line of the figure, on the average these patients not only maintained their range but also made some progress throughout the four week program. These patients started with just over 50 degrees of extension and finished with nearly 60 degrees.

DISCUSSION

The results of this study are very similar to those reported earlier by this institution (1). All centers were successful in maintaining range of motion in those patients displaying full passive range prior to the stimulation program and all but one center (reporting on only one patient) were successful in correcting established contractures. It is a treatment that is easy to apply and can be administered by many patients in their own homes.

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CLINICAL IMPLEMENTATION OF A NEUROPROSTHETIC HAND ASSIST SYSTEM IN THE QUADRIPLEGIC

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A neuroprosthetic system has been developed to restore upper extremity control through application of functional neuromuscular stimulation. This technique enables the C5 and C6 level quadriplegic to utilize his hand in a functional manner. The purpose of this paper is to describe the clinical implementation of the FNS system, and the present results with our subjects.

SYSTEM DESCRIPTION

The system developed has been described in previous communications. Subjects with C5 or C6 level function are candidates for use of the system. Control of the system employs a voluntary command generated by the patient to activate coodinated movement of the hand. The source of the command signal is described below. This voluntary command proportionally regulates the output of up to four channels of stimulation. The stimulus output of each channel is modulated according to a coordination algorithm determined in laboratory studies, to provide satisfactory motion for the set of muscles and electrodes employed in the particular individual.

SYSTEM IMPLEMENTATION

Muscles to be stimulated are those which can be used to provide either a lateral prehension/release or palmar prehension/release and have the lower motor neuron intact. These muscles are implanted with percutaneous coiled wire electrodes, and following a two week stabilization without stimulation, electrically induced exercise is applied nightly to strengthen the muscle and increase its fatigue resistance. Simultaneously, studies are begun in the clinical laboratory to develop the coordinated muscle function and to determine the appropriate command controller. Using versatile computer controlled instrumentation, we are able to determine the appropriate parameters for control and stimulation which will subsequently be utilized in the patients individual stimulator. This phase of the implementation of the functional system requires approximately three sessions of two hours each. Laboratory studies also enable us to determine the proper type of command controller. The choice of command controller is dependent upon an individuals' functional capacity and preference. Command control sources which are available include shoulder position, head position, myoelectric signals, and switch signals. Training in the operation of the stimulation system is initially carried out in the clinical laboratory by the rehabilitation engineer.

PATIENT USE OF FUNCTIONAL STIMULATION SYSTEM

Subjects are provided with the functional system developed at the CWRU-R.E.C. for training and use. The use of the system, is incorporated into the regular impatient occupational therapy program. The occupational therapist and rehabilitation engineer jointly train the subject.

Patients may be fit with the system as soon as they are medically stable and ready to accept an assistive device.

Eleven patients have been fit with this system. Of these five are full time users, three are irregular users, and three have been occasional users. Some of the factors that are involved in whether a patient will utilize his neuroprosthetic hand system are the motivational level of the patient, the home environment of the patient, the patient's acceptance of his physical disability, the time at which the patient enters our program during his hospitalization, and the efficiency level at which the system performs for the patient.

Patients use the system for combing hair, brushing teeth, applying tooth paste to toothbrush and shaving with electric or safety razor, washing face and neck, eating and drinking, writing, and self-catheterization. He wears his neuroprosthesis throughout the day to have the flexibility of independently performing a functional task at his discression.

The present system has had 167 user months of evaluation. Some of the problems encountered include (1) hardware limitations in the number of channels of stimulation and ease of programming. (2) external cables which connect electrodes and control transducer to the stimulator and are encumbering and (3) percutaneous electrodes which require maintenance of the implant site. To overcome these problems, we are presently developing a microprocessor based controller and implantable stimulator. These will enable us to easily program the control algorithm and stimulation parameters by loading them directly from the laboratory computer to the patient's personal device, and eliminate many external leads. However, despite these deficiencies, at the present level of development the FNS system is sufficiently reliable and functional and it is, in general , prescribed and used as the primary functional orthosis for high level spinal injury patients at our center.

ACKNOWLEDGEMENTS

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SURFACE FUNCTIONAL ELECTRICAL STIMULATION OF THE HAND IN QUADRIPLEGICS

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Electrical stimulation of the paralyzed forearm muscle groups can be utilized to provide a controlled hand function in patients with high level spinal cord injuries. There are three approaches for restoration of prehension and release in the hands of quadriplegics with FES:
- by a totally implanted stimulator /1/
- by percutaneous intramuscular stimulation /2/
- by the use of surface electrical stimulation /3/.

Noninvasive access seemed to be most convenient and proper in the early stage of FES application, when candidates for implantable stimulators are being selected.

By choosing a proper combination of surface electrodes, conductive gel and adhesive tape satisfactory selectivity and repeatability of stimulated movements can be achieved.

Three complete quadriplegics with lesions C-5 to C-7 were supplied with position controlled stimulators /3/. The residual movements in the shoulder and elbow were strong enough to control a sliding potentiometer, forming part of the stimulator and attached to the armrest of the wheelchair. In this way one arm was sacrified as the source of the signals, providing opening and closing of the other affected hand (see Fig. 1). Such an orthotic aid proved to be an effective tool for improving manipulative skills needed during the patients' daily activities. Based on experiences gathered during home use of the described orthoses, a new two channel stimulator with time proportional control was designed. Fig. 2 shows the block diagram. Two sensor switches were used as controls to determine the stimulating voltage (0 - 100 V) in flexor or extensor muscle groups. The control logic had the ability to memorize the voltage level reached and to

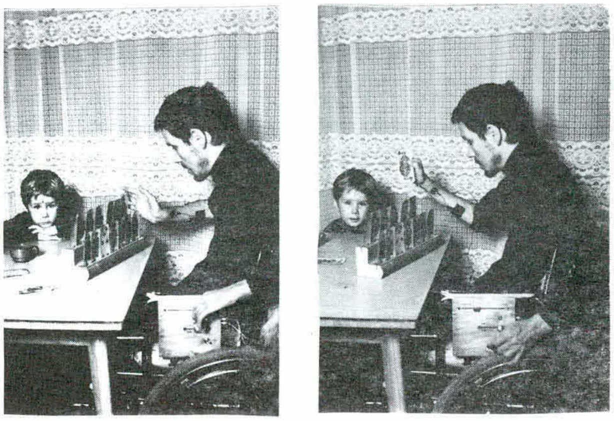

Fig. 1

switch stimulation to the desired pair of electrodes. Other parameters of stimulation were fixed: frequency at 20 Hz and pulse duration at 0.3 ms.

The same stimulator could also be used for therapeutic purposes to provide cyclic stimulation, with the period of stimulation and pause adjustable from 2 to 10 s. In this way the strengthening program of atrophied muscles can be prolonged outside the rehabilitation center, in order to restore the strength and fatigue resistance of the muscles.

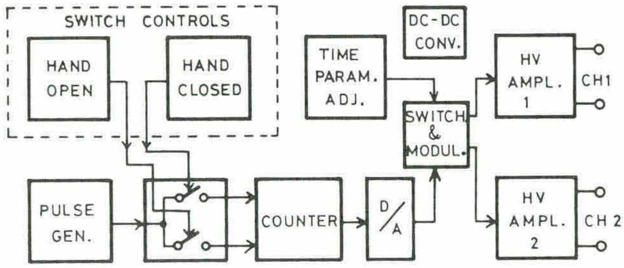

Fig. 2

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POSTURE SWITCHING ENABLES PROLONGED STANDING IN PARAPLEGIC PATIENTS FUNCTIONALLY ELECTRICALLY STIMULATED

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INTRODUCTION

In paraplegic patients functional electrical stimulation (FES) restrengthened muscles are capable of providing FES enabled locomotion functions like standing-up, standing, primitive biped gait and sitting-down (1, 2,). At present the rapid fatiguing of FES muscles limits the useful time of the FES enabled functions. To overcome this disadvantage, different methods were introduced, like cyclical and sequential time divided stimulation utilizing subfusion frequencies (2). If surface FES is used and in functions where the muscle force must be continuously present, neither of the proposed methods can be employed. The method of posture switching can be used to overcome the specified problem.

METHOD

Various postures make use of different muscle activation and weight bearing thus enforcing the use of cyclical FES. Because of that, the posture switching enables the FES of different muscles for standing and gaining reasonable off times for the muscles which served in the previous FES enabled postures. Also posture switching can trigger extension trust reflexes providing additional support. For different standing modes the biomechanical requirements and body weight line alignments and transitions to the different postures must be understood. For the universal standing postures is common the utilization of all three leg joint extensors. If making use of the provided ligament locking at the hip and knee joint different postures can be selected utilizing the advantage that only one or two extensor groups are activated. Fig 1 shows one muscle group standing postures, while in Fig. 2 the two muscle group standing postures are presented. All the standing modes can be exerted in two ways, because of possible left and right leg single limb standing. The required body weight shifting for posture switching is accomplished by the patient's upper trunk lean and assisted by hands. Obviously the shown posture modes provide enough flexibility for selecting the wanted mode and order for ensuring long FES off times, allowing short duty-cycles (on/off ratio) for utilizing low muscle fatiguing.

RESULTS

In all of the standing modes discussed body weight is transferred across the FES legs, and hands are used for balancing. For prolonged standing those postures are important in which the M. Quadriceps is not (Fig. 1A, Fig. 2B) used. These postures allow longer resting times for the important knee extensor muscles. In Fig. 1A FES assisted standing was accomplished. For this reason the patient stood-up by help of FES of M. Quadriceps and once the correct errect posture is established the FES for M. Soleus and M. Gastrocnenius is increased and for M. Quadriceps later gradually discontinued. In Fig. 1 the one muscle mode of standing by help of hip extensors is not shown, but in principle this posture is also usable. The posture of standing given in Fig. 2A was also tried, together with toe standing, as well as the single limb standing using this posture. This standing was tried for periods lasting of about 10 seconds. At present FES standing by using only M. Quadriceps stimulation can last dependent from the patient between 10 to 60 minutes, while by introducing the proposed posture switching the standing times would be prolonged for 2 to 3 times or even more. The results so far obtained demonstrated the feasibility of the proposed method and thus quantitative evaluation is indicated.

ACKNOWLEDGEMENTS

This study was supported in part by Research Grant 23-P-59231/F from the National Institute of Handicapped Research, Department of Education, Washington, D.C. 20202, the Slovene Research Council, Ljublana, Yugoslavia and the Illinois Institute of Technology, Department of Electrical Engineering and Pritzker Institute of Medical Engineering.

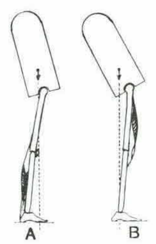

FIG 1

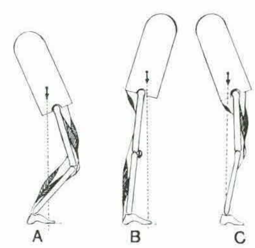

FIG 2

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FUNCTIONAL WALKING OF PARALYZED PATIENTS BY MEANS OF ELECTRICAL STIMULATION

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INTRODUCTION

Lack of functional control of the lower extremities in many stroke and spinal cord injury patients severely impairs their ability to achieve independence in activities of daily living. Many of these patients have intact lower motor neuron systems with the potential of increased function through functional neural stimulation (FNS).

MATERIALS AND METHODS

The study describes three partially paralyzed patients who were unable to walk even after a maximal attempt at a major rehabilitation center. One patient was diagnosed as having transverse myelitis, the second had a stroke and the third received a traumatic brain injury. General problems were inability to actively flex the hips, adductor spasm, weak hip and knee extension and lack of ankle dorsiflexion. Multiple 45 micron intramuscular stainless steel wire electrodes activated by timers were placed in the quadriceps, hip flexors, extensors, and abductors as needed. After training, the patients were provided with portable stimulators to use for exercise and functional activity at home. Muscle force and foot contact evaluation were done using "Cybex" and the Cleveland Veterans Administration Gait Laboratory.

RESULTS

All patients had improved function post implantation but still desired some supervision in walking. A 10 fold increase in knee torque was noted in one patient, thereby providing him with near normal strength. No implant complications were noted.

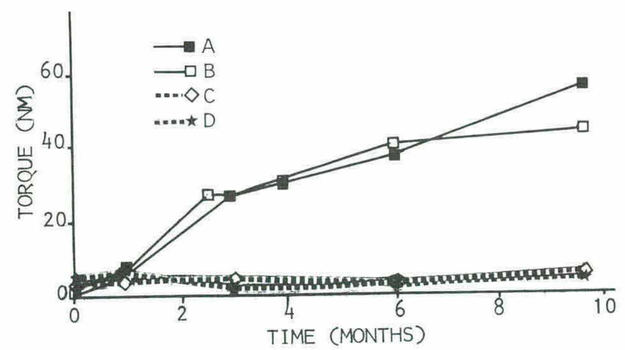

FIGURE 1. Torque about the knee joint measured at 60 degrees per second with (A,B) and without (C,D) stimulation of the right and left leg.

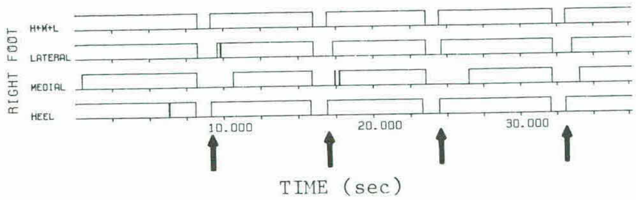

FIGURE 2. Foot-to-floor contact measured during stimulation. Right iliopsoas was stimulated on heel off indicated by absence of heel contact. After 1 second delay the right quadricep was activated to extend the knee and prepare for heel strike marked by arrows.

DISCUSSION

Waters (4), Bajd and Kralj (1), and Brindley (2) have demonstrated functional movements in paralyzed patients using FNS. This study demonstrates the feasibility of using FNS gait augmentation in previously non-walking patients outside the laboratory. Further improvements will require the development of an implantable multichannel programmable microprocessor controlled stimulator (3).

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EXTERNAL MUSCLE STIMULATION FOR THE
TREATMENT OF PROGRESSIVE KYPHOSIS

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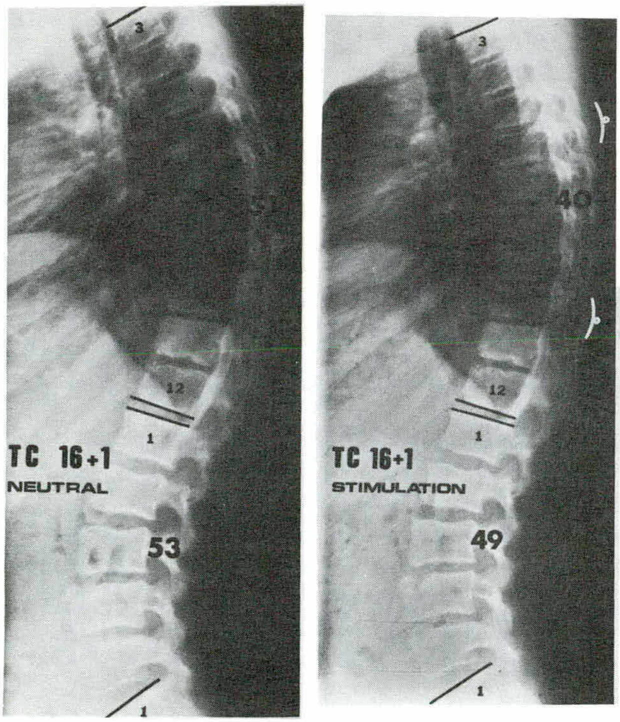
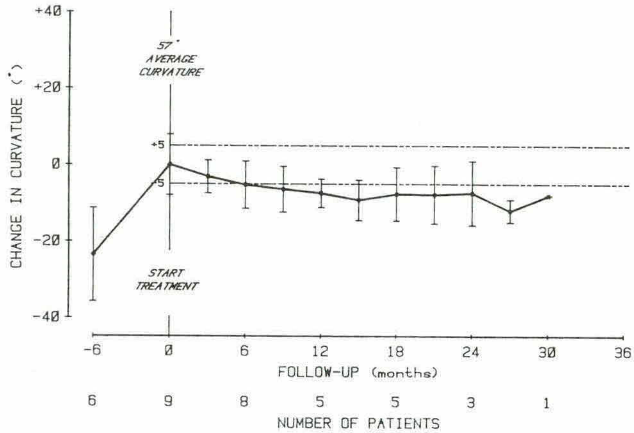
Adolescents with progressive kyphosis (excessive roundback) requiring non-surgical treatment usually are fitted with a modified Milwaukee Brace for full-time wear (1). Often these patients refuse the brace or use it inadequately due to physical restriction of their daily activities, discomfort, skin breakdown or the emotional strain of wearing an orthosis visible to other youngsters. Based on our experience with muscle stimulation for the treatment of scoliosis (2), an alternative to bracing has also been developed for kyphosis.

Transcutaneous electrical neuromuscular stimulation is applied only at night during the hours of sleep. The stimulation is provided by a portable



generator which supplies trains of capacitively coupled monophasic constant current square wave pulses of 0.2 milliseconds duration at a rate of 25 pulses per second. Muscle fatigue is prevented by letting the stimulator cycle on and off 5 times every minute. Ramp-up and ramp-down of the stimulus pulses allow the muscles to contract and relax smoothly. Two carbon-rubber electrodes (5 cm in diameter) are attached to the skin overlying the paraspinal musculature, symmetrically around the apex of the curvature with a distance of 10-16 cm between electrode centers. The picture above shows the biomechanical effect of applying stimulation. When the musculature contracts during the ON period the kyphosis is reduced from 51° (left x-ray) to 40° (right x-ray). Simultaneously the lordosis reduces from 53° to 49°. In the stimulation x-ray the placement of the electrodes is indicated by white markers.

Long term treatment follow-up results of 9 patients with progressive kyphosis are plotted in the graph below. An average progression rate of 4° per month prior to treatment is reversed to an average improvement rate of 0.6° per month for the first



year of treatment and complete curvature stabilization from then on. All patients have stopped their progression with five showing improvement of 8° to 15°. One patient, who corrected 13° during 27 months of treatment, has been discontinued at skeletal maturity. He shows no change in curvature at the 2 year post treatment follow-up visit.

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ELECTRICAL STIMULATION OF DENERVATED MUSCLE

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INTRODUCTION

It is generally believed that the denervated muscle may be directly excited by a special range of electrical waveforms, all of which elicit a non tetanic physiological response /1-3/. Basically, there are present three directions of our investigation: First, optimisation the various waveforms parameters which are related to electrically induced redness such as current and voltage levels, energy, power, injected electrical charge and timing parameters of electrical stimuli /4/; Second, development of clinical useful functional electrical stimulation methods for patients with lower motor neurone lesions, and the third, optimisation of electrotherapy for these patients.

METHODOLOGY

The measurement of redness and ankle joint response was realized in five healthy subjects and in set of eight patient with complete denervated muscle tibialis anterior. The neurological and muscular status was established objectively with I/T curve, EMG records and the muscle test. The patients have no voluntary movements of ankle joint in dorsal flexion and have no response on typical tetanic nerve electrical stimulation - pulse durations from 0,1 to 0,5 ms and frequency from 20 to 40 Hz. The surface electrodes were used and a current and voltage source of the stimulating pulses were applied. A comparative study of the skin response, torque and angle of the ankle joint to four different waveforms: simple monophasic, simple biphasic, chopped monophasic and chopped biphasic was performed. Therapeutic effects of functional electrical stimulation and optimisation of parameters were investigated by comparing the effectiveness of four different waveforms: simple monophasic, simple biphasic, exponential monophasic and exponential biphasic. The current source of the stimuli was used.

RESULTS

The results showed that the redness is minimal with chopped biphasic waveforms. Isometric torque of ankle joint has been largest with the chopped biphasic waveform on normal innervated muscle but has been the largest with simple biphasic waveforms on the complete denervated muscle. The experiment based on voltage source of stimuli. Parameters were: pulse duration 30 ms, pulse frequency 16,6Hz, chopping frequency 500 Hz and voltage was adjusted from 15-50 V.

Because current pulses produced less pain than voltage pulses in the second part of the experiment current source was applied. Parameters of the stimuli were: pulse duration from 10 to 50 ms, pause duration was fixed on 20 ms, and current was adjusted from 10 to 45 mA. The movements of ankle joint in the dorsal flexion was detected with an electrogoniometer. Positive effects were noticed due to electrical stimulation therapy during four weeks of training 2 x 30 minutes stimulation daily. We noticed the significant improvement of the ankle response which may be functional for foot drop correction of patients' gait.

The study shows some possibilities of optimisation of electrotherapy and defines the parameters of functional electrical stimulation to these patients.

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Acknowledgement: This investigation was supported by Slovene Research Community and the Department of Health, Education and Welfare, NIHR, Washington D.C. and carried out within the Rehabilitation Engineering Center in Ljubljana.

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THE DESIGN AND TESTING OF A CLOSED-LOOP CONTROL SYSTEM FOR FUNCTIONAL STIMULATION

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University of Virginia Rehabilitation Engineering Center

Electrical stimulation is effective for the functional and therapeutic management of paralyzed muscles.[1,2] The objective of this project was to develop a closed-loop control system capable of reproducing preprogrammed isotonic limb motions. The controller was intended for therapeutic use on the biceps, but is adaptable to functional tasks of other muscle groups.

The exercise achieved through the use of this stimulator system is expected to benefit the upper limb rehabilitation of spinal cord injured or stroke patients. In addition, the development of stimulators for more complex functions such as feeding, wheelchair propulsion, or gait enhancement will depend upon parallel improvements in stimulator controllers.

The force developed by an electrically stimulated muscle is sensitive to error sources arising in both the instrumentation and physiological system. Amplifier drift, temperature sensitivity, muscle fatigue, load disturbances, and changes in anatomical limb position or electrode placement are factors which make it difficult to control muscle activity using conventional stimulators. By enclosing the entire system in a negative feedback loop, however, the sensitivity to these disturbances can be reduced and the desired force or motion can be achieved.

Methods. The prototype system consisted of a control algorithm programmed on an LSI-11 minicomputer, and a mechanical apparatus for loading the forearm and sensing its' angular position. The actual stimulus was delivered through saline-soaked sponge electrodes by a PULSAR™ Constant Current Isolation Unit (CCIU). For compactness and portability in clinical use the controller is to be programmed on an 8085 microcomputer.

The control strategy is to automatically adjust the stimulus pulse width (PW) to achieve a muscle response which emulates a preprogrammed model. This is accomplished using a general purpose Proportional-Integral-Derivative (PID) control algorithm. This technique has the advantage that the algorithm parameters (KP,KI,KD) can be determined empirically without having to derive a precise mathematical model of the limb's dynamic motor response.[3] Figure 1 illustrates a simplified block diagram of the system. The model is a FORTRAN generated soft-starting step, ramp, or sinusoidal waveform which specifies the desired forearm motion, $\theta_d(T)$. The stimulator acts upon the plant (muscle, skeletal structure, and mechanical apparatus) to produce the actual forearm motion, $\theta_a(t)$. The amplitude and frequency of stimulation are user selectable and are not influenced by the controller.

Results. Initial testing of the system on normal healthy subjects has produced controlled isometric contractions up to 5.0 lbs. without discomfort. The force was measured on the volar side of the forearm just proximal to the wrist. Figure 2 shows the actual muscle force response to a soft-starting step input. Isotonic contractions have been achieved over approximately 75% of the normal range of motion against a torque of 1.25 ft-lbs. The actual position response to a sinusoidal model is shown in Figure 3. Similar results can be obtained on quadriplegic subjects in the absence of intact motor and sensory pathways.

Conclusions. Factors which limit controller performance have been identified to be the limit of attainable muscle force and a response hysteresis with respect to applied stimulus. Increasing the stimulus intensity by frequency and amplitude modulation in addition to the present pulse width modulation would extend the controllable range of muscle function. Antagonistic stimulation would compensate for the response hysteresis observed during the transition from flexion to extension. With improvements in these areas, closed-loop will be feasible for a variety of limb functions.

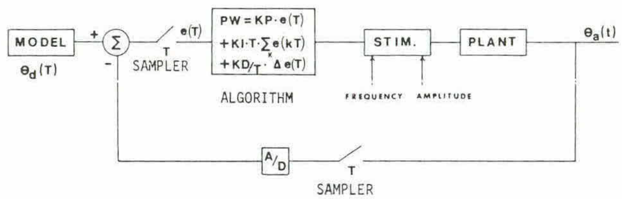

FIGURE 1. Stimulation Control System

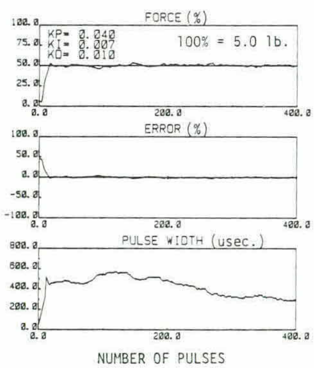

FIGURE 2. Isometric Response.

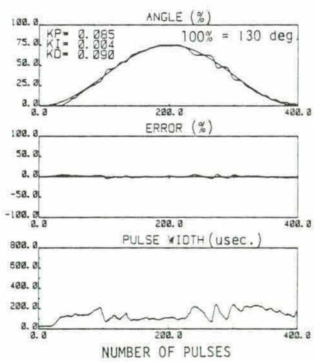

FIGURE 3. Isotonic Response

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REHABILITATION ENGINEERING AT O.R.I.

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D.Roberts
O'Donoghue Rehabilitation Institute

The Rehabilitation Engineering department at the O'Donoghue Rehabilitation Institute is oriented to provide service delivery to clients at the Institute.

Although Rehabilitation Engineering at O'Donoghue is less than two months old, several devices for handicapped people have been produced. Three devices of general intrest are described here.

One handed can opener

An Occupational Therapist was concerned about the reliability of electric can openers. R.E. was asked to develop a manual can opener useable by a one handed person with little dexterity. The carpentry shop acted on the design concept submitted by R.E.. The final design uses a single post to support the can opener and a can opener with offset circles to hold different size cans.

Strecther bed book holder

Educational Services requested a book holder for students in stretcher beds. The solution was a peice of square tubing placed across the bed rails. The tubing has broom clips to attach to the bed rails and a slot to hold a vise base. The vise base holds an easel and allows a multitude of adjustments for best reading position.

ABEC wheelchair speed limiter

After observing clients learning to use proportional ABEC wheelchairs, a speed limiter was constructed. Instead of electrical modifications, an adjustable mechanical limit is attached to the joystick. A short section of pipe is slipped over the rubber boot surrounding the joystick. The joystick knob is pulled off and a washer with a set screw placed on the joystick shaft.

The washer height is adjusted for desired maximum speed and the control knob placed on the shaft. This has proved to be a benifical device to train clients indoors on flat linoleum floors. Its use outdoors, on slopes, or carpeting is probably limited.

Conclusion

These projects are representative of work recently completed at ORI. Electronic devices will be constucted once needed equipment and supplies arrive.

The O'Donoghue Rehabilitation Institute is part of the State of Oklahoma Teaching Hospitals.

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A BIOFEEDBACK EQUILIBRIUM INDICATOR

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Patricia Massengill, L.P.T., Charlotte Rehabilitation Hospital

Victims of cerebrovascular accident, cerebral infections and toxins, or spinal cord injuries with regenerative potential often have a loss, total or partial, of proprioception. Since the awareness of posture, movement and knowledge of position is developed, physical therapists try to reestablish kinesthesia through exercise and training. A biofeedback equilibrium indicator has been constructed to aid in this process. This indicator provides audio-visual signals to let the patient know when imbalance occurs.

Figure 1 shows a block diagram of the system. The system activates as balance monitors are tilted, closing a circuit corresponding to the tilt direction, either lateral or frontal. Power is sent along this circuit through a signal generator into a speaker and light which warns of an imbalance.

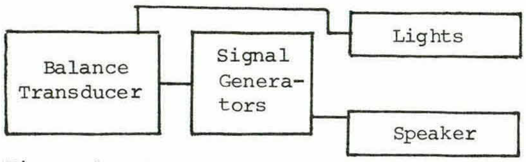

Figure 1. System Block Diagram

The equilibrium indicator is contained in two modules. One module, the A-V unit, houses the power supply, speaker, and lights while the balance transducer contains the balance monitors.

Two nine-volt transistor batteries, connected in parallel, supply the system's power. Located in the A-V unit, they are connected directly to the balance monitors by the umbilical cord. Four mercury bulb switches, balance monitors for each polar direction, make up the balance transducer. These switches are mounted on pivoting bases so the unit can be adjusted. Each monitor is connected to its own light and signal generator by the umbilical cord. Signal generation is accomplished by a linear integrated circuit employing a 555 timer shown in Figure 2. When connected with a combination of resistors and capacitors, this circuit transforms a DC voltage into a square wave with a frequency determined by the relationship:

$$f = 1.44/(R_1 + 2R_2)C$$

The frequency output can be altered by changing any of the resistors or capacitor. There are four signal generators, one for each direction, whose outputs differ in frequency. Connected in parallel with the signal generators are lights which indicate the direction of imbalance. Orange lights indicate a lateral tilt and red lights a frontal. Figure 3 shows a schematic diagram of the system.

In use, the balance transducer is secured to the patient by a belt clip located on the back of the transducer and adjusted for the patient by rotating the sensitivity knobs. These knobs increase or decrease the sensitivity of the balance monitors. Since the rehabilitation exercises for balance are conducted between parallel bars, a clamp on the back of the A-V unit allows it to be mounted directly on a bar in view of the patient and therapist.

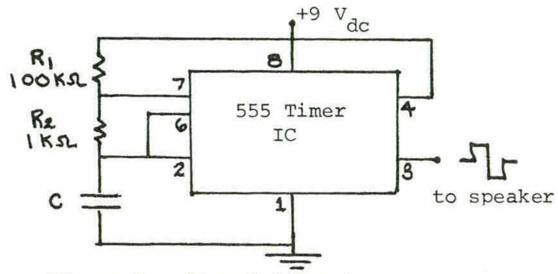

Figure 2. Signal Generators

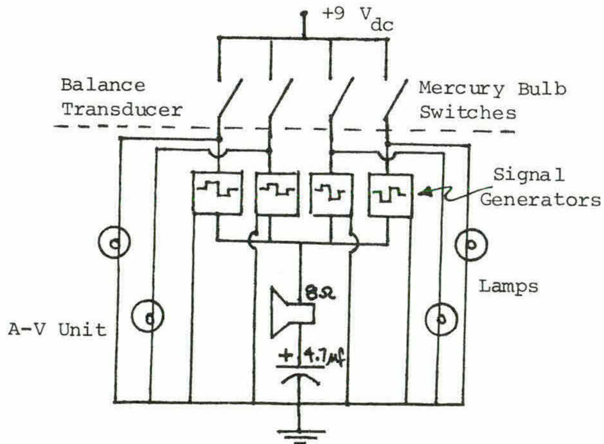

Figure 3. System Schematic Diagram

The equilibrium indicator is now being evaluated at Charlotte Rehabilitation Hospital. It can indicate tilt direction with single signals or angular tilt with a signal combination. One problem is bouncing of the monitors if a patient has a severe gait problem. A future modification could be to have the signal volume or tone increase as tilt angle increases and a delay circuit to eliminate transients caused by gait.

This project was supported by the Charlotte Rehabilitation Hospital, J. Patrick Thompson, Head and the University of North Carolina at Charlotte.

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BINARY CODED NONVERBAL COMMUNICATION SYSTEM

JAMES W. FEE, JR., M.S.

INTRODUCTION

It is this author's experience, in observing communication devices for the nonverbal, that these devices fall within two major catagories. The catagories can be defined as 1) direct selection, and 2) scanning communication equipment. The first of these, the direct select method, most often assumes a physically high functioning clientele. These devices make use of controlling mechanisms such as joystick, breath actuated switches, and the like. Controlling mechanisms such as these may use a code in order to access a given piece of data. The second catagory of device, the scanning communicator, is designed for the more severely handicapped client. These devices most often make use of a single input switch; allowing the access of communicated date by interacting with the device when the desired element of an array has somehow been indicated. The major drawback of such devices is that they sacrifice time for the physically simpler means of input. Such a sacrifice can be particularly frustrating to those severely handicapped clients who have the intellectual capacity to communicate at a rate many times faster than the machine. This paper offers an alternative to these two catagories.

DEVICE OUTLINE

The device proposed in this paper is an attempt to combine the best advantages of both the scanning and select by coding methods of communicating. The communicator to be presented here is made up of a matrix of cells, each of which houses a light behind a sheet of translucent plastic. One datum of information is intended to be placed on the plastic covering each cell. Directly above the cell a system of open and filled circles will be drawn; each representing the a digit in the binary number of that cell. For example, in a matrix of 128 cells the binary code of the 100th box would be: ●●oo●oo. The mechanism for addressing the cells will consist of two rows of small lights, such as LED's, positioned at the top of the matrix. The upper row would be scanned, by lighting and then turning off each LED, one after the other in succession.

The control mechanism for this system consists of a single switch. Each time the switch is activated the LED on the second row, directly below the LED that was lit at the time of switch closure, would be lit. A calling code may thus be set up by lighting the desired LED's on the second row. For the example above, the 100th cell of a 128 cell matrix, a switch closure is made when the first, second, and fifth LED on the first row is lit.

In addition to the seven LED's making up the seven digits of the binary number 128, the first row of LED's would contain several more lights which, if a switch were closed during their lit period, would code for various functions such as correction, cancelation, or reactivation after a period of nonuse.

ADVANTAGES

The major advantage of the proposed system is the speed of communication this device permits. If a conventional matrix of 11 x 11 cells is accessed, row by row and then cell by cell when the desired row is reached, it takes 22 scan times to reach the furthest point in the matrix. Using the deviced proposed in this paper, even when assuming four additional functions for correction etc., the access time for a cell, i.e. the number of scan times, is cut in half. Furthermore, if the size of the matrix is doubled, making a total of 256 cells, only one additional LED need be added to the scanning line. Thus a matrix consisting of 16 x 16 cells can be completely accessed in 12 scan times.

This idea was conceived of and a model was built while the author worked as a consultant bioengineer. No outside funds were involved.

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COMPUTER INTERFACES FOR SEVERELY DISABLED PERSONS

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INTRODUCTION

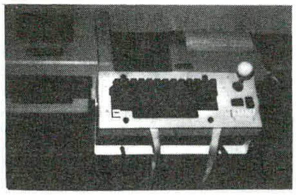
One of the areas of emphasis of the newly established Rehabilitation Engineering laboratory in the School of Rehabilitation Medicine at the University of British Columbia will be the development of a Vocational Evaluation and Training Unit.

Very few higher level quadriplegics, C5 and above are employed and a recent survey conducted by the Adult Services Committee of the Cerebral Palsy Assocation of B.C. yielded a figure of 77% unemployed for the cerebral palsied population of B.C., which totals over 2800 persons.

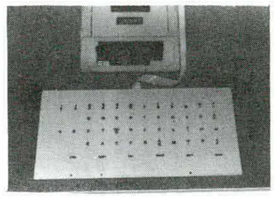
SPECIAL KEYBOARDS

The first step was to provide interfaces for a variety of computers and other devices so that these persons could operate them: A remote keyboard for the Apple II computer was designed in which a standard keyboard was modified by replacing the SHIFT, CONTROL and REPEAT switches with latching switches. The modified keyboard was then mounted in a specially manufactured cabinet with provision for a keyguard to be added at a later date if required. Also in the cabinet was mounted a printed circuit board which provided access to the paddle controls by means of a four potentiometer joystick. PDL(0) PDL(1), PDL(2) AND PDL(3) were able to be controlled by mouthstick or headstick by means of a half table tennis ball mounted on the end of the joystick shaft. Control is by swivelling the ball around with the mouth stick inside it, analogous to a ball joint. This method has been evaluated by high level quadriplegics and found to be satisfactory. Also on the printed circuit board are the three push buttons PB0, PB1 and PB2. PB2 was made a latching switch so that it could be used to produce upper case characters with the Supertext word processing program. The cabinet has a bracket attached which allows it to be mounted vertically. Locking knobs allow the cabinet to be adjusted in height and also to be tilted. The cabinet is connected to the Apple computer by means of two 16 conductor flat cables 2 metres long, one to the keyboard socket and the other to the paddle socket.

An expanded keyboard for the Apple II computer was constructed by means of a matrix arrangement of crossing bronze rods. One set of these rods was mounted on a plywood baseboard and the other on the back of the plastic panel. Silkscreened on the front of the panel were the keyboard characters. Latching switches together with indicator lights were included in the unit for SHIFT, CONTROL and REPEAT so that it could be operated wth a single hand or stylus. The expanded keyboard was connected to the Apple II by a two metre, 25 conductor flat cable. Connection is made by removing the encoder board from the back of the Apple keyboard, slipping the cable connector over the encoder pins and replacing the encoder board. This operation takes less than a minute. After installation, both the original and expanded keyboards can be used.



REMOTE KEYBOARD



EXPANDED KEYBOARD

An Expanded keyboard for the Sinclair ZX81 computer, designed in a similar fashion, was found to operate satisfactorily.

These interfaces, which require no external power supply and which connect easily, enable severely disabled persons complete keyboard access to these computers. They have been refined and are now all commercially available from EKEG Electronics Co. Ltd., P.O.Box 46199, Stn. G., Vancouver, B.C., Canada V6R 4G5 (604)685-7817

ACKNOWLEDGEMENT

Funding for the development of these keyboards was provided by a grant from the B.C. Health Care Research Foundation.

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ADDRESS

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"TOUCH" SENSITIVE INPUT TO COMPUTERS

Per Krogh Hansen
POSITION ORIENTATION SYSTEMS, LTD.

INTRODUCTION

The development of relatively inexpensive and the widespread use of microcomputers holds a tremendous potential for assistance to the disabled person.

One drawback, however, is the interface between the computer and the disabled person. Numerous interface systems have been developed for the computer: light pens, special joysticks, sip/puff switches. However no one has utilized the natural inclination, especially for children, to point at selections without resorting to very expensive equipment such as touch sensitive CRT-terminals with a built-in LED-transistor grid.

THE POS-1 SYSTEM

Touch Sensitive CRT Monitor Or TV Screen

The POS-1 system is a new "touch" sensitive system. The system will convert any CRT monitor, including standard TV screens, into a "touch" sensitive monitor. The POS-1 system measures the position of a pointed finger and converts this information into the identified coordinates on the CRT's screen. The person operating the screen does not need to touch the screen, but need only to point at the selection.

The POS-1 system uses standard digital BCD output and can be directly interfaced with any microcomputer, minicomputer, or mainframe computer. It is mechanically adaptable to any CRT-monitor frame by a unique clamp-on plate. The adaptation is made by a clamp with protective padding.

The POS-1 clamps on to the CRT monitor, but in no way interferes with normal operation of the computer. It's source of operation does not interfere with the monitor. It is adapted to the monitor in such a way that it does not shadow any part of the CRT's screen. It is easy to clamp on/off and it operates with power from the power supply in the computer.

Touch Sensitive Keyboard

The POS-1 system can also be used with a "passive" keyboard. The keyboard consists of a sheet of paper with squares containing the selection in question. The sheet of paper is placed on a tray and the context of the squares is programmed into the computer memory. The POS-1 system clamps directly on to the tray and it is ready for operation. The system contains no switches or extensive wiring. The keyboard size can be altered to the right size for each person. Also the number of squares and the size of the squares can be altered. Changing the keyboard is easy; because a sheet of paper with squares, coding the contents into the computer memory is all that is necessary.

Laboratory Prototype

A laboratory prototype exists of the POS-1 (Figure 1) and patents have been applied for.

The accuracy of the system is better than ± 3 mm in position. The speed for selection is better than 2 selections per second.

The system consists of a transducer box, electronic control box, clamp-on plate, cable to interface with the computer, a floppy disk (with control programs and examples) and a manual. Most microcomputers have a digital input/output port and the POS-1 system interfaces directly with any port containing 8 BCD digital TTL inputs. Interface boards are readily available for other microcomputer systems. For the Apple II+ an assembled and tested board costs approximately $60.00.

Preliminary cost analysis shows that the POS-1 system can be marketed for less than $500.00

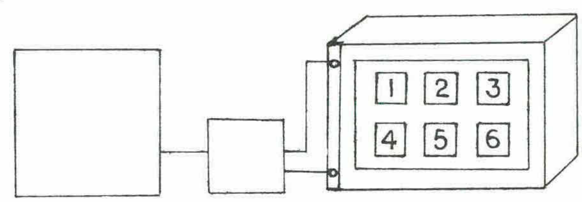

Figure 1: The POS-1 system.

Testing

Testing of the laboratory prototype is underway in cooperation with the Department of Communication Disorders at the University of Vermont. The Department has extensive experience with disabled person's communication problems, especially cerebral palsy.

ACKNOWLEDGEMENTS

The development of the POS-1 system has been made possible by an internal R & D fund provided by Position Orientation Systems, Ltd.

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ADDRESS

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PRESENTATION OF DEVICE FOR PRODUCTION OF CONTINUOUS PASSIVE RANGE OF MOTION IN THE HUMAN KNEE

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Robert K. Clifford, Jr., M.D., Resident, Division of Orthopedic Surgery
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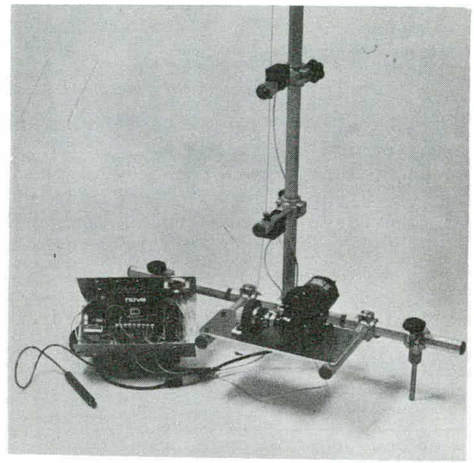
INTRODUCTION

The idea of continuous passive range of motion (CPROM) for the treatment and rehabilitation of a variety of orthopaedic conditions and injuries has been gaining ever-increasing acceptance in recent years. CPROM has been shown already to increase the quality and rapidity of healing in full-thickness articular cartilage defects in the rabbit[1] and to increase the speed of recovery of motion in total knee replacement patients[2]. Other hypothesized benefits include decreased pain, increased speed of healing of tissue, decreased swelling of the extremity and decreased thromboembolic phenomena.

Our objective was to build a simple, safe, inexpensive device that could be readily attached to existing orthopaedic trapeze hardware and would provide CPROM of the knee in patients with intra-articular and peri-articular fractures treated by open reduction and internal fixation.



EQUIPMENT DESIGN

A Bodine motor with a 240:1 gear box ratio developing 1/50 horsepower was selected. Controls consisted of a modified B&B Nova control apparatus allowing for variation in minimum and maximum speed, acceleration, and torque. A patient "panic button" was incorporated in series with this control. A Polyclutch[R] Slipper modified to accept a cable spool was mounted on the motor shaft with the entire assembly fixed to a 1/4" aluminum plate. The control unit was enclosed in an aluminum housing with clear check/adjust windows to discourage tampering, yet allow easy variation of control parameters. Connection to the usual Thomas splint with Pearson attachment rig was achieved with 130 pound test cable passed through standard traction pulleys. The cable was directed along the outside of the vertical post of the trapeze where it was threaded through two modified microswitches allowing motor reversal by simply clamping a brass bead to the cable between them.

DESIGN CONSIDERATIONS

It should be noted that all materials can be mounted quickly to the outside of the standard orthopaedic trapeze apparatus with controls not readily accessible to passersby or the patient himself. This should interfere minimally with nursing care. The Polyclutch[R] Slipper allows the patient to resist the device without damaging himself or interrupting the continuous cycling. The easily adjustable microswitches allow for minute variations in any range, i.e. the knee may be moved from 0^{o} to 90^{o} or from 30^{o} to 70^{o} only.

PRELIMINARY EXPERIENCE

The device was used on a 30 year old male who had sustained a depressed left tibial plateau fracture treated with open reduction and internal fixation. Using the device 18 to 20 hours per day beginning 5 days post-operatively the patient noted decreased pain (verified by decreased analgesic ingestion), decreased swelling of the extremity, and a marked increase in the motion capable in that knee.

CONCLUSION

We have designed and built a safe, inexpensive, simple device usable in a variety of situations for CPROM of the human knee which can be easily incorporated into the existing orthopaedic trapeze apparatus generally available.

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ACKNOWLEDGEMENT

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AN ELECTRONIC READING/WRITING SYSTEM FOR THE VISUALLY IMPAIRED PERSON

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Amy Perkins, Student Research Assistant

Georgia Institute of Technology

The Georgia Institute of Technology in conjuction with the Veterans Administration has conducted research into the feasibility of a large print reading/writing system for the visually impaired that is a digital electronic analog of existing cassette braille machines. The system developed utilizes an electronic typewriter keyboard, electronic display and video output compatible with most CCTV equipment.

This project began with the survey of more than twenty potential users and gathered information about characteristics that the user would prefer to see in the final product. The first prototype was built at Georgia Tech and utilized an 1802 CMOS microprocessor, a forth (.2 inch high) character vacuum fluorescent display, an electronic typewriter keyboard and a cassette recorder for storage of material on cassette tape. It was possible to use this device to type in text materials, edit them, save them to cassette, and later read or edit them as the user preferred. Also a video board was provided to allow viewing on a CCTV display.

This first unit tested well in many of the human factors aspects expected by the users. Physical size was the largest drawback to the design.

Near the time that consideration was being given to rectify these shortcomings the Sony Corporation introduced the first battery powered word processor. We immediately procured one and quickly determined that much of the machine architecture was identical including the choice of the microprocessor and CMOS circuitry.

We therefore directed our efforts towards altering this existing $1400.00 machine to do as much as our survey indicated would be necessary in order to render utility to the visually impaired population that utilizes large print.

The device has been modified to provide an output for video display of information on a CCTV monitor. Also an output was provided for the same vacuum fluorescent display utilized in our previous prototype. This will allow the same flexibility and portability of use that we were attempting to obtain and still provide the increased utility necessary to the visually impaired user. Our efforts have been concentrated on minimal modification to the Sony Typecorder as it is called, and development of an add-on box housing the display and associated hardware to provide the essential outputs to the displays.

We therefore could not address the machine software and correct what might prove to be deficiencies in it. Among these apparent deficiencies is the absence of electronic search and replace or even electronic search for other than pages. Also the 80 character format may be somewhat confusing and awkward to use for some visually impaired persons.

It is felt that the advantages of obtaining a nationaliy distributed and nationally serviced product outweighed some of the user preferences. The system promises to provide good service at a reasonable cost of approximately $2500.00. That is indeed reasonable when compared to the present 40 cents per page for large print books.

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SONA, THE SONIC ORIENTATION AND NAVIGATIONAL AID FOR THE VISUALLY IMPAIRED

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The SONA system was developed at the Georgia Institute of Technology with funds provided by the Veterans Administration. It is an orientation and navigational aid for the visually impaired traveler.

The need for this device begins historically with the need for increased travel for the visually impaired in unfamiliar or semi-familiar surroundings. Mobility for a visually impaired traveler may be divided into three tasks: Cognitive mapping, orientation, and wayfinding(1). In unfamiliar or semi-familiar surroundings, orientation is the most difficult task.

Cognitive mapping begins before the traveler starts on his route and may consist of his own instruction set or a set of directions given to him. During the route it is necessary to have good orientation in order to place oneself on the cognitive map. This is done through a variety of mechanisms, mostly environmental cues. Wayfinding is the acutal technique of travel with the chosen aid such as a long cane or a guide dog.

The SONA project began with a series of semi-structured interviews with more than 60 visually impaired adults. These persons ranged in age from early twenties to late sixties. They had been visually impaired for a number of years and had a diverse background socially, educationally, professionally, and in terms of their mobility skills. The majority were articulate expressive persons with reasonable strong beliefs in what they stated during the interview.

Each person was first questioned concerning his mobility background, history of visual impairment, etc., then the system was described to him in a conceptual manner and in a user-operational manner. Each person would then react to a number of open ended questions concerning the system, its utility, and desired features.

The information gained was extremely helpful in several respects. First virtually none of those questioned used an electronic travel aid and only a few had limited experience with one. Most had strong negative reactions to such devices and considerable skepticism concerning the likelihood of there ever being a low cost usable device.

Their reactions to the SONA system, which was at that time a conceptual design only, can be considered favorable in that two thirds of the sample tested stated that they might well use the system if it were available. All requested that it make pleasant sounds, some that it talked, and all like the idea of the sounds coming from the destination rather than from themselves. None wanted to feel "looked at." The touch-tone configuration found great acceptance as did the feedback tones from the transmitter itself upon pushing any button. The range was acceptable, as was the three digit code concept.

In general, the population had no idea about cost and could not estimate its value to them.

The SONA system is an orientation aid being developed to provide the user with sure cues as to the location of many standard features in the environment. A receiver would be mounted at building locations such as elevators, exits, telephones, restrooms, information desks, and many other standardized places. Each receiver would be assigned a three digit easy to remember code such as 911 for emergency exits, 411 for information centers, 100 for building entrances, etc. The traveler would carry a calculator sized transmitter having a touch-tone keypad with which to transmit the chosen codes. Each transmission would elicit an audio response from that receiver assigned to its code assuming that the traveler is within 75 feet of such a receiver(2). A general code activating any receiver within range can be accommodated to allow the visually impaired traveler to determine that the facility is equipped with such a system.

The system provides the traveler with information that tells him that the facility he wishes is nearby and in exactly which direction it lies. By sound localization he may use his chosen wayfinding technique to "home in" on the sound. He receives a response from the receiver only when he transmits its code, therefore annoyance to others is minimized and he himself is not unduly embarrassed by being the source of strange sounds.

The tones generated by the receivers are musical in nature and designed to be pleasing though distinctive. The estimated cost for each receiver is expected to be competitive with tactile labeling. Each transmitter cost is expected to be approximately $50.00.

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AN UPPER EXTREMITY ELECTRO-ERGOMETER

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INTRODUCTION

Traditionally, ergometry has been performed with the use of a bicycle ergometer. This device was invented at the turn of the centry and lacks the sophistication of today's well equipped clinical lab.

It is simply a peddle-powered wheel that is braked mechanically by a belt running around the rim. The amount of power dissipated is a function of exercise speed, therefore constant RPM must be maintained for a constant load. In the ergometer discussed in this presentation the problem has been eliminated through the use of digital electronics. The device is more versatile than earlier egrometers as it can be used as a traditional exercise bicycle or as a means of studying the work tolerance of an individual using upper extremity power.

This new ergometer (Figure 1) was designed to meet the needs of evaluating and exercising paraplegics and lower extremity amputee subjects. The device permits the evaluator to select a power output requirement within the range of a few watts to 500 watts for the subject. Once the power requirement is set and the exercise speed is set the ergometer will maintain a constant power sink regardless of variation of ± 20 percent in the speed of exercise. The device internally compensates for friction in the mechanical system so that the power readout on the machine is accurate to ± 2.5 watts.

CIRCUIT DESCRIPTION

The heart of the system is a Kollmorgan D.C. motor that is used alternately as a generator and as a motor.

As a generator, the Kollmorgan produces an output voltage proportional to armature speed. A variable duty cycle pulse generator saturates a VMOS power transistor, thereby connecting the generator to a fixed resistancy load. The power produced in the load is calculated by squaring the voltage across the load. The output voltage of the squaring circuit is compared to a power set reference voltage and an error voltage is produced. The error voltage is used to control the variable duty-cycle generator and constant power is maintained within a large RPM range. Intergration is necessary over the cycle to correctly reflect true load power.

As a motor, the Kollmorgan is used during the time when the load is not connected. Just after the load is disconnected, a sample is taken of the motor voltage, which is proportional to motor speed. The losses in the overall system are nearly linearly related to motor speed due to the motor type. The speed sample voltage is summed with a zero-speed compensation voltage, and used with a constant current circuit to maintain a compensation power to reduce friction, windage, and other losses. The constant current circuit operates during the time the load is not connected.

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The Upper Extremity Powered Electro-Ergometer In Use by a Paraplegic Person

ACKNOWLEDGEMENT

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A POWERED MOBILITY AID FOR TWO-TO-FIVE YEAR OLDS WITH NEUROMUSCULAR DISORDERS

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INTRODUCTION

A major goal in rehabilitation is to provide independent mobility to severely disabled persons as soon as possible. There is, however, a paucity of knowledge and experience associated with the provision of powered mobility aids to very young children. Trefler and Cook (1980) identify reasons for this as:

i) the concept that children should be provided with a manual wheelchair if they have the potential to propel it, and

ii) young children do not have the maturity to duly respect an expensive technical item.

These reasons ignore the sometimes prohibitive energy cost to the child, the inability to move at functional speeds, and that providing the young child with independence should serve to facilitate teaching of responsibility.

A manually-propelled caster cart was first introduced at the Ontario Crippled Children's Centre (OCCC) in 1969 as a means of independent mobility for children in the 1 - 5 year age group with little or no lower limb function. The design places the child close to the floor to enable play with toys and interactions with other children who may be crawling. The need for a powered version of the caster cart became apparent when we were challenged to provide independent mobility for a group of lower extremity disabled children with the additional handicap of little or no upper limb function.

DESIGN CRITERIA

The following design criteria were decided on:
i) Vehicle and passenger to be as close as possible to floor level.
ii) Simple to operate for a two-year-old with average intelligence.
iii) Compact and highly maneouverable.
iv) Of modular construction to permit simple modification and adaptation.
v) Simple power drive.
vi) Capable of climbing a one-inch high, vertical obstacle.
vii) Sufficient power for a full day's use between battery charges.
viii) Sufficient torque to allow the vehicle and user to negotiate rough terrain, ramps, and gentle inclines.
ix) Capability to stop the vehicle quickly and prevent rolling when necessary.
x) Low centre-of-gravity to prevent tipping.
xi) Ability to adjust position and type of interface controller.

EXPERIENCE TO DATE

Five prototypes have been built with a sensitive joystick control (see Figure 1) and are presently being field tested (one for 15 months). Comments from the parents of one four-year-old highlighted the impact on the child and family of such a device. They note that their child is now able to exploit natural play opportunities and that he uses the vehicle, "almost like other four-year-olds use their legs".

Figure 1. Prototype miniature powered vehicle

It is our intention to evaluate the performance of children and the device in a more objective manner through regularly scheduled in-depth parent interviews and parent-generated documentation. We are presently constructing ten more vehicles for distribution to families whose children have lower-limb incapacity and upper extremity weakness.

FUTURE DIRECTIONS

By far the greatest population of severely handicapped children who could benefit from the availability of a miniaturized powered vehicle are those with cerebral palsy. It is our intention to develop adequate controls so that this group of children can benefit from the availability of independent powered mobility. Features to be incorporated include ramp up/ramp down, speed compensation between left and right motors, and the ability to use controllers other than joysticks.

Experience to date will be presented together with details of our program and control devices.

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ACKNOWLEDGEMENTS

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THUMB CONTROL INTERFACE FOR POWERED MOBILITY

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INTRODUCTION

Access to powered mobility was provided to a client with spinal muscular atrophy through the development of a thumb control interface. This interface optimized the one half inch diameter limited range of movement of the client's thumb and offered the same directional control provided by microswitch joysticks, plus the capabilities for selective speed control and an interface enable/inhibit function.

We often think of the joystick, either the micro-switch or proportional types, as offering access to powered mobility with minimal required force and range of movement. To some disability groups, and in this particular case spinal muscular atrophy, this amount of force and range of movement does not allow the joystick to be considered an appropriate interface for the more involved clients.

Some basic considerations for an interface that will simulate a micro-switch joystick's directional control while providing for lower exertion force and a smaller required range of movement are:

1) Speed Control. Because of the various anticipated manoevers of the wheelchair, independent selection of speed would be an asset.
2) Interface Enable/Inhibit. The interface should have ON/OFF capabilities to prevent accidental activation of the wheelchair, while the driver is attending to other activities.
3) Visual Feedback. Visual indication of the selected speed range, ON/OFF status as well as directional feedback due to the small interface excursions, is required.

DESCRIPTION

To fully utilize the client's limited movement of her thumb, a splint was constructed to stabilize her forearm and wrist and also to ensure the proper and repeatable orientation of her thumb with respect to the interface. The control portion of the interface consists of a polycarbonate ring attached to the splint, and containing seven contact points on its surface to perform the various functions. A brass guaze thimble intimately fitted to her thumb serves as a ground reference for the interface. See Figure 1 for the physical layout of the interface.

The upper portion of the ring contains five of the seven contact points which are used as directional controls and are correspondingly represented on the visual display. Raising her thumb upwards and in midline produces a forward wheelchair movement, while increasing degrees of left and right thumb movements produce increasing degrees of wheelchair turning.

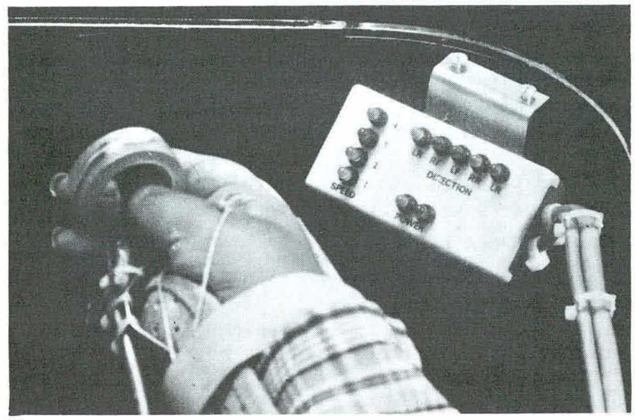

Fig. 1

A single contact point on one side of the ring serves to increment the speed range by one step each time it is contacted, through four possible speed ranges.

The final contact point is contained at the bottom of the ring where the thumb would normally be at rest. This contact represents the OFF or inhibit contact which prevents any of the directional controls from being activated. As described earlier the interface should not be accidentally activated when in the "OFF" state. To meet this criterion, the "ON" state can only be achieved by contacting each of the directional contacts in sequence and within a two second time frame.

A visual display mounted under the polycarbonate lap tray provides instantaneous feedback for direction, speed range and interface ON/OFF status.

The electronic circuitry associated with the thumb control interface is contained within the O.C.C.C. interface power control unit which provides ramp speed control (controlled acceleration rate) to the motor drive units.

CONCLUSION

The client has demonstrated proficient use of this mobility system, in fact, equally as proficient as good joystick interface users. The thumb control interface provides an effective means of accessing powered mobility for those clients who have very limited range of movement and exertion force.

ACKNOWLEDGEMENT

The author would like to thank the Muscular Dystrophy Association of Canada for funding the development and provision of this interface. The Powered Mobility Programme is funded by the Metropolitan Toronto Police Association.

ICE HOCKEY FOR ARTHROGYPOTICS

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SUMMARY

Two severely handicapped boys are able to move about unassisted on an ice surface in their electrically powered wheelchairs by the application of a traction device to the wheels of their chairs. As well, a simple rotating mechanism was designed to fit onto their chairs allowing the boys to shoot and pass a puck independently.

INTRODUCTION AND SCOPE

Arthrogyposis is a hereditary disease confining the subject to a wheelchair. Varying degrees of the handicap are possible, ranging from a form of paraplegia to quadriplegia. Two arthrogypotic brothers, ages 5 and 9, provided the impetus to design a mechanism that would allow them to play ice hockey. The five year-old boy had no strength in his lower body, arms or hands, although good strength was found at his waist and shoulders. The elder brother had the advantage of partial movement of his arms and hands. The severity of the disease required the boys to be in their electrically powered wheelchairs. The design requirement was twofold. First, a method of providing traction for the wheels on ice was needed, and secondly, a mechanism was necessary to allow a hockey stick to be manipulated.

TRACTION DEVICE

A search of the current market indicated that no special wheels or wheel coverings for wheelchair traction on ice was available. The two boys had different types of wheelchairs requiring different mounting approaches of the traction device. The younger brother had a Beck chair with seven-inch diameter hard rubber wheels, while his brother had an Everest & Jennings model with two-foot diameter pneumatic tires. The principle used for traction on each chair was the same, just a different method of attachment was used. Traction was obtained by imbedding steel studs into low modulus rubber. The rubber was attached to a metal frame, which in turn covered the perimeter of the wheel. The studs are flush with the rubber when unloaded. As the wheel rotates and a load exerted, the rubber compresses and the studs protrude into the ice. The metal frame keeps the studs from being pressed into the wheel. As the load is released, the rubber expands, pushing the accumulated snow off the studs. For the Everest & Jennings chair, the metal frame consisted of a circular ring. To insert the traction device, the tire was deflated slightly, the ring slipped onto the wheel and then the tire inflated again. Radial pressure from the tire keeps the traction device from coming off. A slotted ring frame with an adjustable clamp was made for the Beck chair with solid tires for mounting the traction device. Both devices are shown in Photo 1.

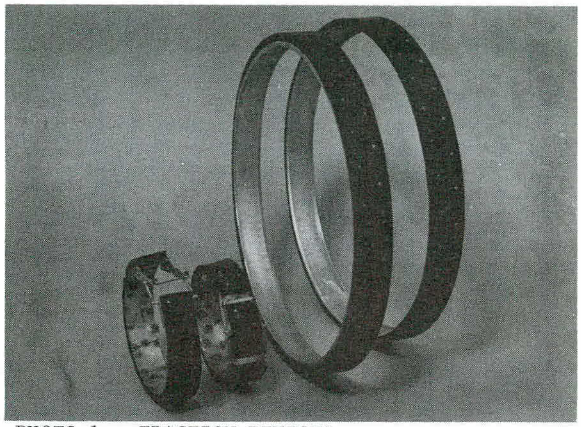

PHOTO 1 - TRACTION DEVICES

HOCKEY STICK MECHANISM

In an effort to make as much use of the youngsters' own abilities, a simple one-degree of freedom rotating mechanism was built and tested. The device consisted of a lever arm rotating about a pivot. The pivot was rigidly attached to one side of the chair, while the hockey stick was mounted on the lever arm. The older subject manipulated the stick with his arm. His younger brother required a mechanical attachment to his body which allowed him to use his shoulders to shoot the puck. A pair of shoulder pads and a connecting rod completed the necessary equipment. Photo 2 shows the two brothers facing off with the assistance of their teacher and friends.

PHOTO 2 - BROTHERS FACE-OFF IN SCHOOL YARD

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Lifting Barriers for Physically Handicapped Farmers

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National Safety Council data for 1980 showed that agriculture is now America's most hazardous occupation with respect to the total number of work-related fatalities and disabling injuries.[1] The same data suggests that approximately 1 to 3 percent of all full-time farm operators have suffered permanently disabling injuries due to farm-related accidents. A recent survey of Indiana farm operators indicated that 3 to 5 percent have permanent disabilities and another 17 percent are unable to perform essential farm-related jobs because of physical handicaps.[2]

In addition to the obvious physical handicaps, often resulting from farm accidents, farmers are also affected by other health-related handicaps which restrict their ability to effectively operate and maintain farm equipment and complete other essential farm tasks. These include:[3]

1. Cardiovascular diseases and disorders which limit lifting, climbing or extensive use of arms but allow tasks such as walking and driving. Heart conditions are considered one of the most common handicaps limiting a farmer's ability to work.

2. Dust and mold allergies which make completion of some farm operations, such as grain harvesting or working in a livestock confinement building, extremely uncomfortable or impossible without special respiratory protection.

3. Back and spinal problems which are aggravated by heavy lifting, certain types of farm equipment seating, tractor vibration and tasks requiring considerable bending such as milking cows and baling hay.

4. Arthritis and other diseases of the joints which limit the range of motion of the fingers, arms, and legs.

To assist physically handicapped farmers who desire to remain active in their farm operation, Purdue University's Department of Agricultural Engineering has initiated a project designed to:

1. Determine the proportion of active farm operators who have physical handicaps.

2. Identify the types of physical handicaps which hinder active farm operators in completing essential farm-related tasks.

3. Evaluate essential operating and servicing procedures on modern agricultural equipment to identify design factors which reduce or contribute to the barriers facing physically handicapped farmers.

4. Develop, identify, and compile practical alternative designs, modifications, and accessories to aid the physically handicapped farmer in operating agricultural equipment and completing other farm-related tasks.

5. Establish a resource center designed to compile and distribute relevant information to physically handicapped farmer's and their families inorder to assist them in remaining productive in an agricultural setting.

Removing, or even reducing, the barriers for handicapped farmers will require the cooperative efforts of a number of disciplines to solve the many economical, physiological, psychological, and technological problems involved. Considering the small population of handicapped farmers and their wide dispersion across rural America, the task of focusing the necessary expertise on their problems will be extremely difficult. It is nevertheless clear that the potential benefits to many handicapped farmers from modern rehabilitative techniques remains largely unrealized.

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ACKNOWLEDGEMENT

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UTILIZATION OF REHABILITATION ENGINEERING SERVICES BY VOCATIONAL EVALUATORS

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Rehabilitation Engineering and Vocational Evaluation Services are relatively new branches of the rehabilitation process. Both are service delivery programs with a goal of helping handicapped individuals become productive members of society. Each service is an important component in the team approach to rehabilitation.

At Woodrow Wilson Rehabilitation Center (WWRC), an individual's program is coordinated to include a multitude of services that are essential to his total success in rehabilitation. Approximately one thousand individuals received vocational evaluations in the 1981 fiscal year; in only five (.5%) cases was the rehabilitation engineer consulted. Discussions with the staff of 10 evaluators have unveiled several factors that may be affecting the lack of improvement in the working relationship between these two services. Perhaps review of these discussions may benefit other programs that are hoping to initiate similar services.

The most essential ingredient needed for improvement of interaction between Vocational Evaluation and Rehabilitation Engineering Services is more education. This needs to be a two-way exchange that can improve the knowledge of both the evaluation staff and rehabilitation engineering staff. One way to initiate this process would be to schedule one day a month that the rehabilitation engineer could work in the vocational evaluation laboratory. This would allow the rehabilitation engineer to better understand the philosophy of evaluation, what is being accomplished, how the equipment is being used, and how evaluators' time is scheduled. It would also allow the evaluators time to get acquainted with the rehabilitation engineering staff, ask questions without all the need for paperwork, show them specific problems to see if improvements can be suggested, and become accustomed to using the service. The time needed for this service should decrease to half a day after several months.

Another suggestion would be to develop a formalized protocol with a minimal amount of paperwork needed. If the Rehabilitation Engineering staff was just a phone call away, services could be coordinated easier and quicker and the necessary paperwork could follow.

Rehabilitation Engineering Services might attempt to use the vocational evaluation staff and facilities as a testing board for some of their clients to see if improvements are occuring. This could be especially effective with clients who eventually get evaluated in the department.

The engineering staff could help increase the recognition of appropriate cases by giving specific examples of services that have been provided for disabilities that are frequently seen in evaluation such as emotional, mentally retarded, brain injured, epilepsy, diabetes, etc.

The supervisors might develop a performance criterion for utilization of new services. It could be a Management and Planning Systems (MAPS) objective to see that those standards are met. If an employee can receive merit increases as a result of utilization of the services, it would increase the incentive to use the services.

A utilization percentage needs to be developed to be used as a guideline for the number of clients in evaluation that need Rehabilitation Engineering Services. A 5% utilization of Rehabilitation Services would be a tenfold improvement over WWRC's 1981 figures, but might represent an appropriate utilization for other evaluation centers. This actual percentage should be developed with the combined efforts of the supervisors of both departments.

A concrete guideline might be supplied as to the costs for consultation, departmental visit costs, advice per telephone conversations and, if possible, an estimate of overall costs of a specific service should be supplied on consultations.

Last, but not least, a client's role in Rehabilitation Engineering Services needs to be established. Should the Rehabilitation Engineering Service be used as a primary source of getting a client in the first immediate job available or should it be part of a total evaluation that looks for a person's full potential? Should the service be used as a means of finding immediate abilities even against a client's will or be used only with the request of the client? These and other questions need to be answered before an optimal working relationship can be developed between these service delivery programs. The first step toward improving this relationship might be to implement the recommendations made in this paper.

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PLACEMENT OF SEVERELY DISABLED PERSONS: MULTI-DISCIPLINE TEAM COMPARED TO REHABILITATION COUNSELORS

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Introduction

The Rehabilitation Act of 1973 has mandated that state vocational rehabilitation agencies prioritize their services to those persons who have a severe disability. In order to effectively place the severely disabled through the use of more sophisticated placement techniques, a few rehabilitation professionals are calling for a new type of professional in rehabilitation. Recognizing that the new placement techniques would involve such things as job modifications and/or adaptations and job accommodations, the need for a rehabilitation worker skilled in engineering was identified.

The Problem

The purpose of this study was to determine if the utilization of a multi-discipline team utilizing bio-engineering techniques was efficient as well as cost-effective in placing severely disabled persons when compared to the traditional placement methods of public vocational rehabilitation agencies.

Procedure

This study was conducted in five midwestern metropolitan areas. The sample for the study was 28 severely physically disabled persons who were ready for placement. Matched pairs were established between subjects for the multi-discipline team and a control group. Successful and non-successful placements were recorded for each group. Further, cost information was maintained for each subject in their placement activities.

A sign test was used to distinguish the differences of the placement rates of the groups. A correlated t test was used to determine the difference in the cost-effectiveness of the two groups.

Findings

In testing the research hypotheses at the .05 level, a significant difference was found between the multi-discipline team and the rehabilitation counselors for the placement rates in the placement of severely disabled persons. There was not a significant difference between these two groups in the cost of placement services for severely disabled persons.

Conclusions

Two general conclusions were drawn from the findings of this study.

1. The movement of severely disabled persons into productive employment was improved through the use of a rehabilitation team that utilizes low cost bio-engineering techniques.

2. The cost-effectiveness of a specialized rehabilitation team over the traditional placement methods of a state's vocational rehabilitation agency cannot be fully substantiated.

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And supported by:

Rehabilitation Education and Services Branch
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THE USE OF MICROCOMPUTERS IN THE ANALYSIS OF GAIT

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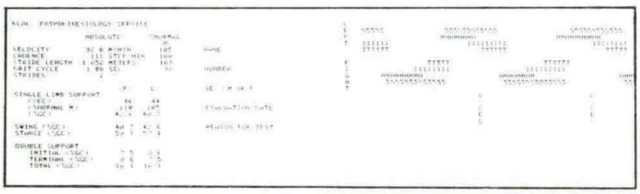
A real need has existed for the development of compact, easily operated and reliable gait analysis systems for use in the standard clinical environment. The powerful microcomputers available today made this goal technologically possible. This paper describes three systems which were conceived to meet this need.

FOOTSWITCH STRIDE ANALYZER

The Footswitch Stride Analyzer is a microprocessor based computer system designed to record foot-floor contact data and calculate all of the gait parameters obtained from these data. This system permits testing the patient in any convenient walking area and provides an immediate printed record. Both development and clinical trials have been completed. The system consists of footswitches, triggering lights, a recorder module, and a calculator unit. The footswitches create the foot-floor contact data required to determine the stride characteristics and the foot support patterns. The triggering lights provide the signals which control the recording of data over a six meter walkway.

The recorder stores the elapsed time of a run as well as the footswitch patterns and the times they change. It is powered by a nine volt transistor radio battery and attaches at the patient's waist by a velcro belt. A low power RCA 1802 microprocessor controls the storage of data in a 1K byte random access memory (RAM).

The calculator is a desk top unit powered by 115 volt AC line current. It transfers the data stored in the recorder into its own memory, checks for footswitch conditions which would modify the results, computes the gait parameters, and prints a record of the changing footswitch patterns. An RCA 1802 microprocessor with 4K bytes each of RAM and PROM is used in the calculator.



TYPICAL STRIDE ANALYZER RECORD

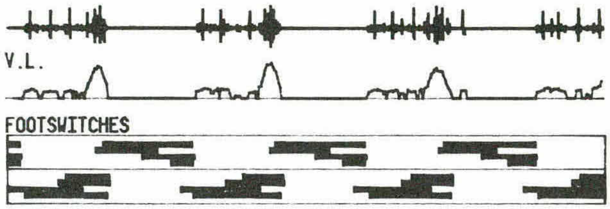
EMG ANALYZER

Patients with gait problems due to stroke, CP, spinal cord injury, and head trauma can show an improvement in their ability to walk through surgical reconstruction. Critical to performing the proper procedure is an accurate definition of the muscle action pattern. Relying solely on standard stretch tests too often gives insufficient information on which to base a surgical decision. Dynamic EMG is an effective alternate.

An EMG Analyzer is being developed for this purpose. It will process EMG signals from the leg muscles, correlating them with footswitch signals. It will detect clonus and rigidity, and determine if the muscles are contracting in normally timed patterns.

A biotelemetry system will be incorporated in the EMG Analyzer to allow the patient to walk unencumbered by data cables. A four-channel 8 bit A/D converter will digitize the EMG data at 2500 Hz. A microcomputer system with "Winchester" and dual "floppy" disks will control data acquisition and perform all data analysis. A graphics terminal will allow the user to enter patient and test conditions prior to printing.

An S-100 bus Z80 microcomputer system is being used for software development and testing. One of the new generation 16 bit microcomputers will be used in the final system. The data processing programs are being written in FORTRAN and can be easily converted to run on the new microcomputer.



RAW AND PROCESSED EMG WITH FOOTSWITCH PATTERN

PHASIC MOTION ANALYZER

Normal gait is characterized by a specific pattern of limb motion. Disability is identified by deviations from this sequence. Timing as well as the amount of motion is critical.

Stroke patients commonly exhibit a "stiff legged gait." Having great difficulty flexing their knee for swing, they drag their toe. Clinically it appears as if the knee were not bending at all, yet electrogoniometric measurements generally identify a good arc of knee flexion. These measurements indicate, however, that the motion occurred much too late to be useful for toe clearance at the initiation of swing.

To more clearly define the motion patterns, swing and stance have been broken up into seven subphases of gait which can be identified from footswitches. Local maximum and minimum values of knee and ankle angle will be determined by the system for each sub phase of gait.

The proposed Phasic Motion Analyzer will incorporate a microcomputer system to analyze bilateral flexion/extension data from knee and ankle electrogoniometers. An 8 bit A/D converter will digitize the data at a 500 Hz sample rate.

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REAL TIME BIOMECHANICAL POSITION SENSING BASED ON A LATERAL EFFECT PHOTODIODE

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In research leading to an ocular communication system at Tufts-New England Medical Center, a technique has been sought to provide the position and orientation of the head of a potential user. This information along with the orientation of the eye is used to compute the line of gaze which can then be used for visual selection of targets (e.g., the letters of the alphabet). Currently the project obtains this information via a 3-dimensional ultrasonic ranging device manufactured by the Science Accessories Corporation (1). While this device offers sufficient accuracy, it does not easily lend itself to a clinically usable system.

LATERAL EFFECT PHOTODIODE

An alternative has been explored in the form of a lateral effect photodiode manufactured by United Detector Technology Inc. (2). The photodiode is a 1cm x 1cm device that is capable of sensing light imaged on its surface. The diode has four electrodes on its edges. The photocurrent is divided among the electrodes in proportion to the relative distances from the image to the edges.

The photodiode has been purchased form United Detector Technology in a very usable form. The diode is mounted in a housing to which is attached a 28mm, f2.8 Pentax camera lens. A data acquisition circuit has also been provided which converts the values of current to voltage, and performs an analog to digital conversion. The resolution of this is 12 bits. The particular data collection circuit is compatible with the bus structure of the Apple II microcomputer.

PERFORMANCE

In laboratory calibration, the UDT device exhibited a 10 degree viewing cone with a sampling rate of 4HZ (with Apple soft Basic) and 2kHZ (with machine language code). The focus of the image is noncritical since the UDT photodiode senses the centroid of the image.

Although the A/D converter has a high resolution (16 bits), the stability of the signal is such that the working resolution is closer to 7 bits.

DEVICE IMPLEMENTATION

The sensitivity of the UDT photodiode is insufficient to detect a continuously illuminated infrared LED beyond 18 inches. A multiplexing circuit has been added that pulses a Telefunken (V194P) IR LED for 1 msec at 400 mA. The pulse duration is sufficiently long to be detected by at least one full sample (at 2 kHZ sampling rate). This allows the distance between the UDT detector and the IR LED to be approximately 5 feet. Multiple LED's can be pulsed in sequence, with the results plotted on the high resolution graphics screen of the Apple II. The data collection circuitry has the capability of supporting up to four photodiodes at one time. Using two diodes with appropirate optics, it is possible to compute the three dimensional coordinates of each IR LED.

The coordinates of three IR LED's mounted on the head (eyeglasses) are then used to compute the position and orientation of the head.

OTHER POSSIBILITIES

While the UDT sensor has been primarily considered for identifying head position and orientation, there are a number of other possible uses which can be speculated upon. Within the line of gaze project, the ocular orientation is sensed by means of a CCD photosensitive array. The UDT device is considerably less sensitive (by at least 2 orders of magnitude) than the CCD camera. A safety consideration with infrared illumination of the eye mandates that the illumination must be less than 10 micro watts per cm^2 for continuous data (3). The fast response time of the UDT can be exploited by pulsing the IR source at high power for short durations. This maintains the average power output at an acceptable level. The technique is being explored as a possible replacement for the more expensive and delicate CCD device.

Other potentially exciting uses of this device include the sensing of hand and limb position. This introduces the possibility of developing a portable (transportable) system for monitoring manual tasks, or measuring range of motion. It will also be conceivable to locate multiplexed light emitting diodes on both hands for the sensing of American Sign Language, thus opening the potential for telephone transmission of ASL.

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ACKNOWLEDGEMENT

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ADDRESS

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A NEW DEVICE FOR AN OLD FIELD: A PORTABLE FORCE MEASUREMENT SYSTEM FOR GAIT ANALYSIS

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The goal of this project was to conceive, design, manufacture, and test a device to assist in gait analysis. The device created provides accurate information about the loads supported by the various regions of the foot during gait, and yet is simple, inexpensive, and easily applied in a clinical setting where there is little sophisticated equipment. These advantages are unique to the system described herein. Many research facilities use an in-ground force plate, but these are expensive and not easily moved. There has been some work in which the transducers are loaded in the shoe, but these have either been expensive, or have required connection to a computer for data collection [1,2,3]. The entire system described in this paper is carried by the patient and thus is both simple to use (no elaborate external equipment is required) and flexible. The unit consists of four thin pressure transducers, placed in an insole, connected to an LED display for recording by either videotape or cinematography.

The force under a given part of the foot is measured by a single strain gage transducer. Four of these are available for placement under different regions of the foot - typically, one under the heel, one under the great toe, and two under the metatarsals. The transducers are only 5/32 in. thick and the insole in which they are set is 3/16 in. thick. Load is applied by the foot on plate 1 (1 in. square), thus inducing a bending moment in plate 2 (0.5 x 1.0 in.). See Figure A. A strain gage is located on the bottom side of Plate 2. The three plates are fastened together by Armstron A-12 epoxy and separated by pieces of piano wire (.031 in.).

The force-induced change in strain gage resistance is converted via a Wheatstone bridge to a voltage differential. Op amps amplify this to produce a 0-0.5 volt signal which controls a ten linear division LED driver chip. A simple coding sequence was devised which allows the ten divisions to be indicated by only six lights. The maximum force range, which is divided into ten segments, can be specified as either 100 or 200 pounds for each transducer. This system may also be switched to an analog mode and connected directly to a computer for precise data collection. The power which drives the LED's and much of the circuitry is from six AA rechargeable nickel-cadmium batteries. A nine volt battery provides the negative voltage supply to the op amps.

Our results are limited but supportive. The transducers respond linearly within the required force ranges. Frequency response has not yet been checked, but is expected to be fast enough to record all forces accurately except the heel strike spike. The coefficient of thermal linear expansion of the strain gages was matched to that of the beryllium copper so as to eliminate resistance fluctuations due to thermal changes. The insole with the transducers is quite comfortable and thus should not change patient gait patterns. Also, the weight of the total system (estimated to be three pounds) will not bother patients.

This system is unique in its simplicity, accuracy, complete portability, visual display mode, and low cost. Researchers in the University of North Carolina Department of Physical Therapy will be using the system for a variety of purposes and thus will establish its practicality. As clinicians in general begin to use more sophisticated techniques for analyzing gait, systems like this may well come into high demand.

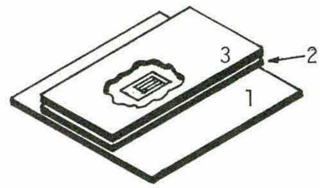

Figure A. Strain gage force transducer. Plates 1 and 3 are 1/32 in. thick, plate 2 is 1/24 in. thick.

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MOTION ANALYSIS AND LOAD-DEFORMATION TESTING OF THE IN-VITRO CERVICAL SPINE

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Introduction. For any specific cervical spinal instability there are a variety of different treatments described. There is little objective information available to evaluate which of the treatments is best.

This paper describes a computerized electromechanical testing instrument developed to study the flexion and extension mechanics of canine experimental cervical spine injuries and repair constructs.

Methods. The test shown on Figure 1 uses two or more in-vitro vertebral segments from the canine cervical spine. The distal vertebra (C4) is embedded in a polymethylmethacrylate (PMMA) base and securely clamped in a holding fixture. To apply a bending load (flexion or extension), a cable is attached to the body of the proximal vertebra (C2). The opposite end of this cable is attached to a lead screw and driven by a motor at a constant 2.5 mm/min rate of linear displacement. The lead screw is mounted on a strain gauge bridge instrumented load bar to measure the applied force. The bending force, applied until failure, causes a rotational and translational deflection of the proximal vertebra with an assumed center of rotation at the disk space.

Instrumentation. Early work used x-ray photographs and a strip chart recorder to collect data. This proved to be both tedious and expensive, and therefore has been replaced by a video system. To record vertebral deflection, several lights are attached to the test specimen. For the case of 2 or 3 vertebral sections, 6 lights are used: 2 are rigidly fixed to the proximal vertebra to record its deflection, 2 are attached to the load cable to determine the line of applied load, and 2 are fastened to the bench as a reference. The video camera then scans these lights frame by frame. The time interval between consecutive frames is determined by an internal clock set by the user. A digital camera interface is required to assign x-y coordinates to the lights. This data is then transferred to a host LSI-11 computer for angular deflection analysis and storage on a magnetic diskett. The simultaneous load bar output is also sampled and recorded.

It is also planned to replace the existing light sources with a fiber optic light system. Each fiber optic bundle will be encased in a .062 OD x .50 in. long stainless steel tubing. This change will hopefully allow attachment of the light source directly to the bone.

Results. On completion of each test the recorded data is analyzed. Load-deformation curves (Fig. 2) and motion trajectory of the lights (Fig. 3) are displayed on an HP-7221A digital plotter. (C4-C5 Vertebra shown on Fig. 3 illustrates relationship between vertebral displacement and movement of the light sources.) It is noticed that the slopes of the curves on Figure 2 demonstrate the normal spine to have a higher stiffness than the wire fixation. The strengths of the two spines are comparable. Both curves clearly show failure has occurred. As a result of this instrumentation, improvement in resolution and reliability in the load-deformation plots have been achieved. The time required to analyze the data is also reduced from several hours to several minutes.

Conclusion. 1) This experiment provides a comparison of the structural integrity of the various spinal fixations tested. 2) The video system and mini-computer provides improvement in experimental procedure.

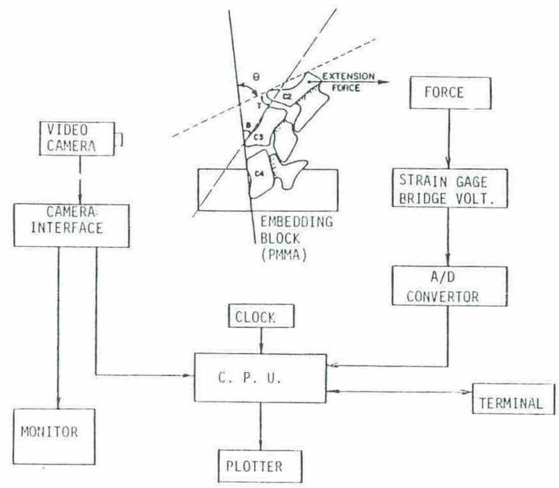

FIGURE 1. SCHEMATIC OF THE EXPERIMENT

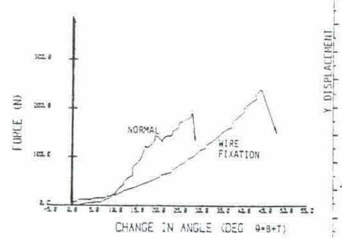

FIGURE 2. FAILURE CURVE IN FLEXION MODE (C4-C6 SPINE) CURVES FOR NORMAL AND WIRE FIXATION ARE SHOWN

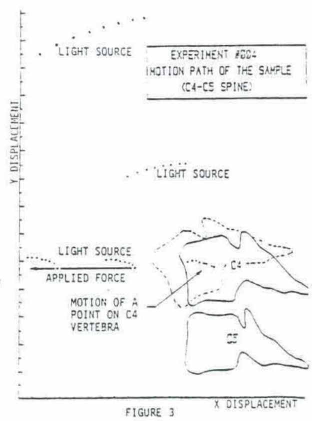

FIGURE 3

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THE PENETRATION OF ACRYLIC BONE CEMENTS INTO CANCELLOUS BONE

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Over the last few years, increasing attention has been focused upon the pathophysiology of loosening of total joint replacements.[1] Several studies have suggested that a fundamental factor involved in the initiation of loosening of the components of arthroplasties is the occurrence of movement at the interface between bone and the acrylic cement mantle.[2,3] For this reason, modern techniques for the introduction of bone cement into bone aim to maximize the degree of interlock between the cement and the cancellous network lining the implantation site.[4,5] Despite the apparent importance of cement penetration upon the long term success of joint replacement, few studies have examined fundamental aspects of the flow of bone cement into bone.

This study has examined the effect of the rheological and setting characteristics of cement formulations upon the depth of penetration of acrylic cements in cancellous bone in vitro. Cylindrical bone specimens were machined from the femoral condyles of cadavers and chemically cleaned and dried to remove all traces of fat, marrow and debris. Following measurement of the mean diameter of the inter-trabecular channels within each specimen, five commercial bone cements were infused into the cancellous specimens under a fixed external pressure of 5 psi at an ambient temperature of 22° C. After the cement had set, each specimen was sectioned longitudinally, and the mean length of the inter-trabecular channels and the depth of cement penetration were measured. In all, approximately 15 specimens were prepared using each cement. The rheological characteristics of each acrylic formulation were determined using an extrusion viscometer technique and the setting behaviors were characterized according to standard ASTM methods.

The depth of cement penetration within individual specimens was observed to range from 1.5mm to 8mm, due to the influences of trabecular structure and varying properties of the formulations. The choice of bone cement was found to significantly influence penetration in bone, particularly in coarse cancellous bone, two low viscosity cements displaying approximately double the osseous penetration of the other materials tested. Although cement penetration was observed to be independent of the porosity of the bone, a strong linear relationship was observed between penetration depth and the estimated volume of the inter-trabecular channels. In terms of the properties of the cements themselves, none of the setting parameters of the formulations (set time, dough time, working time) correlated significantly with depth of cement flow, though a strong inverse relationship was observed between the mean viscosity of the cement during its flow into the bone and its terminal depth of penetration.

It was concluded on the basis of this experimental study that the interlock of bone cement in cancellous bone is fundamentally limited by the magnitude of viscous drag upon the cement mass flowing through the inter-trabecular spaces. Consequently, cements of lower viscosity during the working stage offer the potential of greater interlock into bone provided that adequate pressure may be generated at the acrylic/bone interface. It is postulated that the set time of bone cements has little influence upon the depth of cement flow because penetration is limited by viscous forces opposing flow and not the setting of the cement mass during penetration. As the process of cement intrusion occurs over a limited period immediately following pressurization, it is suggested that if a formulation remains plastic until the critical shear stress needed to initiate flow exceeds that generated by the available driving pressure, subsequent changes in the cement will not affect the depth of penetration ultimately attained.

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The Effectiveness of Preventive Management In Reducing the Occurrence of Pressure Sores

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Pressure sores no longer need be an inevitable consequence of physical disability. However, their occurrence continues to be a major obstacle to the long term rehabilitation of individuals with impaired mobility and lack of sensation, especially those with spinal cord injury. The traditional approach to management of this problem consists of medical treatment of the sore once it has developed into a clinically significant problem. In the past, people were admitted to hospitals under intensive nursing care in order to cure pressure sores once they had occurred, with minimal attention during treatment to the prevention of future skin breakdown. Consequently, this acute care model of service delivery was associated with a remarkably high recurrence rate of pressure sores among the population at risk.

The experience at TIRR, a hospital specializing in comprehensive rehabilitation of persons with severe neuromuscular disabilities (primarily spinal cord injury) is typical of many similar facilities. Prior to 1974, some 75% of patients admitted for treatment of pressure sores returned with a recurrent breakdown within 24 months of discharge.

In 1975 not being satisfied with statistics such as these, the hospital, in conjunction with the Rehabilitation Engineering Center, started to develop a program of pressure sore management that emphasized prevention rather than treatment. The core of this approach has been education, first and foremost, the disabled person and his family have been provided with practical guidance concerning their responsibilities for preventing a sore. A second vital aspect has involved education of other members of the health care team about our understanding of the factors that contribute to soft tissue breakdown and how in this regard, rehabilitation engineering has provided a significant contribution through the development of techniques to establish the risk of each individual developing a pressure sore and the establishment of objective methodologies for the prescription of devices that aid in the individuals prevention program. In contrast to the short term, unscheduled, interactions between the disabled person and the health care professionals that are characteristic of the acute medical treatment model, the prevention program requires an extended series of scheduled and follow-up contacts to reinforce the information provided in the education session and maintaining adequacy of the devices that were provided in the initial assessment.

Since its inception over 300 people have participated in the TIRR program and the 24 month recurrence rate has been reduced to approximately 35%. This reduction in pressure sore recurrence translates into a calculated savings of approximately $8 million that would have been spent on pressure sore surgery. The impact of this reduction is further accentuated when the social costs associated with pressure sores are considered. These costs include: 1) time lost from a productive vocation with its attendant economic impact on individual and family, 2) time lost from school which has far reaching and long term impact as the disabled person's vocational potential is limited which generates long term dependency, 3) loss of time from the family which can have a significant psychological impact on the person's social development and 4) loss of general personal independence and productivity that ultimately contributes to a serious loss of self esteem and self worth.

Our experience indicates that the technology and knowledge developed in the Tissue Pressure Management Program has led to a new independence for many disabled individuals. For these people both the specter of pressure sores has been reduced and a new continuity has emerged in family, social and vocational lives which was previously unknown.

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Relationships between interface pressures and interstitial tissue fluid pressures over the ilia and lumber region of pigs.

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Decubitus ulcers present an important clinical problem involving a wide range of patients with spinal cord injuries, amputations and many forms of debilitating disease. The lesions pose serious obstacles to the rehabilitation of these patients and are extremely costly in both time and money. One of the principal inciting factors is believed to be increasing tissue pressure over "critical areas".

Clinical engineers have made use of the concept that reducing the interface pressure between the skin and a cushion will reduce the incidence of ulcer formation and this approach has been proven valid. However no experimental studies exist which demonstrate how the interface pressure is related to interstitial fluid pressure under load conditions. The objective of this study was, using the white haired pig as a model, to describe the interface pressure to interstitial fluid pressure ratio over the wings of the ilia and the dorsal spinous process of the last lumber vertebra under 2 different externally applied loads.

Data were collected during three separate experiments from 18 white haired, female, weanling, anesthetized pigs. After anesthesia the pigs were positioned over a plexiglas elevated tray. This provided elevation of the wings of the ilia for easy access during external loading and also included a radiopaque marker with which the animal could be aligned, using a fluoroscope, to insure constant positioning of every animal tested. A 10x13x23 cm firm foam pad, with a 3 cm, at the base, triangular notch, was placed over the ilia with the notch over the spine. The notch was used to distribute more of the load to the wings of the ilia, which provide a less complicated geometry for purposes of tissue deformation analysis. The pad extended beyond the sides of the pig so that edge effects were minimized. A 10 cm wide, 1.5 cm thick, plexiglas plate was placed over the foam pad and weights were suspended from each side of this pressure applicator. Loads of 4 and 8 kg were used.

Modified wick-in-needle catheters were inserted exactly over the point of the wings of both ilia and the dorsal spinous process of the last lumbar vertebra and their positions were verified fluoroscopically. During the no load conditions interstitial fluid pressures were found to be negative with respect to atmospheric pressure, a result agreeing with published work (Table 1).

Interface pressures were measured using a balloon catheter connected to a Stathem P23Db pressure transducer by a continuous water column. A 3x5 grid with 2.5 cm^2 squares was drawn over the back of each pig. Positions identified as 2B, 3B, and 4B were located directly over the left ilium, the dorsal spinous process of the last lumbar vertebra and the right ilium, respectively. Interface pressure data over the three points of interest were compared using an analysis of variance. At 4 kg loading no statistically significant difference was seen between or among the three points. With the 8 kg load the interface pressure over the dorsal spinous process was significantly higher than that measured over the wings of the ilia. Table 1 shows the interface pressure, the interstitial pressure, both in cm H_2O, and their ratios for the 2 different loadings, over the 3 points of interest.

TABLE 1

		POINTS		
		2B	3B	4B
Baseline (no load)	interface	0	0	0
	interstitial	- 1.29	- 1.00	- 1.29
	ratio	0	0	0
4 kg load	interface	39.00	53.35	39.76
	interstitial	146.7	122.8	143.1
	ratio	3.75	2.30	3.60
8 kg load	interface	61.79	110.38	57.71
	interstitial	218.3	249.8	196.1
	ratio	3.53	2.26	3.40
load off	interface	0	0	0
	interstitial	- 1.00	- 1.11	- 2.41
	ratio	0	0	0

These data indicate that the use of interface pressures alone may be insufficient in determining how the tissue responds to external loading. However, if the ratio between interface pressure and tissue pressure is constant over a wide range of loading conditions, for a particular anatomic site, it may be possible to predict tissue pressures from measured interface pressures.

This work supported, in part by NIHR #23-P-5788.

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DEVELOPMENT AND EVALUATION OF A UNIVERSAL CONTOURED CUSHION

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INTRODUCTION

Seating and positional needs of the wheelchair dependent population vary according to the nature and severity of the disability. The present day, conventional wheelchair provides little in the way of either body support or prevention of soft tissue trauma for individuals who exhibit extensive loss of sensory feedback or motor function. In an attempt to have an optional seating system, prototype was first developed by taking plaster of paris impression of the seating area in spinal cord injury patients. From those impressions a composite profile was derived and later a plaster of paris model was fabricated. Several stages of development (Mark VIII) since 1977 resulted in making available the present mold with pressure relief under ischial and coccygeal area, insertion of a intracushion insert in femoral and lateral gluteal region, an elevated pommel for hip abduction and recessed thigh contours. This provided a universal contoured cushion with inbuilt postural stability and redistributed weight from ischial and coccygeal areas to the fleshy under surface of proximal thighs. The new profile helped to reduce the humidity build-up throughout the groin and penischial region also.

METHODS AND MATERIALS

The cushion was fabricated out of 2 parts polyurethane foam of 2 psi density with an insert of Ethafoam-220. The cushion has been designated as VASIO-P (Veterans Administration Seating Interphase Orthosis). Subjective and objective evaluation were done on about 100 patients. Sitting pressures under ischii, trochanters, coccyx and underneath thighs were evaluated using balloon with copper grid (Scimedics, Inc.).

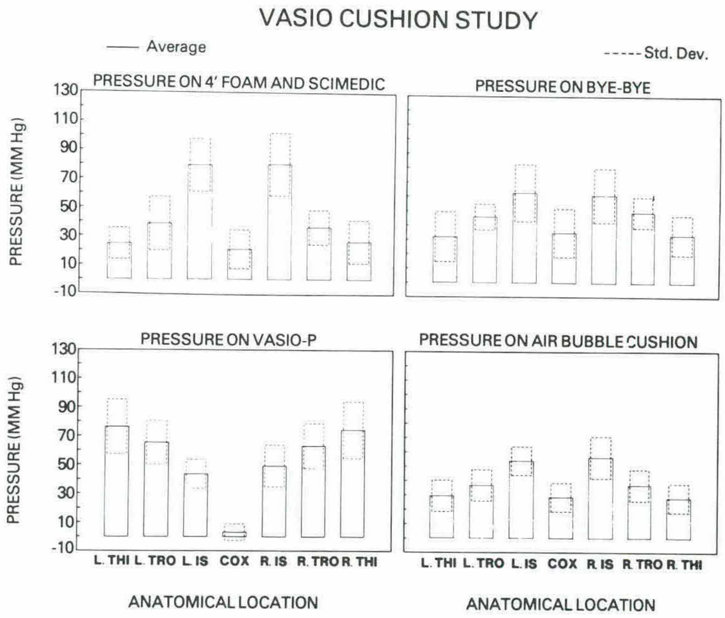
RESULTS

Figure shows comparative pressures on VASIO-P and on 3 other commercially available cushions. It indicates selective redistribution of weight from ischial area to under surface of thighs. The positive responses continue to be stated upon periodic contact for follow up: There are 16 patients who have used the cushion for over 1 year, 6 for 9 months, 4 at 6 months, 11 for 3 months and 11 for over 2 weeks. Early in the trial, 2 quadriplegics showed mild skin erythema. Therefore this version of cushion at present is only recommended for paraplegics. Difficulty in transfer was reported by some patients because of the raised pommel. However it was still favored since it obviated the need for a knee spreader.

DISCUSSION

As a result of many changes in the design and concept, it was decided to name the cusion the "Veteran's Administration Seating Interface Orthosis (VASIO)." To consider it an orthosis is appropriate since it affects the long range management features which promote good body alignment through pelvic stabilization. To distinguish between the system adopted for paraplegics and that for quadriplegics, the letters P and Q is being used respectively: e.g., VASIO-P or VASIO-Q.

As anticipated, the improvements in posture, balance, comfort and practicality have proven to be the most desirable features of the VASIO-P. These improvements result in greater ease for traveling over rought terrain, wheelchair manipulation, enhancement of two-handed and table top activities, and the long-term benefit of deterring pelvic/spinal malalignment and related biomechanical sequelae.



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Real time determination of ^{81}Rb/^{81m}Kr ratio to measure blood flow in subcutaneous tissues under pressure

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An adequate description of the physiopathology of decubitus ulcer formation must include a quantitative description of tissue pressure and deformation correlated with tissue blood and lymph flow. To make noninvasive measurements of blood flow in subcutaneous tissues over a bony prominence we have investigated the unique characteristics of Rb-81 and Kr-81m.

When injected into an artery Rubidium will equilibrate with intracellular potassium in the tissue bed being perfused. We conducted preliminary studies which showed that following iliac artery injection in dogs more than twice as many counts were obtained from the injected leg versus the opposite leg. In the cells the Rb-81 decays (t/2 4.58 h) to Kr-81m (t/2 13 s). Both Rb-81 and Kr- 81m give off high energy gamma rays. The instantaneous ratio of Rb-81 to Kr-81m activity should vary directly with tissue perfusion, since the inert Kr-81m will be transported away from its site of origin at a rate proportional to the perfusion of those tissues.

NaI detectors provide the necessary efficiency for counting these isotopes but their energy discrimination is inadequate for the clear resolution of interfering peaks. These peaks arise from the contaminants present in the commercially available Kr-81m gas generator. Most prominent among these is Rb-82m, (30-40% of the Rb-81 activity). A solution to this problem was found by multiplying a correction factor times the counts summed over a region containing the unresolved peaks of Rb-81 and Rb-82m. The correction factor was obtained for each sample by counting the spectrum using a GeLi detector (figure 1). The factor represented the fraction of the total region counts attributable to Rb-81 at any given time.

The NaI probe was interfaced to a PDP 11/34A which controlled data acquisition and performed data analysis. Software was written to take data in the real time ratio mode. Data acquisition was interrupted at preset intervals and the counts summed in preselected energy windows corresponding to the Kr-81m and Rb-81 photopeaks. Background and scatter corrections were made by the linear interpolation method. The previously calculated Rb-82m contamination correction factor was decay corrected and applied to the data. Dead time correction was made, the Rb-81/Kr-81m ratio was calculated and normalized and the ratio printed out.

The computerized counting system was used to investigate the relationship between Rb-81/Kr-81m and flow both in vitro and in vivo. Phantom studies were done in which a small amount of Rb-81 activity was trapped in a cation exchange resin bed through which a regulated flow of deionized water could be maintained. An S-shaped curve of Rb-81/Kr-81m ratio versus flow was obtained (figure 2).

In vivo studies were done using anesthetized dogs. Hind limb flow was controlled by constriction of the surgically exposed iliac artery.

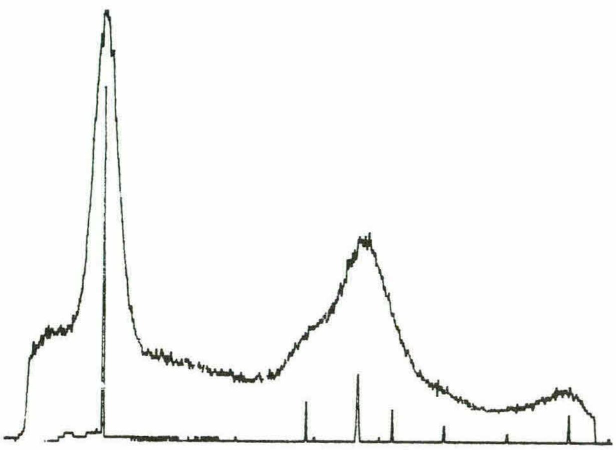

Figure 1: NaI Kr-Rb spectrum superimposed over GeLi spectrum. 1 = Kr-81m peak; 2 = Rb-81 peak; 3 = 511 keV from Rb=81 and Rb-81m; 4 - Rb-82m peak.

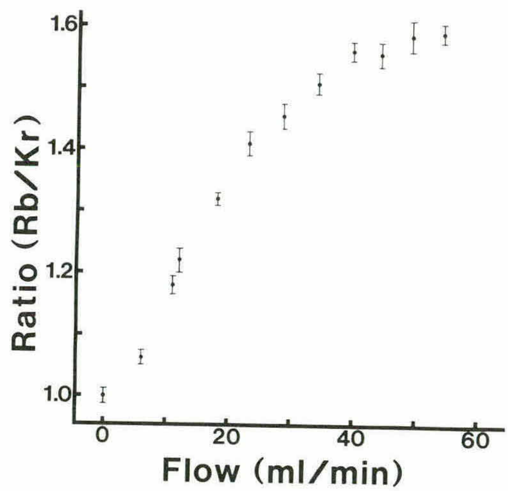

Figure 2: Rb/Kr ratio verse flow from resin bed phantom.

Rb-81 activity was introduced by direct injection into the artery. No statistically significant change in the Rb-81/Kr-81m ratio could be observed between free flow and constricted flow in either the large thigh muscle mass or the paw. In these areas the maximum flow expected would be less than 1 ml/min per gram of tissue. When this was related to flow per unit weight of resin in our phanton it was seen that the tissue flow variation is too small for detection by the ratio technique.

This work supported, in part by NIHR grant #23-P-5788 and a Burroughs-Wellcome Travel Grant.

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LOAD BEARING CHARACTERISTICS OF LUMBAR FACETS WITH IMPLICATIONS TO LOW BACK PAIN

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INTRODUCTION

Lumbar apophyseal joints have been shown to play a critical role in the stability of the lumbar spine. Facet joint instability and degenerative changes have long been implicated in the etiology of low back pain. A better understanding of the load bearing characteristics of facets may provide significant biomechanical insight into facet joint instability and degeneration. The load bearing role of facets has been of considerable interest in the past. Past studies, however show a large variation of data. All of these studies have obtained facet loads by subtracting intradiscal load from total axial load. Since there have been no direct measurements of facet loads to date, there is no data available on contact area, peak pressures and pressure distribution across the facets in normal or degenerated spines. This paper presents experimental findings based upon direct measurements of facet loads, contact area, and peak pressure values at the facet joints for neutral (end plates parallel) and extension (6-8 degrees) positional modes of lumbar segments L2-L3 and L4-L5. These segments were subjected to compressive loads of 20, 40, 70 and 140 Kg. The effect of unilateral facetectomy on the above parameters is also reported.

METHODS

A total of six fresh frozen specimens were used. Each specimen was mounted in metal cups and an axial compressive load was applied to the superior vertebra using an Instron machine. Contact pressures were quantified using a contact pressure-sensitive film. This film was inserted between the articulating surfaces of the two facet joints prior to placing axial load on the motion segment. The posterior portions of the facet capsules were incised to the height of the joint to facilitate the insertion of the film. A scanning device and desitometer were used to measure the contact area and pressure distribution of the film.

RESULTS AND DISCUSSION

The results of the experimental study are reported based upon the mean values at L2-L3 and L4-L5 levels. The facets at L2-L3 generally take more load than those at L4-L5 in neutral as well as extension mode. In extension, the normal load at facets is always higher when compared to the neutral mode for both the L2-L3 and L4-L5 levels. In The neutral mode the maximum contact areas are observed at higher loads (140 Kg) for L2-L3 and L4-L5 levels, whereas in the extension mode for both segment levels the maximum contact area results at lower loads. All pressure readings were generally located in the medial half of the facets for all disc loads at both levels. At L2-3 there is a tendency for the contact area to move upward (cephalad) for extension made as compared to the neutral mode, whereas at L4-L5 level the contact area moves downward (caudal). The average peak pressure is higher in extension as compared to the neutral mode, and is generally higher at L2-L3 compared to L4-L5. A significant decrease in facet normal load and contact area resulted following unilateral facetectomy in neutral as well as extended mode at both levels. Two important conclusions of this study are as follows: First, it is not the magnitude of the facet loads but rather the peak pressures that seem to likely hold the greatest responsibility for degenerative changes in the facet joint. The second conclusion is based upon the result that the peak pressures are significantly higher in extension than in a neutral positional mode. This finding has strong implications for the development of appropriate prevention and rehabilitative programs for patients with low back pain due to degenerative apophyseal joints.

ACKNOWLEDGEMENTS:

This work was supported in part by funds from the RER&D Center, Hines VA Hospital and the Dept. of Orthopedics, Loyola Un. Med. Cntr., Maywood, Il.

ADJUSTABLE STRING MESH FOR CONTROLLED POSTURAL SEATING

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INTRODUCTION

The importance of proper seating for the severely disabled is widely recognized. Benefits include increased comfort and enhanced functional abilities. Several approaches have been adopted in order to achieve these objectives. At the Ontario Crippled Children's Centre, for example, conventional upholstery methods are used to produce wheelchair inserts which can effectively accommodate a wide range of physical deformities. Other approaches have been successfully employed elsewhere including custom-molding techniques. Unfortunately, existing methods tend to suffer from a number of drawbacks. Present seating systems are static by nature, supporting the individual in one particular position. Furthermore, the control of the fitting process is sometimes limited by the required constructional procedures and the resulting products are often very expensive. It is in light of these problems that a new concept is presently being investigated.

DESCRIPTION OF NEW CONCEPT

The proposed concept comprises of a network of individually controlled nylon strings which intersect at right angles to form a mesh. By adjusting the amounts of string released, one can accommodate a variety of three dimensional shapes as well as control the local pressures exerted on the object. An experimental model of this approach is shown in Figure 1. Individual adjusting pegs located on two adjacent sides of the model are used to control string lengths. Each string originating from an adjusting peg passes over low-friction pulleys to the opposite side where it is attached to an extension spring. The string tension resulting from an applied load can then be easily determined by measuring the amount of spring extension. In order to help prevent the separation of the strings when under load a network of small plastic cylinders has been incorporated into the seating surface. The cylinders which have holes drilled both axially and diametrically are threaded over the strings such that they form an alternating pattern in both directions. This arrangement has proved beneficial in maintaining the spatial integrity of the mesh as well as facilitating the free movement of the strings when a load is applied.

Presently, research is aimed at examining the relationships between externally controllable parameters such as string length and tension with the resulting shape accommodation and pressure distribution. This is being explored primarily with the aid of standard geometric test shapes. A given shape and load is first applied to the seating surface. The string lengths are then set and a reading is taken of the resulting string tensions. Pressure readings can also be obtained by placing pressure transducers between the test shape and seating surface.

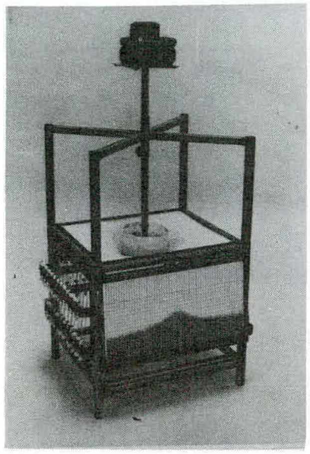

Figure 1
Experimental model of new seating concept shown with testing rig in place. String lengths are controlled by individual adjusting pegs situated on left side. Spring extensions shown on the right side record the string tension profile resulting from the application of a spherical test shape.

Because of the large number of strings and their related measurements, some additional procedures have been incorporated in order to simplify data collection. A photographic technique is employed to record the position of string length markers and the extent of spring extensions. These images are then digitized and the information entered directly into a microcomputer for processing. The resulting experimental data can also be compared to that obtained from theoretical calculations. This comparison provides the basis for future investigations into the causes of any discrepancies.

POTENTIAL APPLICATIONS OF CONCEPT

It is hoped that the research conducted in this and future stages will result in a mathematical model which would enable one to simply and accurately utilize this concept in practical applications. For example, one such application may be in the management of pressure sores. This is suggested by the ability to predictably alter the pressure distribution profile. The open weave design also assists in this cause by minimizing the contributing factors of heat and moisture build-up. Overall postural support could also be provided by adjusting the shape of the seating surface to accommodate the patient while creating the appropriate pressure patterns to provide local support. The concept also lends itself to the development of a dynamic seating system which would permit greater freedom of movement or allow for postural changes. This could feasibly be accomplished by either manually operated controls or a microprocessor-based device which automatically adjusts string tensions and lengths.

ACKNOWLEDGEMENTS

This work was supported by a grant from The Garfield-Weston Foundation.

CONTOUR-U, A CUSTOM TOTAL SEATING SYSTEM

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ABSTRACT

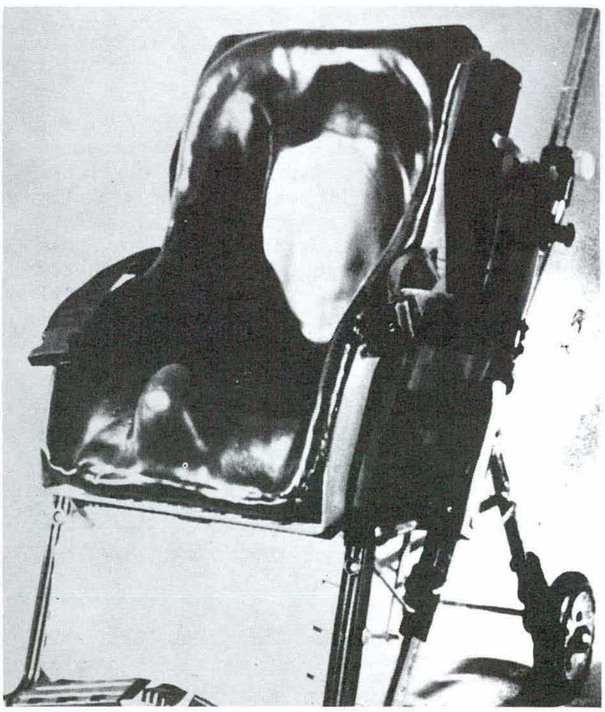
The purpose of this project is to develop a total seating system that will accomodate a wide variety of disabilities and sizes in our patient population. We wanted a seat that would not only mesh with an existing frame, but could be used as a car seat, in the house and possibly the bath as well.

INTRODUCTION

We have been involved in custom seating for a number of years using primarily the Toronto Spinal Support System. The need for a universal system of seating which would be custom made while utilizing some pre-fabricated parts, led us to develop the CONTOUR-U Custom Seating System.

POSITION PHILOSOPHY

The mold for the seat is taken in the presence of the patient's parents and/or therapist. This gives us their input as to proper positioning, because they deal with the patient on a daily basis. Some principles have already been published regarding proper positioning.



Cerebral palsy patients need to be put in a position of function by inhibition of their primitive reflexes. For children with muscular dystrophy, we need to encourage lumbar extension and use lateral support in an attempt to inhibit scoliosis formation. In other cases, we must try to accomodate any deformity in order to obtain a good functional position for the patient. Accomodation is the key, as it is difficult to obtain significant correction in any seating system.

MOLDING TECHNIQUE

The mold is taken using a weather balloon filled with polystyrene beads attached to a vacuum pump. We first encountered this technique with exposure to the DESMO Project of the University of Atlanta. Using this system, the balloon can be kneaded and molded until the optimum shape is found for the patient. This molding technique also has the advantage of taking into consideration the effect of gravity on the body. Once the mold is right, vacuum is increased to fix the mold position and plaster splints are laid down to get a positive impression of the negative mold.

FABRICATION TECHNIQUE

The plaster shell is then filled, squared off and modified accordingly. It is during this last step that we are able to fine tune the position and overall balance of the mold. The seat is then produced by vacuforming vinyl over the mold, positioning a preformed ABS bucket, complete with attachments, overhead and filling the space between with a liquid polyurethane foam. A small amount of final finishing is then necessary to complete the CONTOUR-U Custom Molded Seat.

CONCLUSION

Results so far appear optimistic and we are working toward perfecting the design. Improved attachment interfaces which allow for angular adjustments and quick release have been developed; growth adjustable and reclinable CONTOUR-U are on the boards. A polypropelene bath seat completes the system.

Pin Dot Products, P.O.Box 642, Northbrook
Ill. 60062

INTERFACE CONTROL TRAINING FOR PERSONS WITH CEREBRAL PALSY: A PILOT STUDY

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INTRODUCTION

Technology has been able to help overcome some of the mobility and communication barriers for persons with cerebral palsy through the provision of conventional and powered wheelchairs, environmental controls and communication aids. Unfortunately, the control of these devices often requires some physical manipulation which can be quite difficult or impossible without special individualized interfaces. Further difficulty can also be encountered when physical abilities fluctuate.

The control of any interface presently available requires some action, such as hand movement, the twitch of a muscle, or the blink of an eye. If the client does not already have this skill then it must be trained and practiced until functional competence is attained. Typically however, training is minimal and consists of straight practice. Hence, the user may not be competent with the interface provided and the most effective interface may not be apparent until after some training.

Learning of motor skills is complicated by cerebral palsy. In some instances there is an impairment of the sensory systems. More often, the person with cerebral palsy has difficulty in making sense of the afferent inflow for the purpose of coordinated output. Further, abnormal reflex patterns are often present and must be overcome. Incorrect coordination may become predominant through adaptive repetition of faulty patterns further complicating the motor coordination process. This suggests that practice alone may not be enough to establish functional motor coordination patterns.

A question that then arises is how to best train the motor skills that are necessary to operate an interface. In order to gain insight into this question a pilot study was carried out.

THE STUDY

The goal of this study was to evaluate and compare two methods for training quadriplegically involved persons with cerebral palsy the hand-skills required for the operation of an electric wheelchair. Method #1 incorporated practice on a simulated control system with either a gated joystick or touchplates (pressure-sensitive pads). Practice included: hand on joystick; maintaining contact; activating each direction; and releasing contact. Method #2 utilized the same practice for half the time plus added the training of relevant muscle groups utilizing EMG biofeedback. This method operationalized the hand skills into basic components and taught these concepts first before integrating them into task training i.e. operating the interface.

Sixteen persons with cerebral palsy varying in type and severity of involvement and ranging in age from 6 to 40 years were randomly assigned to be trained with methods #1 or #2. All subjects were, or had the potential to be, independent motorized wheelchair drivers, but had not mastered that task. The design of the study consisted of: three sessions of pretest assessment; twenty 40-minute training sessions; and three sessions of post-test assessment.

During an initial assessment an appropriate interface control system as well as its most advantageous placement was determined. Selection and placement were determined both subjectively by a physical therapist and objectively through performance evaluation on a microcomputer wheelchair simulator developed at the OCCC (Basacchi, Naumann & Milner, 1981). In this, an arrow on a graphics screen moves according to the activations of an interface. The subject is required to move the arrow for a specific time, in each of four directions: forward; back; right; and left, using the joystick or touchplates. Performance measures computed for each direction include: 1) the efficiency with which a specified direction is maintained; 2) the number of times the specified direction is activated during the test (once is a perfect score); 3) the response time after a cue to activation; and 4) the release time after the test is over.

The simulator programme was also used for both the pre- and post-test assessments. Each assessment session included four trials in each of the four directions for a total of 16 trials per session. In the actual training, a portable interface training unit was used. It consisted of the interface optimally placed on a tray utilizing velcro and an LED feedback display that indicated the direction activated by the interface.

DISCUSSION

Both groups improved in almost all measures but the method #2 group improved slightly more. Method #1 represented a more typical training procedure and method #2 a model that the authors propose would be more effective. The fact that both groups improved indicated that the subjects could still learn a motor skill. When the skill was taught in terms of its components it was better learned and the practice was more effective.

REFERENCE

Basacchi, A., Naumann, S., & Milner, M. Microprocessor based assessment of controller interfaces for disabled users. Proceedings of the Fourth Annual Conference on Rehabilitation Engineering. Washington, D.C., 1981, 295-297.

ACKNOWLEDGEMENTS

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A HUMANE DROOL BEHAVIOR MODIFICATION DEVICE

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ABSTRACT

A "neutral" feedback behavioral modification device for droolers was developed and initial test were made with a client. The rationale is to unobtrusively inform the person that he is drooling. A competent therapists teaches the user that the alerting function is private and, therefore, non-threatening information to which he can react or ignore. Certain therapists believe that this approach will be effective with selected stroke victims and other physically and mentally disabled individuals.

BACKGROUND

Certain individuals are not aware when they drool and are pleased to wipe away this exudate when reminded. Others are aware when they drool but give little attention to facial hygiene and appearance. They simply tire of their parents, teachers and others reminding them to "wipe your mouth" or "swallow" or "stop drooling". Still others can do much to control drooling when reminded to do so.

Drooling, quite obviously, is socially undesirable. But even worse, it detracts significantly from employability. A practical and unobtrusive drooling detector and reminder could serve as a behavior modification or an appearance aid for certain droolers. As such, it would relieve the frayed nerves of many teachers and parents; it would also improve employability.

DEVICE DEVELOPMENT AND TEST

A prototype drool detector consisting of a pair of electrodes, an audio oscillator and an earpiece was designed and fabricated by the Electrical Engineering Department of Oklahoma State University. A unijuniction transistor was used as both the detector of presence of saliva and as the active element in a relaxation oscillator. The resistive path created by the saliva serves as the variable base-lead resistance. Almost any unijunction transistor is appropriate; see the circuit diagram, Figure 1.

The test subject is a twenty-five year old, cerebral palsied, mildly retarded woman in a semi-independent living situation in San Antonio, Texas. This client had received intermittent training for many years and had been subjected to many attempts to curtail this undesirable activity. Drooling was the primary cause for her inability to acquire and retain a job in the food service industry. She readily accepted the prototype device and showed marked reduction in the number of times that onset of drooling occurred. She cheerfully wiped her mouth when cued by the device and expressed pleasure in receiving an unobtrusive and non-threatening reminder. The original prototype failed after eighteen days of use; the wire electrodes broke. A more substantial set of electrodes and electrode holder were fabricated using stainless steel rivets mounted on a Kydex strip which was attached to a bail made from a simple FM loop antenna. This assembly was attached to eyeglass frames with shrink tubing (See Figure 2) and tests were resumed.

FURTHER DEVELOPMENT AND VALIDATION

Several improvements are clearly indicated. First, the electrode and electrode-mounting fixture must be redesigned. An orthodontist has been consulted and will assist in this effort. Second, a custom-fitted earpiece is needed because the present one does not reliably remain in place. Third, it may be necessary to design an input circuit with higher input impedance to assure a greater audio output with even a small trace of saliva. After these improvements are made, field testing with a significant number of cooperative subjects will be performed.

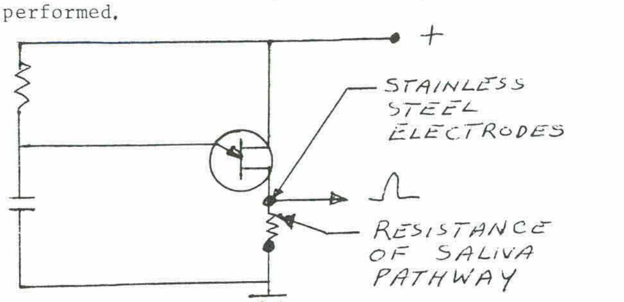

Figure 1. RELAXATION OSCILLATOR

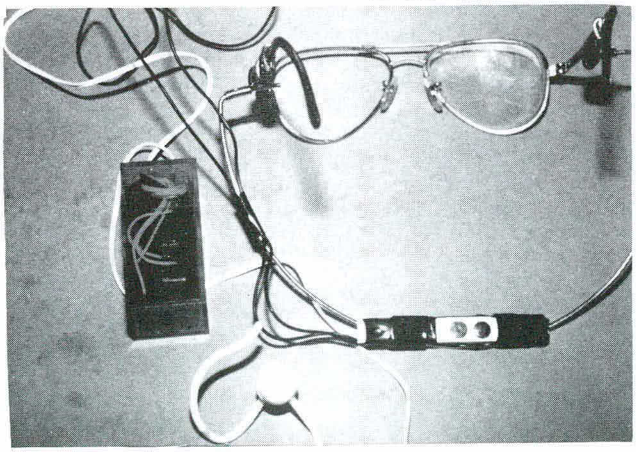

Figure 2. DROOL DETECTOR SYSTEM
Left: Electronic circuitry and battery, Bottom: Ear piece, speaker, Lower Right: Stainless steel electrodes on Kydex, Central: Electrode holder mounted to glasses. (Made from UHF loop antenna; bending positions electrodes.)
Reference: Invention disclosure Laenger, C.J., Sr. and Wilbur, R. L. Drool Detector. Southwest Research Docket No. 1299, May 2, 1978.

DEVELOPING HEAD CONTROL
A BIO-FEEDBACK SYSTEMS APPLICATION
TO THE CEREBRAL PALSY CONDITION

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In review of the state of the art in bio-feedback systems designed for learning and developing head control in the cerebral palsied child it was discovered that most or all of the systems had one or all of the following shortcomings:

- They failed to motivate and encourage learning
- They failed to provide interesting and repetitive stimuli which promotes retention of what's learned
- They failed to accommodate the subject with proper body support during the therapeutic session

It is cerebral palsy which creates the greatest problem in controlling head movement. In a bio-feedback study (ref 12) involving 22 subjects it was discovered that most children had few problems learning head control, but rather problems arose in their retention of this knowledge. An analysis of the primary systems used today, electromyograph (EMG) showed that the major flaw lay in failure to provide an initial stimulus to encourage learning and thus they lacked the ability to motivate the child. Consultation with a group of therapists revealed that accommodating a child during the therapy was as important as the way in which the system works. None of the bio-feedback systems addressed this issue. These three major shortcomings were the focus of design concern throughout the project.

DESIGN CONCEPT

The project involves the design of a bio-feedback system to teach cerebral palsy children to develop head control. The system is to be used specifically in the prone position, and has been designed to accommodate 6 varying positions. The significance of head control is important because head control is the precursor to further motor development. Without first learning head control a child develops nothing else normally. Prone positioning is important because that is the position in which normal infants learn head control, and is thus the position assumed throughout the therapeutic session conducted for head control by the physical therapist.

The way the bio-feedback system works is by a series of electrical contacts (6), lined up parallel inside a flexible plastic tubing. The child wears this tubing on one side of the earphones. The contacts are activated by 3/8 inch ball bearings and are placed 1/2 inch apart so as to measure and sense 15° deviations in head movement up or down. (fig 3) Each contact lights two seven watt light bulbs that are located along a parabolic shaped track. The track is divided into 6 screens. Each screen lights up in proportion to the child's head movement as the child's head proceeds gradually up the track to a near 90° mid-line position. (The near 90° position is the position the therapist associates as the goal for the child to reach.) The Bearing Activating Sensor (BAS) can be adjusted to light up the screen that is at or above the maximum upward gaze point of the child. This is achieved by the parabolic shaped track, providing a constant distance from eye to track. With the stimulus always above maximum upward seeing range, the child is encouraged to move his head up to see the visual stimuli.

The child receives audio stimuli as well as visual. The audio can be programmed to act as positive or negative feedback. When a child's head fails to light screens in sequence or drops down before reaching his goal, a sound can alert the child of the improper alignment (negative feedback). The control unit can change this to positive feedback by setting volume control so that the sound comes on only when the child's head has reached the goal of near 90° mid-line. This way the child receives auditory reward.

To measure deviations in head movement from side to side, a mercury switch has been located inside the speaker of the head phone. When the child's head exceeds a preselected angular threshold the mercury switch will detect this and this activates sound, alerting the child of improper alignment. The system is also designed to provide negative feedback if the child fails to start head movement. This makes the system active as opposed to the passive systems used today which rely on the child to make initial move before becoming active.

As mentioned earlier, accommodating a child during the therapy is equally important to how well the bio-feedback system works. It is an integral part of the therapeutic process and should be incorporated. In view of this I designed an accommodating body support which accommodates the child in therapy. Through analysis it was learned that unless a child is properly supported and made comforable he will not cooperate during therapy. (fig 1) Criteria for the body support includes, safety, lightweight for transporting, adjustable for the many types of conditions such as spastic, a strapping feature to restrict impulsive movement and gives a more steady indication of performance, and an arm support. The body support in the project provides all of these features.

TESTING AND EVALUATION

In the initial demonstration of prototype, it was discovered that the child responded favorably to the visual stimuli. The subject was diagnosed as having mild cerebral palsy with a small degree of visual impairment often found in such cases. The subject responded best to green, yellow, and red lights. (fig 2) The lights were activated manually so as to first discover the visual tracking ability of the child as well as his ability to control head movement. The subject was able to self-monitor his head movement as the lights moved up the track. When the head reached the near 90° mid-line, the subject was rewarded with an audio stimulus of soft music. Each light was operated to flash quickly on and off. This the optometrist suggested would aid in holding attention and promoting appropriate head raising response. Other observations ranged from a need for high contrast in light source with surrounding environment, a need for assistance in head movement during the initial use of the system (fig 1) and a need for a more isolated environment to minimize sight distractions. Additional observations were made of the child's positioning. Here it revealed that the child's first response was to grasp something for self-support. The child appeared to be less apprehensive when the arm support or the system was within range for him to rest arms and hands on comfortably. During the entire testing, the child appeared very relaxed yet attentive and responsive to his task of controlling his head. Two body positions were assumed and each accommodated the child well in the therapy session.

METHOD OF INVESTIGATION

The method of investigation for this project entailed the gradual process of gathering information from a variety of sources, such as: engineering and design departments at the university. Contributing outside sources have been: the Chicago Association for Retarded Citizens (C.A.R.C.) the Illinois College of Optometry, Sonicraft Inc., and the La Paz Child Development Center. It was from C.A.R.C. that I first received the impetus to design a product promoting self-independence of the physical disabled. My field site of study was the La Paz Child Development Center, and a meeting with the therapist was scheduled twice a month for the past year and a half. It is here that the therapist allowed me to observe the subjects for myself so that I may have greater insight into their problems and needs. They provided me information about biofeedback systems and different types of therapy. It was also here that I first realized the importance of the development of head control for cerebral palsy children. The project required a great deal of consultation with the engineering sources on the circuitry design. The optometrist, Dr. Dominick Maino provided the important information in regards to the effective use of a parabolic-shaped track for visual tracking. Pooling the combined efforts of all these sources has been a rewarding challenge that in the long run will benefit the cerebral palsied child and the many sources involved in the design of this project. From this study the sources can learn that man's progress in society is dependent on all their collective efforts.

FUTURE INVESTIGATION

Based on the evaluation made during demonstration, work is currently underway for incorporating the following design needs:

- A more isolated system, possible partitions enclosing child from outside environment
- Bright, high contrasting light source
- Educational related stimuli such as viewing alphabets or numbers in hope that the child will learn to read or count in the process
- Variable audio feed

Further forecast includes an extensive market survey of materials and cost for production, a detailed study of the types of visual and auditory feedback used in promoting learning, and a scheduled demonstration of system with the mild and severely profound cerebral palsied. From this analysis we may draw conclusions as to systems effectiveness in meeting the needs of all cerebral palsy children who demonstrate a lack of ability to self-monitor head movement.

Juding from the positive response to the initial testing and the thoroughness of the research done up to this point, I am convinced that there is an obvious and critical need for such a bio-feedback system. According to the director of the La Paz Child Development Center the system would be the best piece of medical equipment in their facility. Likewise, optometrist, Dr. Dominick Maino highly praised the project saying "A project of this nature fosters continuous research into the child's visual tracking ability as well."

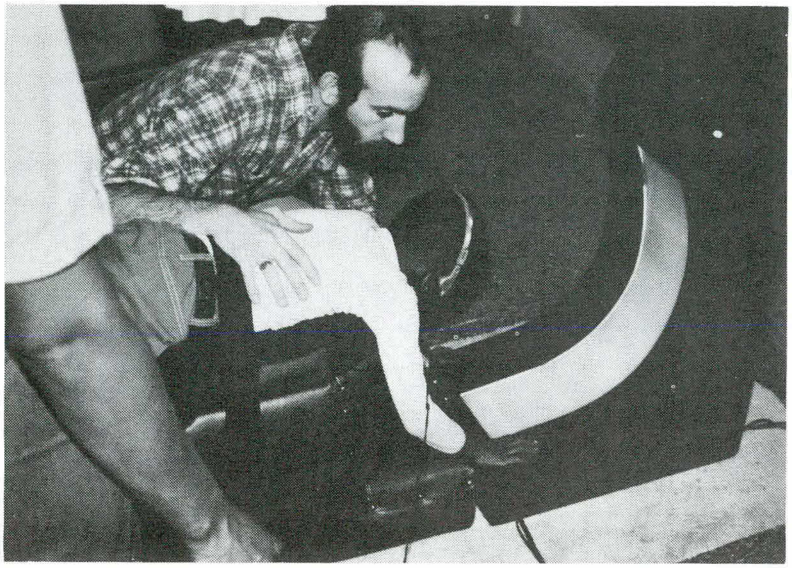

FIGURE 1

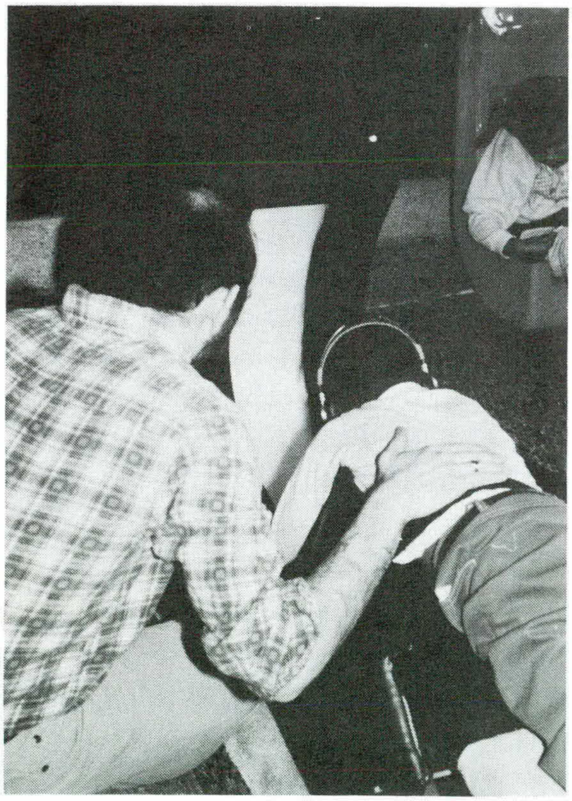

FIGURE 2

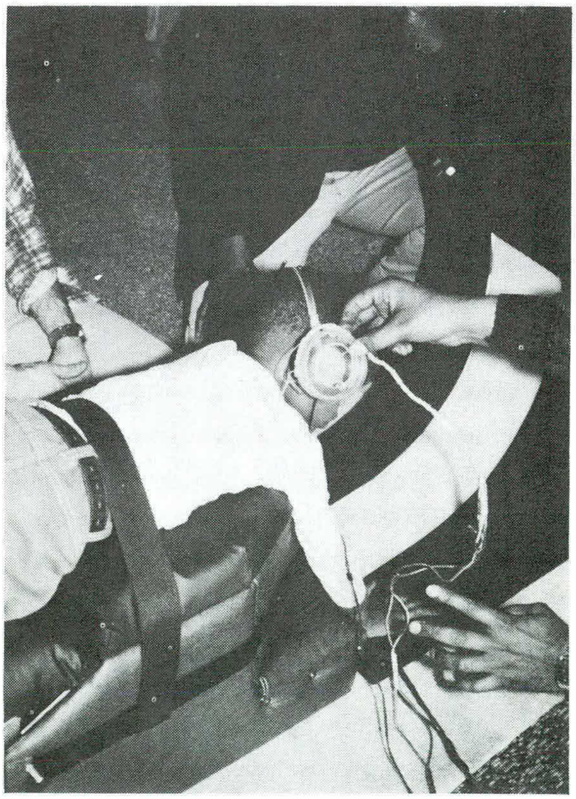

FIGURE 3

BIOFEEDBACK IN THE TREATMENT OF TONGUE PROTRUSTION - A CASE STUDY

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Tongue thrusting is the most prevalent of a group of oral habits (i.e. thumb sucking, tongue sucking, and bruxism) termed "oral myofunctional disorders". This activity may have detrimental effects on orthodontic development and speech patterns. However, in children up to 10 years of age, some degree of tongue thrust is normal during swallowing and at rest (1,2). The purpose of this case study was to assess the efficacy of positional biofeedback (BFB) as a method of decreasing a grossly abnormal tongue protrusion.

THE STUDY

The subject (S), a 7-year-old girl with cerebral palsy, exhibited typical postures associated with spastic diplegia. Psychological tests revealed intellectual functioning in the low average range. While concentrating on work or play activities she exhibited a marked tongue protrusion where the tongue extended onto the chin and remained in that position for lengthy periods. Speech and orthodontic assessments determined the tongue protrusion to be benign and mainly habitual since the child could, upon request, easily contain the tongue within the oral cavity.

The BFB apparatus consisted of: a tongue position sensor, a processing module, and a Time Event Counter (3). The tongue position sensor consisted of two curved wires mounted on an orthodontic chin cup. The wires were separated by approximately 1/4" and were positioned directly 1/2" in front of the S's mouth when the chin cup was in place. This positioning allowed for correction of the gross "tongue-out" position while not demanding a performance level beyond the S's maturational development. The tongue acted as a contact switch between the two wires. The current flowing between the two wires was safe (5nA,0.6v) and the S did not experience any sensation. Feedback was an overt auditory signal each time the tongue touched the contacts. The S chose not to wear an earphone and cosmesis was never a problem.

The experimental design was A_1,B_2,A_2, B_2,A_3,C,A_4,B_3,A_5 (Fig. 1), where A represents 5 no-feedback (NFB) baseline sessions, B represents BFB intervention, and C a 2-month NFB period. All sessions were of 15-minutes duration and 3 sessions per week were conducted. The initial study phase (A_1 to A_3) was designed to investigate whether BFB could effect a change in tongue position. The second phase (C to A_5) addressed the issues of retention of learning (A_4) and the effect of booster training (B_3).

RESULTS AND CONCLUSIONS

A marked improvement in "tongue-in" posture was evidenced with the intervention of BFB by the increased performance rate from 49% (A_1) to 90% (B_1). When BFB was withdrawn (A_2) and reintroduced (B_2) a reversal effect occurred. The reversal effect indicated that it was the BFB affecting the change in tongue position and that learning was occurring. The 87.2% performance (A_4) showed minimal response decay after phase C. The data at B_3(96.8%) showed that more learning had occurred. This higher performance was maintained at a 96.4% (A_5) level. From these results it is concluded that:

1. BFB effected a change in the habitual tongue-out position.
2. The techniques of overlearning and booster sessions should be seriously applied in motor skills training.

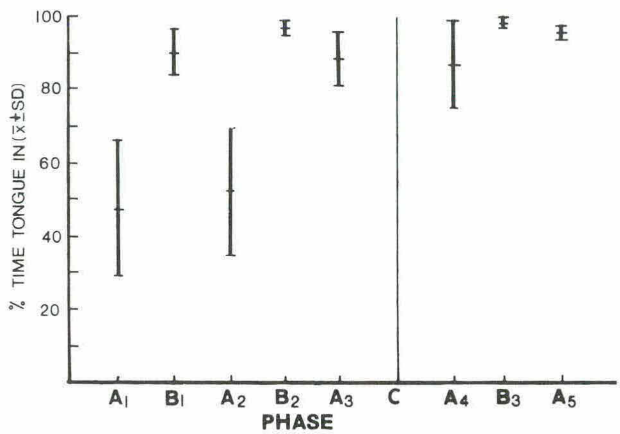

Figure 1. Means and standard deviations depicting tongue position.

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ACKNOWLEDGEMENTS

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FEEDBACK DEVICE FOR LOWER EXTREMITY AMPUTEES

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INTRODUCTION

This paper presents a new feedback device which will be used to assist lower limb amputees in their initial stages of gait training. It will enable them to become mobile again more quickly and optimize their gait and balance within the limitations of their particular handicap.

DISCUSSION

A lower extremity amputee is usually furnished with a prosthesis totally devoid of sensation. Sensory feedback is then obtained through pressure between the stump socket interface or visually (F.W. Clippinger, A.V. Seaber, J.H. McElhaney, J.M. Harrelson, G.M. Maxwell), causing an awkward gait during early prosthesis usage due to the lack of sensation and the necessity for visual attention to the prosthesis configuration. Within the past three years several feedback devices have been developed to aid the amputee during his training period.

Among these gait training tools are Sequential Contact Systems (SCS) (D. Warshal, M. Jacobs, W. Lee, M. Garcia), knee angle potentiometers, instrumented foot mounting bolts (F.W. Clippinger, et al.), and piezoelectric crystals. Use of a SCS or knee angle device allows the patient perception of position and configuration of the prosthetic leg but no sense of weight distribution on the prosthetic foot. While allowing the patient perception of both applied weight and direction upon the prosthesis, the instrumented foot bolt lacks the simplicity and ease of installation necessary for general use in a clinical setting (G.M. Maxwell, personal communication). In a semester project completed by the author in December, 1981, an audio feedback training device utilizing piezoelectric crystals mounted in the heel and toe of a Silastic footpad was developed. While this configuration proved satisfactory to produce a signal which defined heel strike and toe off during normal gait, the device was found unsuitable as a force transducer because of the rate dependent physical properties of piezoelectric crystals.

Commercial gait training devices include the Limb Load Monitor which is available from the Krusen Research Center in Philadelphia, Pennsylvania. Utilizing a capacitance footpad as a transducer, the device produces an audible output when loaded with a preadjusted force. A single tone is produced when the patient exceeds the preload. This has been found to be useful to indicate weight-bearing.

DESCRIPTION OF THE DEVICE

In order to be used clinically, any feedback training device must:

(1) have an output that is useful and easily interpreted by both physical therapist and patient
(2) be easily installed
(3) be reliable
(4) be portable
(5) be simple to operate
(6) pose minimal constraints upon the normal gait of the patient

Consisting of an aluminum footpad and electronics package, a sketch of the recently developed feedback device is shown in Figure 1. It will produce an output of three discrete tones of decreasing frequency upon increasing applied weight in the heel area (heel strike) and three discrete tones of increasing frequency upon an increasing applied weight in the toe area (toe off). The output is thus a musical sequence of tones dependent upon gait pattern; correct weight distribution upon the prosthetic foot during heel strike and toe off will thus produce two simple musical scales.

Designed to be easily inserted into the instep of a shoe, the footpad measures 7x41x172 mm. It contains two instrumented diaphragms which have been sandwiched between two machined aluminum plates which serve to maintain sensor placement and vertical loading. Drawings of a footpad diaphragm and the footpad configuration are shown in Figures 2 and 3, respectively. A force applied to the footpad in the vicinity of a sensor caused the diaphragm to flatten, resulting in a strain in the transducer proportional to vertical force. This strain is detected by two semiconductor strain gages mounted on the concave side of the diaphragm.

The output from the strain gages is processed by the electronics package. A block diagram of the footpad circuit is shown in Figure 4. The four strain gages are connected to compose a Wheatstone bridge. The bridge output is first differentially amplified and then amplified with variable gain (sensitivity control). The gain of the device may be externally adjusted so that 1 kg of applied force will produce an audible output. This signal is processed by comparator circuitry which produces three discrete voltage levels per diaphragm corresponding to pressure upon either sensor. The comparator outputs are connected to a voltage controlled oscillator (VCO) and nulling circuit which allows no output when the footpad is unloaded or during midstance when the weight is evenly distributed upon the prosthetic foot. This signal of six discrete tones is amplified with variable gain (volume control) and used to drive a speaker. The unit is powered by two rechargable nine volt batteries which have an average working life of five hours. The batteries may be accessed for charging via an external plug.

TESTING PROTOCOL

The device will be tested in the Department of Physical Therapy at the Duke University Medical Center in the following manner:

(1) Ten patients without benefit of any feedback training devices will be evaluated by a physical therapist, and the following items about the patient will be noted:

a. age
b. amputation level
c. other medical problems
d. the patient's learning ability
e. training period
   (i) number of sessions
   (ii) total number of hours

(2) Ten other patients with the feedback training device will be trained by the same physical therapist while the above items and those listed below are noted:
   a. the patient's evaluation of the device
   b. the physical therapists evaluation of the device as applied to the patient.

(3) An overall evaluation of the device will be made by the physical therapist after the twenty patients have been trained.

PRELIMINARY RESULTS

In the early stages of testing, the footpad device has been used on one patient in the Physical Therapy Ward of the Duke University Medical Center. The physical therapist indicated that the device was helpful in recognizing a correct gait through the sequence of tones generated during heel strike and toe off. By adjusting the sensitivity of the device, the therapist found that he could trigger an output upon a given loading upon the pad, an option which he felt was helpful in teaching the patient to support himself upon his prosthesis. No problems were encountered due to footpad size or weight.

CONCLUSIONS

The footpad device has the potential to aid a patient in learning to walk again by helping him develop rhythm and timing through the recognition of heel strike and balance during gait. While the device gives the patient a perception of his progress towards regaining a normal gait, the significance of it lies in the decreased training time and consequently the associated expenses involved in the gait training of lower extremity amputees.

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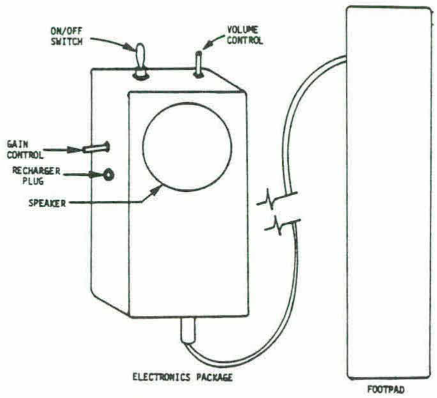

FIGURE 1. SKETCH OF FEEDBACK DEVICE

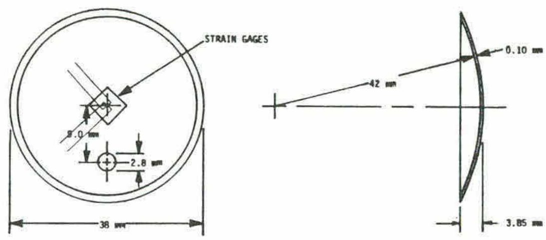

FIGURE 2. DRAWING OF FOOTPAD DIAPHRAGM

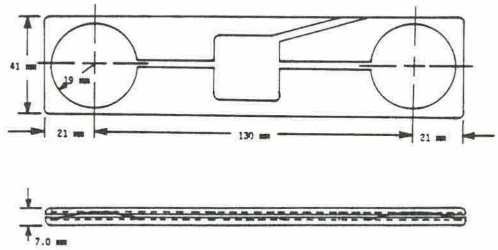

FIGURE 3. DRAWING OF FOOTPAD CONFIGURATION

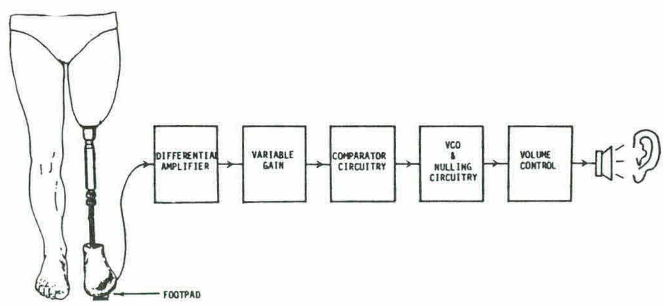

FIGURE 4. BLOCK DIAGRAM OF FOOTPAD CIRCUIT

METHODOLOGY AND PRELIMINARY FINDINGS FROM THE EVALUATION OF AN INTERACTIVE MANIPULATION AID

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ABSTRACT

Medical Robotics is a new field that evokes many sociotechnological questions. To address these issues an unusual multidisciplinary team has been assembled to develop research protocols and a preliminary working model for evaluating prototypic "Intelligent" Aids for the disabled.

INTRODUCTION

It has been hypothesized that industrial grade electrochemical manipulators can be used by severely disabled individuals to regain functional control of their personal space. Technical feasibility of this hypothesis is predicted on recent and rapid evolution of microcomputer controlled manipulators for industrial use. The Rehabilitative Robotic Aid under development and evaluation at the RERanD Center addresses the need for environmental control by individuals with high level spinal cord disabilities.

Medical Robotics is an emerging field. There are many unknowns in the development and evaluation of prototypic intelligent manipulators. There are no historical precedences nor established protocols for validating the worth of this class of assistive devices. In particular, there are few, if any, guidelines which can assure a steady flow of information between developers and potential users. These constraints have led to the formation of a multidisciplinary evaluation team. The team has developed protocols and a working model for Interactive Evaluation of the Human/ Robot/ Environment triad. Team members include: Medical Doctors, Nurses, Biomedical Engineers, Sociologists, Neuropsychologists, Occupational Therapists, Human Biologists, Design Engineers, Psychologists, Vocational Rehabilitation Counselors, Experimental Phonologists, Electronic Engineers, Marketing Analysts, and Users.

The role of this team is to develop flexible, integrated guidelines for both short term and longitudinal studies.

Primary Objective

The primary objective is to examine various interfaces in the Human/ Robot/ Environment triad. Briefly, the following triadic interactions will be investigated:

Human. Human factors research on training procedures, performance variables, needs, applications, acceptance, preference and other psychosocial issues will be implemented. A data base will be developed to define the Successful Users' Profile.

Robot. Subsystem interfaces with human users (such as input modes and vocabulary) will be studied. This information will be disseminated on a concurrent basis to research and development engineers so design changes can be made in the laboratory.

Environment. Situational influences on both Human and Robot performances will be evaluated. These data will be used to develop impact guidelines as a function of environmental settings. Both macro and micro environments of the manipulation process will be examined.

Short Term Progress

- -An informal needs assessment has been completed.
- -User training procedures for control of a 6 DOF Robotic Aid have been designed.
- -A user's training manual has been completed.
- -Pilot testing on a vocabulary/ enrollment/ training study has been completed (9 subjects participated).
- -Studies on input mode preferences have begun.
- -Preliminary designs and administrative liasons for the clinical testing site are near completion.
- -Studies of control modes have begun.

Long Term Plans

The primary long term goal is to design and implement a unique Robotic Learning Center for spinal cord disabled Veterans. The goals of the proposed center have been integrated with the definition of functional uses for Robotic Aids. The objective is to design a modular learning center that will provide multi-media and programmed learning information on a 24 hour basis to disabled patients, their families, and allied health care professionals that work with them. The Intelligent device will be used to manipulate the center and to perform activities of daily living, vocational, and recreational evaluation tasks. It is felt that this clinical application will enhance the effective utilization of resources, facilitate the broadest exposure for the Robot and provide knowledge for and feedback from a variety of users.

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A STANDARD INTERCONNECTION FORMAT FOR ELECTRONIC ASSISTIVE DEVICES FOR HANDICAPPED INDIVIDUALS

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Within the last few years, in response to advancing technology and an increasing attention on rehabilitation of severely handicapped individuals, there has been a very rapid increase in electronic communication and control aids for individuals having severe and multiple physical disabilities. A large variety of different aids, interfaces, and accessories have been developed to meet the very diverse needs, capabilities, and disablities of the different handicapped individuals. As might be expected, nearly every researcher or manufacturer chose a slightly different connector, pin-out, voltage convention, or format for their aids, interfaces, and accessories. The result has been a situation in which clinicians, handicapped individuals, and rehabilitation personnel have an almost impossible task of finding compatible interfaces, aids, and accessories. Since providing a severely and multiply handicapped individual with an effective communication or control system usually involves careful selection and matching of those interfaces which best meet his/her physical abilities with aids which perform the functions that he/she needs with accessories compatible with his/her age, cognitive abilities and activities, the additional restrictions due to the incompatability of different systems has created severe (and unnecessary) problems. The end result is often that the handicapped individual is fitted with an aid, interface, and accessories which do not really meet his/her needs well, because the pieces he/she really needs will not work with each other.

The Common Interconnection Format project has developed, through national and international cooperation, a common format which when followed allows for the easy identification of interfaces and aids which can work together, and in fact ensures that such aids can be hooked together by non-technical personnel. This standard is three-fold, involving:

1) a set of three common connectors (2-, 9-, and 15-pin)
2) a common technical format for aids and interfaces
3) a simple, straightforward naming format (or code) which will enable non-technical people to mix and match aids, interfaces and accessories which are electronically and mechanically compatible in order to meet the specific needs of the handicapped individual.

Some of the constraints which the standard accomodates are:

1) The format is compatible with aids, interfaces, and accessories already in production or in the field.

   It allows for adaptors to enable interconnection of pre-format aids, and resolves power supply conflicts.

2) The format provides a simple, straight-forward naming format to enable parents/teachers/rehabilitation personnel to easily identify and match compatible aids, interfaces, and accessories.

3) The connectors which have been chosen are simple, and are convenient for users; they are a consumer type connector, rather than a commercial or engineering type.

4) The format and connector are convenient to manufacturers, and are cost-effective.

5) The format has identified common, convenient, and effective approaches to interface development, and encourages their use in order to reduce the variety and complexity which currently exists.

6) The format is an open or living format which allows for innovation and future development while maintainint the simplicity and compatibility of the system.

7) The format is compatible with other existing standard formats which apply to such aids and interfaces.

8) The format is able to handle the extremely wide variety of interfaces for the handicapped; it can handle the wide variety of switch arrays available, which may be from 1 to 64 switches, in any of a dozen configurations. It also allows for analog, digital (serial and parallel) and resistive/reactive transducer output signals.

9) The format provides for only three interface connectors, thus ensuring that input transducers/user interfaces which are electronically and functionally compatible with an aid are also mechanically compatible.

10) The format provides maximum flexibility to allow for newer electronic interfaces and "smart" interfaces now being developed.

11) The format allows for multi-input aids which must be able to accept a wide variety of different interfaces (to meet the needs of different users) on a single connector.

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CANADIAN STANDARD FOR ELECTRICAL AIDS FOR THE DISABLED

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INTRODUCTION

With proliferation of technical aids for the disabled population, a need for standardization became apparent. Reacting to this need, the Canadian Standards Association directed its Standards Steering Committee on Health Care Technology to initiate the work on a new standard development. The Technical Committee on Technology for the Handicapped was created, in late 1977, to be added to the 13 Technical Committees already working in the Health Care Technology field.

Later, when the work on standards progressed, the Technical Committee on Technology for the Handicapped was invited, by the Standards Council of Canada, to serve as the Canadian Advisory Committee to the International Standards Organization engaged in the preparation of International Standards for the Handicapped. This work involves reviewing and voting on I.S.O. drafts and submitting Canadian proposals to I.S.O. as working documents.

The committee met for the first time on 9th November, 1977 and decided to initiate work on the standards in four broadly defined areas:

- Mobility Aids
- Prosthetic and Orthotic Devices
- Electrical Aids for the Physically Handicapped
- Aids for Daily Living

The following is a report on the standard produced by the working group on Electrical Aids for the Physically Handicapped.

CSA STANDARD Z323.3.1-1981: ELECTRICAL AIDS FOR PHYSICALLY DISABLED PERSONS.

1. Scope. This introductory section defines the range of aids potentially regulated by the Standard. It was important to specify, for example, what part of an electric wheelchair power and control system is to be accepted as an electrical aid. In other cases, devices which are normally treated as aids had to be arbitrarily excluded and they are listed here. Basic philosophy and goals of the Committee are also stated.

2. Definitions. An obligatory part of any standard, the definition of terms is more important in this fast developing field than in more established disciplines. Electronic Aid, Environment, Physically Disabled, Component and System, for example, are defined here.

3. General Requirements. The standard does not "stand alone" - it is very closely related to other CSA standards in the Health Care Technology field and others. The related standards are listed here.

4. Safety Requirements. This section is subdivided into four subsections:

- Electrical Safety, where a list of applicable standards is provided.
- Mechanical Safety, with information on applicable standards and the intent of this section.
- Chemical and Biological Safety, with a list of applicable standards and the statement of intent.
- Aids Intended for Emergency Use; while the safety of the user was the overriding concern in preparing this standard, it was also recognized that there should be a considerable space left for less sophisticated aids - cheaper and therefore more accessible for certain segments of population. The simplicity of construction may be reflected in less reliable performance, which the potential user must understand and may be willing to accept. There is, however, one category of aids where this compromise is unacceptable - aids intended for emergency use.
  The section describes the special requirements this group of aids must conform to.

5. Documentation. Information about the aid, both before and after purchase, was of special interest to the Committee. The underlying tendency was to require disclosure about all important aspects of the aid, rather than to legislate the design and construction. It is the desire of the Committee to protect the potential user as much as possible without unduly limiting the designer and manufacturer of the aid. Good documentation will help the consumer to make informed decisions about the purchase of the aid and then to use it and have it serviced without major problems.

The following subsections are identified:

- General - the documentation to be made available before the purchase of the aid is outlined here.
- Specification Sheet - the content of this document, to be made available before the purchase, is specified and a note on other material, not required but potentially desirable is included.
- User's Manual - contents of the Manual, as well as its availability are specified. Subjects such as warranty, installation, operation of the device, maintenance and repair are included.
- Marking - considered very important it is described in detail in this section.

Appendix A - Service Manual. Appendices are non-mandatory additions to the Standard. The Committee felt that some information, not appropriate for the mandatory section should, nevertheless, be transmitted to the readers. The appendix describes such desirable portions of the Service Manual as circuit description, maintenance information and schematics.

The standard is expected to be approved in the Summer of 1982 and will be available from the Canadian Standards Association, 178 Rexdale Boulevard, Rexdale, Ontario M9W 1R3 Canada.

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MOTOR VEHICLE SAFETY FOR OCCUPANTS IN WHEELCHAIRS: PROGRESS AND FUTURE NEEDS

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Over the past several years a number of independent investigations have revealed the inadequacies, in terms of occupant protection, of most devices, equipment, and procedures used for wheelchair securement and occupant restraint. Dynamic test results, using both sled impact facilities and barrier crash tests of vehicles, have not only shown that much of the materials and hardware used are of inadequate design and strength but that many of the most common practices used in transportation of severely disabled persons are in violation of basic crashworthiness design principles. Passengers in wheelchairs are generally placed facing sideways, the same belt is often used to restrain the occupant and the wheelchair, forward-facing passengers and drivers generally have no rear head restraint, little attention has been given to the proper placement of belt webbing over skeletal parts of the body, and so on.

In considering the issue of occupant protection for wheelchair seated occupants it is important to distinguish between wheelchair securement and occupant restraint. Both are necessary for effective occupant protection systems. The wheelchair tie-down must be designed to secure the wheelchair as rigidly as possible for the range of possible and likely real-world conditions. For transportation in van-sized or smaller vehicles, the designer must consider the magnitudes of forces that can be generated during decelerations of 20 G's and above (resulting from 30 mph barrier collisions). In addition, he must generally provide for securement of power wheelchairs which can weigh 50 Kg. or more and for the situation where the occupant is lap-belted to the wheelchair. In the latter case, occupant restraining forces (i.e., forces needed to decelerate the occupant) are also transmitted through the wheelchair securement device.

Other practical factors must also be dealt with in designing wheelchair securement systems. Designs should be kept as simple as possible in terms of fabrication, application, and useability so that costs are minimized and proper use is maximized. Some applications may require automated powered lock-down systems while for others a manually operated system is adequate. In either case the system will be most acceptable if it provides minimum interference with wheelchair maneuverability. For some applications the securement system may need to work for a number of different sized chairs while for others it may need to fit only to one chair and occupant situation. And, for the wheelchair seated driver, the system may need to operate in conjunction with a separate wheelchair positioning (lowering) system.

Once effective wheelchair securement has been achieved, occupant restraint can be attained by a variety of belt system configurations if properly designed materials and procedures are used. For public transportation, a simple lap belt to the chair or floor may be considered adequate but will only prevent injury due to the "human collision" (i.e., impact of occupant with vehicle structures) if significant space is provided around the occupant. A full lap and upper-torso belt system (either 3- or 4-point) should be provided for complete occupant restraint and is especially important for drivers who are in close proximity to the vehicle controls and windshield. Anchoring belts to the vehicle is preferable in terms of minimizing forces on the wheelchair and tie-down but it's often difficult to achieve "good" placement of belts over skeletal regions and/or effective restraint due to interference of wheelchair structures with the belts. Open-ended wheelchair arms can help improve the situation by allowing belts to fit over the pelvic region and near the hip. It may also be desirable to anchor the total belt system to the wheelchair itself. As manufactured, however, the wheelchair is not strong enough to handle the belt loads, especially those from the upper torso belts which must be attached on the chair-handle posts. In this regard, a prototype wheelchair add-on structure is now being designed and evaluated at the University of Michigan REC for achieving both rear head restraint and "onboard" anchoring of restraint belts.

While the state of occupant protection for motor vehicle transportation of persons in wheelchairs is still far below that available to the general population, the situation is not hopeless or without solution. Awareness of this safety issue has been increasing over the past two to three years as a result of publications and communications documenting the results of dynamic tests. Informed users and personnel concerned with transportation of the severely disabled are beginning to define and demand performance standards and requirements for wheelchair securement and occupant restraint equipment. In response, a number of manufacturers are beginning to redesign their products and recent sled impact tests demonstrate that considerable improvements are being made. There is still much that can and must be done, however, in order to provide opportunity for equal occupant protection for this increasing population of motor vehicle passengers and drivers. To this end, the cooperation and support of government, charitable foundations, user groups, rehabilitation engineers, vehicle safety engineers, and manufacturers of wheelchairs and wheelchair transportation equipment is needed.

This research was supported in part by Grant No. 23-P-59227/5-03 of the National Institute for Handicapped Research via the University of Michigan Rehabilitation Engineering Center.

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STABILITY CONSIDERATIONS OF ADAPTIVE STEERING SYSTEMS FOR THE DISABLED DRIVER

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ABSTRACT

In order to establish design requirements of adapting steering systems to drivers with disability, a closed-loop computer model of the disabled driver/vehicle system is used to study the effects of the steering gear ratio and driver reaction time on the stability of the system. Preliminary results show that a driver time delay larger than 0.4 sec. or gear ratio smaller than 10:1 caused the simulated system to become unstable.

INTRODUCTION

Many severely disabled drivers are unable to operate conventional power steering systems due to insufficient strength or limited upper limb motion. Adaptation of these systems to the capabilities of the severely disabled driver requires (1) reducing driver effort at the steering wheel and/or (2) reducing the amount of the steering wheel rotation required for a given change in vehicle heading angle. The first requirement is usually met by removing or reducing the stiffness of the torsion bar which connects the steering column to the steering control valve. This reduces the largest amount of resistance encountered by the driver. The second requirement necessitates reduction of the steering gear ratio which produces at high speeds unnecessary sensitivity that taxes the attention of the disabled driver and reduces the margin of stability. Therefore, it is not surprising that almost all of the present adaptations satisfy only the first requirement.

Only one, the Scott Van [1], has addressed both requirements. In the Scott Van, the gear ratio is reduced from the original 17:1 to about 5:1 (i.e. 5° steering wheel rotation produces 1° front wheel heading angle). The amount of assistive power is increased to compensate for increased resistance associated with decreased ratio. Extensive evaluations of the steering system in Scott Vans [2] have shown that the lower gear ratio produces at high speeds unnecessary sensitivity which taxes the drivers attention and leaves him unable to execute unexpected evasionary maneuvers without risking loss of control.

It is clear that steering ratio must be made adaptable to vehicle speed and/or steering wheel position. A speed-sensitive variable assistance steering has been successfully implemented in passenger cars [3]. This system provides full power assistance during parking maneuvers and gradually decreases the amount of assistance as the vehicle speed increases. Variable-ratio steering is becoming increasingly common in recently designed cars. In these systems, the gear ratio changes with steering wheel displacement from the neutral position. Typically, the gear ratio falls from 17 at dead center to about 12 at one half revolution of the steering wheel away from the center. The ratio remains at this level for any further steering wheel displacement. This variation in ratio is accomplished by a variable pitch worm gear. Both of these systems will be considered later as the basis of solving the adaptation problem. The design requirments of a solution are to be based on the results of this study which considers the affects of steering ratio, driver time delay and lower resistance on the stability of the system. A simplified closed-loop driver/vehicle model is used to study the interaction.

RESULTS AND CONCLUSIONS

The effects of increased driver time delay and reduced gear ratio were determined at 80 km/hr. The response of the vehicle to a desired lane position change of 50 mm at three values of driver reaction time (0.2, 0.3 and 0.4 sec.) and at four different steering gear ratios (17.5, 14, 12 and 10:1). Results show that the vehicle becomes unstable when driver reaction time is slower than 0.4 sec. Instability here means that response of the vehicle increases indefinitely in amplitude with time.

Stable behavior was present for all gear ratios above 10:1. Further attempts will be made to obtain stable responses at lower gear ratios that are more suited to the capabilities of the severely disabled drivers. This will be accomplished by altering driver parameters that were not altered in this study.

Intuitively, a driver who cannot react quickly enough or is insensitive to the behavior of the vehicle will continue to overshoot the intended path. A driver with too much sensitivity will overreact and risk loss of control of the vehicle in any sudden defensive maneuver.

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A CLOSED LOOP DRIVING SITUATION SIMULATOR WITH PROPRIOCEPTIVE, RATE AND RATE INTEGRAL FEEDBACK

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BACKGROUND

The purpose of this project was to design an alternative computer-based driver simulator for the moderately severly disabled. It particularly addresses spinal cord injury levels C3, C4 and C5. A driving situation simulator which would allow patients to be quickly and efficently evaluated and trained, and to receive the controls best suited for a driving task, as well as provide researchers with a quantitative tool for developing new controls does not now exist.

There are currently a number of driving simulators for the moderately handicapped on the market, but each one has its drawbacks. The Video Driver Training Terminal is very expensive and is limited in its use for successful response training. The true driving simulators are used for pilot training are prohibitive in terms of expense, even if they were suitable for use in rehabilitation.

Another drawback of the Video Driver Training Terminal, which has no visual feedback, is that proprioception becomes meaningless in that the driver will tend to override it since the visual is in conflict with what his senses tell him. Sustained usage would actually make a worse driver, running in an open loop configuration when there are closed loop controls.

The alternative designed by this research team was partly based on the Grand Prix video game on disc recently sold in limited numbers. The Grand Prix program provides a sports car driving experience on a number of international track configurations comparable to driving on a rain slick road, late at night, with illuminated posts lining the path for perspective. The advantage of the Grand Prix was its simplicity, low cost, and its demonstrated realism at high speeds by veteran users. The main disadvantage of the Grand Prix was the great deal of practice and perseverence required to enable one to use the experience at any driving speed.

The goal of the present project was the design and construction of a prototype simulator which would maintain all the advantages of the Grand Prix, and yet overcome the main disadvantage. This research team's solution to the problem with the Grand Prix was the creation of dedicated generic controls and driving experiences (modules in software) that could readily be learned. The current prototype is basically an implementation of just this solution.

The project was divided into four main tasks with considerable overlap. These were software design, electronic interfacing, human factors engineering of the system and controls design and interfacing. The last was specifically the author's responsibility.

DEVELOPMENT OF A CLOSED LOOP REALISTIC DRIVING SITUATION SIMULATOR

Two elements were considered essential in the development of the realistic simulator. First in order to maintain simplicity and to enhance operator learning, the visual response would have to be consistent and unique at any speed. Second, if normal speed driving were to be achieved, controls and an essential set of driving experiences had to be mastered.

A number of references concerning driver aids and driver training were consulted in order to determine the spectrum of driver controls and program combinations for evaluating and training. An expert in driver evaluation at the Roosevelt Warm Springs Institute for Rehabilitation was consulted in order to determine the most common and adaptive driving controls and his estimate of human factors requirements such as the eye-hand coordination required for successful driving with adaptive controls. These ideas were organized by rank. Two lists were basically matched as to needs and available equipment under the contraint that each individual would have to be provided with a semi-unique set of controls. The experiences were not to differ greatly in terms of add-on hardware but would be flexible enough to differ in "write in" hardware by variations in parameters of program modules.

Thus the author was required to provide a comprehensive control design taking into account not only the hardware control system but also the design of the soft controls. These soft controls included factors such as averaging, or integration, non-linearity, and handedness (right hand vs. left handed control system).

In this manner, a driving situation simulator was created which could efficiently provide for the need because of its simple structure. It is also easily transportable and can gather, process, and provide descriptive statistics for optimizing on the adaptive control configuration.

A basic requirement was that the system be capable of generically duplicating any control now in the market and be expandable to allow the development of new adaptive control systems. The present design possesses the flexibility to do just that.

HARDWARE DESIGN

An Apple II microcomputer with 48k of memory, a monitor, and disc drive were chosen to be used as a base unit. No special interfaces or electronic modifications were necessary for the Apple, nor were they required for interconnections of the controls. A simple monitor support base with both hand and foot controls suffices as a structure to provide the driver station. This serves for both wheelchair users and able-bodied drivers. The system is capable of all audio, visual, and proprioceptive feedback required for realism.

All of the above parts were found readily in local computer shops or electronic and hardware outlets, and were easily fitted together. The complete system weighed under eighty pounds and cost about $3100. A more elaborate system can readily be developed from this basic system by taking advantage of the many possible peripherals available for the Apple II.

SOFTWARE DESIGN

The software written to date allows the user to operate the Apple II as a driving situation computer simulator. The system is self contained. By operator command, the Apple II will remember incoming pre-driving criteria such as the driving track, amount of fuel, speed limitations, road responsiveness (in seven graduations), and the distance to be traversed.

The operator may vary speed level at three levels at any time. In addition, an audio engine noise is emitted continuously proportional to engine RPM, thus reinforcing speed and responsiveness and allowing the operator to hear and correct for variations immediately. Oversteering or lack of coordination and quickness will put two wheels off the road and allow the operator to experience tragedy in form of a crash both visually and audibly. This simulation has the effect of reinforcing actual tracking demands that must be made while driving.

SYSTEM EVALUATION

To date, there has been time only for limited evaluation of the system. However, some startling results demand continued and much more accelerated development from this project. An expert driver evaluator at Roosevelt Warm Springs Institute for Rehabilitation attained a score twice that of any previous operator with phenomenal corrective skill at speeds requiring maximal visual feedback. Because of the system's lack of kinesthetic feedback which had been considered a fault, he was able to experience a positive transfer of learning from his actual driving experiences on zero effort control systems and adapted well to a vehicle with only visual feedback. He did not expect or depend on any other form of feedback, which most other drivers tested to date do initially. His suggestions were (1) slow it down, (2) make it more responsive, and (3) make braking and acceleration proportional.

CONCLUSION

The project has already provided a driving situation simulator which may be utilized as a preliminary driver evaluation aid, a training device, and a vehicle to enable researchers to identify alternate and possible new control configurations.

The proposed solution was a driving situations simulator with closed loop visual and proprioceptive rate and rate integral feedback. A prototype was built which interfaces with an operator in a wheelchair providing a near zero effort small diameter steering wheel with tri-pin adaptor and visuals in a format of easily recognized road and vehicle position and rate changes. The system is easily learned at comfortable operator controlled driving speeds and settings. It is expected that safe driving rates of as least 50 mph are possible.

The structure of the driving situation simulator promotes operator skill through realistic feedback experiences, since good quality experiences and competency are literally synonymous. The software also constantly reinforces the learned visual, audio, and proprioceptive feedback patterns relative to the speed of the required response. The system emphasizes the optimal adaptation of the operator to that particular optimal control system for his disability once that system has been determined through performance criteria which are quantitative, easily recorded, and readily analyzed.

The system is presently undergoing expansion to include additional software that will provide a graphics record of range of motion, reaction times, and coordination with the controls. The hardware requirements for the control interface have been successfully completed, though the addition of more generic controls is essential.

DISABLED DRIVERS EVALUATION AND TRAINING USING AN INTERACTIVE SIMULATOR

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INTRODUCTION

A physical and/or mental disability is recognized as being handicapping when it results in an inability to perform a given job adequately or at all. An inability to drive can, in itself, be viewed as a handicap which could then further compound whatever other disability an individual may have. Those with physical disabilities, e.g., amputees and paraplegics have often been able to regain mobility with specially fitted adaptive devices (1). However, the licensing of other medically impaired individuals such as those with neuromuscular dysfunctions, sensory impairments and those with diseases or medication that can produce altered states of consciousness has been more difficult to address because of difficulties of assessment and evaluation (2). Because of the recent emphasis to rehabilitate disabled individuals where possible, a new emphasis is being placed to evaluate the extent of the disability and to determine if an individual is capable of learning to drive safely. Those so identified can then be trained to drive.

Armstrong and Kochhar (3) have presented a comprehensive list of the different kinds of disabling conditions and their effect on the various perceptual and motor functions in humans. Questions of driver assessment and training are of particular interest in the case of those disabilities which affect the perceptual, sensory, motor and cognitive attributes. For persons with disabilities where the residual capabilities are not fully known, a driving simulator can provide a comfortable and non-threatening environment for assessment and training. Conditions that affect perception, judgment and motor control can be investigated and aspects of several driving related capabilities examined as they affect the performance of the driver and vehicle. In providing a safe environment, a driving simulator can be invaluable in assessing the dimensions along which any training of the disabled could prove to be most favorable.

Both part-task and full-task simulators enable the study of several dimensions of driver behavior and driver performance, including driver vehicle interactions, vehicle dynamics, study and validation of models of driver behavior, and examination of the components of the driving task. Much of our present knowledge of driver behavior and performance is derived from experiments conducted on part-task simulators which permit a study and isolation of the essential parameters of driving and driving skills. In this paper we highlight the use of a part-task, fixed base computer controlled driving simulator as a tool to identify those disabled persons who have the potential to be trained to drive and further to investigate how those so identified could be trained

METHOD

A computer controlled dynamic part-task driving simulator was used for evaluation and training. The simulator has been described in detail elsewhere (4). A computer simulated the longitudinal and directional control dynamics that the vehicle would produce from the driver, road and disturbance inputs and provided the vehicle velocity, heading angle, and lateral position used by the display hardware and in the subsequent data analysis.

Tasks and Results

Two sets of experiments were conducted. In the first set of experiments, a disabled group of five subjects with perceptual and neuromuscular dysfunctions, and an able-bodied group of five subjects performed a two-hour driving session composed of four test conditions. Regression models developed revealed that for both groups as well as for each individual disabled subject, the rate of change of heading angle and lateral acceleration affected steering response the most. Other observations as to the performance and suitability for training of two of the subjects in the disabled group were also made (5).

The second set of experiments were part of a longitudinal research program. Ten subjects with different perceptual dysfunctions were tested over a period of three months. Each subject performed the simulated driving task on five occasions, approximately three to five days apart. Each occasion served both as a training and an evaluation session. It was hypothesized that trainable individuals would indicate a consistent and positive improvement along several parameters over the five sessions whereas the performance of others would not indicate a positive pattern. On the basis of these experiments, a general methodology to identify persons who have the potential to become functional on the road drivers has been evolved. We propose to present and discuss our findings in the oral presentation.

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ROLLING RESISTANCE FACTORS FOR WHEELCHAIR TIRES

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Tests were run to study the relationship between rolling resistance, camber and toe for a pair of wheelchair tires. This testing was directed at two primary goals. One was to determine the comparative evaluation of the tires to determine which tire would be best suited for certain user conditions. The other goal was to determine which factors were most important to monitor during the production and manufacturer of wheelchairs in order to achieve an efficient end product.

Seven different kinds of tires were tested to study the parameters of load, velocity, camber and toe as they related to rolling resistance. The testing consisted of using a specially designed cart that could easily be adjusted to vary the camber and toe of a pair of tire-wheel combinations. The cart was dynamically tested on a treadmill specifically designed for wheelchair testing. A specially designed cart was used both for ease of adjustment and for the ability to isolate the rolling resistance of each pair of drive tires commonly available for use on wheelchairs. This test system eliminated the variable of the rolling resistance of the front casters of a wheelchair. For the actual testing, the test tires were mounted on the test cart and checked to have a maximum static torque needed to turn the tire. This was done in order to check that the wheels had been mounted properly and therefore pressure on the bearings did not contribute a significant amount of resistance to rolling. The test cart was then tethered to one force gauge to measure the rolling resistance and another force gauge to monitor the slight amount of weight of the system not being loaded on the large tires. Due to the cart being a two-wheel system a slight amount of load needed to be shifted forward of the center of gravity of the cart system in order to keep the cart stable (not flip over) during the test procedure. This load borne by the second force gauge was measured and set to be a constant throughout the testing. This constant load was then subtracted from the weight added to the cart to derive the actual load being carried entirely by the tires being tested.

The treadmill was then turned on to test the wheelcart system at four speeds (0, 4, 7, 10 kph) unloaded and with loads of 32, 55, 77 and 100 kilograms force. In addition, camber of 0, 2, 5, and 10 degrees and toe of 0, +1, -1, +2, and -2 degrees was also measured for each set of conditions. These permutations amounted to 240 recordings per tire.

Some trends can be discerned from this data. High-pressure, narrow tires tend to give the least rolling resistance and solid gray rubber tires tend to give the most rolling resistance. The amount of toe in a wheelchair tends to be critical. Accuracy in manufacturing, and therefore alignment, seems to be quite important. As little as two degrees toe can double the rolling resistance over the zero degree toe condition. There is also a slight indication that toe out produces more rolling resistance than inward toe.

Large camber settings are sometimes used by wheelchair athletes to increase their wheel base and provide easier access to the drive rims. The testing generally indicates that camber does not drastically affect rolling resistance however some of the newer, airless tire designs (Wilson LITE-RIDE) show peculiar variation of rolling resistance with camber. This is probably attributable to the varying cross section of the moulded or extruded tire. A difference in rolling resistance is apparent even at low velocity (4 kph) among the tires tested and the difference grows greater as speeds increase.

The rolling resistance of the tires at a low load was not necessarily indicative of the differential rolling resistance among the tires at a high load. In other words, the rolling resistance of some tires, such as the higher pressure tires, did not increase with load nearly as quickly as some of the other tire designs.

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A WHEELCHAIR-LIFT SYSTEM FOR THE SEVERELY DISABLED DRIVER

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ABSTRACT

A mobility system based on a standard automobile is developed as a more advantageous alternative to existing van-based systems. These advantages are lower initial cost, smaller size and inconspicuous appearance. The system provides access for a specially-built wheelchair into a automobile through the driver side door. The lifting function is provided by the wheelchair itself. After the seat section of the chair is attached to a support frame, the seat height adjustment mechanism is operated to retract the lower sections of the chair reducing the amount of head room required. The entire lifting sequence is under the sole control of the disabled person.

INTRODUCTION

Most of the different solutions to the problem of independent transportation of people with disability have focused on persons with some degree of mobility (e.g. paraplegics), which allows them to transfer between a wheelchair and an automobile seat unassisted and to drive with a minimum of control aids. Fewer successful solutions exist for the problems of the severely disabled person (e.g. quadriplegic) who must rely on assistance to transfer between automobile and a wheelchair. Generally these solutions involve the use of vans modified by raising the roof or lowering the floor to provide head clearance for standard wheelchairs having no height adjustment. In addition, the vans are equipped with transfer devices, such as ramps or lifting platforms. Among the disadvantages of van-based designs are (1) cost, since major structural modifications are necessary for all standard vans when a standard wheelchair is used and (2) size, which makes parking, loading and unloading more difficult.

WHEELCHAIR-LIFT SYSTEM

The Rehabilitation Engineering Center has been developing an acceptable wheelchair-lift system based on two-door passenger cars. The system provides access for a specially-built wheelchair through the driver door of GM's x-car. The entry concept is very simple; the variable-height wheelchair acts as its own lift. The chair is driven onto a special docking frame extending from the floor to the side of the car. With seat supported by the frame, the seat height adjustment mechanism is operated so as to lower the seat, but since the seat is held fixed, the lower section of the chair is retracted to bring the overall height of the occupied chair within the headroom available.

A ball screw actuator opens and closes the door under the remote control of the disabled driver. One end of the actuator is bolted to the dash, the other is bolted to the door above the chair support frame. The action of the actuator is replaced by that of a latching device during the last few degrees of door closing in order to exert a large enough force to compress the door seals and latch the door. The latching device, a Cadillac trunk closing unit modified by the addition of an involute hook, draws the door into a locked position. After the door is latched automatically, the chair and occupant are brought into driving position. At this point, the seat is raised off the support frame and the chair is adjusted for proper driving position. Finally the wheelchair resistant system is activated to lock the wheelchair in place.

CLOSURE

The construction of a prototype of the system is just beginning. This represents the second prototype being built. Once completed, the system is evaluated for "operability" and reliability using disabled subjects.

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A TEST OF NICKEL-ZINC BATTERY FOR WHEELCHAIRS

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ABSTRACT

Experimental 80 Amp-hour, 24V nickel-zinc batteries have been tested for electric wheelchairs use. The Ni/Zn battery charge and discharge characteristics were found to be similar to Pb/acid, but the cycle life of the Ni/Zn battery is predicted to be significantly lower than that of the Pb/acid.

INTRODUCTION

The nickel-zinc battery has been under intensive development for electric vehicle propulsion application (1). A comparative list of battery characteristics given in Table 1 shows the Ni/Zn has a significantly larger specific energy, and this reduction in weight for the same energy stored is desirable for electric wheelchairs. The low cycle life, i.e., discharge and charge cycles, must be improved to make the Ni/Zn battery a viable system, and research has shown that 500 cycles is possible at 50% depth of discharge (3).

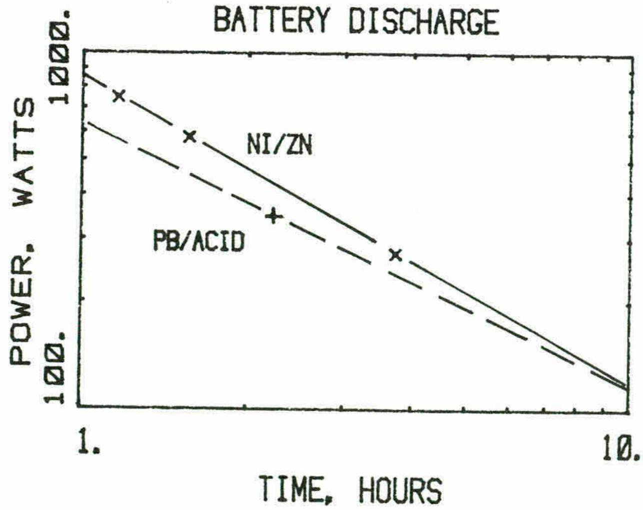
TABLE 1 TYPICAL BATTERY CHARACTERISTICS (2)

(1978-1979)	Nickel/Zinc	Lead-Acid	Nickel-Cadmium
Sp. energy, W-h/kg.	70	30	44
Cycle life	200	700	500
Cost $/kW-h	125	100	175

BENCH TEST RESULTS

Figure 1 is a Ragone charge of discharge time to 21V versus power, shown for a 24V, 55 Ah Gel/cell, and 24V 80 Ah Ni/Zn. The Ah (amp-hour) ratings are SAEJ537b 20 hour, 80°F rating.

FIGURE 1
BATTERY DISCHARGE



Measurements with electric wheelchairs show that 100-200 watts is typical for average power with negligible demand above 1000 watts.

The test Ni/Zn battery has a energy density of 26.4 W-h/lb. A Pb/acid, 24V, 80 Ah deep discharge battery has an energy density of 21.3 W-h/lb. Figure 1 shows that the Ni/Zn has a discharge curve similar to a Pb/acid battery. If the depth of discharge for the Ni/Zn is reduced to increase cycle life (3), the energy density advantage over Pb/acid disappears.

WHEELCHAIR TEST RESULTS

The Ni/Zn battery was tested in a General Teleoperators motor-in-hub wheelchair, and driven over an indoor test route. With the 80 Ah Ni/Zn battery, it was found that it took 9.28 hours to discharge the batteries to 21 volts. The test required 79 laps of the indoor circuit with a total distance covered of 17.37 km.

CONCLUSION

Schiffer (1) states, "on a purely cost basis, Ni/Zn batteries will not compete with lead-acid for those jobs which lead-acid can satisfactorily perform."

If research can significantly improve the Ni/Zn cycle life without derating the battery, the advantage of a high energy density would be of great interest for powered wheelchair use.

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EFFECT OF SEAT POSITION ON HANDRIM FORCE

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This investigation was conducted to determine the effect of horizontal and vertical seat position to the wheel position on the generation of force on handrims.

METHOD

Subjects

Eight disabled males with complete upper extremity function who were either, full or part-time users of wheelchairs gave their informed consent to participate in this study.

Materials

A test platform consisting of a movable seat and handrims connected to strain-gauged beams was used to determine pushing (or pulling) force. The output voltage from the strain-gauges were recorded on a strip chart recorder.

Procedure

Each subject was provided a specific test period which was repeated each week until the tests were concluded. The combinations of seat heights and seat positions were presented in a random order to eliminate serial effects.

The middle, forward (MF) seat placement was established with the rear edge of seat 15.0 cm directly above the axle. The additional positions were established by moving the seat backward 7.5 (middle) and 155 (rear) cm, respectively and by raising or lowering the seat by 5 cm.

Four rim positions (-30°, 0°, 30° and 60°) were measured for each arm, with 0° at the top of the rim.

Results

Typical results are presented in Figure 1 below. An inspection of this plot (and others) reveals that mean values of handrim force vary considerably with respect to seat and rim positions.

An overlay plot (not shown) of the 36 handrim positions based on nine seat positions has revealed that there are six common points where the hands are in the same position for two different conditions. These are LR-30 and MF, 0; MR-30 and HF, 0 and LF, +30, HR, 0 and MF +30, HR +30 and LM +60; and HM +30 and LF +60.

Discussion

It is evident from figure 1 and related data that the subjects were able to exert more force when holding the rims at -30 and 0 in the middle and the rear seat positions.

This is further consistent with the better grip available in the -30 and 0 positions where the pulling effect tightens the grip.

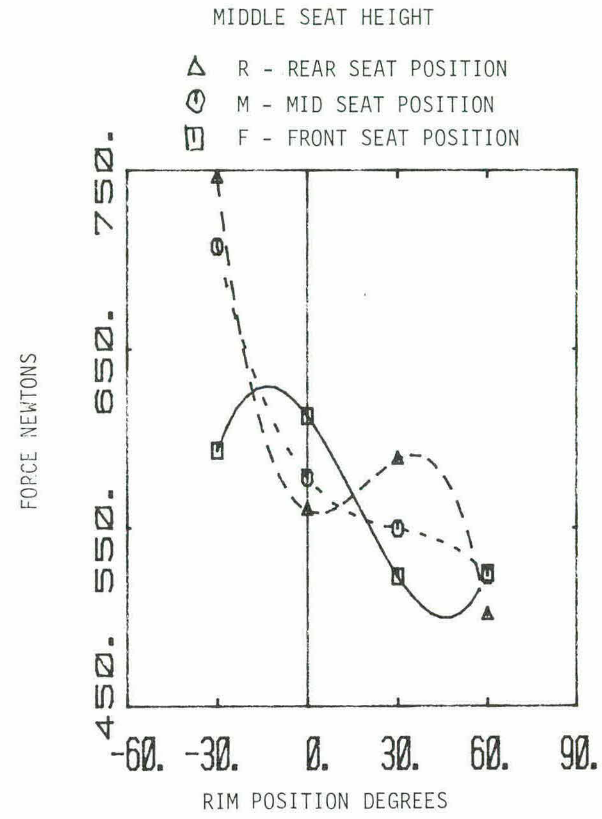

Figure 1

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A Measure of Activity Capacity in Blind Rehabilitation

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Rehabilitation of the blind involves increasing blind persons' capacity for activity. To see whether this goal is met, a suitable measure of activity capacity is needed. We have developed an 'activity' measure by applying the Rasch psychometric model (1,2) to self reports on a number of specific activities. We began with 90 activities representing the 7 general areas of functioning: self care, home care, travel/work, machine use, recreation, reading and writing.

Two equivalent lists of these activities were formed by having 28 rehabilitation workers at the Hines V. A. Blind Rehabilitation Center (BRC) rate the activities into eight categories of difficulty for a blind person. Scale values for the activities were obtained from these ratings by Rasch analysis. Seventy of the original 90 activities were selected for the subsequent matched lists, with 50 activities each so that 30 activities were common to both lists. The lists were made equal in average difficulty.

These lists were used to make alternate forms of an activity questionaire. We asked about the frequency of performing each activity, the difficulty of performing it, and the reasons for 'never' performing it.

This questionaire was administered to 100 blind persons who had completed rehabilitation training at the Hines BRC at least 6 months previously. The respondents were interviewed over the telephone by trained interviewers. The forms were administered alternately; each form was completed by 50 persons.

Then the activities were scaled according to difficulty. Specific combinations of a person's responses to the questions about an activity resulted in one of three difficulty scores for each activity: 'easy', 'medium', or 'hard'. The total score for each activity was the sum of its difficulty score across all persons. Rasch analysis arranged the activities on a linear scale, with logits as the unit of measurement.

The two forms were found to be similar in difficulty as expected. There was only a 0.2 logit difference in the average scale value of the linking activities between Forms 1 and 2. The difference in scale value on Form 1 versus Form 2 did not exceed for any linking activity two standard errors of estimate.

The activities from both forms were combined onto a single line, taking into account the 0.2 logit difference between forms. The activities cover a range of about eight logits of difficulty. The mean standard error of estimate for activity scale values is 0.3. The activities cover about six distinct difficulty strata.

Next, the 100 blind persons were located on the same linear continuum as the activities. The range of scale values for person ability was seven logits. The mean standard error of person scale values was 0.3. There were four distinct strata of person activity levels.

The arrangement of activities by the blind was similar to the arrangement by rehabilitation workers. Self care activities were generally easiest to do, while reading activities were hardest to do. The other areas, in order of increasing difficulty, were machine use, home care, travel, writing and recreation. Within areas, the order of activities in difficulty was also similar between the blind and rehabilitation workers. These similarities suggest that the arrangement of activities on a linear continuum of increasing difficulty is useful and reproducable.

A prime feature of Rasch scaling is that the probability of a difficulty score for a person on an activity is a simple function of the difference between their scale values. A person or an activity 'fit' on the scale to the extent that their actual score pattern is predicted by the scaling. Twenty one of 100 blind persons and seven of seventy activities misfit by two or more standard errors. Person misfit usually called attention to special attributes, such as multiple handicaps or chronic illnesses, that warrant special consideration in rehabilitation training. Person misfit could be attributed to diversity of the sample in these and other special attributes. Activity misfit was caused by interactions between the activity, personal preferences of persons in performing the activity and the scoring procedure for difficulty.

The present scale was used to guide the development of a final 'activity' instrument, which includes the following improvements: 1. difficulty scores are obtained with a single question, 2. the question is confined to skills that people usually do regardless of demographic attributes or personal preferences, 3. the question assesses 'expected difficulty' even if the activity is never performed, and 4. the question assesses difficulty of performing the activity without help from others. This new instrument is in use in our current evaluations of blind rehabilitation at the Hines BRC.

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ETCETERA: A COMPUTER ACCESS PROJECT FOR THE VISUALLY IMPAIRED

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ABSTRACT

The Electronic TeleCommunications Evaluation, Training, Education and Research Activity (Etcetera) is a joint Veterans Administration and private project designed to provide the visually impaired with information about computer aids. Of equal importance is its goal of developing and evaluating innovative software and hardware designed for visually impaired users. As computer technology becomes more prevalent these goals will become increasingly critical in the independence of the visually impaired.

INTRODUCTION

In December 1981 the Western Blind Rehabilitation Center, Veterans Administration, Palo Alto began development of training programs for visually impaired veterans interested in the use of computers. The computers included the Kurzweil Reading Machine, a Maryland Computer Products Total Talk and a Telesensory Systems Versabraille. The training programs were facilitated by telephone access to computers located in the Department of Electrical Engineering, Stanford University. Indeed, researchers at Stanford were instrumental in helping the Etcetera begin operation.

While this training was met with a great deal of enthusiasm by veterans, several problems became evident. Among these the largest was the difficulty veterans had in transferring their new computer skills into the "real" world. Included here are difficulties in finding jobs, adapting computer aids to employer's computer systems once a job has been found, "unfriendly" computer aids, and many other general and situation specific problems.

These problems are not unique to veterans, nor are they unique to the visually impaired, yet they are major hurdles. The Etcetera project has attempted to overcome these hurdles in two ways. First, an affiliation with the Sensory Aids Foundation of Palo Alto provides employment counseling and job development among other benefits. Secondly, research cooperation with the Rehabilitative Engineering Research and Development Center, Veterans Administration has provided valuable technical information and produced projects to develop improved computer aids and devices. It has also become an umbrella under which researchers from the local community can contribute to the Etcetera.

A unique benefit of the affiliation with the Sensory Aids Foundation is that it allows access to Etcetera by non-veterans. These include rehabilitation professionals who need to become familiar with computer aids, as well as, visually impaired consumers. This also reduces the need for duplication of training facilities in the local community, which is an important economic consideration.

GOALS

Several short term goals have evolved. These include the purchase of additional computer aids to provide more comprehensive training and the development of training materials. Also included is an update of the Computer Aid Manufacturer's Listing, which is a project currently being conducted with the Computer Center for the Visually Impaired, Baruch College, New York.

The Etcetera's long term goals include the development of valid and reliable evaluation methodologies for computer aids and the development and dissemination of a body of knowledge concerning computer hardware and software for the visually impaired. Another major goal will be the development of a voice output bulletin board accessible either by voice or computer. This system will be the major information gathering and dissemination mechanism of the Etcetera. It will also be the mechanism through which evaluative information is gathered from users of new devices. It is anticipated that the hardware and software design of the bulletin board system will be made freely available to other groups to facilitate local and regional communication between visually impaired computer users.

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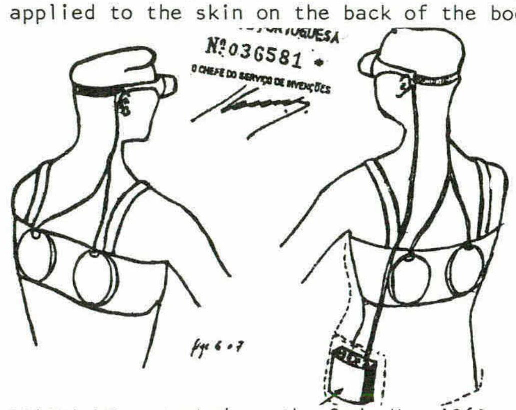
CIDEF - CENTRO DE INOVAÇÃO PARA DEFICIENTES - LISBOA

BRIEF HISTORY

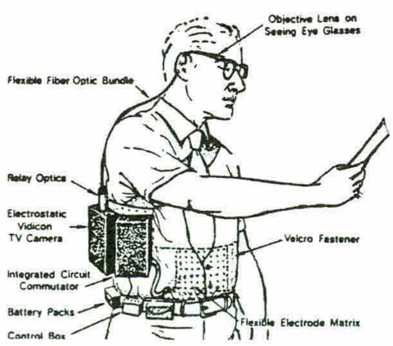
In October 1959, an invention which was given the name of "Electrovisor" (Patent nº 36581) was registered at the Department of Patents in Portugal. It was a device consisting of an electronic system, capable of taking a visual image to blind people by means of pulses on the skin.

For this purpose it would make use of television cameras, mounted on ordinary eye-glasses, the electric pulses generated in the cameras being amplified and then conducted to the matrixes of electrodes applied to the skin on the back of the body.



The patent was granted on the 2nd. May 1960 and must be the first document in existence in any country on visuotactile systems by the use of electronic devices, as it was only in 1967 that a similar project began to be developed at the Smith Kettlewell Institute and Department of Visual Sciences.

The tests carried out in the United States proved the feasibility of the initial idea and had the greatest repercussion in the scientific world.



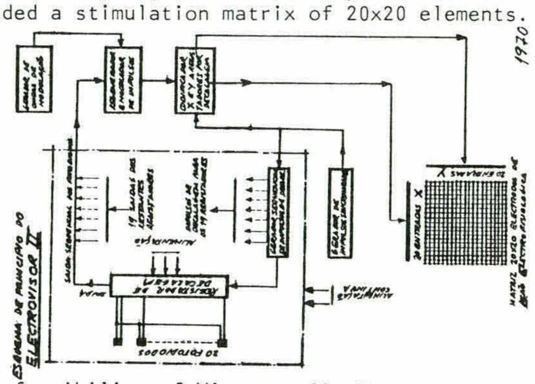
An American drawing of the invention analogous to the initial project (Electrovisor)

Photodiodes an Digital Electronics

With the coming of these new techniques, it became possible to rethink the "Electrovisor", so that the 1959 project underwent thorough modifications.

From this new concept was born the Electrovisor II patented in 1970 under nº 56.739, which was awarded a gold medal at the 21st. SALON INTERNATIONAL DES INVENTIONS ET DES PRODUITS NOUVEUAX-BRUSSELS 1972.

The Electrovisor II, in addition to a system of sequential reading of the cells (photodiodes), included a stimulation matrix of 20x20 elements.



The feasibility of Visuotactile Systems

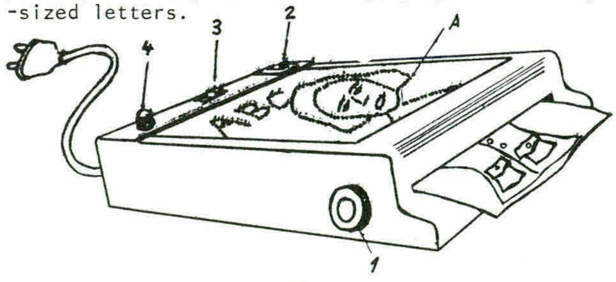
There are nowadays various devices that demonstrate the feasibility of the Electronic Visuotactile Systems.

The best known of all is probably the Optacon, created at the University of Standford, which makes use of a 144 photodiode television camera, applicable to the characters of a text. The image of the character framed by the camera is felt by tactile means on the index of the left hand by the vibration of piezoelectric crystals, thus enabling blind people to read printed or typed texts.

The Tactovisor

In March 1981 I applied for a patent, which was given nº 73.002, referring to a new device intended for the tactile perception of the outlines of drawing, graphs and large-sized letters, intended for blind people.

By making use of principles of Photoelectricity, Electronics and Electromagnetism, the new device has been endowed with a pin matrix, the pins of which stand out whenever the photoelectric cells pick up the image of a drawing, graph or of large-sized letters.



This is a device of difficult execution, which has not yet reached the stage of a project, but which can become e reality with international cooperation.

CHARACTERISTICS OF BLIND READING AND MANUAL SCANNING WITH AN ELECTRONIC READING AID

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INTRODUCTION

Sighted reading involves the coordinated use of the visual and oculomotor systems. Reading aids for the blind usually involve a substitute sensory system and, if scanning is necessary, a substitute motor system, most commonly the hand/forearm system. A common electronic reading aid, the Optacon (1), utilizes a tactile input in coordination with manual scanning. During reading with the Optacon, the print-sensing camera is used to scan text with one hand, and the index finger of the second hand is presented with a vibrating-pin facsimile of the print. We have examined the effects of text difficulty and order of text presentation on reading rate and manual scanning parameters in an attempt to understand the basic processes involved in tactual reading by the blind.

METHODS

We examined tactual reading behavior by 10 adult blind Optacon readers. Subjects were asked to read a random selection of 10 texts from a set of 35 that have been rank ordered (2) according to the level of text difficulty (LTD). Each text was typed using a font with 12 letter spaces per inch. Horizontal and vertical position of an LED attached to the Optacon camera was monitored during reading by using a video camera and specialized circuitry. Analog voltages proportional to horizontal and vertical LED position were recorded on a chart recorder.

Reading rates measured in letter spaces per minute (LSM) and words per minute (WPM) were derived from the chart recordings. Also, scanning performance was examined by determining the number and magnitude of regressions (right to left movements within a line of text) as well as the time required to change from one text line to another. The data for each of these rate and scanning measures was plotted against LTD and order of text presentation (OTP). These plots were then statistically evaluated using the linear least squares regression procedure.

RESULTS & DISCUSSION

No statistically significant correlation (5% level) was found between any of the rate or scanning measures and OTP. If adaptation and/or fatigue phenomena were operative during the experiment their effects were not reflected in our measures. The lack of a significant correlation between any of the rate/scanning performance measures and OTP allows a straightforward interpretation of the relationships, if any, between the same measures and LTD.

The overall average (100 texts) of the number of regressions per 100 letter spaces was 7.4, and the overall average of the time required to change lines was 3.0 seconds. Neither of these scanning measures was found to be significantly correlated (5% level) with LTD, but regression magnitude, with an overall average of 4.4 LS, was found to be positively correlated with LTD. The least squares line indicates an increase in regression magnitude from 3.8 to 5.0 LS over the entire range of LTD. The reason for this correlation is not obvious, but may be related to an observed similar increase in average word length with LTD.

Reading rate in LSM (overall average 151 LSM) was not correlated (5% level) with LTD, but rate in WPM (overall average of 28.2 WPM) was found to have a significant negative correlation (5% level) with LTD. Why is one rate measure uncorrelated with LTD, and the other correlated with LTD? A plausible explanation is based on the observation that as the texts become more difficult, the average word length increases. Therefore, for two texts having the same # of LS, the more difficult text will contain fewer words than the easier text. But if it is assumed that rate in LSM is constant, (based on the lack of correlation of LSM with LTD) easy and difficult texts of the same physical length (same # of LS) will take the same time to read. However, the WPM rate will be less for the difficult text simply because it contains fewer words. If each of our measured WPM rates is recalculated based on a "standard" word length, the correlation of WPM with LTD disappears. Hence, the observed correlation is a "pure" text phenomenon, and does not reflect changes in reading behavior as LTD increases. These results are similar to those that have been observed for sighted reading (3).

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Research Section
Hines, Ill. 60141-0020

FIELD TRIALS OF TELESENSORY SYSTEMS HAND-SCAN VOICE OUTPUT READING SYSTEM

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HISTORY

In 1976, Telesensory Systems, Inc. began an extensive research effort to develop a voice output reading system (VORS) based on the Optacon (OPtical to TActile CONverter), a hand-scan, direct translation reading system for blind people. The project sought to develop a system which could take the letter images as presented by the Optacon and perform optical character recognition and text-to-speech conversion resulting in high quality synthetic speech output. Research on the project was partially funded through an interagency grant from the Veterans Administration, the Bureau of Eduction for the Handicapped, and the Rehabilitation Services Administration. The research and development culminated with the building of eight demonstration units of the HS-1 system which have been used in this project's study of the utility, functionality, design, and performance of the system. In total, seven of the eight field test units were placed in field sites. One remained at TSI for technical backup. The sites were: The Veterans Administration Blind Rehabilitation Centers in Palo Alto, California, and Hines, Illinois, a school district in DeKalb County, Georgia, various individual employment sites in California, The Braille Institute of America, Los Angeles, California, the Cleveland Society for the Blind, Cleveland, Ohio, and a site divided between the American Council of the Blind national office in Washington, D. C., and one of their state affiliate offices in St. Louis, Missouri. This project, although largely funded through a grant from the Veterans Administration, has remained interagency in scope, evaluating the system in education and vocational settings, and rehabilitation facilities.

RESEARCH OBJECTIVES

While data reduction has not been undertaken at this writing, data reduction will be completed by the time of the conference, and the following areas will be discussed during the presentation:

- The applications to which the system was applied will be considered, providing information concerning most appropriate educational, vocational, and personal uses for this technology.
- The evaluation will provide a detailed profile of best users of the system, and for those who are not successful, or who choose to discontinue system use, a review or whether system or non-system factors were involved.

SUMMARY

This project has focused on specific feedback concerning the HS-1, the first hand-scan voice output reading system. The paper will provide detailed review of user feedback, and current status of research on this technology at Telesensory Systems. Finally, the presentation will summarize the overall experience with this concept of reading system, and outline recommendations for the future of this approach to print reading for people with visual disabilities.

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VIDVOX, A FEASIBILITY MODEL OF A COMMUNICATION AID FOR DEAF PERSONS

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INTRODUCTION

By recent estimates, approximately one million people in the United States are profoundly deaf, i.e., cannot be helped with hearing aids. Presently, these deaf persons communicate by sign languages, lipreading, or by lipreading augmented with manual cues. Each of these methods has severe shortcomings. Major improvements in deaf communication, probably using a new technique, are needed.

Sensory Aids Foundation is funding development of a feasibility model of Vidvox (Latin; video = I see, and vox = voice), a speech recognition device which will enable deaf persons to understand speech.

DESCRIPTION OF VIDVOX

Vidvox, as presently envisioned, will display, as the speaker talks, a stream of phonetic symbols. Vidvox speech recognition will not be perfect; wrong symbols, missing symbols, and extra symbols will be displayed. However, accuracy must be higher than that of lipreading to be useful.

To achieve acceptable performance, i.e., high user understanding, prosodic speech features may also be detected and displayed. These might include:
1) Stress, identified by underlining or high intensity,
2) Duration, identified by stretching symbols or spaces across the display,
3) Relative pitch, indicated by relative vertical position of an overline.

Requirements for a fairly high performance Vidvox are:
1) Recognition of speech segments, not words,
2) Continuous speech at a normal or slower than normal rate,
3) Unlimited vocabulary,
4) Real time response, i.e., display must keep up with speech,
5) Limited machine training,
6) Limited number of speakers,
7) Moderate accuracy (greater than 60% phoneme accuracy).

With further improvements, later Vidvox devices would probably require less training, accommodate more speakers, have higher accuracy, etc.

DEVELOPMENT OF FEASIBILITY SYSTEM

Vidvox will likely be developed in several steps. The objectives of two initial projects, now underway, are to demonstrate feasibility. Subsequent projects with objectives of actual device development will follow, if feasible. The initial projects are a human factors investigation and a speech processing development. These two projects are being funded separately but are progressing in close coordination.

Some specific objectives of the human factors investigation are to:
1) Determine the best phonetic alphabet for deaf users with good reading skills,
2) Determine the types of probable recognition errors and determine the error tolerance, i.e., accuracy required,
3) Determine the best strategies for error handling,
4) Determine the benefits of displaying additional prosodic information such as stress, extended phonemes, or pitch level.

Some specific objectives of the speech processing development are:
1) Determine the general approach, including which speech segments to detect and what analysis techniques to develop.
2) Develop those analysis techniques, using, if necessary, large computer facilities.
3) Develop sufficient accuracy, using the large computer resources, without limiting response time or training.
4) Demonstrate feasibility.

Surveys of information on human factor requirements and the state of the art of speech recognition technology were completed in February, 1982. Contracts for the two initial feasibility projects were awarded in June, 1982. These are estimated to be completed on or before June, 1984.

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COMPUTER-ASSISTED INSTRUCTION IN LIPREADING FOR HEARING-IMPAIRED ADULTS

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The purpose of our project is to increase the effectiveness of lipreading instruction for hearing-impaired adults. Computer-assisted instruction (CAI) is being examined as a way to provide supplementary drill and practice in lipreading for hearing-impaired clients in a Veterans Administration aural rehabilitation program.

Hearing loss is not life threatening, but its consequences can have a devastating effect on an adult's psychosocial and vocational adjustment. The hearing handicap stems primarily from reduced efficiency in oral communication. Programs of aural rehabilitation have been developed to help the hearing-impaired adult improve his receptive communication ability. Lipreading instruction for the hearing-impaired person is one element in the aural rehabilitation process.

The advantages of computer-assisted instruction in education have been well documented, and these advantages can be applied equally well to lipreading instruction. Computer-assisted instruction increases the availability of the teacher's time, provides equivalent instruction for all students, students learn at their own pace, and learning time is reduced. As the student uses the computer, data are gathered and summarized, thus building a more scientific base for learning. This information helps educators determine which instructional techniques are best.

In the current project, CAI is being used as a research tool to examine the effects of auditory redundancy and linguistic redundancy, as lipreaders receive drill and practice with sentences. Auditory redundancy will be provided by increases in the auditory signal level to the degree necessary for the lipreading student to identify a particular practice sentence. First, while wearing TDH-49 earphones, the lipreader will see a talker say a sentence on the TV monitor. If the sentence is not identified correctly, a programmable attenuator, under computer control, is set to 0 dB sensation level, and the video segment with a low level auditory signal is given again. The sentence is repeated until the lipreader identifies it correctly or until the auditory signal level is increased to a maximum of 15 dB sensation level. The auditory signal level is then turned off by the computer, and the next sentence in the sequence is presented. This sequence is repeated until all sentences in the series have been presented.

In the linguistic redundancy, a lipreader views a talker saying a sentence on the TV monitor. If he fails to identify the sentence correctly, markers on the TV monitor are spaced to show the number of words and the number of letters in each word. If the lipreader fails to identify the sentence, a clue word is shown in the margin. During the fourth presentation, one clue word is correctly placed in the sentence, and on the fifth presentation, two clue words are correctly placed in the sentence. If the lipreader does not respond correctly to the fifth presentation, trials for a given sentence are terminated, and a new sentence is presented with no linguistic clues. This sequence is repeated until all sentences in the series have been presented.

The instrumentation for this project includes a DAVID Instructional System, a programmable attenuator, and a Grason-Stadler Model 1701 audiometer with accessories. The DAVID system was developed at the National Technical Institute for the Deaf to provide CAI for young adult deaf students. DAVID is an acronym for Data Analysis Video Interactive Device. It consists of a combination of a color video screen, a random access video cassette player, microcomputer electronics, and an interactive keyboard console. The microcomputer serves to provide CAI decision making, text, and answer analysis for the completion of lipreading drill and practice sentences.

Twelve lists of drill and practice sentences for use with CAI will be developed for use in our project. These lists will be arranged so that they are sequentially and progressively more difficult. They will provide material for CAI drill and practice during a series of 12 lipreading lessons which will be administered to hearing-impaired veterans. Materials developed for this project will subsequently be incorporated into a set of lipreading lessons for use by Veterans Administration programs in aural rehabilitation.

(This project was supported by Veterans Administration Contract V674P-693.)

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VOCATIONAL REHABILITATION OF A DEAF QUADRIPLEGIC

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Margy Gillispie, Sr. Physical Therapist, Tulsa Rehab Center
Charles J. Laenger, Sr., Rehabilitation Engineer, Tulsa Rehab Center

ABSTRACT

A thirty-five year old, prelingually deaf quadriplegic was successfully vocationally rehabilitated by collaborative effort of Oklahoma Rehabilitative Services, IMPART, Lowrance Electronics, Inc. and Tulsa Rehabilitation Center. Administrators of Oklahoma Rehabilitative and Visual Services (OR&VS) and Lowrance Electronics are to be commended for accepting and serving this individual who is now a productive member of society.

CASE HISTORY

Client D.F. became deaf as an infant due to spinal meningitis. He graduated from the Oklahoma School for the Deaf at seventeen years of age and shortly thereafter broke his neck in a diving accident. He was committed to a nursing home where he lived for eleven years! He was referred to the Oklahoma Department of Human Services by a deaf friend.

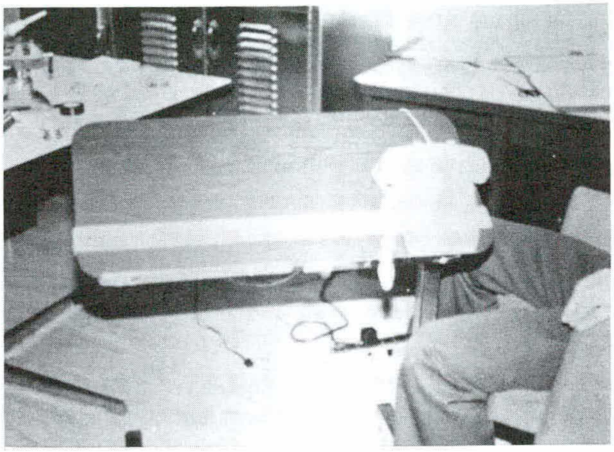
He spent five months in Tulsa Rehabilitation Center where he received extended medical rehabilitation, physical and occupational therapy and training in communication skills. He also received independent living training and was sent to the Rehabilitation Engineering Center in Virginia for training in both vocational and independent living skills. Oklahoma Rehabilitative and Visual Services provided a powered wheelchair, a Hoyer lift and other equipment, and assistance in locating and setting up an apartment. This agency also provided funds for transportation of the client to and from work for more than two years.

The client was accompanied by his vocational rehabilitation counselor and a rehabilitation engineer of Tulsa Rehabilitation Center to Lowrance Electronics, an electronics assembly plant, to identify jobs that might be adapted to his capabilities. This team agreed that it was questionable whether the client could perform any of the jobs available at this site in a productive manner. Nevertheless, the employer hired the client as an electromechanical assembly worker on a trial basis. Client D.F. demonstrated that he could do productive work and was hired permanently. Much credit goes to the Lowrance Electronics industrial engineer who fabricated special assembly-assist devices for the client. The administrator and other plant personnel provided special training and personal assistance which helped this severely disabled man to become a truly productive employee.

But further technological intervention was required to facilitate independent living. Once transferred to bed the client was unable to turn off the lights and television, answer the door, call his deaf care-provider or use his TDD machine. An over-bed table was modified by installing velcro strips to the table and complementary velcro to the telephone, TDD machine, deaf-alert equipment and BSR environmental controls. See Figure 1. The client received instruction and training in the use and management of this equipment and his care provider received additional training in use of the Hoyer lift and assistance in bowel and urinary care from therapist of Tulsa Rehabilitation Center.

In summary, rehabilitation engineering assisted significantly in helping the client to acquire and retain employment. The main contribution of rehabilitation engineering was in-home modifications to improve independent living capability and cost containment relative to care provider expense. This successful experience of vocational rehabilitation of a deaf quadriplegic was attributable to cooperative participation of the public and private sectors and great effort by a pleasant and determined disabled individual.

Figure 1. An overbed table was modified by installation of strips of velcro. Telephone, TDD, deaf alert and environmental control equipment were mounted via velcro for convenient access by the deaf, quadriplegic client.



ACKNOWLEDGEMENTS

Various problems were submitted via the IMPART program which is sponsored by the Technology Utilization Division of the National Institute for Handicapped Research. Lowrance Electronics, Inc. made unusual effort and successfully accommodated this client through internal industrial engineering effort. Tulsa Rehabilitation Center staff members worked after hours since funding for independent living was not available.

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WHEELCHAIR USERS' RESPONSES TO HANDRIMS WITH OVAL CROSS SECTION

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Twenty-seven spinal cord injured wheelchair users aged 21 to 65 with 6 months to 34 years of wheelchair experience field tested a prototype handrim. The test rim had an oval cross section designed to increase contact between hand and rim as compared to conventional circular cross section hand rims. The test rim was made of wood, but finished with 8 coats of polyurethane varnish to provide a smooth surface.

The subjects' own rims were replaced with test rims for several days of ordinary use. Following this, they rated the test rims against their own in 12 specific circumstances, and commented on comfort, dollar value and potential problems with the prototype design.

Level of injury among the subjects ranged from C6 to L1. For data analysis they were divided into two groups: paraplegics with at least normal grip strength and quadriplegics with grip strength well below age adjusted normals.

In 9 of the 12 categories of daily use, at least 2/3 of the paraplegics rated the oval cross section hand rims better than their own. In pushing along side slopes, a 10th category, the test rims were rated better by 55% of the users and no different by an additional 28%. The two remaining categories were braking and going down ramps. These required prolonged contact between hand and rim and resulted in excessive heating from the wood material; users' ratings were as expected.

The rim designer estimated that the add on cost of a wheelchair with oval cross section hand rims would be between $20 and $60. Among the paraplegics, 79% said they would be willing to pay the low estimate and 58% would pay as much as the high estimate for a wheelchair with the new rim design. The oval rims were rated by all as requiring the same or less effort and providing as much or more comfort when compared to the users own hand rims.

Among quadriplegics, the responses were generally favorable, with at least half the respondents preferring the test rims in 10 of the 12 categories of use. However, individual grip characteristics varied, and so this was not considered to be a homogenious group. Notably, quadriplegic users with the smallest hand sizes were the least likely to benefit from the experimental design. This might be expected since the oval cross section has a larger circumference, but the numbers were too small to make valid inferences.

This study, with a consumer oriented approach to assessment of an new experimental design for wheelchair hand rims, indicates that the oval cross section offers users substantial improvement over the standard round cross section design.

Supported by Rehabilitative Engineering Research and Development Center, Palo Alto VAMC, Palo Alto, California 94304.

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RAMP-HOLDING AND ANALOG CONTROL AUGMENTATIONS TO A COMPUTERIZED WHEELCHAIR CONTROLLER

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The use of a microprocessor in a wheelchair control device allows the implementation of a variety of control schemes and the inclusion of parametric changes in control functions. The first prototype of a system previously described, the Microprocessor-based Wheelchair Control Interface (1), utilizes a two-switch control protocol with a scanning, interactive display. A heirarchical series of selections gives the operator a choice of display scanning speed, maximium forward speed and direction of travel. The processor accelerates the chair at a predetermined rate and controls course tracking and speed maintenance through a closed-loop system employing rotary motion encoders mounted on the driven wheels.

RAMP-HOLD FUNCTION

This system was designed as a plug-compatible add-on for the Everest and Jennings 3P Powered Wheelchair. The 3P, as with most other powered chairs, exhibits a tendency to roll when left in an unpowered state on a hill or ramp. The slope can be as small as 2-3 degrees. While mechanical braking has been employed experimentally (2), the common response to rolling is for the wheelchair user to activate the motors, through the joystick control, in a direction opposite to the slope.

The scanning-control user may have need of such a facility while trying to change course and driving on a ramp or on hilly terrain. The processor can emulate the joystick function in this situation. One method is to employ a totally electronic motor controller along with a high-resolution motion sensor to switch the motor current at high speed while conducting a trial and error determination of the appropriate direction and magnitude of motor torque to keep the chair still. With electromechanical relays, such as those used in the 3P, high-speed switching could damage the relay contacts. An alternative approach adopted for this system is to bias the motors on in opposition to the expected direction of roll and then adjust the output current as necessary. A fluid-filled level-vial with electro-optical sensors at each end is used as a tilt sensor. This configuration provides high damping to avoid false readings due to vibration. Motion is sensed with medium-resolution shaft encoders with 2 channels in quadrature to provide directional information, allowing rapid motor adjustments without interval timing requirements. Operation of the tilt-hold system commences when the "Run" switch is released and the tilt sensor indicates a slope condition. Holding continues while a new direction is selected, if desired, until the "Run" function is again initiated.

ANALOG/PROPORTIONAL CONTROL

Control modes for the wheelchair may include division of the speed and steering functions into two discrete proportional-control tasks or into hybrid schemes in which both proportional and encoded switch inputs are used. To facilitate the use of such controls, an analog input circuit has been developed which allows the use of any proportional type device including passive devices such as potentiometers and the use of active devices such as pressure sensors or strain guages with on-board amplifiers. The Control Interface provides a five volt output which may be used as a low-current supply or reference voltage by the input device. An op-amp network receives the input from each control device and in turn connects to an analog-to-digital converter. The input can be any voltage range between 0 and 5 volts. Computer-aided ranging provides rapid full-scale utilization of the votage swing available from each device and enables the user to compensate for variations in device output range secondary to user fatigue, motion limitation, or other dynamic factors.

Software has been written to implement the speed-steering modification. This includes the input auto-ranging and chair-speed range functions.

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KNEE CONTROLLED INTERFACE FOR CEREBRAL PALSIED PATIENTS

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ABSTRACT

A knee-controlled interface has been designed and clinically evaluated on two severely disabled cerebral palsied adolescents. This paper will discuss the results obtained in designing an interface that can control both the speed and direction of an electric wheelchair and the need for careful and systematic evaluation and training program, the study time covers a 3-year period for one subject and a 1-year period for the other.

INTRODUCTION

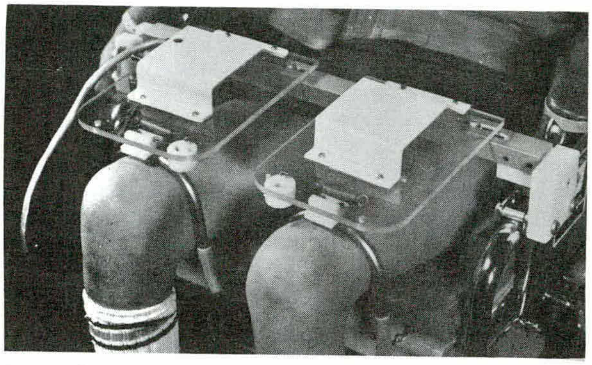
This project was initiated following requests made by two schools for physically handicapped students in the Montreal area. They showed a need for an interface that would allow severely involved athetoid C.P. students to gain mobility and independance.

Evaluation

Not all cerebral palsied subjects are affected physically, emotionally, socially or intellectually in the same manner. Both subjects assessed were non-verbal and communicated using Bliss Symbols. They were alert and highly motivated.
The evaluation consisted of observing; 1) pathological reflex activity, (stereotype movement), 2) seating posture, 3) voluntary movement and range of motion, 4) visual acuity and perception, 5) associated reactions. This was done by observing head, arm, hand and leg movements of the subjects in different sitting positions and situations resulting in finding adequate control of the knees.

Design and Operation of the Control Interface.

The two potentiometers normally found in a joystick control were conceived to operate independantly i.e. each one controlling a separate motor (1). Although the interface can be hand operated, the prototype was designed to be used by lateral movements of the knees such that; inward movements of both knees would cause the chair to move in a forward direction. Lateral movement of one knee or outward movement of the other knee would turn the chair in the same direction; thus giving the subject alternatives for turning. Outward movements of both knees would move the chair backwards. As these subjects are unable to achieve symetrical, controlled or sustained movements in their extremities, the interface was designed with adjustable stops to reduce the maximum speed and to limit the range of movement in each leg. It was observed that increased upward involuntary movement occurred at the knees and it was necessary to hinge the interface to accomodate these extraneous movements. The ability to adjust the chair's response time in order to minimize the effect of these movements on the steering stability was also included in the interface. A more costly alternative would be to incorporate a velocity and torque controller to the electronic module(2). This would facilitate the chair's steering abilities especially when outdoors.



TRAINING

The initial training consisted of the subject experiencing movement, direction and control thus allowing for proper adjustment and modification of the interface.
The training program was systematic and progressive to limit the possibility of frustration and error.
The training period varied for both subjects resulting from the complexity of each of their individual difficulties. It is necessary that the training be intense and repeated as the subject is just learning to move developmentally. This usually occurs during our first two years of life.

RESULTS

Both subjects were able to learn direction, their spatial awareness and their ability to control their own actions improved. The interface gave them independant mobility and greater possibility for interaction with their environment.

Acknowledgement

This work has been supported by the F.R.S.Q. The authors wish to acknowledge - K.Waksvik, M.Monette, M.Manelli and P.Chevalier for their participation in the training program.

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CP/TREADMILL WHEELCHAIR

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ABSTRACT

A prototype wheelchair has been developed for the group of wheelchair users who propel a conventional wheelchair in reverse with a backwards kick. This is achieved by the use of a treadmill drive.

OBJECTIVE

The objective of this project has been to design and develop a wheelchair for production and marketing which would convert a backward kick into forward motion, be functional, simple, reliable, and reasonably priced.

INTRODUCTION

The population of individuals with cerebral palsy is about 750,000; it is estimated that 1/3 of this population are wheelchair users (1). Of the 250,000 wheelchair users, about 5% propel their wheelchairs in reverse using a backwards kick (2). The backwards kick is used by this group because it involves the powerful lower limb extensors and a natural extensor synergy pattern. This makes the backwards movement easier than pulling forward with their foot or feet.

Unfortunately, in order to see where they are going, individuals propelling backwards often adopt grotesque seating positions. This poor positioning is obviously undesirable because of discomfort, potential postural problems, appearance and steering difficulties.

DESIGN PROCESS

Two prototypes have been made in an attempt to test the feasibility of converting the backwards kick into forward motion.

The first, had a wheel which was attached to a frame with two rear casters, one of the casters had a gear drive to a steering lever. A conveyor drove the front wheel, see Fig. 1. This provided an effective propulsion system which was well received by the small group of people who tried it. Unfortunately, the rear wheel steering made maneuvering an awkward process, requiring a lot of anticipation.

Fig. 1

The second, was designed to eliminate the above problems with the objective of producing a prototype suitable for production and marketing. It was felt that the required features could be built into the chassis of an existing three wheel electrically propelled wheelchair. This would be a very distinct advantage in that tooling costs could be kept substantially lower than producing a completely new wheelchair design. A manufacturer provided us with the chassis components necessary for the project.*

The chassis featured a swivel seat, front wheel steering and locking brake. Features that we built into this chassis were the conveyor drive (with roller clutches, for coasting without belt movement), a reverse gear, and dynamic braking (see Fig. 2). As far as possible, standard components were used in the construction of the prototype. Reverse gear is engaged by positioning a small lever operated wheel in contact with the drive wheel (see Fig. 3). This operation lifts the drive wheel ¼" clear of the gound and the small wheels become the reverse drive. Protection against tipping backwards is incorporated into the reverse mechanism.

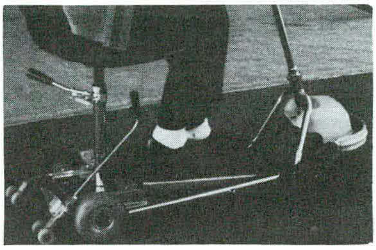

Fig. 2

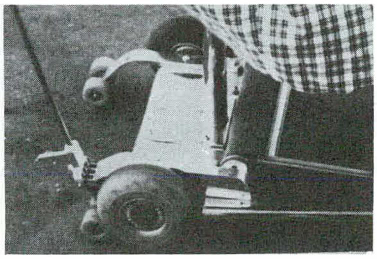

Fig. 3

EVALUATION

At this time, the wheelchair is being evaluated at the Cerebral Palsy Research Foundation in Wichita, Kansas. Preliminary results indicate that with minor modifications to the treadmill position, up to 15% of the cerebral palsy population could benefit from this device (2).

Further evaluation will be carried out by the chassis manufacturer at a later date.

ACKNOWLEDGEMENTS

The cooperation of the following organizations is gratefully acknowledged.

Amigo Sales Inc., Bridgeport, MI, (Chassis)*
Walton Manufacturing Co., Dallas, TX (Rollers)
Globe Albany, Winston Salem, NC (Belt)

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CONTINUED DEVELOPMENT OF THE IRM/NYU CLOSED LOOP PROPORTIONAL SPEED CONTROL FOR POWERED WHEELCHAIRS

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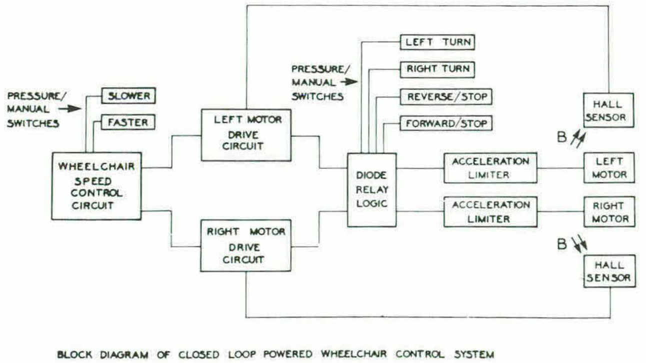
We have previously described the IRM/NYU pneumatic (breath) control system for the control of powered wheelchairs by the severely disabled[1, 2] and a proportional speed pneumatic control system for powered wheelchairs with automatic (closed loop) speed control.[3]

In the latter system the wheelchair drive motor speed is measured with Hall effect proximity sensors utilizing 30 pole ring magnets, one of which is mounted on the shaft of each drive motor. Each magnet is seen by a semiconductor sensor contained in a threaded tubular housing and mounted in close proximity to the magnet. The rotating magnet produces an alternating induced voltage whose frequency is directly proportional to the speed of the driving wheel. Major advantages of these sensors are that no mechanical linkage is required between the rotating member and the sensor; and the cost of the magnet plus sensor is considerably less than the cost of a tachometer. Hall effect devices are free from the effect of optical or dirt problems and are not affected by non-ferrous metals since they sense only the presence of a magnetic target.

The frequency of the pulse width modulated power drive output is the same as the frequency of the feedback signal produced by the ring magnets as they rotate past the Hall effect sensors. With the 15 pole pair (30 poles) magnets the output frequency at very low speed (approx. 0.8 feet/sec) is of the order of 45 Hz. The low frequency power drive output pulses are communicated to the wheelchair frame through the motor supports and may cause discomfort to the disabled driver. From previous evaluations it is known that this throbbing effect can be minimized by increasing the output frequency. Increasing the ring magnet to the maximum diameter which can be accommodated without modification of the wheelchair frame resulted in a ring magnet having 30 pole pairs (60 poles), thus doubling the frequency of the power drive output. This increase in frequency was not adequate. To further reduce the vibration, the frequency of the power drive output was quadrupled, i.e., for each pulse produced by the sensors, four pulses were produced in the power drive output. This increase in frequency seems to have solved the problem. Further evaluation is scheduled.



BLOCK DIAGRAM OF CLOSED LOOP POWERED WHEELCHAIR CONTROL SYSTEM

It was also observed that the acceleration at the start of travel was great enough to produce a jerk even when the speed control was set at minimum. The high instantaneous acceleration occurs during the short time interval required for the speed control to take hold. This has been eliminated through the utilization of a time delay switching circuit which reduces the amplitude of the output power pulses to 12 volts at start-up, and increases then to the normal 24 volts within a short predetermined time interval which can be easily varied from 0.3 sec and upwards.

A block diagram of the system is shown in the figure. The wheelchair can be controlled either pneumatically ("puff and sip") or manually (joystick). Velocity can be varied by "puff and sip" or by means of ribbon switches (mounted on the head rest) when the wheelchair is controlled by breath or joystick.

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DEVELOPMENT OF MOBILITY AID CONTROLLED BY THE MICROCOMPUTER DESIGNED FOR THE USE BY THE PHYSICALLY HANDICAPPED PERSON (CP)

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PREFACE

How to provide the means of mobility to the physically handicapped, especially to those who have the paraplesia of their lower limbs, is the problem of extreme importance. At present, the crutches, manual and electromotive wheelchairs are available as the mobility aids for such people, but the use of this kind of instruments is greatly difficult in the cases of those who have the heavy cerebral palsy and are regarded as the subjects of our research for the development of the new mobility aids, and now so many of these people need the personal care by others, since the existing mobility aids are not suited for the use by the people having the heavy cerebral palsy because of their problems concerning the controllability, travelling ability and the safety.

In order to overcome such problems of the existing mobility aids, we have developed a means of the aid with the power-steering system and the control system by the handicapped persons with heavy cerebral palsy, and the details of this new mobility aid will be discussed in the following.

COMPOSITION AND FUNCTION OF THE NEW MOBILITY AID

As illustrated in Figure 1, this mobility aid consists of the command unit, central control device, driving circuit, body of the mobile system and power source.

The body of the mobile system is designed tc take the front-wheel power-steering type so that the mobility aid can be directly driven and concurrently be steered by the front wheels. The motor for the power-steering system is equipped with the encoder. The rear wheels are provided with the suspension system so that the mobility aid can travel safely even on the uneven or rough road.

The command unit is designed to comply with the touch-switch type and the voice-command type in order to satisfy the various requirements depending on the conditions of the individual physically handicapped with the cerebral palsy.

The symbols of the touch keys and their meanings are as shown in Figure 2, and each symbol has one-to-one relationship with the conditions of the mobility. The voice command is given through the electric condenser microphone that picks up the vibration of the man's vocal cord when it is attached to the larynx. The pitch of the vibration of the vocal cord is extracted as the information, then the conditions of the movement of the mobility aid are determined depending on the combination of the number, duration and tone of the voice produced from the man's vocal cord as shown in Table 1.

The microcomputer unit (Z80, 2.5MHz, ROM of 2k byte, RAM of 1k byte, I/O, PPI) is used for the processing of the kinds of command signals, control of the drive motor and the control of the steering motor.

SOFTWARE

The drive of the mobility aid by the vocal command can be accomplished by interpreting the vocal command codes which is equivalent to the description in Table B of Figure 3, and the same procedure will be followed for the drive of the mobility aid. The speed of the mobility aid is controlled when it starts to move and when it stops so that the necessary acceleration or reduction of the speed can be obtained depending on the situation. When the mobility aid has changed the direction of its movement, the directions of the drive wheels and the driven wheels will be adjusted when the adjustment instruction is executed so that they will be able to move towards the same direction. When any one of the wheels has deviated from the normal course due to the conditions of the road, the position of the wheel will be corrected according to the instruction for correction, then after the necessary correction, the original instruction will be executed. The first priority is given to the instruction for the stop in view of the importance of the safety in comparison with other functions.

CONCLUSIONS

As the results of our research and development project, we have succeeded in developing the mobility aid that can be used by the people suffering from the cerebral palsy causing the compound physical handicap. From now on, we intend to improve the command system, the drive program and other parts so that they will be able to fill the various needs of the individual users, through the field test.

Incidentally, this study has been made as a part of psychosomatically handicap study of Ministry of Health and Welfare since 1981.

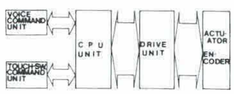

Fig 1 MOBILITY AID SYSTEM

CODE NUMBER	DISPLAY STEP	DISPLAY RHYTHM	PATTERN	MOVEMENT
0	[illegible]	[illegible]		STOP
1	[illegible]	[illegible]		FORWARD TURN IN FORWARD
[illegible]	[illegible]	[illegible]		BACKWARD
[illegible]	[illegible]	[illegible]		FORWARD
[illegible]	[illegible]	[illegible]		MIDDLE VELOCITY
[illegible]	[illegible]	[illegible]		LOW VELOCITY
[illegible]	[illegible]	[illegible]		HIGH VELOCITY
[illegible]	[illegible]	[illegible]		FORWARD TURN FREE FORWAD
[illegible]	[illegible]	[illegible]		TURN THE RIGHT
[illegible]	[illegible]	[illegible]		TURN THE LEFT
A	08	00		ADJUSTMENT R
B	0E	00		ADJUSTMENT L

Table 1 CODES OF VOICE COMMAND

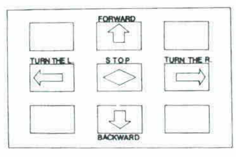

Fig 2 THE SYMBOLS OF THE TOUCH SW. AND THEIR MEANINGS

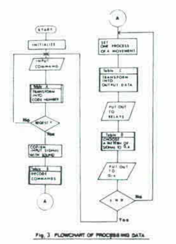

Fig. 3 FLOWCHART OF PROCESSING DATA

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STAND-N-GO:-A SELF PROPELLED STANDING WHEELCHAIR FOR CHILDREN

M. W. Silverman, C.O., O. Silverman, C.O., F. Netznik

ABSTRACT

The purpose of this project was to design and construct a standing device for children which would also allow them independent mobility. Emphasis was placed on making the device, STAND-N-GO, appear more a vehicle of enjoyment and less a therapeutic tool which it actually is. It incorporates special features and is meant to be an alternative to the static standing devices available today.

INTRODUCTION/RATIONALE

We began the design for the STAND-N-GO because we were disappointed with the lack of mobility in the standing devices available today. We aimed our design at the child with spina bifida, but the STAND-N-GO can be used for any child demonstrating paralysis of the legs and fair to good upper limb strength.

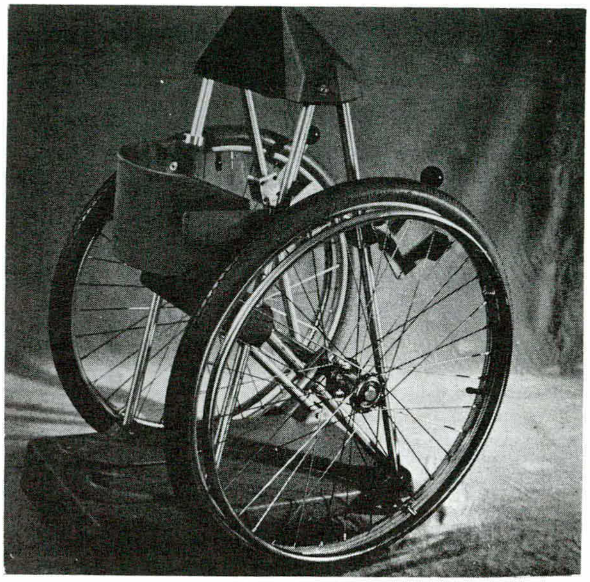
The therapeutic benefits of vertical positioning have long been known. When the abdominal viscera are not pushing against the diaphragm, it is easier for the child to breathe. The bladder drains and the bowel functions better and the lower limbs are less prone to osteoporosis. Also, by holding the child's hips and knees in extension and ankles at neutral, the STAND-N-GO helps to prevent contracture formation.

The commercially available standing frame designs on the market today allow for self-mobility. Many times the children are placed in these devices for therapeutic benefits and placed in front of a television set to keep them occupied By allowing these children independent mobility, they have the same opportunity to explore their environment as other children. Combining this with the fact that they are upright and eye level with their peers, aids in their psychological and psycho-social development as well.

DESIGN FEATURES

In proceeding with the design of STAND-N-GO, certain criteria were established. These include growth adjustability, mobility, proper positioning, positive control, accessability for hand function and appearance.

The design allows for easy growth adjustability by altering only the length of the aluminum tubes and pad position. The same STAND-N-GO can be used from age 3-8 years approximately.



The wheel size and position is adjustable to allow for the greatest mechanical advantage in transferring power from the child's arm to wheel rotation. The sternal pad, sacral strap infra-pattelar pad and heel cup provide a three point pressure system to hold the child in a proper therapeutic position. Brakes were added to allow the child more positive control of motion. A clear acrylic tray allows for games or educational materials to be easily manipulated. Plastic parts are molded in colors and shaped to give STAND-N-GO a "sporty" appearance.

CONCLUSION

Preliminary results with the first few prototypes are quite encouraging. We were pleasantly surprised when a 5 year old girl with poor grade shoulder flexors could propel herself for the first time in her life. This may indicate a wider market for STAND-N-GO than previously envisioned. Children think of it as a bicycle and want to ride it which makes their parents and therapists happy. STAND-N-GO is available in red or blue, pre-assembled or in kit form.

Pin Dot Products P.O.Box 642 Northbrook Ill. 60062

THE VERTICAL WHEELER
A New Mobility Aid For The Handicapped Child

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Introduction

An adequate quality of life for handicapped children with locomotor impairment is only possible if these children are provided with a means for independent freedom of movement. Devices currently prescribed include calipers, trunk supports and crutches, or standing frames fitted with walking paddles. However, calipers and crutches are unsightly, ambulation is slow and labored and the child needs to use his hands to maintain balance. The swivel walker does allow motion without relying on the hands for body support but movement is slow and is only possible on a flat, smooth floor.

Such limitations with hardware designed to keep the child upright means that the most commonly prescribed mobility aid for the non-ambulant child is the wheelchair. Although the arms are once again needed for motion , wheeled platforms do provide a more adequate speed of movement and the frame acts as a stable platform from which to undertake simple tasks. However, long-term sitting causes a range of developmental problems which include paralytic scoliosis, flexion contractures, osteoporosis and lack of long bone growth. Furthermore, a child confined to a wheelchair develops tremendous psychological problems as lacking the mobility to experience and explore his environment he becomes retarded in his psychological development. Normal communication and interaction with his peers and his community is further denied him as normal eye contact for his age is not attainable due to his sitting posture.

Vertical Wheeler

Our approach to solving the physical and psychological problems of the non-ambulant child is the so-called vertical wheeler which is shown in Fig. 1. The wheeler consists of a vertical column structure to which is mounted supports for trunk, pelvis, knee and feet and these in turn support the user in an upright posture. The position of the trunk, pelvis and knee supports is infinitely variable upon the column to allow modification of posture and growth of the device with the child. Pushing rims which allow the child to propell himself forward are also fitted on the column and again can be adjusted for height to account for growth. The supporting column is mounted on a space frame fitted with wheels and castors. Connection between the pushing rims and the drive wheels is through a chain drive.

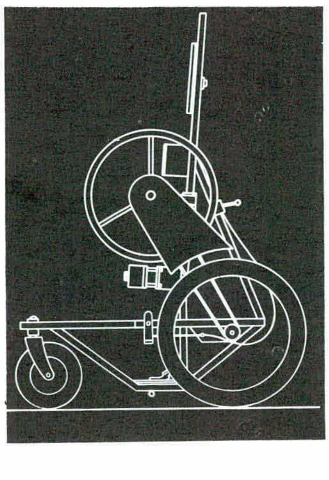
In overall design the wheeler was specifically fabricated to be as attractive to children as possible and go cart appearance and bright colors were considered to be an essential prerequisite for the device. Attraction is further enhanced by using fat tires and fat castors and by ensuring that all attachments such as brake levers are of modernistic design.

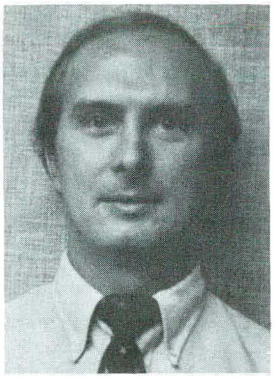
The wheeler was originally designed to be arm propelled so that a child learns to become completely self reliant. However, children whose handicap prohibits them from propelling the device manually have been supplied with a powered version fitted with a finger-tip or mouth control joystick.

Results

Some twenty vertical wheelers have now been fabricated and are in use in both Houston and Cape Town. Patient acceptance of the devices has been remarkable and user training has been found to be unnecessary. The wheeler has proven safe to use up ramps and sidewalk edges and mobility has been shown to be fast and precise both on finished and unfinished surfaces. The original parking brake system has been replaced by a robust hub brake system as the children learned to employ single wheel braking to make rapid turns.

We have found that the wheeler has revolutionized the rehabilitation of our physically handicapped children as it supplies them with much of the mobility that they crave and enables them to explore their environment as individuals. They have proven to be more alert, appreciably happier and more readily able to communicate with their peers. In many cases academic results at school are appreciably better. The results have also shown that scoliosis and flexion contractures are less of a problem and that the child's bladder drainage has been greatly improved. The wheeler has been found safe to use both in the clinical setting and at home and parents have been particularly happy with the improved psychological status of their children.





James R. O'Reagan
Chairman
Student Design Competition

The Student Design Competition has been a valuable and informative part of every RESNA Conference. This year was no exception.

Although the number of entries was somewhat disappointing (19 compared to last year's 60), the winning designs this year are quite impressive considering the constraints that are always present for student projects. The limited number of entries has made it possible to publish all the entries in this year's contest. Inasmuch as the proceedings of the RESNA Conference is a major annual document on rehabilitation engineering, members of the Conference Committee agreed that it would be informative to the practitioner and consumer to see all of the documentation on rehabilitation engineering design effort, not just the winners. Although not all papers meet professional publication standards, by publishing all of the entries, potential contestants for next year's contest can see the scope of student work being attempted around the United States and Canada. A number of the non-winner designs included worthwhile advancements to aid disabled individuals even if they were deficient in some design competition judging areas.

The published papers have been edited because precise guidelines on the format of the student papers were not provided before the contest.

The committee acknowledges gratefully prize money provided by the Paralyzed Veterans of America, which has provided incentive to attract and reward quality work.

August 1982

THE DESIGN OF AN ELBOW PROSTHESIS SIMULATOR FOR TESTING NEUROPHYSIOLOGICALLY BASED CONTROLLERS

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INTRODUCTION

Loss or impairment of a limb is a common disability with trauma, disease, congenital anomalies and age being the predominant causes. The goal of this project is to develop a means for designing and evaluating assistive devices, such as prostheses and orthoses, which restore the controllability and performance achieved with the natural limb. Although the effort is dedicated to elbow prostheses, the results can be generalized to other devices.

The hypothesis underlying the proposed work is that the inherent mechanical impedance characteristics of the intact limb--that is, the stiffness, viscosity and inertia--play a crucial role in the planning and execution of movements. These properties are varied appropriately by the individual in order to match the task at hand, and consequently similar capability should be built into a prosthesis.

The approach to this problem is a novel combination of state of the art neurophysiology and state of the art technology. A programmable controller, which emulates the control of the natural limb, will be incorporated into an elbow prosthesis worn by an amputee. Tests will be performed with the device to allow direct evaluation from both the amputee and the experimenter, and subsequently improvements can be made simply by modifying the software.

BACKGROUND

There are basically two types of prosthesis available to the above-elbow amputee today. First there is the body-powered device, commonly referred to as the conventional cable-operated prosthesis, which was first developed after World War II and since has changed little[1]. A single cable attached to a strap around the shoulder of the intact arm actuates both elbow flexion and terminal device prehension when the shoulders are rounded. The terminal device is held closed (or open) with tensioned bands so that it does not open (or close) unless the cable force exceeds the preload. By shrugging the shoulder supporting the prosthesis, the user can lock the elbow and implement the terminal device only, but unfortunately cannot operate both degrees of freedom simultaneously. Also, it is not uncommon for the cable force to exceed the terminal device preload while lifting an object causing the object to fall.

Secondly, there are actively-powered, myoelectrically-controlled elbow prostheses, which have been refined significantly over the past twenty years. Representative of the state of the art are the Boston Elbow[2], and the Utah Arm[3]. Both offer powered elbow flexion/extension and accept standard terminal devices, either cable-operated or electrically powered. However, the Utah Arm will eventually offer additional powered degrees of freedom. Also, both use the difference of processed myoelectric activity from the remnant biceps and triceps in the amputee's stump to control the velocity about the elbow.

The myoelectrically controlled device offers the user significant advantages over the conventional device and hence is a better choice for restoring natural capability. In particular: 1) powered elbow extension in addition to flexion is possible; 2) the live lift capability is greater; 3) independent and simultaneous control of the degrees of freedom is possible; 4) the control is more natural since muscle groups which power the joints of the intact limb are used to actuate the corresponding prosthesis joints; and 5) more than two degrees of freedom can be controlled.

Unfortunately, despite its many benefits, the myoelectric device requires further development in some crucial areas and as a consequence has met with poor acceptance among the amputee population. First of all, the processors currently in use generate a noisy output which limits the performance of the prothesis. Since the frequency band of the noise overlaps the bandwidth of natural elbow movements (about 2Hz), desired information in the myoelectric signal is lost. If the prosthesis had dynamic capability comparable to that of the natural elbow, erratic movements corresponding to the noise would result, and hence a low-pass filter and/or slower mechanical hardware are required. Secondly, as is demonstrated shortly, velocity control is very unlike control in the natural system. As a result, the prosthesis movements lack the agility and grace of natural limb movements.

In developing the proposed prosthesis, measures have been taken to eliminate the aforementioned difficulties: 1) the improved myoelectric signal processor developed by Hogan[4], and 2) a more natural form of control, discussed below; both will be implemented.

A NEUROPHYSIOLOGICALLY BASED PROSTHESIS CONTROLLER

Recent neurophysiological research by Bizzi and coworkers[5] has demonstrated that for some simple movements the patterns of neural motor commands to the limb are essentially precomputed and stored in the central nervous system. Execution of these movements is believed to be carried out in an open-loop control path via the inherent mechanical impedance properties of the muscle. More specifically:

1) The equilibrium position of the limb after movement is determined by both the steady state level of neural activation and the length/tension curves (i.e., stiffness) of the antagonist muscles spanning the joints.
2) The trajectory of the limb during movement is determined by the time history of the neural activation, and the length/tension and the velocity/tension curves (i.e., stiffness and damping) of the antagonist muscles.

It is important to note that the muscle impedance is a complicated function of the muscle length and rate of shortening (or the angle and the angular velocity of the limb about the joint), and the neural activation.

Clarification of the first postulate is given in Fig. 1. Accordingly, the equilibrium angle of the elbow occurs where the antagonist muscle torques balance. Using this simplified representation of the limb, the model of Fig. 2 can be derived in order to illustrate the second postulate. From the corresponding equation of motion:

$$I\ddot{\theta} + B\dot{\theta} = K(\theta_{ref} - \theta)$$

it is apparent that activation of the agonist muscle relative to the antagonist increases θ_{ref} causing flexion, whereas coactivation increases the effective impedance which tailors the shape of the trajectory.

A prosthesis controller, which implements the control scheme hypothesized above, is presented in Fig. 3. This device permits control of: 1) the mechanical impedance about the elbow; 2) the reference trajectory of the limb; and 3) the equilibrium position of the limb. Myoelectric activity, which provides a measure of neural activation, is used to command the machine. The gains of position and velocity feedback loops about the prosthesis are used to modulate the effective stiffness and damping, respectively.

THE DESIGN OF THE ELBOW-PROSTHESIS SIMULATOR

The elbow prosthesis presented here is referred to as a simulator since desired hardware dynamics and controller characteristics will be specified by programming a computer which will interface the amputee with the prosthesis. Since the simulator is a laboratory tool only, it does not have to be self-contained, and power and control can be supplied externally via an umbilical cord. Hence, for given size and weight constraints on the device, a more powerful actuator and a more versatile computer are used allowing a range of torque, speed and mechanical impedance comparable to that of the natural elbow. With such dynamic capability not achieved previously with an elbow prosthesis, the scope of experiments which can be performed is greater.

The simulator is shown in Fig. 4. A torque motor powers the elbow via a two stage reduction (ratio=7:1), the first stage being a specially designed cable drive and the second a "backlash-free" gear pair; backlash is reduced by varying the center distance of the gear shafts. A standard hook-type terminal device is used, though others may be substituted. The important design considerations for the device[6] are summarized below:

A. It was desired to match the maximum torque and maximum angular velocity of the intact elbow as closely as possible.
B. The center of gravity, weight and moment of inertia of the prosthetic limb were made comparable to the natural limb values in order to emulate both the flail behavior during gait and the coupled motion during voluntary movement of the intact forearm/upperarm combination.

Forearm Properties (Measured from elbow)	Value for Prosthesis	Value for Avg Adult Male
Center of gravity (cm)	14	18
Moment of Inertia ($N \cdot m \cdot sec^2$)	0.046	0.059
Weight (N)	14	15
Maximum torque ($N \cdot m$)	8	60
Maximum speed (rad/sec)	12	18

C. The simulator can achieve the range of mechanical impedance (expressed as the angular stiffness K, and damping ratio ξ) of the natural elbow:
$0.15 < \xi < 1.5$ $(1.0 < K < 200)$ $N \cdot m/rad$
D. Compliant drive-train elements, and nonlinearities such as backlash and static friction were avoided to allow specification of the impedance within the physiological range without unstable or limit-cycle behavior of the device.
E. The full range of flexion of the intact elbow, 0 to 140^0, is feasible.
F. The simulator is similar to the natural forearm in shape and size; this includes the provision for a variable length wrist to accommodate different sized amputees.
G. Most importantly, considerations have been made for the amputee's safety: flexion and extension limit stops have been added, all moving parts will be shielded, and the forearm padded.

FUTURE WORK

An immediate goal with this project is to develop a musculo-skeletal model of the upper extremity to allow prediction of the elbow torque and mechanical impedance given physically measurable quantities, i.e., the elbow angle and angular velocity and the myoelectric activity of pertinent muscles. This model is essential to the implementation of the natural controller presented above. Next tests will be performed with amputees in order to verify the model and the variable mechanical impedance control scheme.

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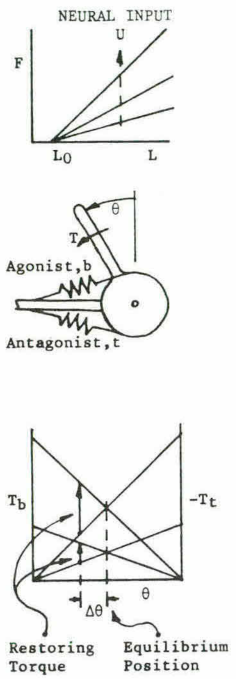

The force/length curve for muscle may be approximated by:

$$F = Uk(L-L_0); \quad \frac{\partial F}{\partial L} = Uk$$

Simplified Joint Model: Assume fixed pivot, constant moment arms. With appropriate scaling:

$$T_b = U_b\,(1-C\theta)$$
$$-T_t = U_t\,(1-C\theta)$$
$$\text{for } -\pi/2 \leq \theta \leq \pi/2$$

Net musle torque is:

$$T_n = (U_b-U_t) - (U_b+U_t)C\theta$$

Net stiffness is:

$$\frac{\partial T_n}{\partial \theta} = -(U_b+U_t)C = -K$$

If external torque is zero, $T_n = 0$ at equilibrium. Thus,

$$\theta_{ref} = \frac{U_b-U_t}{(U_b+U_t)C} = \frac{U_b/U_t - 1}{(U_b/U_t + 1)C}$$

For flexion: $U_b > U_t$ and

$$\theta_{ref} \rightarrow 1/C$$

For extension: $U_t > U_b$ and

$$\theta_{ref} \rightarrow -1/C$$

Fig. 1. Control of joint stiffness and angle with antagonist muscles.

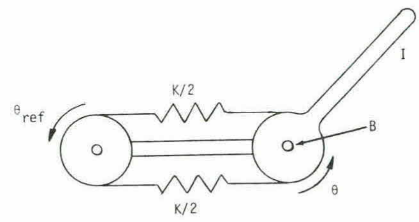

Fig. 2. Simple model of natural limb.

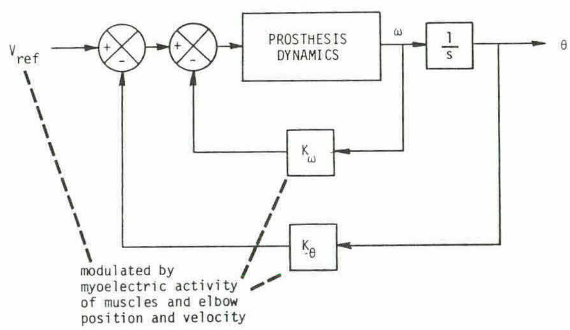

Fig. 3. Proposed control scheme for elbow prosthesis.

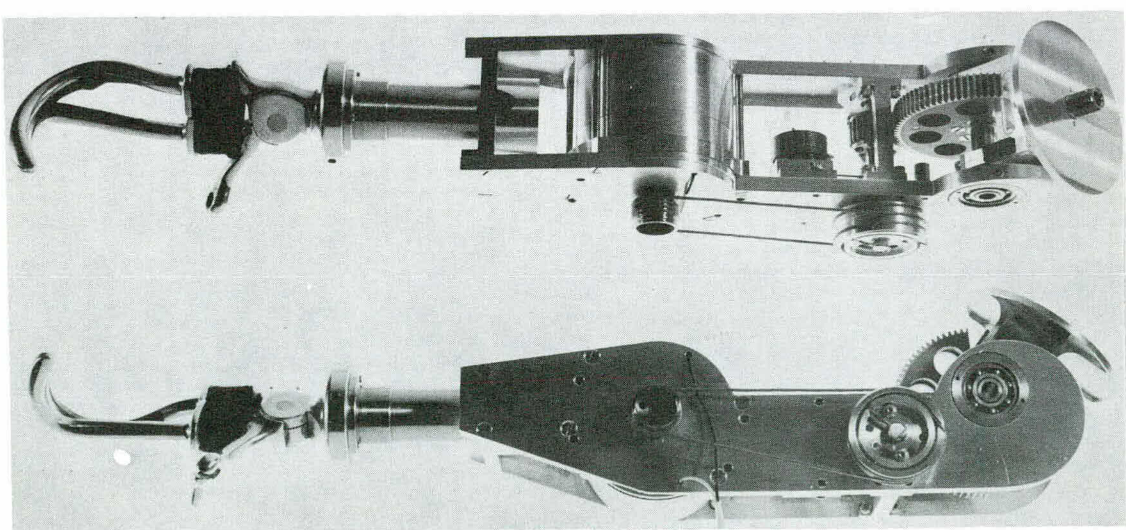

Fig. 4. The Elbow Prosthesis Simulator.

HAWAIIAN LAUHALA LEAF STRIPPER FOR THE SEVERELY AND PROFOUNDLY RETARDED

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Tourism is Hawaii's number one industry and a large percentage of Hawaii's employment opportunities are centered around this field. One of Hawaii's major goals for its retarded citizens is for these citizens to become gainfully employed and live independently within the community. Opportunities for the Retarded in Honolulu, Hawaii, offer the severely and profoundly retarded adult citizens prevocational and vocational training. The clients at Opportunities for the Retarded operate a store in central Honolulu, where they sell various articles that they have made to Hawaii's worldwide tourist population as well as to the members of the community. The clients at Opportunities for the Retarded are currently being trained in the ancient Hawaiian art of lauhala basket and mat weaving. The clients are engaged in all aspects of the production, from the construction to the selling of the finished product. The most time consuming aspect of the entire production is the stripping of the lauhala leaves into the proper width prior to weaving the article. Prior to the introduction of the "lauhala leaf stripper" into the training program the stripping of the leaves was a pell-mell affair of hit and miss efforts. The results of these efforts were:

1) Loss of production time due to wasted lauhala leaves. Prior to stripping the leaves the clients are engaged in a lengthy process that includes collecting lauhala leaves from the community then hand cleaning, drying and pressing the leaves into shape. If the leaves are not stripped to a uniform width, the finished product will be unattractive and not a salable item. Ergo, a large loss of income has been sustained by the clients.
2) Loss of production time due to injuries sustained by the clients due to using unsafe methods and tools used for stripping lauhala leaves.
3) A sense of failure and frustration was established within the clients engaged in this task.

Various methods and tools were implemented into the training program to try to solve this production dilemma. All previous efforts were unsuccessful until the construction and implementation of the present lauhala leaf stripper. This device has completely eliminated all previous production problems at the workshop. It has significantly increased production by eliminating lost production time due to wasteful lauhala leaves and injuries received by clients from unsafe tools and methods. The quality of work has significantly increased and is readily proven by the increased sales of the finished product. Lastly, it has created a sense of pride and accomplishment within the clients.

A review of the literature relating to this ancient Hawaiian art has not revealed a device such as the present lauhala leaf stripper that is comparable or as suitable for the severely and profoundly retarded population. Several major drawbacks of tools or methods suggested in the literature fall into negative categories such as the safety factor involved, amount of eye-hand dexterity required and/or complexity of operation.

In conclusion, the present lauhala leaf stripper has been proven in actual workshop situations that it is a highly effective means of preparing lauhala leaves for weaving. This increase in production means not only increased employment opportunities in Hawaii's largest industry for the clients but a chance for the retarded citizens of Hawaii to become independent citizens in the community.

LONG RANGE SCREEN BASED HEADPOINTING

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ABSTRACT

The use of direct selection headpointing has proven a very powerful communication technique. The problem with current techniques is that users either have to punch keys with a head stick, with the speed similar to one finger typing, or tend to easily drift off the desired elements because of the lack of continuous feedback associated with optical headpointing systems. The long range light pen detects the raster scan on a computer controlled television screen. The computer calculates the position of the detection and provides continuous feedback on the position of the user's head by displaying a dot on the television screen. The television also provides a dynamic display for varying the vocabulary for selection.

INTRODUCTION

Headpointing techniques have been used for a long time to allow severely involved clients, who may otherwise use slow scanning aids, to use direct selection by pointing with their head. The first headpointers were simply long pointing rods mounted to a client's head so that he/she could point to characters on a laptray. To decrease the awkwardness of having a long rod mounted to the head, small, narrow beam light transducers have been developed and are commercially available from several sources (e.g., the Viewpoint Optical Indicator, by Prentke Romich[1]). The Viewpoint mounts on the client's forehead and shines a small light beam onto a language boards or objects near the client. The next step was to use the light beam to shine on a photodetector array[2]. These detectors proved to be unreliable due to ambient light shining on the detector array and causing false detections. To eliminate this problem, the photodetector matrix was replaced by an active LED matrix, and a single photodetector was mounted on the head to detect the light from the LEDs. The use of optics stopped ambient light from reaching the photodetector. This technique is used with the Express I, II, and III manufactured by Prentke Romich[1]. The disadvantage of this technique is that the feedback to the client is only in the form of discrete LED positions, making it very easy to drift off the desired element on the display. Aids using this technique are also expensive because of the limited population that need to use headpointing as a communication technique. All of these techniques also suffer from the limited vocabulary that can be displayed on a laptray or LED array.

The long range light pen (LRLP) uses the direct selection headpointing technique with continuous feedback. The LRLP detects the raster scan of a television screen when pointed toward it. The detected area is continuously displayed as a white spot, with 1 to 2 pixels of stability, on a 192 X 280 pixel screen, to show the relative position the client is pointing to. Fig. 1 shows the LRLP pointing toward the screen with the feedback spot above "SPACE". This alleviates the problem of LED arrays in which the client can drift off to another character on the display board by not knowing the specific position he or she is pointing to. The dynamic characteristics of the television screen allow the vocabulary to be changed very quickly. The computer could have several selection screens with different vocabulary elements, allowing the client to quickly change screens and thereby select from a larger vocabulary. The dynamic display capabilities of the television screen allow the vocabulary to be changed under client control, which is not possible with most other aids. The light pen uses standard commercially available computers and interface hardware. The prototype was designed using the Apple personal computer and a commercially available light pen interface board. The only non-standard component was the LRLP.

The use of personal computers and standard peripherals is very advantageous because of the low cost that results from the much larger market for the equipment. Personal computers are becoming very inexpensive, with powerful complete systems available for under $500. The computers are widely available throughout the country, making them very easy both to obtain and maintain. In addition, the client can easily take advantage of any new techniques or programs without having to buy a new custom system or do extensive modification to his current system. Personal computers have a wide range of peripherals available to them, such as letter quality printers for word processing, speech synthesizers and appliance controllers for environmental control. These and other devices have the advantage of being commercially available and unmodified for lower cost and serviceability.

DESIGN CONSIDERATIONS

The prototype is shown in Fig. 2. The LRLP has four parts to its construction--the lens, photodetector, amplifier and comparator. The lens focuses the surface of the screen on to the photodetector. The diameter and the focal length of the lens define the amount of light and size of the area seen by the detector. The lens is also critical in determining the overall physical size of the LRLP. The larger the diameter and the longer the focal length of the lens, the larger the physical dimensions. The active area of the photodetector also figures into the determination of the number of raster lines detected. Many photodetectors have bonding pads on their active areas which can hide part of a raster line from the active area. This can be a problem not because of the light lost, but because of the possibility of the detector producing two detections on a single raster line. This could happen due to the sensing circuit's characteristic of looking for changes in light levels. As the raster begins to cross the active area the detector detects one change in light intensity when the raster reaches the bonding pad the light detected remains constant. After the raster scan leaves the bonding pad, however, it may still contact part of the active area, producing another change in the light level for the same raster line.

The amplifier must have very special characteristics in order to amplify the signal from the detector. The signal from the most photodetectors is a current. Since the light levels from the television screen are very dim, the currents are in the nanoamperage (nA) range. The signal is also very high speed, with each raster scan line displayed for only about 40 microseconds. The high speed and low signal level require a low input impedance and high gain. The low input impedance is required because the junction capacitance of the photodetector forms a low pass filter to the signal current. Decreasing the input impedance increases the filter's cutoff frequency and the response time of the amplifier. The gain of the amplifier must be a transconductance in order for the current to be transformed into a voltage for use with the comparator. The extremely small input current requires a transconductance of over 50 Mohms to produce a 50 mV output for a 1nA input.

The comparator is the final stage in the LRLP and determines the signal level at which to produce a TTL compatible active low signal for the light pen board. The trigger level of the signal must be greater than the noise level at the output the amplifier to eliminate false signals to the light pen board. The comparator must also have a little hysteresis to eliminate false signals to the light pen board when the amplifier signal decays and the comparator resets itself.

PROTOTYPE

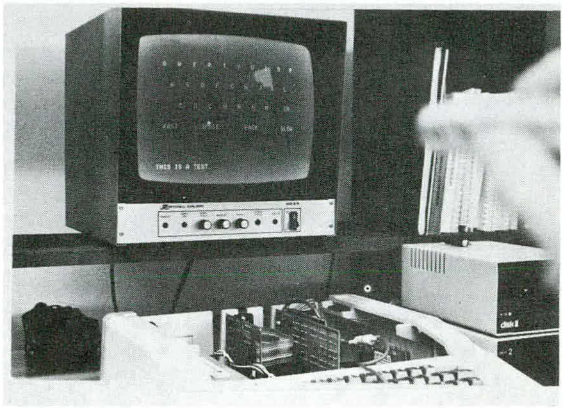
The prototype used a 19mm diameter lens with a focal length of 51mm which allowed the physical dimensions of the light pen to be less than 25mm in diameter and 140mm length. A photodiode was used in the prototype because of its small junction capacitance and lack of bonding pad on the active area; this reduced the possibility of multiple detections from a signal raster line. A transistor amplifier with feedback was used to obtain high gain, low input impedance and stable operating characteristics. The output of the amplifier for detection of a single raster line is shown in Fig. 3. The comparator uses a low pass filter to establish a reference for triggering. The low passed signal is also attenuated by about 40 mV to move the trigger level out of the noise. The hysteresis is set at about 10 mV to provide signal trigger level of 50 mV and to reduce retriggering of the comparitor as the amplifier signal returns to steady state.

The test program that demonstrated the feasibility of the concept was fairly simple, and took advantage of some of the video display capabilities of the Apple. The program used a mixed hi-res and text mode to select English characters from the television screen. The hi-res portion of the screen displayed the characters in a typewriter keyboard arrangement and the position of the light pen with a spot. The bottom three lines of the screen displayed the last three lines of text which had been selected. When the LRLP was pointed away from the screen the screen would switch to an all text mode and show the last 24 lines of text entered. When the LRLP was pointed back toward the screen the screen would switch back to mixed mode for selection (the keyboard display on the top half of the screen and the text on the last three lines). This allowed a long message to be entered and displayed on the same screen as the selection vocabulary. The selection of a character was made by pointing the LRLP at a character for a preset time period. The selection time could be varied by selecting to the words "FASTER" and "SLOWER" on the screen.

DEVELOPMENT

There is still much work to be done on refining the prototype into a finished product. Hardware and software implementation considerations, and evaluation and testing of the device, must still be done. The evaluation will be done by the staff at the TRACE center under another program which is evaluating a number of similar techniques. The evaluation will consist of three parts--mathematical modeling, direct comparison, and examination of practicality of implementation. The mathematical model will determine the conceptual properties of the technique in terms of speed of selection and the size of selection vocabulary. The direct comparison will evaluate utility of the aid directly with clients and compare the results against other techniques tested. The last part will look at the cost, durability, availability and ease of replication to determine the practical application of the aid.

There are three hardware options for implementing the LRLP--standard light pen interface board, a custom interface board, or use of a low cost computer with built-in light pen interface. The first uses the standard hardware configuration with which the prototype was developed. The light pen interface board would use the LRLP as the detector instead of its standard light pen. The light pen then could easily adapt to a number of different types of computers with a minimum amount of hardware modifications. The second option would be to develop a custom interface board, which would increase feedback stability and allow the board to produce an interrupt when a detection is made. The stability can be increased by averaging a number of raster line position detections on the same video frame. By averaging, the effects of bright and dark spots will have less of an effect on the point detected on the screen. The last option would be to use a low cost microcomputer with built-in light pen interface as a keyboard emulator for another computer[3]. This would allow the use of standard hardware for most of the system. The second computer could run all standard software for any of the functions the client needed. The custom hardware modifications to the first computer would include the LRLP and a keyboard emulation circuit. Special software would need to be written for control of the light pen, display and the emulator. Additional software could also be developed for abbreviation expansion and other acceleration techniques. The emulation circuit may be able to use standard hardware in the form of serial and parallel parts to further reduce custom hardware components.



Light pen in use with standard Apple computer

Fig. 1

ACKNOWLEDGEMENTS

I would like to thank Gregg Vanderheiden, Director of TRACE, and Dave Kelso, Technical Director of TRACE, for their patience, guidance and ideas that lead to the development of the LRLP, and the support staff at TRACE for all their support and help in preparing this paper.

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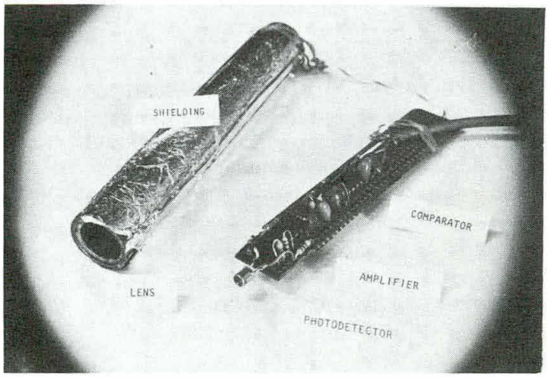

Detailed view of light pen components

Fig. 2

THE DESIGN OF A PAPER MONEY DISPENSING MACHINE FOR THE PHYSICALLY HANDICAPPED

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INTRODUCTION

To assist integrating cerebral palsied or spinal cord-injured individuals into an employment position, a machine to deliver paper money is necessary. The machine should be similar to a coin changing machine, and be operable in a supermarket or theatre environment. The need was suggested by Mr. Raymond Fulford, Rehabilitation Engineer, Courage Center, Golden Valley, Minnesota.

MACHINE DESIGN CRITERIA

The device must:

1) Deliver only one bill reliably on command.
2) Be completely operable, excluding loading of bills into the money tray, by the disabled individual.
3) Be powered from the wheelchair battery; the motor is restricted to a 12 or 24 volt power source.
4) Be of a size approximately one-half that of the wheelchair tray.
5) Produce no noise above a sound level of moderate fifty decibels, that of an average office.
6) Deliver bills approximately once per two seconds.
7) Handle crisp bills as well as old ones.
8) Cost less than three thousand dollars.
9) Be adaptable to accommodate three demonstrations of bills.
10) Permit loading as simply as possible.

MACHINE OPERATION

1. Money Ejection: Roller/Tab Release

When one bill denomination is desired, the appropriate solenoid relay is activated by the user. See Figure 1. Money tray upward indexing starts a drive motor. When the bill passes between pinch rollers, it trips a microswitch via a lever arm which magnifies the motion. This switch activates an intermediate relay, which in turn deactivates the solenoid relay and allows the motor to continue to run. After the bill has passed through the pinch rollers, the microswitch is reset and deactivates the motor.

If more than one bill is released from the tray, a slightly different sequence results. The lever arm then trips another microswitch which activates a time relay to cause bill rejection. A time delay relay is used to prevent activation of the system by a folded bill. The system remains activated until one of the other buttons is pressed.

2. Power System

The power necessary to operate the machine is supplied by the direct current battery of the wheelchair; therefore, a DC motor was chosen to operate at the same voltage as the wheelchair battery. As the motor runs for short intervals, a permanent magnet motor was chosen. It is easy to pulse and is small.

3. Circuitry

The circuitry for the machine includes a light sensor, to ascertain that only one bill is delivered, and a double-contact relay to activate the motor. The light sensor has high resistance when a bill passes across it, and induces an open circuit. Alternately, low resistance occurs when no bill obstructs the light, and induces a short circuit.

The circuit diagram is shown in Figure 2. The direct current (DC) battery is in parallel with the controlling switch (S1), the light sensor, and the relay. The controlling switch (S1), the light sensor, and the relay are in series. Switches S1 and S2 are in parallel, and switches S2 and S3 are in the same relay.

4. Machine Control

The controls required to activate the machine must be consistent with the type and range of motions characteristic of the cerebral palsied or spinal cord-injured individual. Consequently, since the motions of the two individuals are completely different, two separate controls will be used, but both will be incorporated into one control panel, allowing for machine-use flexibility.

The control panel is approximately 40 cm by 16 cm in plan. It could be placed either in front of the individual on the wheelchair tray or simply attached to the side of the chair.

An appropriate control system for the cerebral palsied person cannot require exacting motion. Our proposal is to use toggle switches, arranged on the control panel to resemble a "hill-valley" profile. The toggle switch would be located at the base of the valley, and the "hills" would act as guides for the individual. The user would then only move a hand or arm into the "valley" and make contact with the switch to activate the machine. In this way, activation of more than one switch is prevented.

Alternately, the spinal cord-injured individual has minimal use of hands or arms and must use a mouthstick to activate the controls. Since his motions are more certain, but of limited range, controls will use push buttons.

CONCLUSION

The paper money handling machine we have built has met its design objectives. In addition, considering the time constraints and availability of materials and tools, the model works reasonably well. With more time, further testing, and added refinement, the model utilizing a roller and corner tabs is capable of assisting a cerebral palsy or spinal cord-injured individual in dispensing paper money.

ACKNOWLEDGEMENTS

We acknowledge the preliminary work performed on this concept by two preceding design teams: T. Determan, J. Gilbertson, M. McKenzie, A. Mokhtari, D. Olson, T. Sheridan, M. Swanson, J. Todd, T. Walsh. We thank Dr. D. Frohrib, Professor of Mechanical Engineering, our Faculty Advisor, for his motivation and assistance in guiding this development.

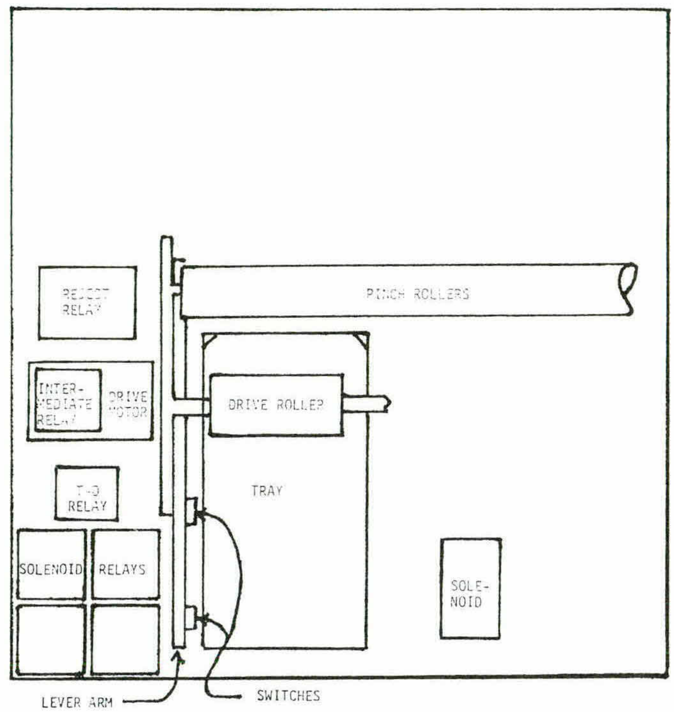

FIGURE 1

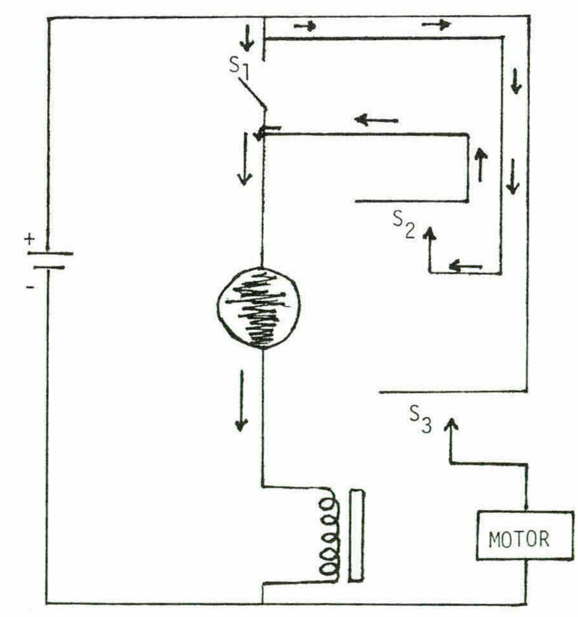

FIGURE 2

THE POWER CHEST HALTER

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A hoist device was designed to adjust and hold the upper body position of a wheelchair patient. The device is designed for wheelchair occupants who have lost the use of their back muscles through neuromuscular degeneration. This condition does not allow them to sit upright in a chair without external support.

This particular project involves a person with muscular dystrophy. He works out of his home as a freelance book reviewer and author. He does not have the use of his back muscles, and his arms and legs are severely weakened.

When he is in his desk chair, the patient can prop his shoulders up by placing his left arm between his chest and knee. When he uses his powered wheelchair, he needs his left hand to activate the chair controls. Also, when stopping with the wheelchair, there is the tendency for the body to fall forward. A restraint is required to hold the body and to free the left arm.

Previously, an automotive seatbelt restraint was clamped to the powered wheelchair. This provided sufficient support to the upper body and freed the left arm. This arrangement had to be adjusted by another person if the patient wanted to change his position.

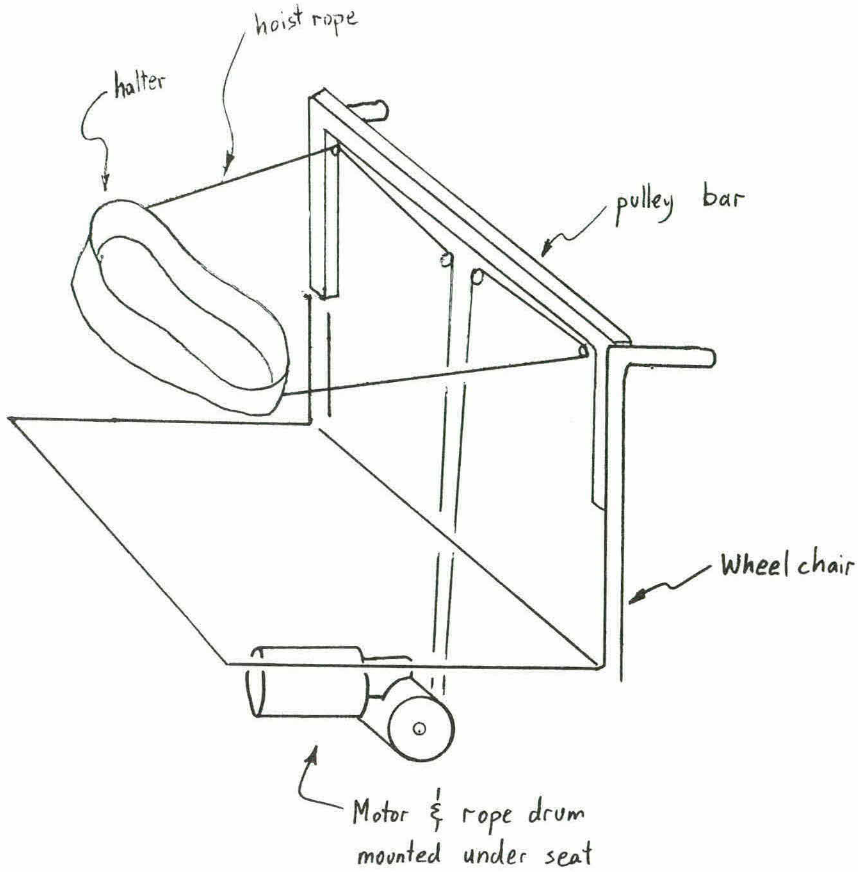
An electric hoist, powered by the existing chair batteries, was designed to replace the seatbelt restraint. The hoist would provide the upper body support, and be adjustable by the user. The hoist would allow a range of upper body positions, from a fully prone sitting position to a fully upright position. The device would eliminate the need for another person to adjust the upper body position. The patient would still require someone to help with transferring in and out of the chair, but this was also required with the seatbelt restraint. The hoist would provide a greater degree of convenience and independence to the patient.

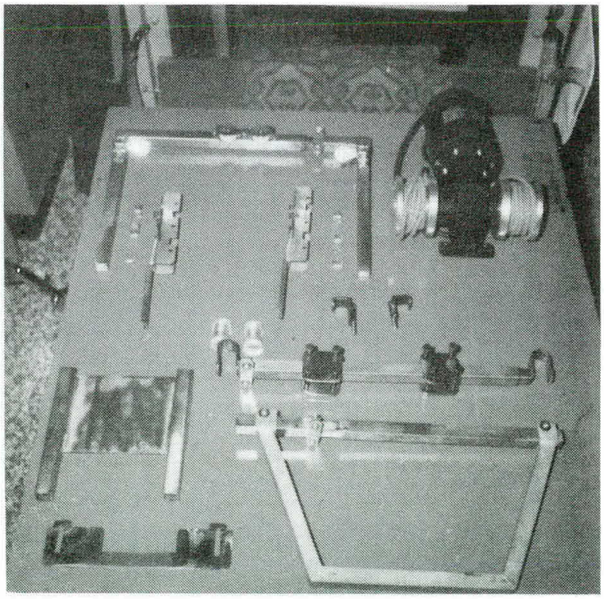
The patient's comments and suggestions were used through much of the initial design work. The positioning of the hoist control, characteristics of the lifting, and halter design were discussed with the patient. He wanted the hoist control located at his knees, so that he could use both hands on the unit. The lift must be gradual and gentle so as not to jerk the body. The halter must be worn all day, so comfort, good pressure distribution and appearance become important considerations.

The prototype consisted of a pulley bar, the motor mount frame, and a control unit. The pulley bar holds the pulleys which direct the hoisting rope path. The hoisting is done with an electric motor. The motor was purchased, and was originally designed for industrial uses. It contains a worm-geared output, providing a high torque capacity at low speed. The motor was rewound to operate with a 24 volt DC power source. The motor mount framework holds the motor directly underneath the seat of the wheelchair. The entire hoist apparatus attaches to the wheelchair using bolts or hose clamps. No modification of the chair was required. The framework is adjustable to permit use with different size wheelchairs.

All existing side and bottom clearances of the chair were preserved. No parts of the hoist extend past the existing equipment on the chair. The entire apparatus weighs about 30 pounds, most of which is the weight of the motor.

The results of the field trial were positive. The motor, with its control unit, worked very smoothly. The lifting was gradual and the motor was strong enough to carry the load. The hoist framework proved to be very sturdy. All those involved with the project deemed the project a success.





Hoist Hardware

A MICROCOMPUTER-BASED VOCA FOR THE NON-VOCAL

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ABSTRACT

A microcomputer-based communication aid for the non-vocal was designed and tested. The user presses keys on a partial keyboard to select letters and commands which are sent to a speech synthesizer. The computer program allows the user to add, change, and customize the vocabulary, and provides abbreviations for common words and phrases. The program incorporates next-letter prediction and displays letters via a dynamic display on a TV or monitor.

INTRODUCTION

Numerous individuals have lost their vocal capability due to injury, stroke, cancer and cerebral palsy, and thus are unable to vocally communicate. This severe social handicap that impairs integration into society can be lessened by the use of a Voice Output Communication Aid (VOCA).

There are a number of products currently available for the non-vocal that allow them to speak via a synthesized voice. Portable speech synthesizers such as the Phonic Mirror Handivoice 120 are available and popular, but lack an adequate vocabulary to make stimulating conversation. Other computer-based synthesizers are available, primarily for the Apple II computer, but these have been mainly talking keyboards that speak each letter as the key is struck, or which use the full typewriter keyboard for encoding speech. No existing products combine unlimited, extensible vocabulary, and word, phrase and alphabet encoding.

SYSTEM DESCRIPTION

The previously mentioned features have been implemented and tested on the author's Atari 800 computer system. The system consists of the Atari 800 console, 48K bytes of memory, Atari 810 disk drive, Atari 850 Interface module, Votrax Type-'n-Talk with speaker, and Pink Noise Studio's version of Fig-Forth. The system cost is under $1850 ($1600 with Atari 400, 48K). A comparable Apple II system costs $2200.

PROGRAM DESCRIPTION

The challenge inherent in this design problem is to make a communication aid that is both economically feasible and reasonably fast, while at the same time giving adequate vocabulary selection. It was essential that the full-featured device be usable given the limitations of the non-vocal user. To limit the scope of this initial project, I chose to limit the user population to those who have adequate neuromuscular control for single-finger keyboard entry. It is possible, however, to adapt the computer interface to accommodate single-switch, joystick and fully dexterous users.

The computer program was developed and written entirely in FORTH, a modern, procedure-based computer language. The FORTH language structure and programming features inspired many of the following device features, and these might not have been included had other programming languages been used.

- Display/Keyboard
  The Display/Keyboard considerations are perhaps the most important of the design factors, for it is through the display and keyboard that the non-vocal person will receive and transmit information. The display consists of a 3x3 array of letters, with an additional 4 line text-input display area (Fig. 1). The display shows the letters that are currently available for selection. There are 3 base arrays (hence called screens) that contain 26 letters arranged according to their frequency in spoken English[1] (Fig. 2). In addition to these base screens, there are 26 secondary screens, each containing the 9 most frequently used letters that follow a specific letter. The user selects a displayed letter by pressing one of 9 keys on the keyboard (Fig. 3) and a secondary screen would appear that corresponds to that letter. For example, the 9 letters that most frequently follow E are A, E, L, M, N, R, S, T and V. These letters would comprise the secondary screen for E (Fig. 4). If a letter cannot be found on the display screen, the user can press one of three keys to access the base screens which contain all 26 letters (Fig. 5). During approximately 80% of the time, the user will be able to encode his desired speech by the use of the various secondary screens and not return to the base screens. Even with the use of base screens, access to a specific letter is never more than two keystrokes away. The secondary screen layouts were designed to standardize locations of commonly occurring letters, such as A, E, and T, and this allows the user to memorize letter locations and speed his input.

  The user can use special function keys which allow the text in the input buffer to be spoken, commands to be executed from the buffer, or base screens to be called. The commands include erase and repeat letters and erase lines; these can be used to edit the text to be spoken. So, with 9 letter-selection keys and 3 base-screen keys, one has access to the full alphabet. In a comparison with a full keyboard, this keyboard only requires 20% more keystrokes while greatly decreasing finger and hand travel.

- Abbreviations
  One of the most attractive features of this design is the ability for the user to design abbreviations that represent commonly used words and phrases. If a person uses the phrase "Hello, my name is Fred R. Jones" frequently, he can abbreviate it as INTRO, or any other

letter combination that he can remember. Then, when he wants to introduce himself, he need not type in every letter of his introduction, only INTRO. In the same way, if Mr. Jones is a Mechnical Engineer, he can abbreviate this as ME. If someone asks him his occupation, two letters, ME, will produce the speech "Mechanical Engineer." Using these abbreviations, the user can increase the amount of speech output with a limited number of input keystrokes.

CUSTOM VOCABULARY

An important feature of this design is the ability to customize the vocabulary. The user can select keywords and abbreviations that are meaningful to him and that can be easily remembered and used quickly. These words and phrases might be unique to his job, family, religion or outside activities. This feature was included to allow the user to be an integral part of the device, to allow him to tailor it to his speciic use, and to allow it to be functional at his level. This increases both independence and quality of life.

USER EVALUATION

A limited number of user evaluations have been performed, and these served primarily to foster feedback concerning letter placement, input speed and program design. There is a required learning time for this device, but with practice one can easily memorize letter and letter sequence locations. The maximum input speed using a single finger has been approximately 60 characters/minute, which corresponds to 10 words/minute. This figure is roughly analogous to the speed of a one-finger typist on a standard keyboard. With abbreviations, an effective input rate of 60 words/minute is possible. More important than the input rate is the output rate, for this directly affects listener comprehension; from the Votrax Type-'n-Talk, this rate is about 130 words/minute.

FUTURE DEVELOPMENTS

This project is sponsored by the Palo Alto Veterans Administration Rehabilitation Engineering Research and Development Center, and is part of a larger endeavor to design a portable speech synthesis aid. This general scheme will become miniaturized and self-contained, so a person can easily use the device in their hand or on a wheelchair. A detached input device will be designed for the computer-based aid so one does not need to be at the computer keyboard to use the synthesizer. Other input devices such as joysticks and single-switches will be investigated to expand the applicability of this project.

CONCLUSION

A microcomputer-based communication aid has been developed which allows unlimited vocabulary, next-letter prediction, abbreviation of words and phrases, and the ability to be customized by the user. This device combines function and economic feasibility, and allows the utilization of current technology to increase the independence of the non-vocal.

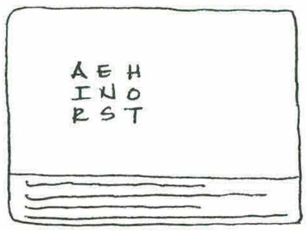

FIG. 1 DISPLAY SCREEN

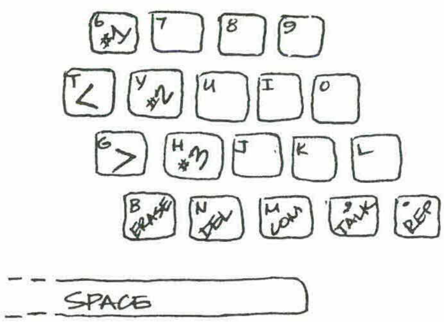

FIG. 3 KEYBOARD LAYOUT

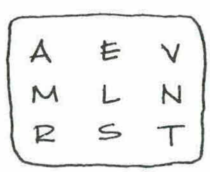

FIG. 4 SECONDARY SCREEN FOR E

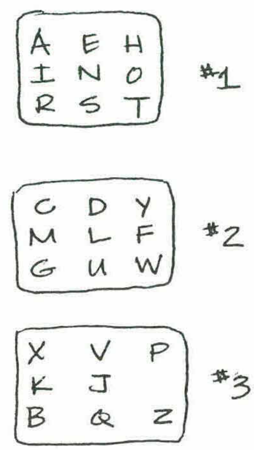

FIG. 2 BASE SCREENS

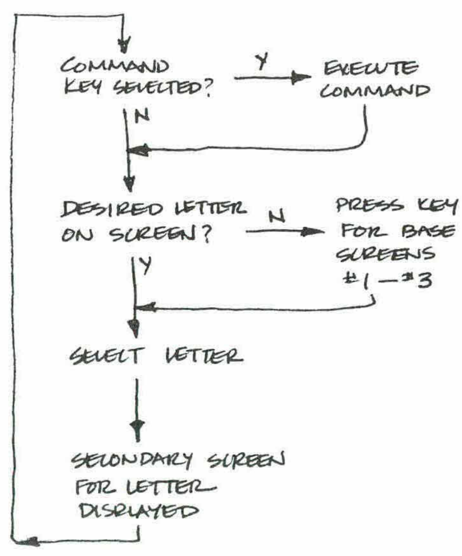

FIG. 5 ENCODING SCHEME

A WEARABLE ORTHOSIS SIMULATOR

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Orthotic research and development has long been hindered by the lack of an efficient method for preliminary evaluation of new concepts and designs. The conventional approach, constructing numerous experimental prototypes, is often costly and time-consuming. In addition, acquisition of pertinent gait data may be a problem The orthosis simulator is a device which as been designed to overcome these problems in a research or clinical laboratory setting. The only similar device described in the literature (1) uses finite state control to restrain a knee orthosis, but apparently has neither the loading flexibility nor loading capacity of the orthosis simulator.

The orthosis simulator is wearable, electromechanical brace which simulates the mechanical behavior of an articulated, below-knee ankle orthosis. Computer control of the simulator (via umbilical to a laboratory computer) allows for software-based flexibility in controlling the mechanical characteristics of the orthosis. It also facilitates data collection, allowing immediate analysis of the gait parameters measured by instrumentation mounted on the simulator.

The simulator has a single axis of rotation. Vertical and horizontal adjustments on the foot-piece allow approximate alignment of the simulator axis with the anatomical ankle axis. The length of the foot-piece is also adjustable. The foot-piece and calipers are secured to the foot and shank, respectively, by Velcro straps.

The device is instrumented with : (1) a rotary potentiometer, to measure ankle flexion angle; (2) a semiconductor strain gauge bridge, to measure loading torque; and (3) footswitches, to provide timing information relative to the gait cycle.

The angle signal is hardware-differentiated to yield angular velocity. A surface EMG electrode can be used to monitor muscle activity. Although some signal processing is performed on board the orthosis, all control and data signals are passed to a main control unit via an umbilical cable. The control unit interfaces with the input-output ports of a PDP 11/10 minicomputer.

The main control unit houses low-pass pre-aliasing filters for the angle, torque and EMG signals; a 60-Hz notch filter for the velocity signal; a voltage-controlled current source to control the particle brake; and the required power supplies. Velocity, torque and EMG undergo further off-line digital filtering before display.

In designing the simulator, efforts were directed at maximizing the loading capabilities without unduly increasing size, weight, inertia, or frictional drag. Loading capability must exceed the maximum torque that can be exerted by the subject during gait since it is desirable to have the ability to simulate rigid bracing. On the other hand, inertia and drag must not be so large as to restrict angular acceleration, especially when the intended load torque is zero. The effects of the simulator weight and inertia on lower limb dynamics can be compensated, to some extent, by adding comparable mass to the contralateral leg. The total weight of the simulator, including shoe and foot piece, is approximately 3.5 pounds; the maximum load is on the order of 500-750 inch-pounds; drag torque is approximately 10 inch-pounds.

A magnetic particle brake was chosen as the source of resistive torque. This device exerts torque in opposition to shaft rotation that is roughly proportional to the input current. This effect is generated by modulating the alignment of iron particles by magnetic field between the housing and a plate coupled to the shaft. Torque multiplication is achieved by means of a ball screw and pin-joint linkage (see Fig. 1). The ball screw achieves a very large gear ratio (75) which means that a small, lightweight particle brake can be used (Force Limited, Model B20SF3).

The relatively slow time constants ($\sim$ 50 msec) of the brake/ball screw assembly create some problems when using the device to effect damping. As the damping amplitude is increased, oscillations in the velocity output appear. The only practical way to reduce these oscillations is to speed up the response time. Torque feedback around the particle brake was unsuccessful in reducing the oscillations as saturation severely limited the value of feedback gain that could be attained. Lead compensation reduced phase lag but ultimately degraded system performance by amplifying the higher frequency velocity oscillations. In the end, satisfactory open loop performance was achieved by eliminating the low-pass filter on the velocity signal which was found to be contributing significant phase lag.

It should be noted that some velocity oscillation still occurs at higher damping setting. It is not clear, at this time, to what extent these oscillations are a result of non-ideal simulator performance, and to what extent interaction with the neuromuscular system is involved (see Fig. 2). This issue cannot be resolved at the present time, because a constant torque loading apparatus is not available to test the simulator.

Typical performance, using the simulator to effect frictional, viscous and "vesquous" (torque proportional to angular velocity squared) damping is shown in Fig. 3. Note that foot switch signals can be used to implement mechanical loading or rigid restraint during selected segments of the gait cycle. Angle and velocity signals are used in controlling the compliant loading and in setting motion limits and thresholds.

The orthosis simulator was initially developed for a specific application, namely to study the modification of spastic gait by means of mechanically damped orthoses (2). However, it is becoming increasingly evident that the device will find application in other areas of clinical practice and rehabilitation engineering research. One obvious clinical application is custom prescription of orthotic devices for individual patients. The additional information made available to the clinician would allow more methodical orthosis prescription, rather than the time-consuming and costly trial-and-error approaches commonly used at the present time. A potential research application extending beyond orthotic development could involve the study of basic neuromuscular function, normal and abnormal, using the simulator to introduce torque perturbations during gait.

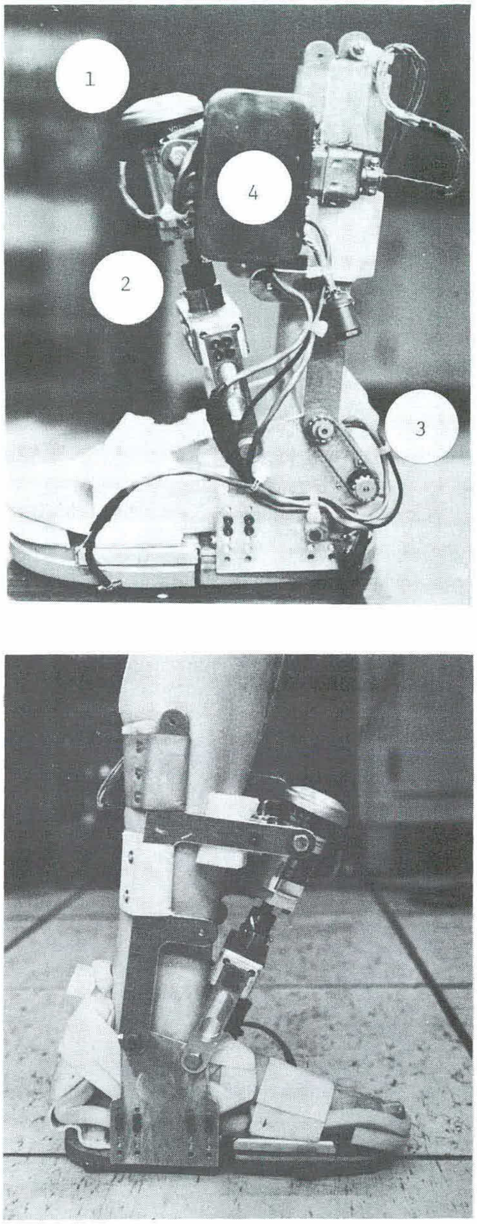

Fig. 1. The orthosis simulator. Above: lateral view; below: medial view.
Legend:
1 - magnetic particle brake
2 - ball screw and nut
3 - potentiometer
4 - on-board electronics

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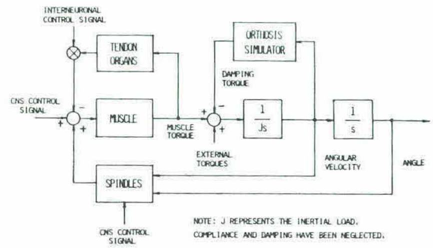

Fig. 2. Interaction of the orthosis simulator with the physiological control system.

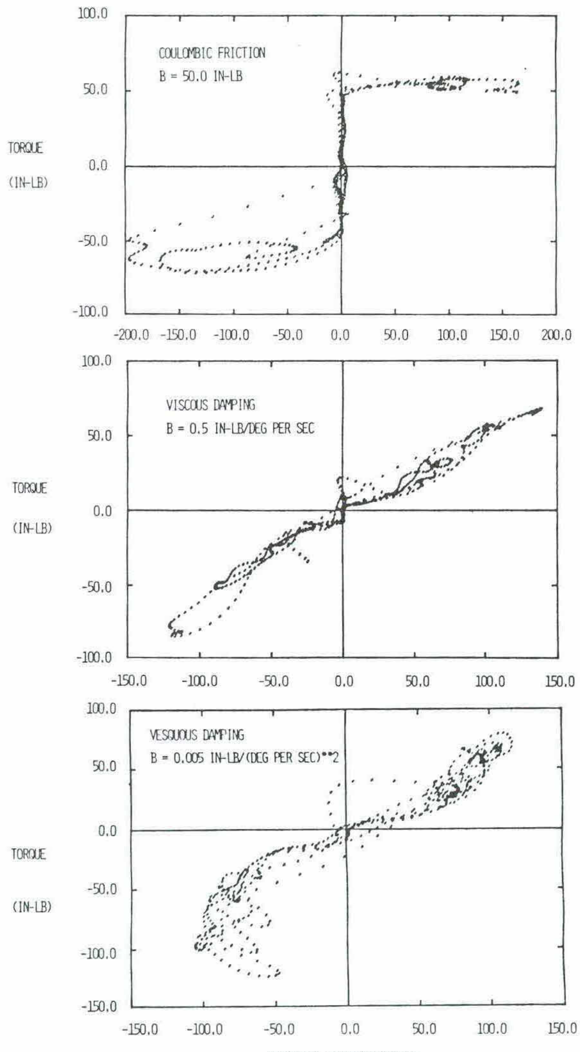

Fig. 3. Typical damping performance. Above: frictional; middle: viscous; below: vesquous.

THE DESIGN AND TESTING OF A CLOSED-LOOP CONTROLLED THERAPEUTIC STIMULATOR

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Electrical stimulation has recognized value in the functional and therapeutic management of paralyzed limbs. This project involves the design and clinical testing of a transcutaneous elbow flexion stimulator to be used in a biceps strengthening program for spinal cord injured patients. Incorporated into the design is an automatic closed-loop control system as an advancement of the current State-of-the-Art. The purpose of the control system is to improve the performance, reliability, and utility of therapeutic stimulation.

REVIEW OF RELATED WORK

Related developments in functional stimulation have come from research programs at several institutions. At the Rancho Los Amigos REC functional stimulation is used to increase the strength and range of motion of the wrist in stroke patients. The Rancho system consists of a stimulator, training table, and audio and visual feedback devices which provide incentive for maximum contraction against an isotonic load. Stimulation is triggered by an adjustable threshold set near the limit of the patient's contraction capability. Users of this system are reported to have made dramatic improvements in wrist function.[1]

The Ljubljana Rehabilitation Institute has also been successful in a variety of projects for stroke patients involving gait enhancement and upper extremity control. Hemiplegic patients exhibiting foot drop have benefited from the use of an electronic orthosis which triggers peroneal stimulation by a heel switch placed in the user's shoe. The stimulation causes dorsi-flexion of the ankle to prevent the foot from dragging during the swing phase of the gait cycle. Another project is the development of a multichannel stimulator as an electronic replacement of the long-leg brace. This stimulator has several independently programmable channels to provide the proper stimulus parameters and timing to a number of different muscle groups.[2]

A research effort at Case Western Reserve University has produced a percutaneous stimulator to provide functional prehensile grasp in quadriplegic patients. Pulse width and frequency modulation of the applied stimulus are used to control the force of muscle contraction and allow the user to adjust the strength of his grasp. The stimulator is controlled by a shoulder position transducer and has a built-in "HOLD" function for tonic operations.[3]

These systems illustrate three different approaches to stimulator control in which the stimulus parameters may be preset, preprogrammed, or user controlled. The preset stimulator is the simplest, but is restricted to stimulation of gross motor function. The preprogrammed system is appropriate for cyclic motor functions in which the same time-varying stimulus regime is applied for each cycle, while the user controller stimulator is suited for volitional control of complex operation. The stimulator designed in this project, however, adopts a more advanced closed-loop control system which automatically and continuously adjusts the stimulus parameters to achieve the desired motor function.

THE AUTOMATIC CLOSED-LOOP CONTROLLER

Functional stimulation using preset or preprogrammed stimulus parameters has the disadvantage that the force developed by an electrically stimulated muscle is sensitive to error sources arising in both the instrumentation and the physiological system. Amplifier drift, temperature sensitivity, muscle fatigue, load disturbances, and changes in anatomical limb position or electrode placement are factors which make it difficult to control muscle activity using conventional stimulators. The muscle output is also nonlinear and time-varying with respect to the parameters of applied stimulation. By enclosing the stimulated muscle in a negative feedback loop, however, the effect of these disturbances and nonlinearities can be reduced and the desired muscle activity can be achieved. In this way closed-loop control has been used to produce consistent and uniform muscle contractions which result in effective therapeutic exercise.

The controller is designed to automatically adjust the stimulus pulse width (PW) to develop a muscle response which emulates a predetermined model. This is accomplished using a general purpose Proportional-Integral-Derivative (PID) control algorithm. This technique has the advantage that the algorithm parameters (KP, KI, KD) can be determined empirically without having to derive a precise mathematical model of the limb's dynamic motor response.[4]

A simplified block diagram of the control system is illustrated in Figure 1. The model is a FORTRAN generated simusoidal waveform that specifies the desired forearm motion, $\theta_d(T)$. The actual forearm motion, $\theta_a(T)$, is measured by an electric goniometer and is fed back into the control algorithm. The difference between the actual and desired motion results in an error signal, $e(T)$, which is used by the controller to determine appropriate adjustments in stimulus pulse width. These adjustments are such that they cause the plant (consisting of the arm and mechanical load) to follow the model precisely and drive the error signal to zero. A flowchart of the controller operation is shown in Figure 2. The amplitude and frequency of stimulation are user selectable but are not influenced by the controller.

SYSTEM HARDWARE

For developmental purposes the control algorithm was programmed on an LSI-11 minicomputer and system variables were displayed using a Hewlett-

Packard X-Y plotter. The computer has access to the goniometer output through an analog-to-digital (A/D) converter and interfaces with the stimulator by a digital-to-analog (D/A) converter. The control system will be programmed on an 8085 microprocessor for compactness and portability in clinical use.

The mechanical apparatus consists of a rigid base, an arm brace with a rotating elbow joint, a weight and pulley, and an electric potentiometer. The weight and pulley generate a torque about the elbow joint that is transmitted to the forearm by the pivoting arm brace and a velcro strap. The potentiometer, which is mounted at the elbow joint, measures the forearm's angular position. To meet the needs of an individual patient, this device can be used in either the seated or supine position.

The stimulator is a PULSAR™ Constant Current Isolation Unit (CCIU) which is operated as a slave to the minicomputer. This device produces adjustable amplitude constant current pulses at the rate and duration specified by the control algorithm. The stimulus pulses are delivered through saline soaked sponge electrodes which are secured over the motor point of the biceps by velcro straps. Since the stimulator is battery powered the patient is completely isolated from line currents.

RESULTS

The prototype system has been tested on normal healthy subjects with promising results. Figure 3 is a plot of system variables over one complete cycle of flexion and extension against a constant torque of 1.25 ft-lbs. The actual position response is superimposed on the sinusoidal model and demonstrates an accurate reproduction of the desired motion. The controller adjusted pulse width maintains a near zero error signal over the entire 98 degree range of motion. Similar results are anticipated in testing on quadriplegic subjects in the absence of intact motor and sensory pathways. From these results automatic closed-loop control appears to be an attractive technique in therapeutic stimulation.

FURTHER RESEARCH

A factor that affects controller performance is the limit of muscle force that is attainable under artificial transcutaneous stimulation. Increasing the stimulus intensity by frequency and amplitude modulation in addition to the present pulse width modulation would extend the controllable range of muscle function. Improvements in delicate control and system stability may be obtained through antagonistic stimulation. This would compensate for the response hysteresis with respect to applied stimulus that is observed in the transition from flexion to extension. Advancements in these areas would benefit the performance of the elbow flexion stimulator.

Further development and testing of the system is planned at a rehabilitation center for spinal cord injured patients. Evaluation of the instrument by the patients and physical therapy staff is anticipated to result in additional improvements appropriate for clinical use.

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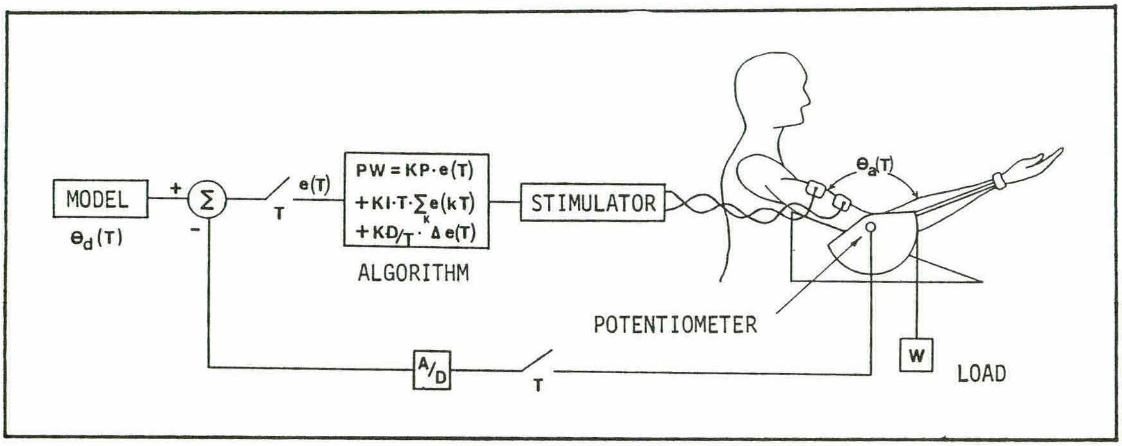

FIGURE 1. Stimulator Control System

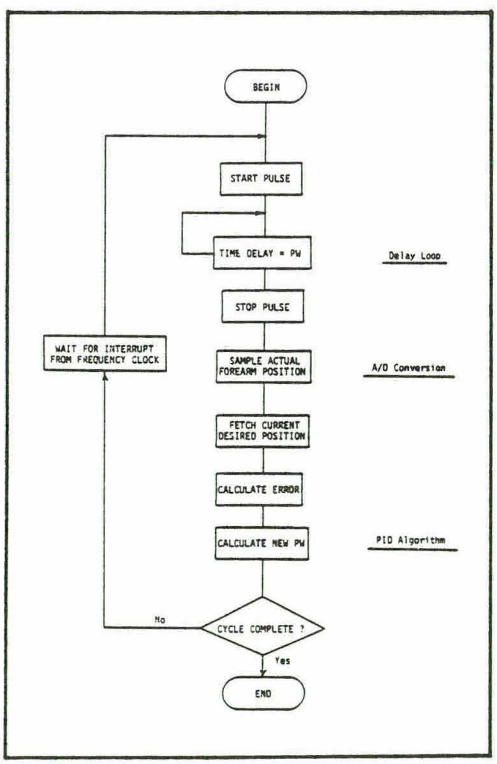

FIGURE 2. Control Algorithm Flowchart

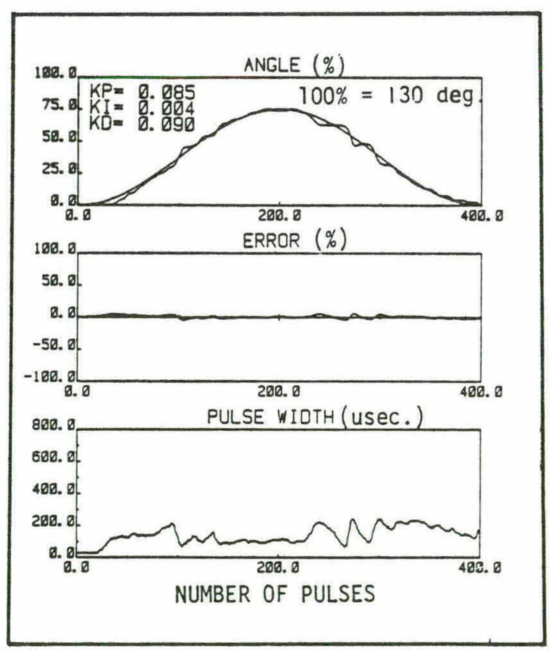

FIGURE 3. System variables over one cycle of flexion and extension.

THE DOOR TO OPPORTUNITY

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Lower handles, switches, and railings, wheelchair ramps, and bathroom modifications are but a few examples of the work being done to help a disabled person become more independent in his daily activities. The Timbers, a housing community for disabled persons in Wichita, Kansas, employs these and many other adaptations in its housing units thus enabling Timber's residents to enjoy a moderate or even total degree of independence. Though the apartments represent a disabled person's dream, there still exists an aspect which prevents many of the residents from enjoying a higher degree of independence. That aspect is the process of locking and unlocking the residents' deadbolt door locks with a key. The activity of opening and closing the door had been solved for many of the disabled residents by the use of an elongated door handle but the actual action of retrieving a key in the lock proved to be quite difficult for many residents. Consequently, an aide or friend was usually needed to assist an otherwise independent person in locking or unlocking their deadbolt doors.

This problem, encountered by many disabled people who have poor grasp or restricted motion, is what Curt Robertson and I set out to amend. We are freshman students at Wichita State University majoring in Electrical Engineering and we have extensive interaction with the EE professors. Because of this interaction, we were able to obtain a schematic of a device which was not unlike that of a touch-sensitive control panel on a microwave oven, so could one press buttons to somehow unlock or lock a deadbolt mechanism. This idea was reinforced by the fact that a non-electrical door lock mechanism that employed the pressing of buttons was already on the market. Unfortunately, it could only control a bevel-edged door lock and could not be adapted to a deadbolt system. We therefore decided to somehow integrate the electronic control device onto a deadbolt system; a task that through our own observations had apparently not yet been accomplished.

The device we designed is powered by batteries and uses all the existing components of a normal deadbolt lock system save for the decorative washer and inside knob. The system has the following two main components: the switch box which contains the lock mechanism and push-button switches, and the gear box which contains the gears, motor, and electronic brain (see picture 1).

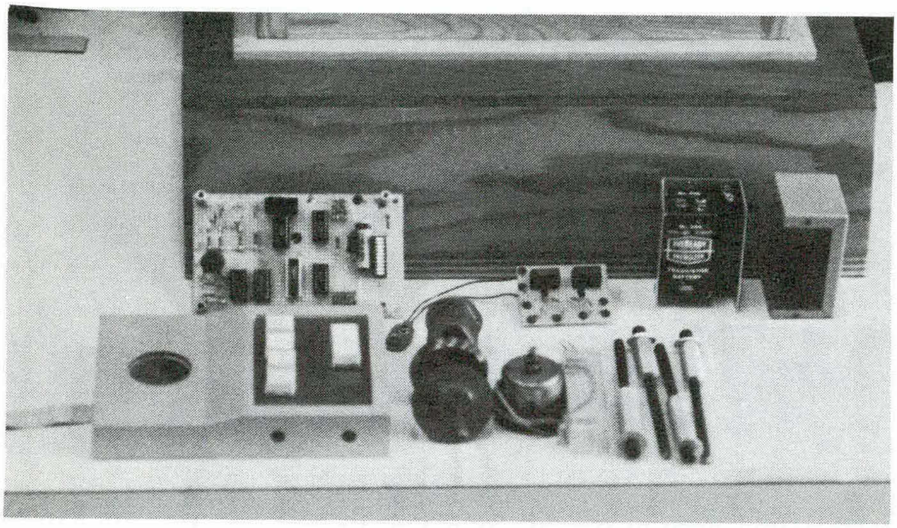
The switch-box and gear-box are mounted to the door with four bolts that are screwed from the inside. This gives the switch-box maximum security and beauty and means that only four holes need be drilled in the door to mount the deadbolt system. The switch-box is constructed from aluminum and has milled recesses for the existing lock mechanism and a ribbon cable. The five switches are pressure-sensitive buttons from a discarded desktop calculator and are mounted on an aluminum plate (see picture 2). A ribbon cable is connected to the contact points of the switches and passes along the grooved recess through the door and plugs into the electronic brain on the other side. The five switches meet the input pulse needs of the electronic schematic and the ribbon cable allows the switches to be separated from the electronics thus again providing maximum security. If in the unlikely event the switches or switch box is pried off, the would-be intruder still cannot unlock the door without the key as the gear-box and electronics are located inside. The numbered buttons, 1,2,3,4, serve as the coded number inputs and the '0' button serves as the lock or reset key. For example, if the device were programmed to accept the code, 0-1-1-2, only those buttons pushed in that order will activate the system and unlock the door. Our system gives no indication of code errors such as 0-2-1-2, except by the virtue that the door remains locked and one must press the '0' or lock button to clear the device and begin again. This and the 1024 possible combinations prevent almost any unwanted opening.

Most deadbolt mechanisms operate on the principle of a flat pin passing through a slot that throws a lever which pushes the deadbolt out of the door. The turning of the key twists the pin which pushes the deadbolt out or in. By the mounting of a brass rod, the pin is extended and a gear system may be mounted to it. Thus the turning of the key on one side is imitated by the turning of the rod on the other as both actions twist the pin and lock or unlock the door. An easily obtainable tape-recorder motor is mounted to drive the gear in the same way the human hand turns the key (see picture 3). The pulse inputs, the coded number sequence or the lock command, control which direction the motor rotates and consequently, the movement of the deadbolt. When powered by a 9V battery, the motor can spin the deadbolt in or out in a time of 200 milliseconds. Under the guidance of Dr. Hoyer, professor of EE, we modified the electronic brain and put time delays on the duration of power that is passed to the motor. Namely, upon activation of the system, power is allowed to flow to the motor only for the time of 200 milliseconds. This adaptation allows power to the motor to be automatically shut off when the deadbolt is either fully in or out (see picture 4). Another advantage of this system is that,due to the low torque of the motor, the system may be at any time over-ridden with the key. This allows the door to be unlocked in emergencies or daily activities by aides or maids who have no physical need of using the pushbutton switches.

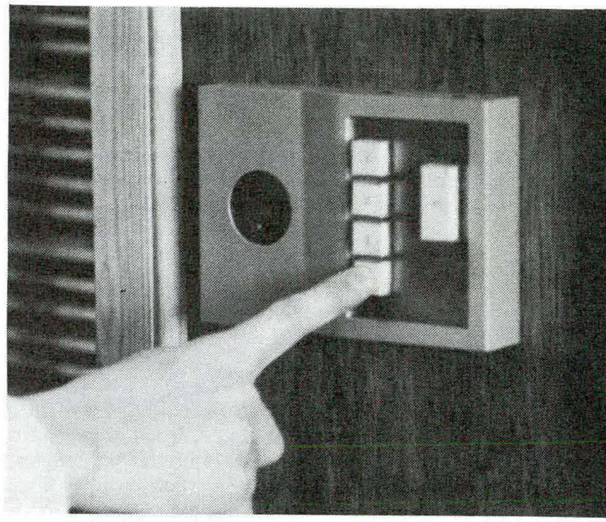
The entire system is powered by 2 batteries. A 6V which can for over 1 year power the electronic components and a 9V which powers the motor for 600 lock activations or approximately 3 months.

Another problem encountered was the fact that the deadbolt was originally locked and unlocked by a small knob when using the lock from the inside of an apartment. Many Timber's residents do not have sufficient grasp to use such a knob so consequently we designed our own. The new inside knob is long and thick enough to be used by persons with little or no grasp and stops on the gear-box prevent the handle from overtwisting the lock mechanism pin.

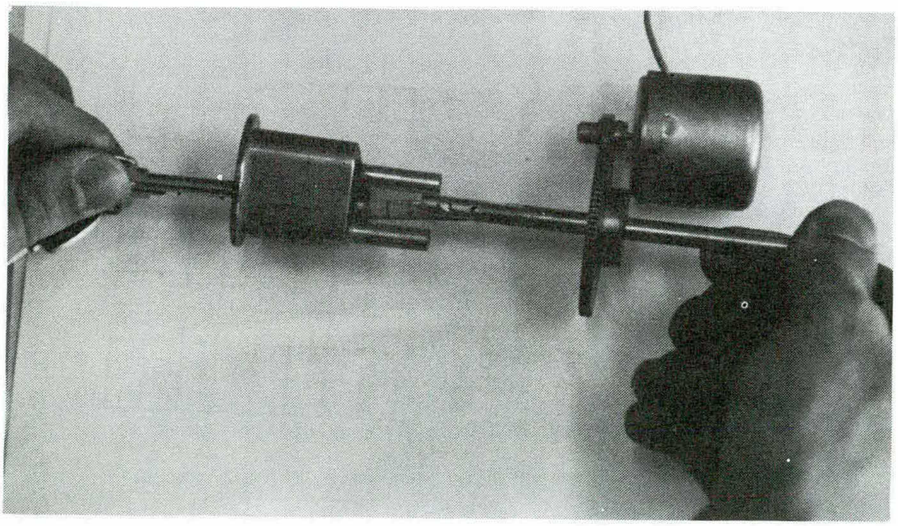
The prototype we built has a plexi-glass casing for ease of viewing and we expect the true dimensions of the gear-box to be around three inches by four inches; possibly being constructed of a decorative wood. The cost of the system is estimated to run between thirty and fifty dollars; certainly a price break-through compared to the non-deadbolt mechanical systems which can run upwards of two hundred dollars. Our system is also weatherproof as any water or dirt will not affect operation of the switches since a metal plate separates them from their contacts and the electronic components are located inside the home. Our device has been very well received by the handicapped community at Timbers and several residents have inquired about possible installations of our device on their doors. After all, the door to independence should not be hard to open.



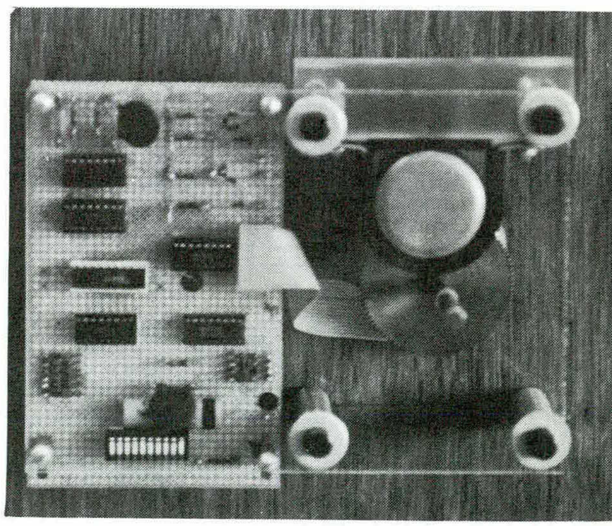
Picture (1)



Picture (2)



Picture (3)



Picture (4)

SCHOOL BUS FOR CHILDREN WITH PHYSICAL DISABILITIES

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DESIGN DEPARTMENT
SYRACUSE, NEW YORK

INTRODUCTION

This project is being submitted for the degree of Master in Industrial Design at Syracuse University. It is a two year study dealing with the transportation of children with physical disabilities.

Since 1975 the United States Mass Transportation governmental regulations require that children with disabilities have to be transported by the School District at public expense. School buses, however, do not meet the school transportation requirements for safety and comfort, especially when loading and unloading, since they are built on chassis designed for trucks.

When exploring and developing a means of transportation for disabled children, it is necessary to consider the needs of all the people concerned with the problem, which includes children, parents, school personnel, school district personnel, and the public. Primary considerations are the safety, comfort, and pleasure of the children during their trip between school and home. Presently there are not any satisfactory solutions and there are no standards fixed for the vehicles.

An analysis of the entire school transportation system was essential in order to establish the criteria necessary to design a school bus.

DESIGN CRITERIA

SAFETY: The first objective in the design of a bus is to improve transportation safety. The exterior structure, edges, and bumpers are shaped to provide a minimum of injury to pedestrians and provide proper visibility for the driver.

The distribution of seats is made according to the general collision impact of vehicles, as well as the emergency door locations. Rear and forward facing seats are the most appropriate to absorb impact. Seats are designed to provide appropriate strength, absorb energy, and protect passengers against impact. They are equipped with a restraint system: A bar which the children pull down when they sit.

Wheelchairs are oriented forward and secured by the back wheels. In addition, the passenger is secured by a restraint bar which when pulled down fixes the back wheels.

The vehicle structure is strong enough to withstand a roll-over and the body is built with large parts with special joining systems, to avoid failure of both body and frame.

COMFORT: Psychological comfort is a subjective concept which is difficult to define and measure; besides, the physical aspects of comfort can be improved.

A low floor provides easy and fast entry-exit for wheelchairs. Steps are avoided and a simple system has been designed for loading wheelchairs. The low floor is achieved by a low chassis made with a honeycomb structure, as used in aircraft structure, plus a hydropneumatic suspension to provide height variation, which allows wheelchairs to board with the help of a ramp. The ramp is the bottom part of the door.

The characteristics of all the categories of disabilities have been considered when designing the vehicle. Attention has been given to access, the surface of the floor, seats, seat restraints, wheelchair securements, student circulation, as well as the information system. In order to accommodate children of different size, seats are adjustable.

Great concern has been expressed for the need to rapidly evacuate wheelchair children in case of an emergency.

ENVIRONMENTAL ASPECT: Good maneuverability of the vehicle is provided by a small turning radius and suspension stability.

Care in the choice of proportions, treatment of details and color schemes achieve good standards of visual acceptability.

Because of its low floor and light structure, the school bus is better adapted to urban and suburban areas. Its short length, small turning radius and low weight provide good response to traffic conditions.

COST: There are four sources of cost in a school transportation system: Wages, vehicle cost, and general cost, such as administration and insurance.

Operating cost is reduced with better designed equipment allowing less maintenance, faster repair, easier cleaning, and cheaper parts.

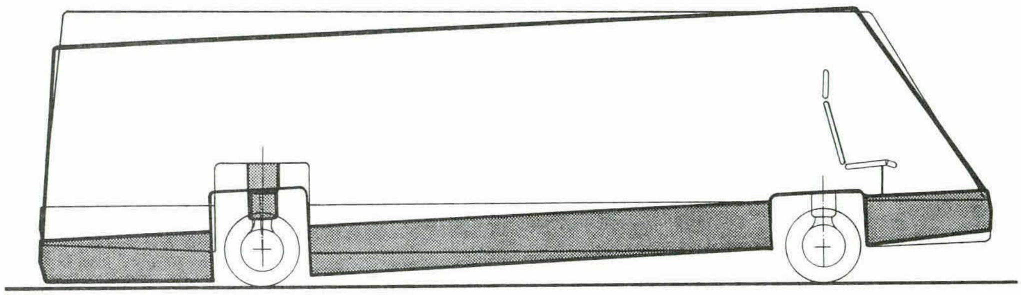
BUS SPECIFICATIONS

The solution which was developed to meet the needs of children with physical disabilities, conforms with the technical objectives of a low degree of sophistication and easy maintainability.

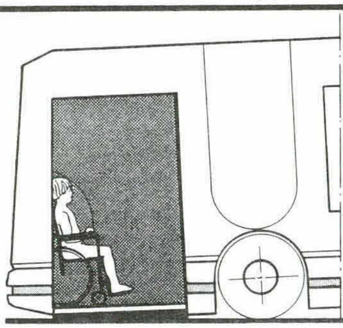
- This vehicle provides transportation of children with various physical disabilities and great differences of mobility.
- Rapid wheelchair entry-exit is provided by a simple low angled ramp directly into the vehicle. Wheelchair securement is provided.
- Removable seats allow different distribution and variation in the number of wheelchairs. Passenger securement is provided.
- A honeycomb chassis permits a low floor of 32 cm from the ground.
- In addition, 25 cm height variation is provided by a hydropneumatic suspension system.
- The bus is 850 cm long, 250 cm wide, 250 cm high, has small tires of 65 cm diameter, and weighs approximately 3500 kg.
- Diesel engine of 120 hp with automatic transmission.

- Speed: Maximum 100 km/h.
- Structure: Steel. Body: Polyester sandwich panel with foamed core.
- Exhaust system: The pipe will discharge above the roof.

The result of the study includes a scale model and a document with concepts for structure, specific hardware components and interior arrangements. This provides enough design information to proceed with the engineering details and construction of a prototype vehicle.



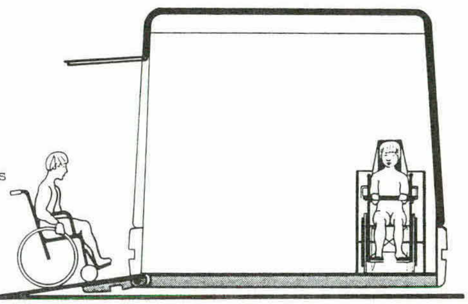
KNEELING SYSTEM: the hydropneumatic suspension brings the honey comb chassis close to street level.



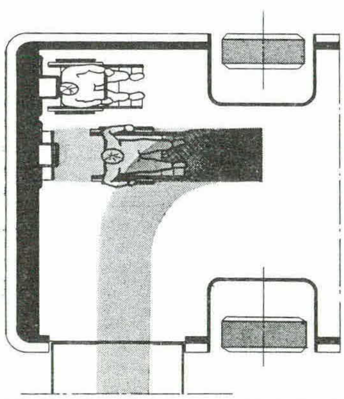
LOADING SYSTEM

1 The rear of the bus kneels down to the ground and the rear door opens.

2 The bottom part of the door is a ramp which allows the wheelchair passenger to enter.

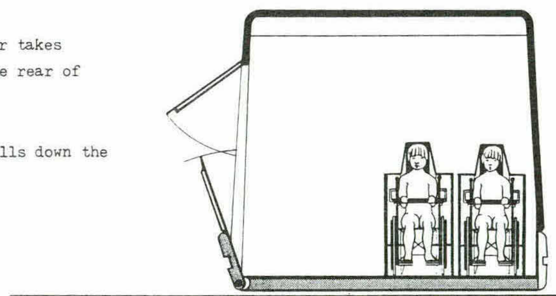


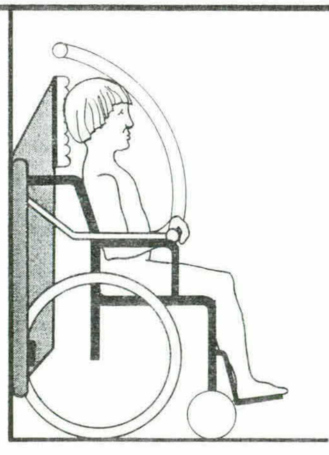
1	**2**
3	**4**



3 The passenger takes his place at the rear of the bus.

4 The child pulls down the restraint bar.

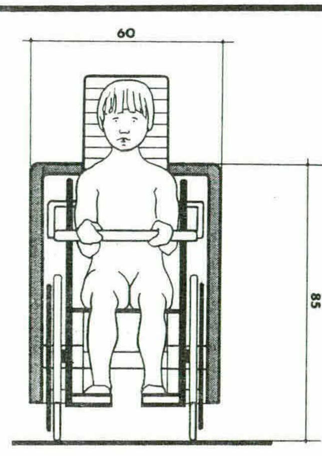




Detail of the wheelchair unit restraint:

The unit is oriented forward in the bus and secures the wheelchair by the back wheels. The child is also secured by the restraint bar which when pulling down fixes the back wheels.

design P. PICAUD



LEG BAG EVACUATION SYSTEM

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Many quadriplegics in powered wheelchairs collect their urine in leg bags. This can limit social interaction and job placement. With Veterans Administration funding, a system has been designed that enables quadriplegics in powered wheelchairs to use rest rooms independently. One solution in existence is simply a remote valve that relies on gravity flow to drain the bag. This is not versatile enough to work in most circumstances, since the system cannot accommodate use of most restroom facilities. It was determined that a pump system to empty the bag and move the urine into a commode was a more usable solution. Since the powered wheelchair already carries either a 12 volt or 24 volt battery package, sufficient power is available to allow the use of such a system.

Since we are dealing with the human body and its fluids, much care must be taken. Also, urine is highly acidic, therefore material choices are very important in the solution of this problem. The following design criteria were derived in cooperation with a potential user: simplicity of design with innate high reliability, a sterile fluids design with simple cleaning routine, simplicity of operation, and a basically invisible system, not apparent to other persons.

To meet the criteria a medical lab pump was chosen. The peristalic pump is a design that uses flexible plastic tubing and a roller system to create fixed volume chambers. This pump is sterile because the hose that carries the fluid does not need to be cut for connection to the pump - just threaded through it. Given the proper choice of tubing, worry over possible leaks in the system or damage due to the corrosive effects of urine is eliminated. In addition, high reliability and ease of cleaning is assured.

Once the pump was sized a motor was found. Presently available pump/motor combinations did not exist for this application (12V or 24VDC) much less at an affordable price. We have found 12 VDC motors met our specifications as well as being small. The pump/motor box finally assembled is approximately 7" x 9" x 15"; small enough to mount under a small powered wheelchair seating system. This permits a design that is largely invisible to other persons.

Positioning the outlet end of the hose away from the wheelchair without interfering with the chair's mobility by changing its outside dimensions requires the use of a telescopic arm system that will stow underneath the seat and reach far enough to clear the foot rests with plenty of length to spare. This extendable arm was made from a retractable automobile antenna, which provided adequate reach extended and retracts to a small enough length to fit underneath the chair seat. This arm was designed for 12 VDC operation.

These subsystems are brought together by the control system, itself an offshoot of other research done at the Georgia Institute of Technology. This controller is a coded digital radio transmitter-receiver system with two (2) separate codes: one to control the arm functions and the other to control the pump function with internal safety connections so that the pump will only function when the arm has been extended and the proper code is sent by the transmitter. This controller also senses when the bag is empty and automatically returns the system back to its resting state.

The total system functions as follows: starting at rest, the user keys the arm code on the transmitter; the arm will extend as long as the user sends the signal until the arm is fully extended, at which point the motor switches off. The user then keys in the pump code and the pump will empty the bag as long as the code is sent until the bag is empty, at which point the system purges the hose by pumping backwards just long enough to clear the arm - this also prevents the bag from sealing by placing a small amount of fluid bag in the leg bag. The system then automatically retracts the arm, without further input from the user, but the user can control the purge function himself as well as the retract/extend of the arm.

This system has developed from an initial prototype that was constructed in June 1981 and tested the basic idea, mounting location, and bag sensing system. From this first prototype, and later while working with several users, the need for the extendable arm as well as a more sophisticated control system was defined.

The decision to use our coded radio control was made to prevent accidental triggering of the system by small children. A similar system for those who transfer into desk chairs has been developed that is not as complicated because it is permanently planned into the building. Both systems have met with much success and are eagerly awaited as the second prototypes are being readied as of April 20, 1982.

AMPUTEES CAN OPEN CANS TOO

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Modern can openers are designed to be used with two hands. Amputees and individuals with limited use of one or more arms or hands are faced with a difficult dilemma when attempting to open canned goods. These individuals are unable to use two hands required in can openers of current design. This paper addresses this problem with a design modification that allows the use of current electric can openers and/or derivatives thereof.

Electric can openers marketed today necessitate the use of two good hands. One hand picks up the can and inserts it in position under the opener's cutter, while the other steadies the device and engages the cutter and drive motor. The can is then opened by the opener's turning action against the cutter. When finished, two hands are again required to remove the opened can. Individuals with one arm or those without full use of one arm are unable to follow this procedure. This can be corrected with a simple design removing the necessity of coordinating two hands. A spring loaded platform is the basis for the design which solves this problem. The platform is mounted strategically under the electric can opener's cutter where cans may be placed upon it. The can is pressed down on the platform and the lip of the can slipped into a slot just under the cutter to position it correctly. This operation is easily accomplished using one hand and a limited amount of force. When the can is positioned correctly, the hand is removed and used to engage the cutter bar and the can subsequently is opened. All of this time the can is held in place by the spring loaded platform and notched bar. When the can is opened, the cutter is lifted to disengage it and the opened can can now be depressed using one hand out of its locked position for use. The technique has proven quite simple and easily accomplished on the prototype.

The prototype uses a common Rival model 739 electric can opener mounted on a base along with the spring loaded platform so that they become an integral unit. The only modification to the model 739 was the addition of a brass slot on the cutter bar pivot arm. With this knowledge, it is apparent that kits could be produced to alter existing can opener designs to change them over to one handed operation. However, it would be more desirable to integrate the spring platform and system of containing the can with existing hardware in a new, well developed design.

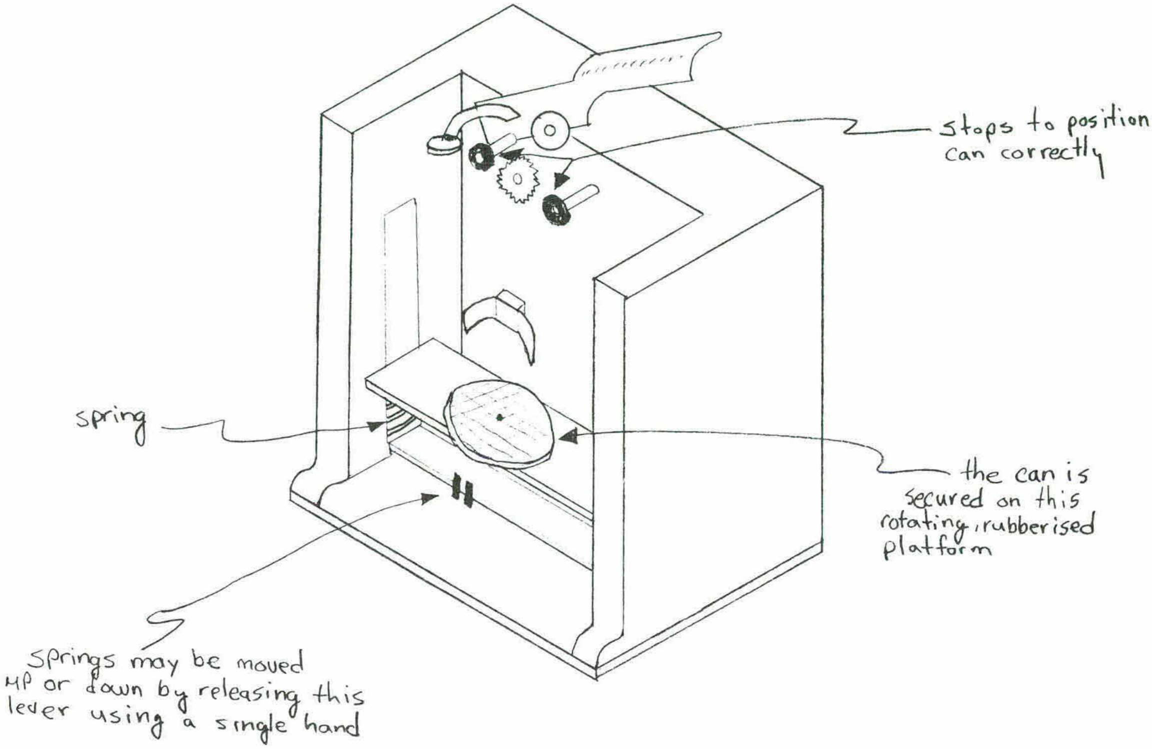
Most of the apparatus necessary for a design incorporating the features for single handled operation are presently in production for many different models of electric can openers. This apparatus, in conjunction with a housing designed to accept a spring loaded platform and provisions for anchoring the can in position could be easily mass produced.

The modifications planned here should not add significantly to the final price of a modified can opener. The Rival model 739 was purchased for under eighteen dollars and with modifications could easily be produced for under twenty-five dollars putting it in financial reach of most people.

It should be noted that the prototype developed here will accept only standard fifteen ounce cans and those of similar dimensions. The intent was to prove the capability of the design and not develop it initially for the full range of can dimensions marketed. Production design would naturally provide a means of adjustment for many different can dimensions. An adjustable platform would be a desirable solution to this problem.

One other notable addition to a production model would be adding a rotating support on the spring supported platform. This would have the can seated on it and would turn as the cutter opens the can to alleviate unequal forces on the platform.

The design proposed here calls for an inexpensive integration of existing hardware to create an easily used electric can opener. It would be useful to anyone with restrictive or loss of movement in one arm and could be marketed at a price compatible with most pocketbooks. This product could also serve as a labor saver for nonhandicapped individuals so is not only suitable for the handicapped.



* Possible Production Design For One Handed Opener

The spring loaded platform can be moved to a position suitable for opening a wide variety of can sizes. A bar with the springs resting on it held in place by tension devices which can be released using one hand makes this possible. A rotating holder on the spring loaded platform that has a cover of rubber or other material to grip the bottom of the can transfers the rotating force of the opener's cutter to the platform

This design can be produced in a compact, aesthetically pleasing housing. It could also be a valued labor saver for anyone who opens cans and should not be limited to individuals with handicaps only.

MICROPROCESSOR-BASED WHEELCHAIR CONTROL SYSTEM FOR THE PROFOUNDLY HANDICAPPED

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INTRODUCTION

As we know, the most severely handicapped persons are cerebral palsied, spinal cord injured and ALS victims. In order to design a universal wheelchair controller to be usable for that population as well as the less severely handicapped, it is necessary to provide for the most sensitive switches with a very high response multipurpose system.

By using today's powerful tool, the microprocessor (μP), it was possible to solve the problem of designing a complete system slow enough to respond to a person through a scanning display for sequential selection of information, and fast enough to transmit information to devices as simple as a DC motor or as complex as a computer. It also provides the user with environmental control for monitoring his surroundings, turning appliances ON and OFF, doing data processing, etc. Simply stated, it provides access to the daily services that anybody would need during his/her daily life.

DESCRIPTION OF THE CONTROLLER

Let's look at Fig. 1. We can divide the system into three separate parts:

1. Input Gathering Network
2. Analyzing and Processing Network
3. Output Network

1. INPUT GATHERING NETWORK

1-1 Operator Inputs. Different kinds of inputs can be used with this system. For Sections a. and b. following, a scanning display for selection of direction can be used.
- a. Single switch operation allows the user to operate the controller with any single switch coupled to an appropriate part of the body. The switch can be a simple momentary switch, sound activated switch, eye motion detector switch, etc.
- b. Three-switch operation allows the operator to control the chair with one switch and steer with the other two when travelling in forward or reverse.
- c. Multiple switch array operation permits more able-bodied individuals to control the wheelchair in the more conventional ways, like with a joystick or slot control.

1-2 Adjustments. Variable adjustment is offered for user accommodation to control the SCAN RATE of the visual display, the MAXIMUM SPEED of the chair from 0 to 100% of its potential, and ACCELERATION RATE from 4 seconds to 45 seconds. Speed can be electronically changed by the user.

1-3 Power Requirements. The unit can be powered by 12 volts or 24 volts, single or dual (series) batteries.

1-4 Secondary Inputs. A number of secondary inputs can be provided to the controller, such as:
- a.* Tracking information that is continuously gathered from optically or magnetically coupled devices on the wheels for straight tracking.
- b.* Ultrasonic detector input can be used for tracking or automatic steering.

2. ANALYZING AND PROCESSING NETWORK

Management and control of the system is done by an 8 bit microprocessor such as the 8035 or 8748 family through less than 1,000 bytes of memory.

2-1 Primary Function of Microprocessor.
- a. Read and decode operator inputs and act accordingly.
- b. Enable the acceleration and speed drive modules if the proper command is received.
- c. Check the protection priority (hardware module) of the system and then start the motor to function.
- d. Resume system scanning if no switch is closed.

2-2 Secondary Function of Microprocessor.
- a. Sent information to speech processor (SP) for direction 'spoken' outputs to the user like "off", "speed", "forward", "right", "reverse", "left", "off", etc.
- b. Take care of housekeeping information like low battery, or electronic circuit breaker.
- c. Process the information back from the amplifier sensor for better control.

2-3 Expansion Capabilities. There is room for future expansion such as:
- a.* The system can be coupled to a communication system.
- b.* The unit can be coupled to an environmental control system accessible from the wheelchair.
- c.* The system can be interfaced with a computer either through a transmission cable or through an ultrasonic transmitter/receiver from the wheelchair.

3. OUTPUTS OF THE NETWORK

3-1 It can control either field wound or permanent magnet motors at either 12 volts or 24 volts.

3-2 It outputs the display code for the scanning direction display.

3-3 It provides both 'verbal' output and variable tone output for auditory feedback of the direction scan, and chair housekeeping signals.

3-4 ASCII code is provided to interface with a computer, and decimal and BCD code for the communication and environmental control systems is available.

*Future addition.

3-5 Modem and RS232 codes can be simply coupled to the system.

The program is only 1,000 bytes long and can be easily modified by adding some RAM on the board to provide additional capability. For example, the chair can be programmed to go to the wall at night after the user goes to bed and call it to the bedside in the morning.

Since pulse width modulation (PWM) is used to drive the motors, the full loaded chair temperature does not vary more than 10°-20°F above ambient temperature.

The prototype box is under 2 pounds and can be simply mounted in the arm of the wheelchair without taking a large physical space.

Protection is done by hardware that requires three drives to enable it:

1) Operator switch
2) μP ready signal
3) acceleration and speed module signal

If the sensor detects an extraordinary situation, it will activate the software ON/OFF Controll.

This system offers a broad line of input switching to accommodate different individual needs. It gives enough variety as far as scn speed, motor speed, and acceleration that it's very easy to find a comfortable range in which to operate. With other capabilites like interfacing with the environmental control system and computer, it is easy for a person to use the computer through a single switch or joystick, opening education and employment opportunities for that same wheelchair bound individual.

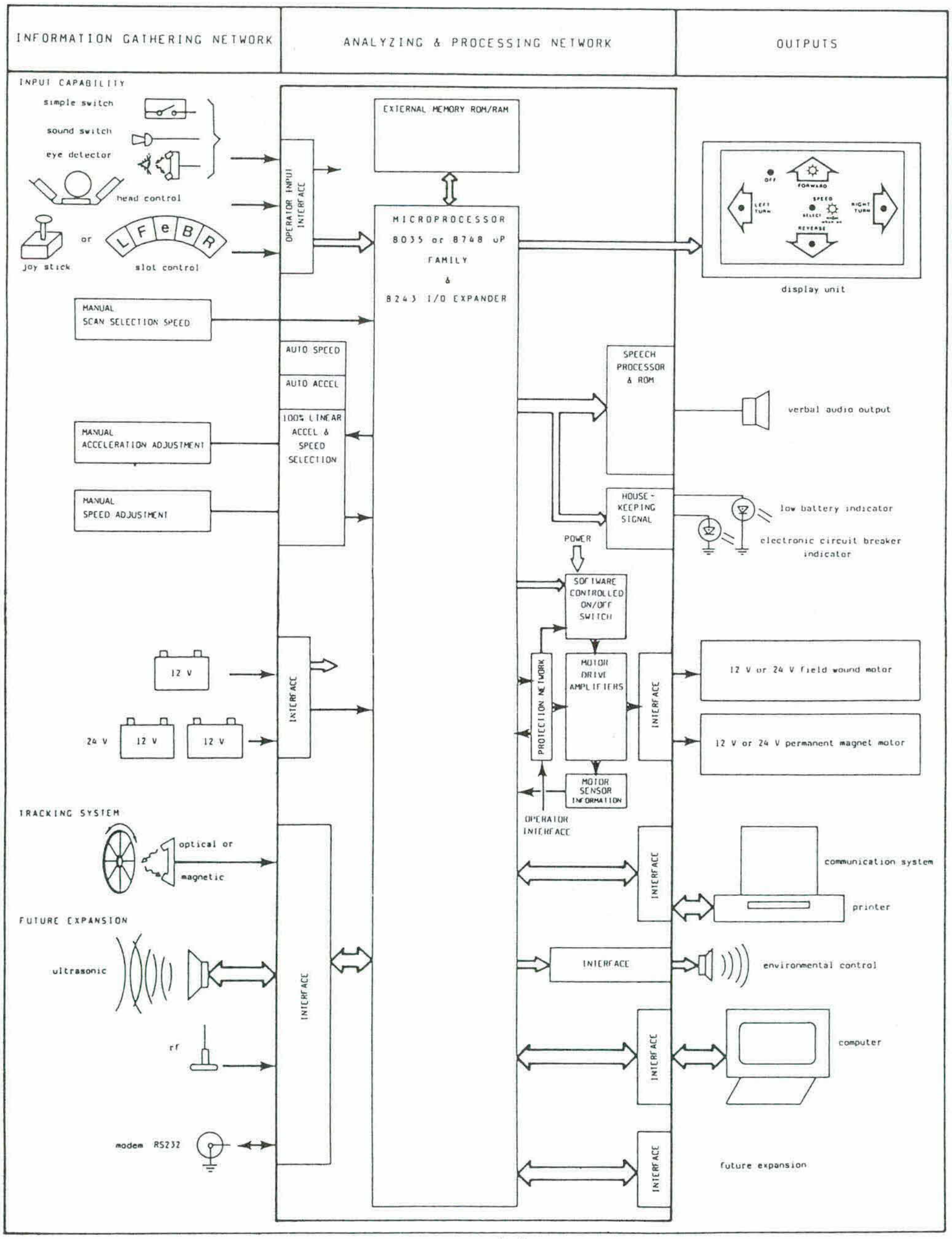

Figure (1)

ENVIRONMENTAL CONTROL FOR THE BEDRIDDEN DISABLED PATIENT

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There are several environmental control devices which have been developed in recent years to aid disabled people. These devices are usually employed to call the nurse for emergency purposes. Each device has two main components, the transducer and the transmittor.

Transducers, which convert the patient's physical activity into another form of energy to activate the desired environmental response, are the liaison between the patient and the transmission device. There are several available transducers, some of which are familiar to all. The touch switch is what is commonly understood to be a button, manual or electronic, and is activated by minimal force applied by the hand or tongue. Sound sensors and light sensors use the patient's voice and eyes to transmit the patient's desires. Finally, there are pressure sensors which detect positive or negative (puff-suck) pressure through a tube. Even biting on the tube will cause sufficient pressure increase to activate this device.

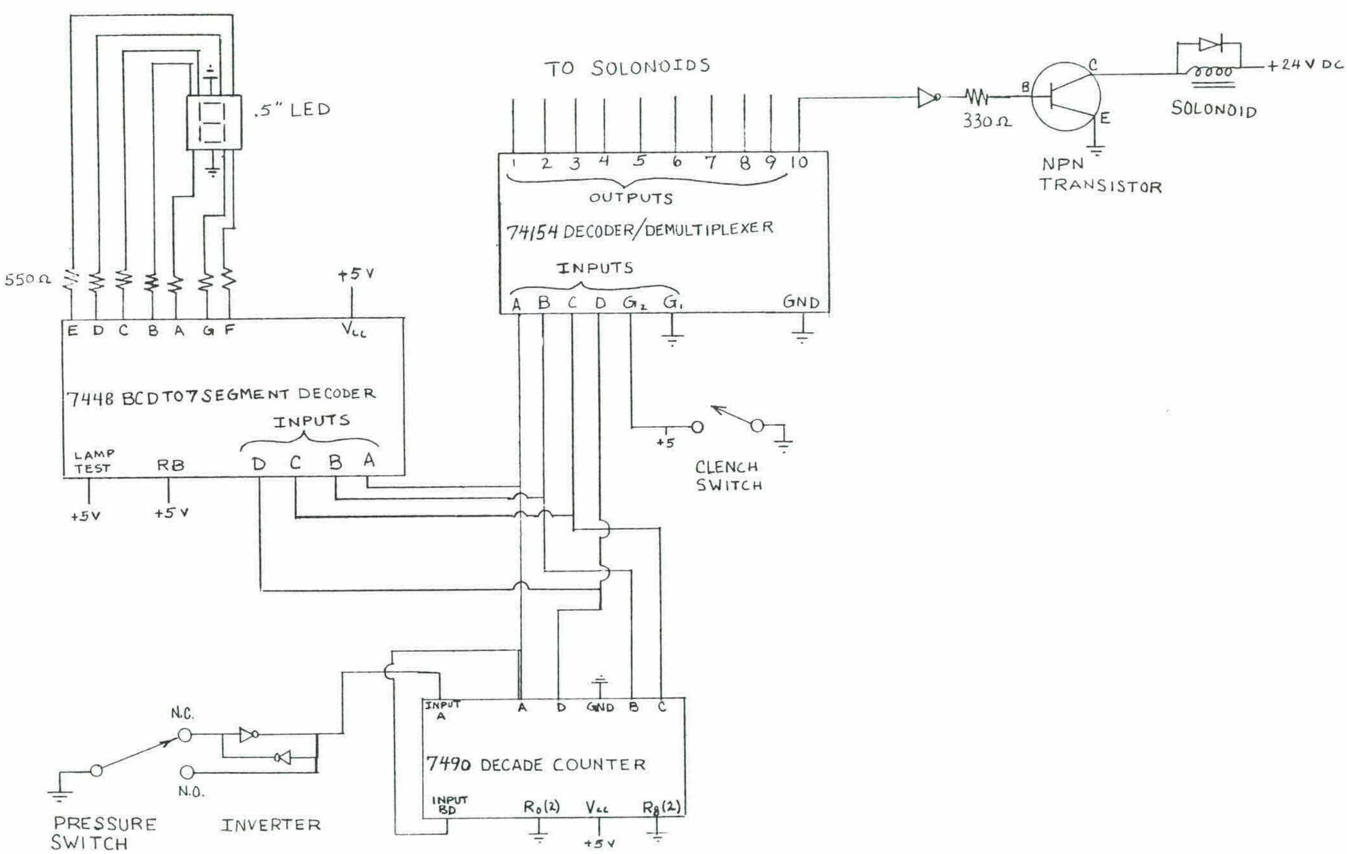
The available transmission devices range in price, complexity and availability. The most common and most practical is electrical wiring. Other forms of transmission include electromagnetic devices which transmit electromyographic signals produced by muscle motion. There is also a device which transmits signals according to the frequency. However, these last two are considerably more expensive than wire and are usually out of the question for a cost effective design.

These devices are very helpful to disabled people, however, none has been used to aid the bedridden patient to control his environment. Such a problem was recognized in the physical therapy department at Duke University Hospital. The problem was realized by those who treat patients with spinal injuries and therefore remain in the hospital for periods of three to six months. These patients are unable to use the manual control panel to raise and lower their beds, control the light or the television, or to call the nurse. So the design objective is to solve this problem.

The solution uses a variation of the puff-suck device. The new device uses a pressure switch activated by the patient blowing into a tube. The pressure switch is wired into a binary decade counter. Each advance of the counter corresponds to one of ten environmental controls. The counter is connected to an LED readout display which indicates the control which can be engaged. To engage the control, the patient closes the circuit by biting on a waterproof switch. Through a function multiplexer, a solenoid which is mounted directly over the control button, is activated and so depresses it (see diagram).

The LED readout is mounted in a box which is attached to a semirigid tubing. This was used to make the system stable but adjustable so that the readout can be moved to the spot most visible to the patient. The flexible tube through which the patient blows also has a guide wire so that it can be placed conveniently near the patient's mouth. All parts are solidly clamped to the bedrails.

Preliminary testing of all the electrical components was successful. The pressure switch is easily activated by even shallow breaths. Also, the solenoids were successfully activated by the waterproof switch when clenched in the teeth. At the time of this writing, the assembly had not yet been installed for use, but expectations are positive. The slides enclosed with this description do not show the entire assembly because those slides were not yet available from the developers. However, such slides will be forwarded when they are available.


.5" LED
550Ω
+5V
E D C B A G F
V_{cc}
7448 BCD TO 7 SEGMENT DECODER
INPUTS
LAMP TEST
RB
D C B A
+5V
+5V
TO SOLONOIDS
1 2 3 4 5 6 7 8 9 10
OUTPUTS
74154 DECODER/DEMULTIPLEXER
INPUTS
A B C D G_2 G_1
GND
+5
CLENCH SWITCH
330Ω
B
C
E
NPN TRANSISTOR
+24V DC
SOLONOID
N.C.
N.O.
PRESSURE SWITCH
INVERTER
INPUT A
A D GND B C
7490 DECADE COUNTER
INPUT BD
$R_0(2)$
V_{cc}
$R_9(2)$
+5V

THE HANDLE: A SKIING AID FOR THE HANDICAPPED

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Over the past few months, my interest in and instruction of handicapped skiers has led me to design a device, which I call "The Handle," that aids not only the skier but also helps the instructor teach.

In January of this year I attended a Monday night session of the Lansing, Michigan, Handicapper Ski Group as part of an industrial design class assignment dealing with handicapped therapy. From that point on, once a week, I joined the Lansing group to help instruct handicapped skiers. Most of the people I worked with were children who had complications due to Cerebral Palsy (CP).

Within the first few sessions I noticed a similar problem amongst some of the children. These children had a tendency to sit way back on their skis, a position which is not very conducive to learning how to ski properly. With this in mind I began thinking of a means to keep the skier's weight forward on the front of the skis rather than the backs. I figured if the skier had something to hang onto that forced him or her to reach forward then the skier would not be able to sit back on the skis. At that time the only aid our ski group had for the students to help their instruction was what we call a Ski Bra. Briefly, the Ski Bra keeps the tips of the skis from crossing. With this being another problem (the tips of the skis crossing) among CP students there was also this area to consider. From here I developed The Handle.

The Handle is basically what its name says--a pair of horizontal handles mounted onto vertical tubes that connect to the front of a skier's skis. In accomplishing its primary task of keeping the skier's weight forward, The Handle also keeps the tips of the skis from crossing and allows the instructor to easily steer the student.

The Handle system consists of a set of handles, with handgrips to hang onto, mounted to a series of vertical metal tubes, which in turn connect to a ball-joint system and then to the tip of each ski.

In the upper part of the handle, there exists a spring system to act as a shock absorber in case the skier is forced against the handle in the event of hitting a bump. Moving down from the upper spring section there is an adjusting area. The tubes are pushed in together to shrink the size of the handle for shorter individuals and pulled apart to accommodate taller skiers. A clevis pin is used to hold the tubes securely, once in place. The bottom of the adjusting tube is connected to a device which fastens The Handle to the ski. In this case, I used an existing Ski Bra and welded my handle to it. This gave me a means of fastening the system to the skis without having to design a new means since that was not one of my concerns.

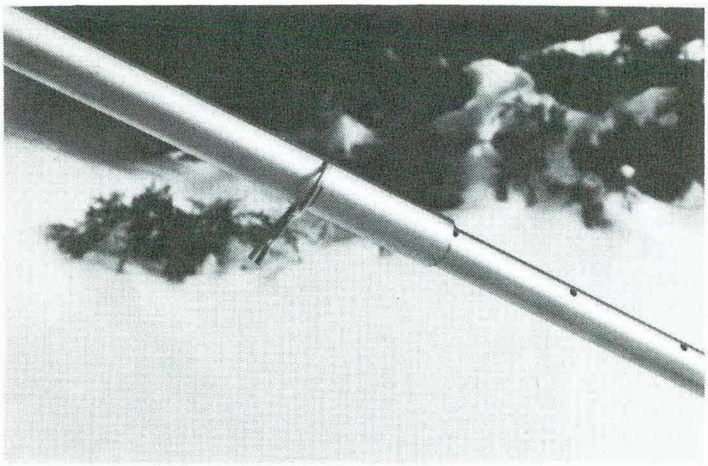
In the first prototype manufactured it was found that a ball and socket joint was necessary at the base of the adjusting tubes. Therefore, the idea of a simple joint that allowed The Handle to move forward and backward only was replaced by a ball-joint.

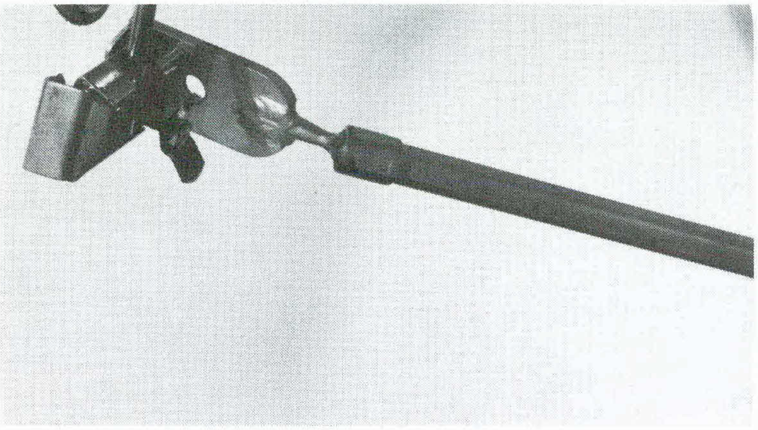
With the insertion of a ball-joint in the second prototype, The Handle now could move in any direction that a beginning skier would need to move. The ball-joint system allowed the skier to start with the skis parallel and move into a wedged, snowplow position for stopping. In using a snowplow for stopping, it is necessary for the skier to slightly dig the inside edges of the skis into the snow; the ball-joint also allows for this movement. In order for The Handle to flop forward so an instructor could hang onto it and guide the skier (often the instructor skis backwards down the hill facing the skier so he can easily assist and stop the student if necessary), it was necessary to grind out the front of the socket. The Handle now functioned as it was designed to on flat ground so it was ready for a test run.

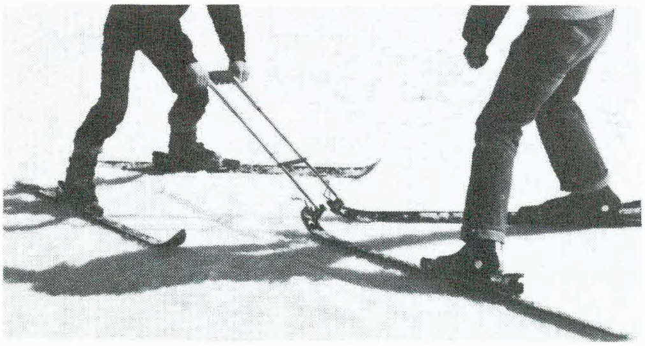
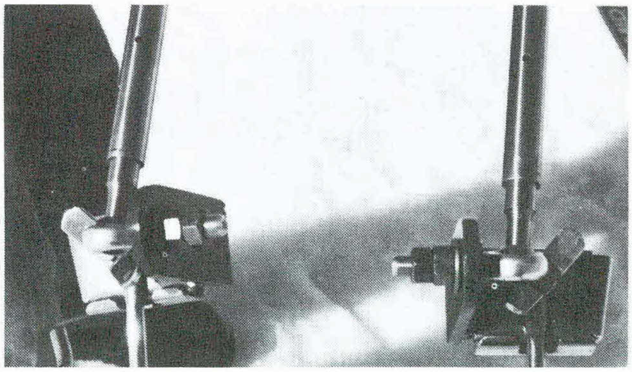
On the first run the ball popped out of the socket when a student lost her balance and twisted The Handle as she went down. This proved that the existing ball and socket joint was not strong enough to withstand the applied forces. The ball and socket joint which is now part of The Handle system is a joint manufactured to withstand 3500 pounds of pressure. I believe this is most suitable for my purpose.

A few weeks ago I contacted the Handicapper Ski Group in Winter Park, Colorado, and told them of my design. They were very interested in The Handle and wanted to test it out to see how it performed. Presently, The Handle is being tested in Colorado to see if it functions as it was designed to. The results will not be known to me until sometime after the deadline of this paper.

In building the last prototype many new ideas came up that I would like to try, such as: 1) modifying the handgrips so that they stick up more vertically rather than the horizontal position that they are now in; this would make them more like holding onto ski poles; 2) using aluminum tubing instead of steel, this would cut down on the weight of The Handle; and 3) replacing the clevis pins that secure the adjusting tubes with a push button that, when pushed in the tubes, would be able to slide, and upon reaching one of the adjusting holes, the button would pop out to lock the poles securely in place. Another suggestion is to lighten The Handle even more by using one tube instead of the present two, over the middle section of The Handle. then branch out into two tubes near the bottom of the system so it can connect to the individual skis. These and other ideas for a more improved design of The Handle will be considered more in-depth when the results of the present tests have been evaluated.





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