About Adaptations for Computer Users with Mild to Moderate Orthopedic Disabilities

Orthopedic disabilities can result from many causes: accident, stroke, birth defects, viral infections and neurological disorders, to name a few. Individuals with orthopedic disabilities make up the largest segment of the disabled population. For persons with orthopedic disabilities which affect the upper body, productive use of computers must address three critical issues: keyboard positioning, keyboard access and typing speed.

The range and scope of mobility impairment resulting from such disabilities is enormously varied. It can be as relatively trivial as reduced dexterity in the finger of one hand as a consequence of injury or as dramatic as complete loss of all gross and fine motor control as in a case of cerebral palsy. To provide a structure for evaluating the computer access requirements for orthopedically disabled persons, we have established a working range of disability extending from mild to severe. Within the context of providing appropriately adapted computer technology, the following definitions are applied:

> **Mildly orthopedically disabled persons do not require repositioning of the keyboard or computer, are typically one-handed typists and can accurately access all keys on the keyboard using one or more fingers.**
>
> **Moderately orthopedically disabled persons typically require repositioning of the keyboard and/or screen, and can accurately access all keys on the standard computer keyboard using a hand held touch stick, head or mouth stick, toes or other body extremity.**

Severely orthopedically disabled persons cannot access the standard computer keyboard and require an alternative input device (i.e., scanning system with single switch, communicator boards, voice entry, optical selection, etc.).

There are three important factors which must be considered when determining the computer access needs of persons with orthopedic disabilities in post-secondary education: keyboard positioning, adaptations to provide keyboard access and adaptations to enhance typing speed.

Keyboard Positioning

2.2 Correct keyboard positioning will allow persons with moderate levels of orthopedic disability to minimize physical exertion and thus reduce fatigue. Properly positioned keyboards also help to decrease the spasticity and resultant keyboarding errors which frequently occur from straining to reach portions of the keyboard. An in-depth description of procedures for determining correct keyboard positioning is provided at the end of this chapter.

Keyboard Access

Adaptations which provide keyboard access are vitally important. The multiple keystroke commands common to many computer applications can be an obstacle to persons with virtually any degree of orthopedic disability. How, for example, can a one handed typist or headstick user hold down a key on the left hand side of the keyboard while simultaneously pressing another key on the right hand side of the keyboard? Additionally, most standard computer keyboards have an automatic key repeat feature which is triggered after a key is held for more than one second. For persons with limited fine motor control, this feature frequently results in unwanted keystrokes and much time wasted in error correction. Well designed keyboard adaptations can remove all of these obstacles and greatly improve keyboard access, reduce keyboarding errors, enhance speed and diminish fatigue in orthopedically disabled computer users.

Enhancing 1~ping Speed

Given the sophistication and flexibility of adapted computer technology available for individuals with orthopedic disabilities, it is a relatively easy task simply to provide access to the computer. Although computer access is vitally important, it is not the complete solution. Adaptations which enhance typing speed are vitally important to disabled persons who are unable to type more than 10 to 12 words per minute. This becomes a particularly critical consideration for persons with moderate to severe orthopedic disabilities who typically type at a much slower rate. The orthopedically disabled computer user in a post-secondary educational setting must be able to produce written materials (research papers, essays, reports, etc.) in a timely manner. Adaptations exist which can significantly improve the rate at which such persons are able to produce written materials.

The Target Audience

Functional and effective adaptations presently exist which can provide excellent computer access for persons with mild to severe orthopedic disabilities. Adaptations for mild to moderately orthopedically disabled persons can be implemented easily, inexpensively and with a minimum of training. Frequently, such adaptations are capable of providing a high level of computer access for many who would previously have been considered severely physically disabled.

Adaptations for severely physically disabled persons, using our definition of the requirements necessary to provide truly functional levels of computer access, tend to be considerably more elaborate, uniquely configured systems designed to meet the highly specialized needs and abilities of a particular user. The highly specialized technologies required to meet the computer access needs of severely orthopedically disabled individuals are addressed in a separate chapter of this book.

Adaptations which allow mildly to moderately or-
2.4 thopedically disabled persons to access microcomputers must address the following areas.

Specialized Adaptations to Control Keyboard Functions

Some of the most useful computer adaptations available for individuals with orthopedic disabilities are programs which provide control of fundamental keyboard functions. For many disabled persons, use of such an adaptation is basically all that is required to gain computer access. Programs of this type should meet the following criteria:

- It must be software based.

  Such adaptations should themselves be computer programs which can be easily loaded into the computer. In this way, the disabled computer user can easily move from computer to computer without being dependent upon specialized hardware modifications attached to a single computer system.

It must stop the automatic key repeat function.

The automatic key repeat function common to many computer keyboards can be a serious impediment to many physically disabled individuals. Limited fine motor control often makes the quick release of keys difficult to impossible. This is particularly true of persons who use touch sticks of various kinds to access the keyboard. Keyboard control programs must be capable of turning off the key repeat function.

It must "desensitize" the keyboard.

For moderately orthopedically disabled computer users, one of the most frustrating aspects of accessing a physical keyboard is the unintentional pressing of keys. Individuals with limited fine motor control often brush unwanted keys with a protruding finger or misdirected touch stick in the processing of pressing the desired key. A great deal of time is thus spent erasing unwanted characters from the computer display. The traditional approach to solving this problem has been through the use of key guards; keyboard covers which limit access to an area directly above each key thus reducing the occurrence of accidentally pressing unwanted keys. This same result can be created by keyboard control programs which in effect tell the keys on the keyboard how long they must be held down before sending a letter to the screen. By introducing a very small delay factor, the great majority of accidental keystrokes can be eliminated without significantly reducing typing speed.

It must "latch" the Ctrl, Alt, Shift and/or other special purpose keys.

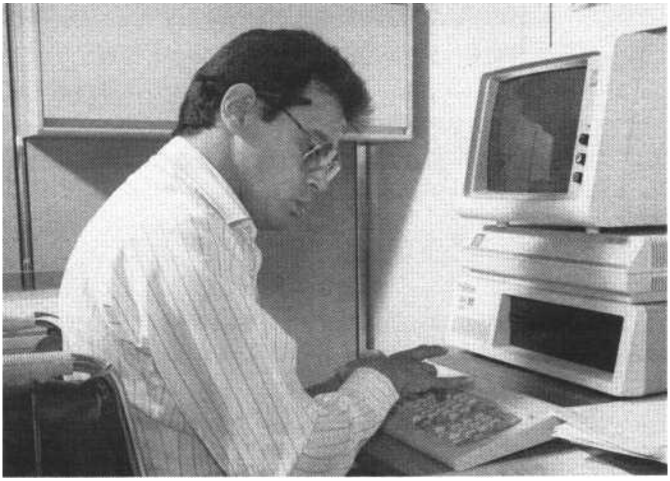
Pressing several keys at the same time to issue a command can create a tremendous obstacle for one handed or touch stick computer users. Many widely used computer programs make frequent use of special keys on the keyboard such as the Ctrl and Alt keys to carry out commands. PC type computers, in fact, require the user to simultaneously hold down two keys on the left side of the computer keyboard while pressing a key on the right side of the keyboard in order to restart the computer in the event of a system "crash." The complex feats of dexterity required by many programs are difficult enough for individuals with a complete set of working fingers; without keyboard control programs, such programs are virtually inaccessible to orthopedically disabled persons. Such programs must be capable of "latching down" the Ctrl, Alt and Shift keys individually or in combination. The program should provide an automatic release feature to "unlatch" these special keys after a second, non-special, key has been pressed. This is particularly useful in the case of the Shift key which must be held down in order to type the characters on the upper half of the numbers row and other keys.

It must not interfere with the operation of other programs.

In order to provide the disabled computer user with complete access to the full range of commercially available software, the keyboard control program must not interfere with the simultaneous operation of other programs.

It must provide a high degree of flexibility.

Because of the great variability and range of orthopedic disability, keyboard control programs



must allow for great flexibility in the choice of which control features will be activated. Unneeded adaptations can themselves be a barrier to successful computer access. It is always best to use only those adaptations which are truly necessary.

- It must provide a method for replacing selections made with a mouse or other pointing devices with selections from the keyboard. Selecting on-screen choices with a mouse, joystick or other pointing device is an exercise in fine motor control. The point and click operation which makes use of such systems easy for persons with good fine motor control may create a serious difficulty for persons with reduced fine motor control or hand/eye coordination difficulties. The system should be capable of assigning pointing and clicking control to other keys on the
2.8 keyboard.

Alternative Methods for Entering Program Commands

Increasing the speed with which orthopedically disabled persons are able to enter text or carry out program commands will allow them to work faster. Generally, increases in the speed and efficiency with which orthopedically disabled persons can use computers is gained cumulatively and in small increments through careful selection of appropriate adaptations. One of the most productive areas in which gains in processing speed can be obtained is in the issuing of program commands. The complex, multi-keystroke commands used by word processing programs, spread sheets and other such programs can often be issued much more quickly through the use of alternative input devices which bypass the keyboard entirely or modify its function.

Touch tablets.

These tablets are external pads generally around three quarters of an inch thick and measuring approximately 8 by 10 inches on a side. Such tablets have a grid of touch sensitive locations. Each location can be programmed to carry out a particular command. When a particular location on the tablet is touched, the preprogrammed command stored at that location is sent to the computer just as if it had been typed at the keyboard. Cells on the touch sensitive grid can be labeled in ways which are meaningful to students and easily reprogrammed for use with a wide array of computer applications. Touch tablets are generally most useful for mildly orthopedically disabled persons. If they are used with moderately orthopedically disabled individuals, the user must have good control of the touch stick, and the tablet must be carefully positioned for maximum access.

Speech recognition.

Speech recognition systems allow program commands to be spoken. An external microphone transmits the verbal command to the speech recognition system within the computer where a complex interaction of computer hardware and computer program attempts to match the sounds of the spoken command with a list of sounds the system has been programmed to recognize and respond to. If a match is found, the commands associated with the sound are sent to the computer just as if they had been typed at the keyboard. If you think all of this sounds a little complex and error prone, you are generally correct. However, used carefully and appropriately, speech recognition systems can be extremely useful provided the following guidelines are observed:

1. The user must have completely unimpaired speech.
2. Speech recognition is only used to augment, not replace, keyboard entry.
3. The list of spoken commands to be used is restricted to 25 or 30 items, each command is multi-syllabic and auditorially distinct from all other commands. Avoid commands like "GO," "YES," "TOP," etc. Use "SAVE DOCUMENT" rather than "SAVE," and "TOP OF PAGE" rather than "TOP."
4. The user is willing to devote many hours to "training" the system to recognize his/her voice.

Speech recognition for microcomputers is still very much in its technological infancy. Used selectively and with the appropriate individuals, it can be a powerful aid to faster text production.

Keyboard "macro" programs.

"Macro" is a bit of computerese which says absolutely nothing about what macros actually do or how useful they can be to persons with orthopedic disabilities. Essentially, keyboard macro programs allow the user to redefine what a particular key or combination of keys does. Program commands can be assigned to unique key combinations and entered just as if they were typed from the keyboard. The key combination "Alt S," for example, might be assigned a series of word processing commands which would save the document being written, load the spell check program and begin proofing the document. Whenever the user presses the Alt and S keys, this series of commands will be carried out. Keyboard macro programs are easy to use, extremely versatile and, once a set of special keys have been assigned commands, can significantly improve the speed with which orthopedically disabled persons are able to use many common computer applications.

Real Time Spell Check, Correction and Thesaurus As an Aid to Faster Text Production

Spell check and correction programs which monitor spelling and offer to automatically correct errors as a document is being written can substantially reduce the amount of time ordinarily required for such tasks. The kinds of spelling errors which sometimes occur as a result of miskeying due to limited fine motor control can be instantly corrected. Computerized thesauruses which perform automatic word replacement also enhance the text production process.

2.11

Smart Word Processors for Enhanced Typing Speed

Smart word processors employ the newly emerging technology of artificial intelligence to make accurate predictions about word choice while a sentence is actually being written. Using a predictive rule base about how the English language works, word frequency patterns and a history of the user's word choice preferences, such systems can very accurately predict the completion of a word being written based on its first two or three letters. The user is shown a list of likely choices and may elect to complete the word or phrase by pressing a single key. Such systems also automatically manage such tasks as inserting the correct number of spaces after periods and other punctuation marks and beginning each new sentence with a capital letter. Additional options allow the user to insert com-

monly used phrases, add header and signature blocks to letters or modify verb tense. The utility of such a program becomes markedly apparent when used with individuals having moderate to severe orthopedic disabilities. Perhaps more than any other single adaptation, the interventions provided by smart word processors can dramatically increase the speed of text production.

Screen Reading Systems

The same screen reading system and sophisticated speech synthesizer which allows blind computer users to hear what they cannot see can become the "voice" of orthopedically disabled individuals whose speech production is impaired. Reading aloud what we have written, hearing the flow and cadence of sentence construction, is a vital step in the process of developing well constructed prose. Using screen reading systems and sophisticated speech synthesizers, individuals with speech impairments resulting from orthopedic disability need not be restricted from this process.

A unique design feature makes the IBM PC type computer ideally suited for use with orthopedically disabled individuals. On the majority of other com puter systems, when a key (for example, the A key) is pressed down on the keyboard, an electrical impulse representing the letter A is immediately generated and sent directly to the display screen. There is virtually no way to modify the process, thus making it extremely difficult to alter keyboard function so that it works more in accordance with the needs of orthopedically disabled users. The PC type computer does something quite different. Rather than sending a letter when a key is pressed, it sends a location code in effect saying "The key at this location has been pressed, what would you like to do about it?" The architecture of such a system provides ample opportunity to modify the basic functioning of the keyboard. This ability to drastically alter keyboard function using only software based adaptations makes the PC type computer specially "user friendlv" to individuals with orthopedic disabilities.

The Apple Macintosh computer supports many high quality macro programs, but provides for limited keyboard modification through software selection. Good macro programs exist for the Apple 11 series computers although the keyboard can only be effectively modified through the use of hardware adaptations.

An excellent selection of alternative input devices exists for each of these computer systems. Speech recognition, however, is not recommended for the Apple 11 series.

Smart world processors are presently only availa-
2.14 ble for PC type computers. However, Macintosh systems are easily capable of supporting the technology and should offer such programs in the near future. Excellent continuous, real-time, spell checkers and thesauruses are available for both Macintosh and PC type computers.

Determining Correct Keyboard Positioning for Persons with Orthopedic Disabilities

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The optimal keyboard position and adaptations for a student are those which can be used accurately and quickly and are adequate to satisfy the specific needs of the individual. For most disabled students needing access to computer keyboards, it is essential that the keyboard can be used for long periods of time with minimal physical exertion or fatigue, and that consistent performance can be obtained from day to day.

An essential prerequisite for keyboard use is a stable and comfortable seating system. If a person cannot sit comfortably in a well-balanced position, requires his arms to support body position or needs to make constant position adjustments while using the computer keyboard, the seating system should be modified. There are several commercially available and custom positioning systems or seat inserts used in a wheelchair to optimize comfort and function and minimize the development of physical deformities. An occupational or physical therapist can help determine the most appropriate system.

The following systematic approach designed to optimize an individual's use of the keyboard is derived from Barker and Cook (1981) and Cook and Barker (1982). The process to determine optimal use of the keyboard includes the following steps: 2.15

1. **Review the user's history with keyboards and other technical aids.**
2. **Identify controllable anatomic sites (CASs).**
3. **Screen each CAS.**
4. **Match each CAS to a keyboard configuration (position and adaptations).**
5. **Comparatively evaluate the combinations identified in step 4.**

The Student's History

A student's history provides insight when making decisions during the evaluation process. This will help in determining controllable anatomic sites, appropriate positioning of the student and the keyboard, and identification of needed modifications. This information should include

The nature of a student's disability.

The student's experience with keyboards and assistive devices.

The problems and acceptable solutions encountered by the student with previous use of keyboards.

The known learning disabilities.

Identification of Controllable Anatomic Sites

2.16 To use a keyboard, the possible controllable anatomic sites (CASs) include the hands, head and feet. Specific potential anatomic sites are listed in Table 2.1. All possible CASs should be scrutinized. Not only should the student's opinion of physical ability be considered but so should all anatomic sites at which the student can demonstrate purposeful controlled movement.

The minimum requirement to use a keyboard is one isolated "pointer" that can press one key at a time. "Pointers" include a finger, a hand held dowel, a mouthstick, eye blink switch or headstick. An isolated pointer minimizes errors related to pressing or hitting keys with other parts of the body (i.e., another finger unintentionally activating a key when using the index finger as the pointer).

When a hand is used, there are several strategies that can be used to isolate a finger as a pointer and minimize errors due to key hits by other fingers. These

Table 2.1 Potential controllable anatomic sites useful with a keyboard, listed in order of potential optimal keyboard use

2 Hands, all fingers
1 Hand, all fingers
2 Hands, <5 fingers/hand
2 Hands, able to isolate 1 finger per hand*
1 Hand, <5 fingers/hand
1 Hand, 1 finger, isolated*
The head, with a mouthstick with a headwand
The feet, toes demonstrate fine motor control, 1 toe isolated*

*Isolated-no other fingers or toes demonstrate fine motor control or can be used in conjunction with a "pointer."

include (1) putting a sock or a mitt, with a hole cut out for the pointer finger, over the unused fingers that are held in a fist, (2) to have the student hold a dowel to maintain a fist with the potentially interfering fingers. A handheld dowel or a dowel secured to the hand can also be used as the pointer. There are several writing aids designed to hold a pencil which could also be used to hold a pointer. Utensil cuffs can also be used to hold a pointer. The writing aids and utensil cuffs can be acquired from distributors of aids for daily living or hospital supplies.

For someone with good head control, a headwand or a mouthstick can be used. These are commercially available or can be made. It is important that these fit well and are sturdy so that keys can be consistently and accurately pressed.

Screening for Controllable Anatomic Sites

Each CAS is evaluated for range of movement and for the degree of motor control or resolution. Range is the area in which the user can produce functional, controlled movement. Resolution is the smallest possible spacing between two points that the user can reliably and distinctly select. Screening forms used to determine range and resolution are included in the Appendix, which starts on page 2.22. The screening of CASs can result in the identification of several anatomic sites with sufficient control to use a keyboard.

Matching Controllable Anatomic Sites to Keyboard Position and Adaptations

The next step is to match the range and resolution measurements with placement and adaptations of a keyboard. Table 2.2 is used to match range and resolution to keyboard position and adaptations. For each CAS, the keyboard should be positioned in the middle of the range demonstrating fine control. For example, when using the right hand with a full range of motion,

Table 2.2 Matching range and resolution to keyboard position and adaptations

Range	Limited	Limited or typical	Typical	Typical
Resolution	Fine	Gross	Fine in limited area	Fine everywhere
Initial evaluation with *hardware*	Keyboard positioned in middle of range	Keyboard with adaptions and positioned in middle ofrange	Keyboard positioned in middle of range with fine control	Keyboard positioned in middle of range or centered about CAS

the keyboard is initially positioned to the right of the user's midline, perpendicular to the resting position of the right hand and arm and at a comfortable height for the student, usually with the elbows bent at about 90 degrees. As another example, when using the head with a headwand with a full range of motion, the keyboard is placed at midline and elevated and angled so that the user does not need to lean over to activate the keys.

Keyboard Position. The primary considerations to optimize keyboard position are table height, keyboard angle and wheelchair accessibility. People in standard wheelchairs usually sit higher than people sitting in typical chairs so that desks are usually too low to accommodate a wheelchair. The table that supports the keyboard for the wheelchair user must be high enough and have legs positioned such that they do not interfere with the wheelchair getting under the table. Blocks or bricks can be placed under the table legs to increase the table height. Tall tables such as those used for computer printers, drafting tables or adjustable height tables are commercially available. Adjustable height tables are useful when several people requiring different table heights use the same computer.

If increasing the table height for wheelchair clearance results in too high a keyboard position, standard arms on wheelchairs can be replaced by desk arms so that a lower table can be used. A wheelchair laptray can also be used to address this problem.

To angle the keyboard, wedges made of wood or hard foam (which can be carved with a knife) or a drafting table can be used. It is essential that the key board is secure. A ledge can help keep it in place. To keep the keyboard from sliding, use Dycem (available from distributors of hospital supplies) or non-skid carpet pad.

Keyboard Adaptations. For a potential keyboard user with limited fine control, keyboard adaptations would be used. Adaptations may make the difference between using a standard keyboard or resorting to more complex and expensive solutions. Adaptations can be in the form of hardware or software.

The time required to activate a key can be lengthened using software solutions. This time is referred to as activation time. For example, a pressed key usually sends a character to the computer immediately. If the activation time is lengthened, the user must hold the key down for the duration of the activation time in order for a character to be sent. This strategy can help improve a person's accuracy if a person is hitting keys unintentionally while reaching for the desired key.

If accuracy is not improved by lengthening activation time, a keyguard can be used. Keyguards help prevent accidental activations, help isolate and line up the pointer with the intended key (particularly useful with a headwand) and can provide support for the hand. Hand support can also be provided with a ledge positions or a buildup in front of the keyboard to provide support at the wrist.

Hardware or software modifications can be used to disable the automatic repeat feature. This is useful if the user tends to hold a key down for an extended period after the initial activation.

Comparative Evaluation

Following the initial screening, several combinations of controllable anatomic sites, keyboard positions and adaptations are identified. One optimal combina tion is determined using a performance evaluation to compare the combinations against each other. To evaluate the use of these combinations, functional performance of each combination is measured (see Appendix). The evaluation measures include speed and accuracy when using the keyboard, the degree to which the use of a combination causes fatigue, and the degree to which the performance with a combination can be repeated over time, e.g., from week to week. Other considerations for adequate performance are the time necessary to develop the skill and the user's satisfaction. Performance should be satisfying and should be such that tasks are done with the greatest possible accuracy within the shortest period of time.

Speed is measured during a task by using the combination of CAS, position and adaptation. Speed is broken into two components, track time and select time. Track time is the time required to move the anatomic site (hand, head with headstick, foot, etc.) to the keyboard. It is measured by recording the time it takes to activate the keyboard from a resting position. Select time is the time required to move between keys once the anatomic site is positioned at the keyboard. It is measured by recording the time required to activate several predetermined keys and subtracting the track time.

Accuracy is measured by evaluating the number and pattern of errors. The error pattern reflects whether keys adjacent to or far away from the target key are unintentionally activated.

Speed and accuracy are measured using either a marked keyboard test or a typing test (see Appendix).

For most keyboard applications, optimal use of the keyboard is dependent on its continual use. Consistent use of a keyboard depends on the degree to which it causes fatigue. Fatigue is related to the comparisons of measures for speed and accuracy taken at the beginning and at the end of a session. The amount of effort required to use the keyboard should also be subjectively evaluated, and the students opinion should be solicited as well. The student's opinion will have a great deal to do with the likelihood of successful use of a keyboard on a day-to-day basis.

Repeatability is used to measure the degree to which performance is maintained over time. The measures of speed, accuracy and fatigue are compared be tween sessions. A lack of repeatability can be due to many factors including inconsistent positioning of the keyboard or of the user's seating position.

Summary

The outcome of these tests, which are performed for each of the combinations of CAS and keyboard position and adaptation, is a rank-ordered list of the combinations which are deemed to be potentially useful to the specific student. The rank order should be based on the comparative evaluation as well as the degree of satisfaction expressed by the student. The position of the keyboard and the equipment used during

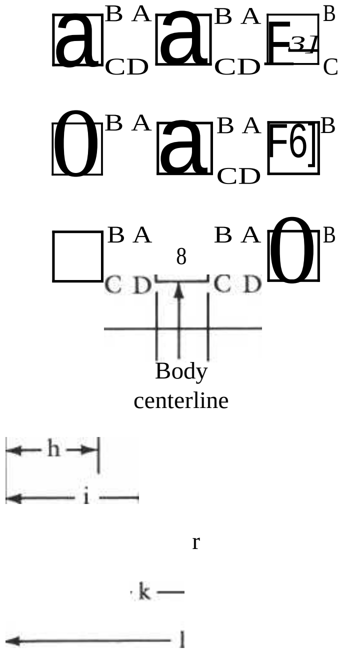
the evaluation to position and adapt the keyboard should be carefully documented for ease of replication. A photograph of each configuration is useful.

This evaluation method will identify an optimal method of keyboard for a particular student. If the identified method is not satisfactory to the student or a method to use the keyboard cannot be identified, other computer access methods should be explored.

The identification of a method to access the keyboard is only part of the total evaluation regarding the use and application of computers. Cognitive, language and perceptual abilities also must be considered to insure success.

Appendix

Range and Resolution. Arm range within the workspace is determined using a sheet of cardboard with 9 drawn rectangles (Figure 2.1). The client is



Notes:

1. Material is 1/8 inch thick cardboard
2. Cover with clear contact paper to protect surface

	Hand	*Foot/child*
a	18.0 inches	15.0 inches
6	15.0	13.5
c	12.0	10.0
d	9.0	8.5
e	6.0	5.0
f	3.0	3.5
g	3.0	3.5
h	6.25	5.0
i	12.25	10.25
j	15.5	11.75
k	21.5	17.0
l	24.25	18.5

Figure 2.1 Plan of testing sheet used for range measurement of hand and foot. The foot sheet is also used with small children with limited reach. (Cook andBarker,1982)

asked to touch each of the corners of each of the rectangles on the range sheet. An estimate of resolution can be determined by observing how closely the client is able to touch each of the corners. Data recorded includes furthest reach, closest reach, maximum left and right reach and the resolution in each of these areas (Table 2.3). Range is described as large or small, and resolution is described as being fine or gross in order to determine keyboard placement and adaptations. For keyboards, if the range is less than one square foot, the range is considered small. The numbers together with a subjective determination of the difficulty of the task for the client's usable workspace (range) and the degree of motor control in that range (resolution).

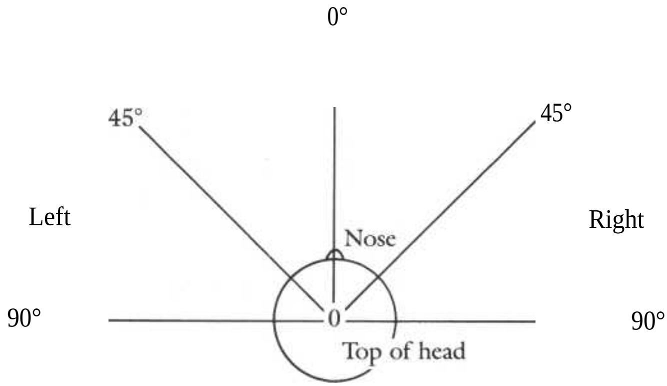
To evaluate the head, the range is measured using a protractor that is placed under the chin or beside the head, and the number of degrees of neck rotation and flexion are recorded (Figure 2.2). If the full excursion of the head from left to right is less than 30 degrees, or up to down is less than 15 degrees, the range is considered small.

Quantitative Evaluation. To measure speed and accuracy, use the marked keyboard test or a typing test. A typing test is used only with users that are (1) familiar with the keyboard (do not need to look at the keyboard to find selections) and (2) using more than one "pointer" (i.e., single finger, headwand, mouthstick). A typing test consists of timing and recording errors while a given set of sentences is copied. The marked test is used by those who are not familiar with the keyboard or are using one pointer. The marked keyboard test requires that the user look at the keyboard. Several keys are labeled in a similar manner, for example with 1/2 inch diameter dots of the same color. Timing and recording errors are done while the keys

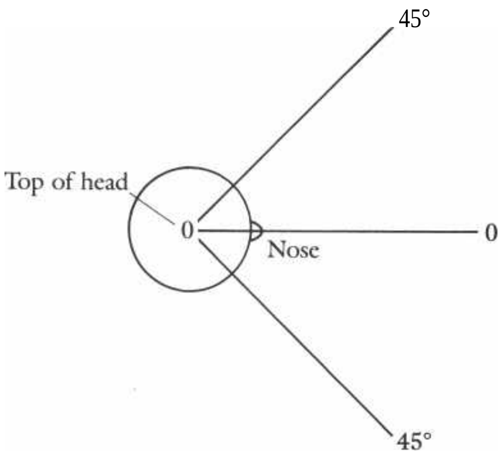
Table 2.3 Controllable anatomic site screening for hands analfeet

CAS	1	2	3
Description			
Range-measure in inches			
Furthest reach			
Closest reach			
Max left			
Max right			
Resolution-record fine or gross			
Far			
Close			
Left			
Right			
Comments/ interference/ problcm<			

Indicate maximum head rotation to the left and right and note resolution to the left and right (gross or fine):



Indicate head flexion and extension and note resolution in flexion and extension:



Comments, problems, interference:

Figure 2.2 Controllable anatomic site screening for the head

Table 2.4 Chart used to record speed and accuracy during typing test or marked keyboard test

CAS	1	2	3
Description			
Track time			
Recorded selected time			
Calculated select time*			
Error type: A-adjacent T-track S-second site R-remote			
Error number			
Effort			
Other comments			

*Calculated select time = total - track time
keys requested = 1

with the dots are pressed in any order. For both tests, timing should include both track and select time. Track time is recorded from when the user is instructed to start until the first key is pressed. Select time is recorded from when the user is instructed to start until the sentence is complete or all of the keys with the dots have been pressed. To calculate select time, subtract the track time from the select time and divide this by the total number of keys in the test minus one:

$$\text{Select time} = \frac{\text{Timed select time - track time}}{\text{number of keys in test - 1}}$$

The keys in the test are the number with a dot on top of them or the number of key strokes needed to complete the test sentence during a typing test.

During the tests to measure speed, the number and types of errors are recorded. The types of errors
2.28 include those that are adjacent (A) or remote (R) to the intended key, those which are activated in the track (T) between the last key activated and by a second (S) anatomic site. For example, when an index finger is used as an isolated pointer, an error is recorded if another finger activates an undesired key.

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