ACCESS TO THE SAS(r) SYSTEM
FOR BLIND OR PHYSICALLY DISABLED PEOPLE

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1. INTRODUCTION

In this era of "user friendly" software, computing with SAS(r) system products is now truly accessible to just about everyone. With the introduction of the SAS/AF(r), application facility, SAS/ASSIST(tm), windows, and more, what could be easier? You pull up a chair to a sleek desktop computer, slip in a disk, flip the power switch, and a moment later a bell beeps, a menu of options appears on a multi-color screen, you tap a conveniently labelled key, and you're off and running. Sure, sometimes the manual is less than clear but in most cases even an inexperienced user can be up and running quickly.

Think again. This time imagine that you are blind. That multi-colored menu is no longer available, and the welcoming "beep" is just an annoyance. Or imagine that you are paralyzed. Ordinary typing is a slow and tortured process with a pointer held between your teeth; even the function keys are a major effort; and key combinations like CTRL-ALT-DELETE are simply out of the question.

Certainly for many persons with disabilities, this is exactly the case: a world of exciting new technology, which is inaccessible to those who might benefit from it the most. Fortunately the situation is improving. Thanks to imaginative individuals and organizations around the world, including SAS Institute, major advances are being made to eliminate or reduce such barriers to computing for persons with various disabilities. And as the barriers to computer technology are falling, a wealth of resources are becoming available to improve the lives, and livelihoods, of disabled individuals thru greater access to educational and employment opportunities, improved communication, and greater independence in daily living.

Adaptations which permit disabled persons to use computers do so, generally, by supplementing or replacing those functions that are involved in the person's disability. In each case, the individual must first be evaluated to determine the extent of function lost and, equally important, the existence and strength of residual functions that can be called into play.

This paper will illustrate several specific ways in which we are attempting to make the SAS system for PCs accessible to persons who are blind or physically disabled. Each employs commercially available hardware and/or software, if available at moderate cost, requires no modification to the SAS system, and little or no modification to SAS application programs. Each is currently being tested for installation in an accessible computing lab being established for use by disabled students at Washington University.

2. AIDS FOR PERSONS WITH VISUAL IMPAIRMENTS

Most of our work to date has been in providing adaptations for those with visual impairments. Since most visually impaired persons can learn to type, the problem a potential user faces in using SAS is not how to get information into the computer, but how to verify their own input, and to read SAS's display of messages, menus, windows and output screens. The extent of vision loss, of course, determines the degree of adaptation necessary to make the system accessible.

For example, someone who is "legally" blind, but with some residual vision, might be assisted by providing a much larger than standard screen, or by providing a means for enlarging portions of the text (scrolling) on the standard screen. For total blindness, however, visual displays must be replaced by auditory (synthetic voice) or tactile (braille) output.

Several computer programs are available that enlarge "windows" of text on the screen, and allow the user to move the window around to review all the screen's contents. In some, individual characters can be enlarged to an inch or more. The effect is like placing a magnifying lens in front of the screen, and can be quite effective for persons with modest vision loss.

2.1 Artic Business Vision(tm)

The system we have been using, Artic Business Vision(tm), provides synthetic "voice" output for persons who are blind or visually impaired, and gives them the ability to have all or portions of the video screen selectively "read" to them. A speech synthesis card is installed in the PC, and software provides text-to-speech translation and a means for selecting and reading or spelling text. We are developing custom setups and macros for use of this system with SAS.

2.2 Operating procedures.

Business Vision operates in two modes--"applications tracking", or "ApTrack", and "review"--which are selected at any time by toggling the "break" key.

In applications tracking, or "Ap Track" mode, all keystrokes are echoed to the user, in synthesized voice, then passed to SAS or some other application program. While in "Ap Track", SAS operates normally. In addition, whenever SAS or the user moves the cursor, Business Vision will also "read" the information the cursor has moved to. The amount of information that is read is determined by setting the "context unit" to character, word, line, sentence or paragraph. For example, if character units have been so-
Software pronounces most words quite well, although moving the cursor will cause the new character to be read out; if word units are selected, the new word containing the cursor will be spoken.

Most of the value of the Business Vision program comes, however, in "review" mode. In this mode, all key strokes are used by Business Vision to permit the user to review the current contents of the screen. Functions are available to read the current line, a specific line, or the entire screen. Pressing "n" moves the cursor down a line and reads that line; pressing "m" reads the previous line. In review mode, the user can also search the contents of the current screen for a specific character string, then continue reading from that point.

2.1 Functions and features.

Some additional features and functions that are of special interest for users of SAS include the following. All of these options, and many others, can be set and changed from within SAS or other application; and the settings can be saved as part of a personal configuration and reloaded automatically whenever Business Vision is loaded.

Speech Windows: allow the screen to be divided into logical windows, each of which can be entered individually (when in review mode). When in a speech window, page-up and page-down, etc., move only within the current window. Pressing the escape key moves the entire screen. For display manager, we have the output window defined as window 1, from line 2 thru 11, column 2 thru 79. The LOG window, lines 12 thru 18, column 2 thru 79, is window 2, and the PROGRAM EDITOR window (number 3) is lines 19-24, column 2-79. Finally, columns 65-80 on line 25 are used as a status window, window #4.

Number Processing: Ordinarily number strings are spoken as words (e.g. "four-thousand seventy-five"). Business Vision provides the option to instead read each digit individually (four-zero-seven-five). The ability to toggle between the two modes appears to be particularly useful when editing numerical data, or reviewing SAS statistical output.

Dictionary Management: The voice synthesis software pronounces most words quite well, although it takes a little practice to get used to the synthetic voice. When used with SAS, terms such as "proc", "ANOVA", "univariate", and "freq", are pronounced almost normally. "GLM", since the software can't determine an acceptable pronunciation, is spelled "G-L-M", just as we would like. Other words are a little more difficult: "NLIN" comes out badly slurred, "PROBIT" rhymes with "profile", and "TTEST" sounds like stuttering.

To improve the pronunciation of such words, there is the ability to provide an alternate spelling. For example, the variable ISQUARED in one of our test datasets, has been entered in the speech dictionary as I SQUARED, with the space added. And VAR is entered as VARIABLE to pronounce the abbreviation in full. TTEST is entered T TEST to eliminate the stuttering.

Color change announce, and field attributes: Whenever screen colors are useful in interpreting the contents of a field, or in "navigating" around the screen, Business Vision can be set to announce whenever either background or foreground colors change. The user can also request BY to read only highlighted fields, or those displayed in reverse video. These options appear to be particularly useful in SAS window displays which use color and field attributes extensively.

Voice Settings: The user has control, from the keyboard, of how the voice will sound. Settings for volume, pitch, tone and speed of the voice can be adjusted from a "voice window" which can be invoked at any time.

Spelling: Ordinarily, when Business Vision reads a section of text, strings of characters are spoken as words. Occasionally, however, the user may be unable to understand the pronunciation, or may wish to have a word spelled out. Business Vision allows the spelling of words to be toggled on and off at any time.

Turbo Pedals: An exciting new option provides the capability for the user to "fast forward" and "rewind" the speech buffer (the current screen) using a foot pedal. We have not had the opportunity to test this new facility, which is known as Turbo Pedals.

2.4 Hardware and software requirements: installation and setup.

The SynPhonix(tm) model 215 voice synthesizer is compatible with IBM PC/XT/AT and slot-compatible computers, and with the IBM PS/2 models 25 and 30, and works with CPUs operating at speeds up to 20 megahers. While SynPhonix itself requires less than 40K of memory, a minimum of 256K RAM memory is recommended. A single disk drive, and MS-DOS version 2.1 or greater are also required.

The hardware consists of a half-length circuit board which easily plugs into any available slot in the PC. The card itself contains an internal mini-speaker, and there are subminiature phone jacks for connection of earphones or an external speaker, and the "Turbo Pedals" controller. Volume and treble can be adjusted from control dials extending out the back of the PC.

To facilitate use of the keyboard by a blind user, we have also affixed small adhesive-backed velcro dots to several keys (F, J, I, 0, ALT, BREAK and keypad-5). This makes it easier to position the fingers on the "home keys" and to locate often-used special keys.

The Business Vision software requires no special installation, and can be run from diskette or loaded onto a sub-directory on a fixed disk. For convenience in use, a batch
startup file can be created, including commands to (1) load the voice synthesis software, then (2) start the SAS system with any appropriate options as pressed, then the lock is released. These locks are often incorporated into a keyboard overlay, or "key guard" that provides support and guidance to persons with spasticity or weakness

in the hands. Public domain software is also available to provide a "logical" equivalent of this locking function. Both the software and hardware solutions have been tested with various SAS procedures, and do not generally interfere with SAS in any way.

3. MANIPULATIVE IMPAIRMENTS

In contrast to the situation for blind persons, for whom the problem is one of getting information out of the computer, for persons with manipulative disabilities, the problem is entering information into the computer.

When using the term, "manipulative impairments", I am here referring to conditions which restrict the person's ability to effectively use an unmodified keyboard. This is distinct from "mobility" impairments which, alone, reduce only the individual's access to the computer, not necessarily impairing its use. Thus, providing an elevator or ramp, adequate aisle space, and a work table with clearance for a wheelchair, will permit many individuals to reach the computer. But upper-extremity impairments which reduce the ability of the arms/hands to manipulate a keyboard are somewhat more difficult to overcome. It is these impairments, which keep an individual from effectively using a standard keyboard, that are the focus of the rest of this discussion.

For some persons, only one hand is usable for typing, for reasons ranging from arthritis to amputation, making multi-key commands such as CTRL-ALT-DELETE difficult or impossible. For others, lack of fine motor control in one or both hands (due, for example, to Cerebral Palsy), makes accurate typing a tortuous process. And for still other persons, major paralysis may make keyboard use, and such tasks as inserting a diskette and turning the PC on/off, impossible.

We'll look at various aids, and their use with SAS, beginning with modest disabilities requiring the simplest level of mechanical adaptation, progressing to more severe disabilities requiring more sophisticated adaptations.

3.1 Aids for one-hand typing

Both hardware and software solutions are available to permit multi-key combinations to be entered by "one-hand typists" and by disabled individuals who must use a mouth-stick held between the teeth to press the keys.

Mechanical locking mechanisms are available to hold one key down temporarily while another key is pressed, then the lock is released. These locks are often incorporated into a keyboard overlay, or "key guard" that provides support and guidance to persons with spasticity or weakness

3.2 PC Serial A.I.D.

A system called the PC SERIAL A.I.D. (for Alternate Input Device) allows disabled users to communicate with the computer using several enhancements or alternatives to standard key entry. Options include software to "assist" normal keying, replacement keyboards, and the use of various non-keyboard controls for sending Morse code or for selecting the characters to be entered.

The system makes use of an interface that plugs into any serial port on the PC, and software that interprets both standard keyed input and the user's non-keyboard signals, then sends the appropriate character code to the PC operating system.

"Assisted" keyboard: This software solution provides three functions, allowing 1) one-finger typing of 2- and 3-key combinations, 2) control over repeated transmission of keys held down for more than a moment, and 3) redefinition of keys to move characters to a more easily reached position on the keyboard, or to assign a string of characters to a single key.

In one-finger typing, 2- and 3-key combinations are pressed in sequence rather than simultaneously. For example, Control-Y is entered by pressing the control key first, then the letter Y. Most combinations of Shift, Control and Alt, with another key are supported, as is the re-boot command, CONTROL-ALT-DELETE. The only problem we have encountered using this feature with SAS, is that CONTROL-BREAK appears not to be supported, making it impossible to interrupt the execution of a program in one-finger mode.

Key repeat can be toggled on and off to assist individuals who have impaired muscle control in the hands, and who hold keys down too long, resulting in repeated characters rather than the single character desired. With key repeat off, only a single character is sent regardless of the length of time the key is depressed.

The Serial A.I.D.'s key redefinition function is similar to common keyboard macro programs. It allows the user to reassign difficult to reach keys to a different position on the keyboard, and assigns a character string or "message" up to 60 characters in length to be assigned to a single key. Key redefinitions can be toggled on and off so that the original meaning of each key is not lost. This flexibility means that at one moment "p" can be the letter "r", and at the next moment "PROC FREQ DATA=". For example, in addition, redefinition files can be saved on disk, then reloaded as necessary for particular applications.
Alternate keyboard: The next level of assistance involves replacement of the standard keyboard with a 1-foot by 2-foot programmable matrix keyboard (the "Unicorn" keyboard), in which each of 128 "keys" is 1-1/4 inch square. By programming only a limited number of keys, each can be made larger: 2-1/2 inch by 2-1/2 inch for 32 keys, or 5 by 5-inches for only 8 keys. The Unicorn keyboard will let someone with limited finger dexterity type by pressing the larger "keys" with several fingers or with the entire hand.

Non-keyed input methods: We now shift from what are essentially familiar keyboarding methods of input to methods in which various on/off switches are used to enter text or select commands. For example, a paralyzed user can blow into a straw to stop a moving cursor when it stops at the desired letter, or can wink an eye to send the Morse code equivalent of that letter.

In both Morse code and scanning methods, input is achieved by way of one of many kinds of switches which send "on/off" signals to the software. Switches may be as simple as a hand-held push-button or a foot-activated treadle switch, or as complex as a myo-electric device which senses the very slightest electrical activity in a muscle. Switches can be operated by any muscle which is unaffected by the user's disability: an eyebrow switch mounted on the forehead is activated by a wink of the eye; a sip-and-puff switch works by sucking and blowing on a straw.

In both these methods the user can also set such options as the rate at which the software reacts, and can store those options on disk to be loaded either on demand or automatically when the system is loaded.

Scanning Input: Scanning is a means of communicating with the computer by selecting "keys", or key combinations, from a menu. In this case the menu appears as a string of characters overlayed on the screen at line 1 or line 25. The characters are displayed in groups, organized not alphabetically but in a way which statistically optimizes speed of access. The default scan line has the letters organized as follows: "ETNSHYW, OWYDCQ, ARUPGXJZ, NLBKIl, A". A blinking cursor moves at a selected rate from one group of characters to the next until the user "selects" the group containing the desired character by pressing the switch. The cursor then begins highlighting individual characters within the selected group. Again, the user selects a specific character by a press of the switch.

Included in each scanning line are several codes which cause a new scan line to be loaded. For example, the alphabet scan line contains codes to load a line containing numbers and punctuation, and one containing function keys and other special keys used in computing. The default scan lines contain all of the keys from the standard PC/XT/AT keyboard, and others can be added by the user. In fact, the entire layout of the scan lines can be changed rather easily. User defined scanning lines can be saved to disk and reloaded as needed.

Morse Code: Two forms of Morse Code are available. In the single-switch form, "dits" and "dashes" are distinguished by the length of time the switch is held closed. A distinctive tone for each provides feedback to the user, a low tone for the short "dit" and a longer, rising tone for the "dash". In dual-switch Morse Code, one switch is used to send "dits" and the other sends "dashes".

In order to provide full flexibility for use of Morse code in computing, the standard set of codes has been extended to provide Morse code representations for all keys on the IBM keyboard, including not only the alphabet and numerals, but also all punctuation marks, function keys, cursor keys, numeric keypad, and all other special keys.

Extended Morse Code (for Selected PC Keys)

```
--- control ------- PageUp
-..- alt ------- Page Down
----- delete --.- Left
-. Return .... Right
--- Escape ..... F1
------ Ctrl-Scr ..... F2
```

Note that key redefinitions and "message" strings discussed earlier are accessible from any of the input methods, including Morse code and scanning, so that the "F" key redefined as "PROC FREQ DATA"", can also be accessed by scanning, or by its Morse code equivalent.

3.3 Hardware and software requirements: Installation and setup.

The PC Serial A.I.D. is compatible with IBM PC/XT/AT, the PC Jr and PS/2, and with most true compatibles. The AID consists of a small interface box which plugs directly into any serial port on the computer (either COM1 or COM2), and doesn't require opening the PC or any permanent installation. Power is supplied either by an AC adapter or by internal battery. Switches plug into either of two "phono" jacks on the adapter box.

The software (SERAID) requires no special installation or setup, and can be run directly from diskette or loaded onto your fixed disk. The interface is activated by loading the program into memory prior to loading or running any other "background" or application program. For convenience in use, a batch startup file can be created, including commands to load SERAID, then the SAS system with any appropriate SAS options. A typical batch file to load SERAID, then start a SAS application, might look like this:

```
\SERAlD\SERAlD
SAS MAINMENU (NOCENTER ....

SERAlD remains in background memory until
needed, or until the PC is powered off (when not
in use, the keyboard operates normally). SERAID
requires only 58K of memory; the assisted key-
board portion of the system can be loaded sepa-
ratey (without scanning or Morse code
capability) and requires only 44K.
4. THE SAS SPEECH RECOGNITION FACILITY

The SAS(r) Speech Recognition Facility (SRF), represents what might be considered the cutting edge of adaptive technology for disabled persons. SRF is an experimental product now under development by SAS Institute which will allow paralyzed individuals to "talk" to the computer, dictating programs, Display Manager commands, and data, rather than typing them. The system is suited to individuals with severe losses in the effective use of their hands for entering information into the computer, but with reasonably intact speech; persons with double amputations, paralysis, or severe spasticity, for example. The system uses the IBM PC's Voice Communications Adapter and a custom interface to the SAS(r) system, developed by SAS Institute.

SRF is a user sensitive recognition system, which requires that the system be "trained" to recognize the speech of each particular user. Before outlining the training process, and then discussing how recognition is actually used with SAS, it may be helpful to review some of the terminology used.

An "utterance" or word, is a particular sequence of sounds spoken without pause. For example, "ProgramEditor", "DisplayWindow" and "proc" are all utterances recognized by SRF. In training, SRF creates a "model" for each utterance, consisting of a digital encoding of the speech pattern for a particular user speaking that utterance. A "grammar" contains the rules which specify how utterances can be put together, and the keystrokes to be sent to SAS when each utterance is recognized. And finally, a "vocabulary" consists of all words that can be spoken, and which can be recognized by SRF, in a particular context. A vocabulary is trained uniquely for each user of the system.

The key to the system's operation is the design and layout of grammars. Because SRF can distinguish only a limited number of utterances in a particular context, each vocabulary is restricted to 64 utterances. Some of the words in each grammar are "transition" words, which cause a new grammar to be loaded for recognition of subsequent utterances. For example, when SRF is using its DATASTEP grammar and it recognizes "proc" as one of the the words included in its associated vocabulary, two actions occur: first, the characters "PROC " are sent to SAS, then a new grammar, PROCS, is loaded along with its vocabulary containing the names of SAS procedures that can follow the word "PROC".

4.1 Training procedures.

As indicated, the recognition ability in SRF is sensitive to the particular speech patterns of each individual. Accordingly, the system must be "trained" to recognize each individual's voice, and the resulting set of models is stored in a separate subdirectory for that individual. If more than one person is to use the system, each must train the system to recognize his/her voice; then, when speech recognition is invoked, the

proper trained vocabulary must be loaded by specifying the subdirectory for that user.

Each vocabulary is trained separately, and the user only needs to train those vocabularies, and only those words, that he/she expects to be using. From the Display Manager's program editor window, type (or, once trained, speak) SPEECH to enter training mode. A window appears, in which the user enters the subdirectory in which the vocabulary is to be stored, the input device (microphone or telephone), and the vocabulary to be trained. A new window will appear, and the user indicates which words are to be trained. Then the training window appears.

From this window, the user is prompted to speak the designated word. The system analyzes the utterance and creates a model of the user's speech pattern for that word. Each word is spoken three times to build a reliable model, then SRF proceeds to the next word. Vocabulary words can be tested or re-trained at any time.

One of the vocabularies that will be important to most users is "Spell": Spell, which can be called from the base grammars, contains a phonetic alphabet to be used in spelling the names of variables and datasets, for entering data, and other situations where a standard vocabulary entry is not available.

After training the necessary words in each of the vocabularies that are likely to be needed, the user leaves the SPEECH mode and returns to Display Manager. Speech recognition can then be activated by the RECGU command, and its options. For example, the command

RECGU ON "JFA" MICROPHONE 25;

turns recognition on using the trained vocabularies in the JFA subdirectory, with a microphone as the input device, and a "rejection" level of 25. The rejection level specifies a minimum level of confidence necessary before SRF will accept an utterance.

4.2 Using SAS with speech recognition.

Whenever speech recognition is active, voice commands spoken into the microphone are interpreted and an attempt is made to match the utterance with a word in the current grammar. If a match is found, the appropriate text is sent to SAS for processing just as if it had been typed at the keyboard. In some cases, not only is text sent to SAS but a new grammar is loaded, containing vocabulary words appropriate to the context implied by the last utterance.

To illustrate, suppose you are in Display Manager's program editor and wish to run the CONTENTS procedure on a temporary dataset, TEMPI (see figure 1). Saying "proc" while in the editor will send the text "PROC", followed by a space, to the editor, just as if it had been typed, then load the "procedures" grammar. Included in this vocabulary are the names of all SAS PROCs. Saying "contents" next will send the text "contents" to the editor, and the grammar
for the CONTENTS procedure will be loaded. Saying "data" will send the string "data".

To spell the name of the dataset, saying "spell" will produce no text, but will load a phonetic alphabet which will recognize "tango" and "go back" and add those characters to the growing program. You must then say "go back" to return to the CONTENTS procedure vocabulary, and "semicolon", "enter" and "run" to complete your program. Finally, "escape" will return you to the program editor, and "submit" will need your program to be processed by SAS.

Figure 1: Voice Input

This is not an easy process, to be sure, but for someone with a disability, voice access may provide the only reasonable access for communication, education and employment. The voice recognition process is surprisingly accurate and reliable; and the design and layout of the grammar and vocabularies is well thought out. By reducing the number of grammars, and the necessary transitions between them, and by providing on-line help and improved error messages, future versions of the system would greatly ease what appear to be the major stumbling blocks for users.

4.3 Hardware and software requirements: Installation and return.

The IBM Voice Communications Adapter must be installed in an available full-length slot in an IBM XT/AT or IBM 3270 PC/AT hard disk. The Voice Operations Subsystem, which drives the Adapter, and the necessary speech recognition software require 60K internal (RAM) memory, in addition to the memory required by the operating system and whatever SAS system products are in use.

The Speech Recognition Facility adds 311K to the SAS System storage on your fixed disk, and requires about 64K main memory. Vocabularies add up to 350K additional disk storage.

The standard SAS INSTALL procedure is used to load the Speech Recognition Facility into the SAS directory on disk, and the required changes in the SAS configuration file are easily made with any text editor. We encountered no difficulty in installing the facility.

5. SUMMARY AND CLOSING REMARKS

None of the facilities described in this paper is a panacea. Each does work quite effectively to reduce the impact of a particular disability, and each works well with SAS, requiring no modifications to the SAS system or rewriting of SAS application programs.

Synthetic voice is often difficult to understand, and the process of reading the screen is not without pitfalls. It is easy, for example, to miss an unexpected error message that flashes across the screen and disappears. Voice input using the SAS Speech Recognition Facility is still an experimental product; it shows tremendous potential, yet much remains to be done. While voice recognition itself is surprisingly accurate and reliable, the necessity for grammar transitions can leave the user lost in an unfamiliar vocabulary, unsure how to proceed. And alternative input systems using scanning and Morse code, while very reliable and almost trouble-free, still require a significant training effort, and can often be slow and cumbersome to use. While the financial cost for each of these systems is moderate (none more than about $1000), the investment in time and effort in learning and becoming adept in its use can be significant.

Yet the investment—both by the developers and manufacturers of adaptive systems, including SAS Institute, and by the end-users—will yield tremendous returns in eliminating the technological barriers, and barriers to technology, that many disabled persons face.

Why is all this important? First, because we are required in some cases, to make accommodations for the handicapped. As educators, the law requires that we make "reasonable accommodations" to provide the greatest possible access to educational facilities and services for disabled individuals. And as employers, we are prohibited by statute from discrimination in hiring based on an applicant's disability.

This is important, secondly, because we are morally obligated. As educators, we are obliged to welcome students of all circumstances, to unlock from within each student the greatest possible potential, and to inspire in each the will to succeed. And as employers, we should support those who have served us well prior to the injury or disease that caused their disability, to welcome productive employees whose disabilities need not interfere with their employment, and to create an environment in which individuals are recognized for the particular talents and strengths that they contribute, not the quirks of nature and of man that have befallen them.
APPENDIX: AVAILABILITY AND COSTS

The following are provided for reference and comparison purposes only. Current prices and product specifications should be obtained from the suppliers.


The PC Serial A.I.D., is sold with AC adapter and serial connecting cable, for $310. The assisted keyboard software can be purchased separately. Available from: DADA, Designing Aids for Disabled Adults, 253 College St, Toronto, Ontario, M5T 1R5 Canada.

A wide variety of switches are available for use with the PC Serial A.I.D., ranging in price from $30 to several hundred dollars. The Unicorn keyboard costs $325. Switches, keyguards, the Unicorn and other adaptive keyboards can be purchased from various companies providing adaptive equipment for the disabled, among them Don Johnston Developmental Equipment, Inc., 1000 N. Rand Rd., Bldg 115, Wauconda, IL 60084.

The IBM Voice Communications Adapter (with Voice Communications Operating Subsystem and Application Program Interface) is purchased from IBM for $995. A microphone and adapter are purchased separately from any electronics supply store.

The SAS Speech Recognition Facility software is still undergoing testing. It may be obtained from SAS Institute by special arrangement.

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