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COMPUTERS, COMPUTER TECHNOLOGY AND THE PHYSICALLY DISABLED

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ABSTRACT

At least 20,000,000 people in the U.S. are afflicted by physical disabilities which interfere with their lives. The number and distribution of disabilities such as visual, hearing and mobility impairments is considered, to motivate an examination of a variety of computer aids for the handicapped. Computerized braille systems are found to be practical and cost-effective, and a variety of devices for embossing braille are described. Research in reading machines for the blind, using voice synthesizers, appears to be proceeding rapidly.

The need for large print (large type) output has not generally been sufficiently emphasized, and the use of electrostatic printers is suggested as a possible output device. A computer-independent device, the Optacon, which provides tactile input to the blind is currently in use, and is especially helpful to blind programmers.

The deaf use teletypewriters and acoustic couplers to communicate via the telephone network. Intelligent typewriters, and automated letter boards are practical alternative methods of communication for some people with motor impairments.

Ignorance of the needs of the physically disabled can result in operating system designs which present barriers to them.

Introduction

At one time or another, almost every person will experience a non-trivial physical disability. In addition to those professions who deal routinely with physically disabled people (e.g. physicians, rehabilitation specialisits, etc.), some professions have come to recognize their impact in this area. Thus one notes the promulgation of an American National Standard (formerly ASA, then USASI) on architectural barriers, directed towards making buildings more accessible and usable by the handicapped [6]. One hopes that as computing services become yet more widespread in our society, similar care will be given to ensuring that <u>all</u> people may get the full benefit of these services. This report is directed towards identifying some of the needs of the physically disabled, some of the services computers and computer related technology currently provided them, potential new services and recommendations on the design of computer systems and computer related devices.

Some Statistics

The President's Task Force on the Physically Handicapped included only one table in its 1970 report (p. 2, [49]). It is:

Age Groups	Estimated total number	Estimated number needing services
0-4 years	270,000	270,000
5-19 years	3,660,000	3,660,000
20-64 years	15,000,000	10,000,000
65+	6,690,000	6,070,000
Total	25,620,000	20,000,000

Table 1. Physically handicapped people in the United States

This table was composed from sources spanning a period from 1966 to 1968, when the total U.S. population was an estimated 190,000,000. The Task Force went on to state "the number of physically handicapped persons of all ages is increasing at a rate faster than our present ability to meet their needs" (p. 1, [49]).

The physically disabled or handicapped are people with physical disabilities which interfere with a "normal" role in society. This is necessarily a vague definition; a unique, precise definition is not available, and statistics on the nature and distribution of physical disabilities are not very accurate (e.g., see the discussion in [37]). The principal disabilities are shown in Table 2 (from Table 9 in [37]).

Type of Impairment	Average no. (1000)	%	Rate/ 1000
All impairments	23,815	100.0	141.4
Blindness	960	4.0	5.7
Other visual impairments	2,064	8.7	12.3
Hearing impairments	5,822	24.4	34.6
Speech defects	1,098	4.6	6.5
Paralysis	940	3.9	5.6
Absence of fingers or toes	1,428	6.0	8.5
Absence of major extremities	282	1.2	1.7
Impairment of extremities	4,836	20.3	28.7
Impairment, except extremities	5,026	21.1	29.9
All other impairments	1,359	5.7	8.1

Table 2. Number of impairments, percent distribution and rate per 1000 persons by type of impairment: U.S. 1957-58

The discrepancy between the rates of incidence of impairments for Tables 1 and 2 (131.1 and 141.1 respectively) reflect not only the different time periods involved, but the differing definitions in use as well as the sources of raw data. Furthermore, tables such as these tend to obscure the fact that many people are afflicted by multiple handicaps (e.g. some 200,000 deaf people also have a severe visual impairment (p. 21, [29])).

Tables such as these are necessary, but they tend to focus interest on the dominant groups, despite the fact that a smaller number of people may be afflicted by a much more severe disability. The distribution of physical disabilities by age group is also of interest, since it sheds light on the nature of the needs. Table 3 provides some of this information as it applies to the blind (from Exhibit 2.4 in [21]).

Age Group	%
0-19 years	9.8
20-39	13.5
40-64	29.5
65+	47.2

Table 3. Distribution of legal blindness (1965 sources)

It may also be helpful to view the incidence of various physical disabilities in the context of other disabilities. The following table displays the incidence of physical and other disabilities for school-aged children in the state of Wisconsin [54].

Nature of disability	%	Count
Speech impairment	3.5	36,000
Mental retardation	2.3	23,000
Emotionally disturbed	2.0	20,000
Special learning disability	2.0	20,000
Crippled and other health disorders	.5	5,000
Deaf and hard of hearing	.1	1,100
Blind, partially sighted	.1	600
Totals	10.5	105,700

Table 4. Distribution for disabilities among school-aged children in Wisconsin, 1972.

The above percentage could be used to extrapolate to obtain national counts.

Assistance Sources for the Physically Disabled

Assistance to or for the physically disabled is provided by a variety of means. Many devices have been constructed to overcome certain problems (e.g. a device to turn pages of a book). Many of them are illustrated in [27]. Recognition that disabled people may wish to travel has led to identification of travel barriers with respect to public transportation [48]; similarly architectural checklists have been prepared to make colleges and universities accessible to handicapped students [44]. Volunteers acting individually or in organised groups anually contribute hundreds of thousands of hours in a variety of tasks, from the preparation of braille to the tutoring of homebound handicapped children [4,13]. Government agencies at all levels administer "an incomprehensible multitude of programs for the handicapped" (p. 13, [49]).

Research specifically directed towards the discovery of scientific principles and application of new engineering techniques for the benefit of the physically disabled has been going on for some time, dating back to Alexander Graham Bell's research on hearing, one hundred years ago. More recently, universities have taken an interest in such scientific-engineering approaches; for instance, formal Sensory Research Discussions were begun at M.I.T. in 1959 [19] and continue today under the auspices of the Sensory Aids Evaluation and Development Center [41]). A paper by Nye and Bliss gives an excellent overview of the problems and challenges related to the development of sensory aids for the blind [32]).

The Blind

The blind includes the totally blind and those with serious visual impairment. Since a great deal of the information we acquire is presented in visual form, the problems posed by a visual impairment can be ameliorated by presenting the same or equivalent information in other ways. Most people are aware of the use of braille by the blind, and many assume that most blind people use braille. This is not so. An examination of Table 3 indicates that serious visual impairment is largely a problem of the elderly. Since braille must be learned and practiced, and since the percentage of published works available in braille is small (less than 1% [23]), it is not surprising that only 10% of the blind use braille (p. 13, [21]). However, from the same source we note that over half of the blind in the 0-20 year group use braille.

There are many papers which discuss the fundamentals of braille and the generation of grade 2 braille ("literary" braille), which involves the application of an elaborate set of some 60 pages of rules to reduce the bulk of brailled material (see chapter 1 of Goldish [21]), Sullivan's paper on a braille translator [46], or the Allen-Boroz paper [3] which discusses many of the difficult issues in translating braille).

Information can also be provided through the use of audio tapes. However most of the so-called "spoken books" are produced by volunteer readers who may take 3 to 6 months reading and recording on a part-time basis to record a textbook or novel [34]. Non-textual information such as photographs and three-dimensional moving objects presents a difficult information processing problem, and some approaches are outlined in [32].

Computerised Braille

The use of computers to translate inkprint text into braille dates back at least to 1955 when an IBM group produced a braille translator for the IBM 704 [39]. Other IBM initiatives (e.g. an electric braille typewriter, a 1403 printer braille print chain) made it a practical matter to produce high-quality braille. The availability of computer-produced braille naturally led to the publishing of computer-related documents in braille, which in turn made it possible for blind people to gain entry into computer-related careers. The ACM Education Committee recognized this potential and formed a subcommittee on Professional Activities of the Blind. In its years of activity from 1964 to 1970, this group fostered the training and job placement of the blind in computing [45]. Having succeeded in helping over 400 people in this manner, it then disbanded. The scope of its efforts is reflected in [20]. The ACM Special Interest Group on Computers and the Physically Handicapped (SIGCAPH) has adopted many of the objectives of the previous subcommittee in line with a broader character [43].

Many braille translation programs have been written. Most of them generate grade 1 braille, which is a simple transliteration of the original text, which appropriate formatting of the output [52]. Some of these programs generate the much more complex and concise grade 2 braille. One of these was originally written at M.I.T. [16], then rewritten in COBOL by the MITRE Corp [46] to promote wider use. This latter version of the program was prepared in conjunction with the Atlanta Public Schools Vision Center [11]. The Vision Center used it to prepare brailled text books and classroom materials for blind children in their school system.

The Atlanta Vision Center has recently rewritten this program in PL/1, improving its speed while reducing its memory requirements [26]. These programs drive an IBM 1403 printer; the lease of a braille print chain and the modifications of the 1403 to use this chain cost approximately $165-228 per month [24]. The brailled material is produced at some 300 lines per minute and the embossing quality is very good. Several lower cost alternatives to produce the hard-copy braille have been developed. The least costly of these involves replacing the print cylinder of a model 33 Teletype with a special print cylinder for embossing braille. The embossing occurs one 3 bit column at a time (each braille character needs two columns of three bits each). The hardware or the software must also take into account the fact that the embossing is reversed. The braille cylinder is described in [7]; a minicomputer handler which buffers and interprets standard computer printer output and drives the modified Teletype is described in [38].

A more expensive but directly useable braille printer called the BD3 accepts ASCII codes at Teletype speed (10 cps) and produces a braille transliteration on paper type (embossed, not punched) [8]. Another braille printer, the MIT Braillemboss, operates in a manner similar to the BD3, except that it is a page printer, far more convenient to work with than a strip printer [40]. On the other hand, the BD3 fits into a suitcase and is portable, whereas the Braillemboss is not. Many blind programmers have obtained useable braille merely by using the dot or period found on any printer and mapping each inkprint line into three lines of dots. A platten sleeve for improving the embossing quality is available from Volunteer Services for the Blind [51].

Large Print

Many people have a visual impairment which renders the use of normal printed material difficult without the aid of a magnification device. Some materials are available in a large print format [22] in addition to the standard print format (e.g. the New York Times Large Type Weekly). Few textbooks (beyond the primary grades) are available in large print, and volunteers are called upon to prepare classroom material using large-type typewriters.

Computer-driven phototypesetters [9] can of course produce large print economically in high volume applications. The use of now conventional electrostatic printer-plotters for computer output should be investigated as a low cost alternative for low volume large print needs.

A visit to a public library demonstrates how scarce large print material is; this is of special concern to senior citizens for whom visual impairment is commonplace. A visit to a school's instructional materials center will illustrate a similar lack of large print material for schoolchildren. Similar remarks also apply to the availability of braille material [13].

New Technology for the Blind

Integrated circuit technology has made it possible to construct a portable device that converts the visual images of letters, numbers and two-dimensional figures into tactile forms which can be sensed with a finger. This device, called the Optacon [35], does not generate braille; it does require an intensive training course in order to develop proficiency in its use. An interim evaluation of its use, particularly by blind people employed in computing, is found in [5]. A full report will shortly be released by the American Foundation for the Blind [4].

An Optacon with an adaptor can be used to sense text on a CRT display, or on an illuminated display found in the solid-state calculators and in many other instruments using digital readouts. A paper by Munson [28] investigates the feasibility of using an Optacon as a computer input device and providing a character recognition system combined with a speech synthesis system which could provide vocal output on a dial-up demand basis.

Research on a Reading Machine for the Blind

There are a number of research and development efforts well underway to construct systems which will read printed material and generate spoken output (e.g. Allen's work at MIT [2]). A 1972 conference on speech communication and processing [1] had several papers on these and related efforts. The object of the project undertaken by the Haskins Laboratories [31] is to provide a centralized service facility which can process requests for "spoken books" by using one of several input techniques (optical character recognition, publisher's typesetting tapes, etc.) to feed a system capable of driving a voice synthesizer and recording the voice output as an audio tape. These tapes can then be easily reproduced and distributed. A prototype system is being evaluated, and interim results of human evaluation of the quality of the voice synthesis output are given in [33]. The author has had an opportunity to sample some of the synthesizer output and can appreciate why the intelligibility test scores for monosyllabic synthetic speech are within 5% of those for natural speech.

The Haskins project is oriented towards the generation of the best feasible synthetic speech, and the economics of such a system is likely to lead to a small number of them being constructed, each serving a large metropolitan area. Other developments might ultimately make it possible to produce lower quality speech systems based on exceptionally low cost voice synthesizers [17].

The Deaf and the Speech Impaired

The problems faced by the deaf can perhaps best be approached by contrasting them with those faced by the blind. Quoting Dr. F. Cooper, "blindness primarily hinders communication with the environment while deafness hinders communication with people" [29]. Some 8 million people in the U.S. suffer from some degree of auditory impairment, and some 900,000 of them have a severe auditory impairment. Within this last group, some 200,000 also have a visual impairment [29].

The role of computers as an aid to the deaf is not as direct as it is for the blind. The use of computer-assisted instruction for the deaf is being investigated, and it shows some promise of being of greatest assistance in the language skills [18]. The use of computers in speech diagnosis and therapy is also being investigated [30], noting that many deaf people can and do learn to speak.

On the other hand, one finds a variety of computer-related technology in use by the deaf. Some 5,000 people communicate over the telephone network through the use of teletypewriters and acoustic couplers [47]. Most of the teletypewriter equipment has been donated by the Bell system, Western Union and other communication companies, and much of this equipment uses Baudot code (5 bits) and runs at 60 words per minute (45.5 baud). Unfortunately most of the teletypewriters and CRT devices used on computer systems use 7 or 8 bit codes, operate at 100 wpm (110 baud) or faster and are therefore incompatible with these older devices. Some firms have begun using new technology to produce low-cost ($500-1000) telecommunication terminals; some of them capitalize on the availability of low cost home television sets. For instance, one new device displays 8 lines of 32 characters on any TV set; it has a built-in acoustic coupler, keyboard and display controller with switch selection of 45.5/Baudot vs. 110 baud/ASCII [36]. A paper by Jamison [25] describes a number of other means of communications over the telephone network.

Earlier we referred to the use of synthetic speech in reading machines for the blind. It would appear reasonable to investigate the possibility of developing hearing machines for the deaf, which could "understand" spoken English and produce equivalent visual output. Research in speech recognition is underway [1]. However the system we have described must be portable if it is to be used by a deaf person, and the present state of the art precludes a good, low-cost portable unit.

The speech impaired are often grouped with the deaf, even though a hearing impairment need not prevent learning to speak. In principle, synthetic speech could be used by the speech impaired. In practice, in addition to the limitations and costs of present synthetic speech systems, there may be a reluctance to accept a synthetic voice which is to be directly associated with its user.

The Motor Impaired

We shall use the term motor-impaired to refer to those with disabilities of the nervous or muscular system, amputations or the non-ambulatory (homebound or shut-in).

In some instances, lack of sufficient hand control to prepare legible handwriting can be overcome by using a typewriter. In cases where a typewriter cannot be used, a "masked" typewriter which provides a rest for the hand and a guide for one-finger typing may be adequate. It may then be likely that the typing rate is very slow, and the error rate (due to lack of hand and finger control) is high. This suggests the use of an "intelligent" typewriter. For those who have access to computer time-sharing services, a remote teletypewriter terminal with a reasonable editing-filing system provides such an "intelligent" typewriter, with which correct copy can be prepared without manually retyping the entire text to eliminate errors. Such an approach was taken at the University of Wisconsin [15], where a model 33 Teletype was equipped with a plywood mask, foot pedals to activate the shift and control keys, and a dial-up connection to the campus computing center. This system provided a disabled student with his only independent written means of communication.

Typewriters not connected to computers have had some degree of "intelligence" for some years (e.g. IBM's Magnetic Tape Selectric Typewriter MTST). The decreasing cost of electronics is leading to more systems with like capabilities becoming available.

In situations where a disability interferes with both the ability to write or type and the ability to speak (not uncommon for those afflicted with cerebral palsy), the use of a letter board (or word board, or sign board) permits the spelling out of one's thoughts by pointing to the desired letters or words in turn. This is a very slow process and it requires the continuous attention of the other party. A group of engineering students at the University of Wisconsin became aware of a young boy who could only communicate in this way; they proceeded to equip him with an automated letter board which displays the text of a CRT, and provides hard copy on a teletypewriter [50]. They now have almost a dozen copies of the automated letter board in the field for evaluation, and extensions which would in effect automate a word board are under study [12].

Other Aids for the Motor Impaired

The use of a telephone may be difficult for some people. A rotary dial telephone might be replaced by a push-button (Touch Tone) telephone, or by a telephone in which the dialing is accomplished via a pre-punched card. Some newer automatic dialing systems permit the selection of one of several dozen pre-recorded numbers simply by positioning a pointer. Automatic telephone answering devices may also be helpful. Automatic dialing and answering devices are now priced within the reach of an average person.

The multiply handicapped or those affected by total paralysis may be able to control a variety of devices (even a typewriter) through the use of systems such as POSSUM, a patient operated selector mechanism [27]. In cases of total paralysis, the mouth is usually able to function, and the patient can use his mouth to alternately blow and sip to activate a number of devices.

Factors in Designing Devices and Systems

Devices such as a teletypewriter or CRT to be used with a computer system should provide redundant feedback through the use of visual and audio signals (e.g. bell signal for right margin). They should be equipped with locking shift and control keys (to facilitate one finger operation).

Conventionally organized computer operating systems may require modifications to support some of the devices or some of the services useful to the physically disabled. For example, few operating systems easily accommodate a user specified device handler to support a Teletype with a braille print cylinder (the system at the Lawrence Radiation Laboratory does, [53]). Too few operating systems provide a command language macro facility [10]; this is a valuable service for the motor impaired who would benefit from the ability to abbreviate sequences of system commands.

Establishing a connection with a dial-up computer system can be a time consuming endeavour, especially for the handicapped, moreso for handicapped children. Elaborate logon procedures concerned with accounting charges and safeguarding privacy of information may warrant re-examination. Inexpensive classes of system services should be accessible through simple logon procedures, with supplemental authorization requests issued as needed. At some increase in cost, a user's terminal could be equipped with an identification code which could be transmitted as part of the logon procedure, as with the "here-is" key on the model 33 Teletype. Of course an operating system must expect such a code as part of its logon procedure. Conversely it might be convenient for the consumer to have the central computing facility originate calls to customer terminals on a scheduled basis, or upon voice request by a third party.

Few time-sharing systems permit the user to define the basic unit of interaction. Most systems accept a line (as indicated by a carriage return or other special signal) as the unit of interaction. In supporting some devices of use to the disabled, it would be very useful to allow the user some definitional capability. For instance, an automated letter board could conveniently be used as an automated word board, if character-by-character interaction with the operating system could be allowed upon demand.

The reader is urged to refer to the Nye and Bliss paper [32] and the Goldish report [21] for a thorough discussion of other important issues in design of aids for the physically disabled.

The Future

A class action suit filed in Pennsylvania led to a 1972 ruling requiring the state of Pennsylvania provide a free public education for all retarded children in the state. Formerly the state assumed an obligation in providing some educational services to some retarded children. The new requirement emphasises providing public education in the same facility. The impact this ruling is having on the state and on the affected families is the subject of a videotaped Public Broadcasting System program [42]. Subsequent class action suits in other states have led to court rulings which extend the right to a free public education in an integrated setting (with other "normal" children) to all handicapped children.

These rulings force already financially burdened school systems to provide services to new groups of children requiring special assistance. This is bound to present educators, and ultimately computer professionals, with challenges to their sensitivity and ingenuity.

This paper has focussed on the physically disabled in the U.S. . The challenges we faced are magnified when we consider that the prevalence of some disabilities (e.g. blindness) is five times greater in developing countries [55]. Some of the aids described above are inherently language dependent (e.g. braille translation, speech synthesis) and thus a great deal of work must be done to provide similar aids to different language groups.

We also note that the rate of prevalence of some disabilities is increasing on a world-wide basis. "... unless active measures are taken by the year 2000, the number of blind will rise to over 30,000,000. This figure does not include persons with severe visual impairment" (p. 6, [56]).

Recommendations

Persons professionally involved in computing should develop a sensitivity towards the needs of the physically disabled, and the evolving manner in which computers and computer related devices may assist. They must attempt to transmit their insights to colleagues professionally involved with the disabled. Many technical problems have been solved; e.g., the feasibility of braille translation by computer was demonstrated in 1954 [39]. Cost-effective solutions to some problems, already field tested, are available; e.g., the Atlanta Public Schools Vision Center can produce the braille equivalent to an inkprint page for $3.00 (including initial text entry) plus $0.05 per embossed copy. However those who have the resources to serve those who have the needs must be made aware of the existence of these and other practical cost-effective solutions. To the extent these solutions involve computing, then computer professionals must share the responsibility in disseminating this information [14].

Developing a sensitivity to the needs of the physically disabled can be done in many ways, but it is suggested that one should meet them, and get the benefit of the ultimate consumers advice. A sensitivity to their needs includes not raising false hopes. Let us not however through ignorance build any architectural barriers into our computer systems.

ADDENDUM

The BD3 portable braille device is manufactured and marketed by Triformation Systems, Inc., P. O. Box 127, Wall Street Station, N. Y. 10005. They have just recently begun selling a braille line embossing device, the LED-120, which operates at speeds up to 120 cps and accepts a number of standard codes (ASCII, EBCDIC, etc.). It sells for $9,000.

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16. Abstracts

At least 20,000,000 people in the U.S. are afflicted by physical disabilities which interfere with their lives. The number and distribution of disabilities such as visual, hearing and mobility impairments is considered, to motivate an examination of a variety of computer aids for the handicapped. Computerized braille systems are found to be practical and cost-effective, and a variety of devices for embossing braille are described. Research in reading machines for the blind, using voice synthesizers, appears to be proceeding rapidly.

The need for large print (large type) output has not generally been sufficiently emphasized, and the use of electrostatic printers is suggested as a possible output device. A computer-independent device, the Optacon, which provides tactile input to the blind is currently in use, and is especially helpful to blind programmers.

The deaf use teletypewriters and acoustic couplers to communicate via the telephone network. Intelligent typewriters, and automated letter boards are practical alternative methods of communication for some people with motor impairments.

Ignorance of the needs of the physically disabled can result in operating system designs which present barriers to them.

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