The human/technology interface (HTI) is a major part of the assistive technology component of the Human Activity Assistive Technology (HAAT) model (see Chapter 1). Bailey (1996, p. 173) defines an interface as "the boundary shared by interacting components in a system" in which "the essence of this interaction is communication or the exchange of information back and forth across the boundary." The HTI is the boundary between the human and the assistive technology (AT) device across which information is exchanged. In practice, the HTI describes the way in which the human controls the device.

If the individual has good fine motor control, she may use a keyboard or mouse to control a computer, phone, tablet, or AT device. This ability would also let her drive a powered wheelchair using a joystick. If another individual has poor fine motor control, it may be necessary to find alternative ways for him to control assistive or mainstream technology devices such as computers, tablets, or phones using gross motor movements.

In this chapter, we discuss the possible movements that can be used to control an assistive or mainstream technology electronic device and the most common ways of accommodating for lack of motor control in electronic devices.

## ACTIVITY: ENABLING PARTICIPATION

Electronic assistive devices play a major role in supporting participation by individuals who have disabilities. Assistive device **control interfaces** enable users to interact with many types of technologies. As discussed in Chapter 2, these technologies may be mainstream devices such as phones and tablets (see Chapter 9) or specialized ATs such as electronic aids to daily living (EADLs) (see Chapter 14), power wheelchairs (see Chapter 11), cognitive ATs (see Chapter 17), or communication devices (see Chapter 18). Each of these technologies can contribute to productivity in work or school, support recreation, and enable social participation on a broad basis. None of these benefits can occur without a well-designed and well-implemented HTI that links the user to the technology.

## Human: Anatomic Sites for Control of Assistive Technologies

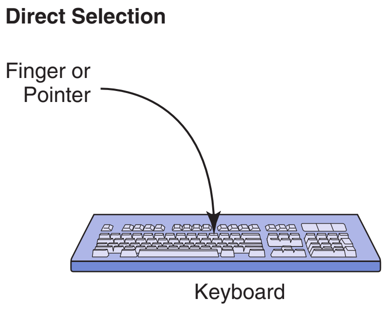
The HTI for AT devices described by the HAAT model links two major components, the human and the device. In this section, the range of human capabilities that can be accommodated by control interfaces is described.

Muscle tone (high or low), strength, endurance, range of motion, the presence of tremor, and the type of tremor can all lead to reduced motor control that would require specialized HTIs. Disabilities that affect fine motor control can result in conditions that limit fine motor control (Case Study 7.1) People with neuromotor impairment, (e.g., CP, TBI, ALS) in which there is an impairment of motor control due to abnormalities of tone, SCI where there is limited/absent motor function, MD and other dystrophies where there is low endurance and limited ROM, and musculoskeletal (e.g., RA) that also affects ROM, endurance, andstrength, can all benefit from adapted HTIs.

Adapted HTIs are typically used by individuals who have reduced fine motor control that makes it difficult to use common HTIs such as computer keyboards and pointing devices (e.g., a mouse, or touch screen; see Chapter 9); light switches; controls on entertainment devices such as TVs or DVD players; and similar everyday items (see Chapter 14). Adapted HTIs are also useful to people who need to use a powered wheelchair (see Chapter 11) or use adapted controls to drive a vehicle (see Chapter 12).

Fig. 7.9 shows the body sites that can be used to control a device. These are called **control sites**. Control sites include the hand or finger, arm, head, eye, leg, foot, and mouth (for switches based on respiration or phonation). Each control site can perform a variety of movements or actions. When the interaction between a person with a disability and an assistive device involves relatively fine control, the hand and fingers are the preferred control sites because they are typically the most dexterous body parts. Adapted HTIs can also accommodate for limitations in fine motor control. Existing function can be improved by using control enhancers (Chapter 8).

If fine motor control limitations prevent hand use, then the use of the head as a control site is preferred. It is possible to obtain relatively precise control using head movements




| Input | Output |
|---|---|
| Press S | S |

**Fig. 7.1** This figure shows the input required to obtain the letter *S* using direct selection. (From Smith RO: Technological approaches to performance enhancement. In Christiansen C, Baum C, editors: *Occupational therapy: Overcoming human performance deficits,* Thorofare, NJ: SLACK, 1991.)

such as tilting side to side, horizontal rotation, and tilting up and down. In practice, very few functional head movements correspond to a single rotation described above; rather, they combine more than one rotation (e.g. rotating left and tilting down).

If both hand and head control are poor, then adapted HTIs, generally switches, can be used to detect movements of the shoulder, elbow, forearm, hand, or finger. The use of the arm or leg is less desirable for precise tasks because these represent naturally gross movements controlled by large muscle groups. Shoulder and scapular movements include elevation/depression, protraction/retraction, internal/external rotation, abduction/adduction, and flexion/extension. The movements of the elbow are flexion and extension. The movements of the forearm consist of pronation (turning the palm down) and supination (turning the palm up). The wrist can flex or extend or move from side to side (radial deviation or ulnar deviation). The fingers can individually flex and extend or, together, perform a grasp and release movement. The thumb can flex and extend, abduct and adduct, and oppose each of the fingers. Each of these types of movements can be detected by an appropriate control interface.

Another control site is foot movement. For fine manipulative tasks, the foot is less desirable than the hand or head because visual monitoring can be difficult, and the foot is generally not as finely controlled as the hand. However, some individuals can develop fine control of their feet for typing. Control movements used in the lower extremities include raising and lowering of the leg at the hip (e.g., flexion and extension), ankle plantar flexion (toes point down) or dorsiflexion (toes point up), and foot inversion or eversion (rotary movement, similar to pronation and supination). Switches of various types can be controlled by these movements.

Finally, respiratory air flow can be detected and used as a control site by sip (inhaling) or puff (exhaling) to access switches. *Phonation* may produce sounds (including clicking or whistling) or speech. Adapted HTIs can detect sound or recognize speech. Tongue movements can also be used for control.

## ASSISTIVE TECHNOLOGY: CONNECTING THE USER TO THE TECHNOLOGY

### Elements of the Human/Technology Interface

Three elements of the HTI contribute to the operation of a device: the control interface, the selection set, and the selection method. These three elements are interrelated, and careful attention must be given to each element to have an effective HTI. Most electronic AT devices can be accessed by more than one type of control interface and selection method. Adapted input apps for mainstream devices also typically have a variety of selection methods. The selection set on most devices also can be varied to match the user's needs.

#### Control Interface

The **control interface** is the hardware by which the human in the AT system operates or controls an AT device. It is sometimes also referred to as an *input device*. Examples of control interfaces include a keyboard, one or more switches, a touch screen or touch pad, a mouse, and a joystick. Several control interfaces are discussed in Chapter 8.

#### Selection Set

Each control interface allows the user to choose one or more items that provide input to the AT device or control its operation in some way. The group of items available from which choices are made is called the **selection set**. For typing on a computer, the selection set is the entire keyboard. On a power wheelchair control, the selection set is the controls that move the chair forward/backward, right/left, or make the chair stop.

> **CASE STUDY 7.1 Comparative Evaluation**
>
> Max is an 18-year-old young man who has cerebral palsy. He lives in a residential facility and attends a work program through United Cerebral Palsy. Max has been referred to ABC Assistive Technology Center for a communication device. He currently communicates with others using a manual communication board and eye blinks for yes and no.
>
> Through evaluation of Max's range of motion and fine motor control ability, it has been determined that his best control sites are his right hand and his head. However, he does not have fine enough control at either site to use direct selection. You decide to perform comparative interface testing (see Chapter 8) using a paddle switch with his hand and a lever switch at the side of his head. Data collected during the comparative testing phase of the evaluation show that Max is more accurate and faster activating the switch with his head (versus his hand). However, Max has indicated a preference for using his hand instead of his head.
>
> **Questions**
>
> 1. Given Max's limited verbal communication, how would you gather information from him regarding his opinion on the hand and the head switches?
> 2. What type of subjective information would you want to gather from Max regarding his use of, and preference for, each of these two switches?
> 3. Your data indicate that Max is faster and more accurate using the head switch. However, Max has indicated to you that he prefers the hand switch. What would your recommendation be and why?

Selection sets can be represented by traditional orthography (e.g., written letters, words, and sentences), symbols used to represent ideas, computer screen icons, line drawings, or pictures. The modalities in which the selection set is presented can be visual (e.g., letters on the keyboard or icons on the screen), tactile (e.g., braille), or auditory (e.g., spoken choices in auditory scanning).

The size, modality, and type of selection set chosen are based on the user's needs and the desired activity output (see Chapter 1). Activity outputs in the HAAT model include communication (replacing or augmenting speech or writing), mobility, manipulation (e.g., things we would normally do with our hands and arms), and cognition (assisting with mental activities). An EADL (see Chapter 14) or a power wheelchair (see Chapter 11) typically has fewer choices in the selection set than an augmentative communication device (see Chapter 18) or computer (see Chapter 9). The size of the selection set may also vary according to the user's skills and age. For example, an individual who spells and has good physical control has the skills to use the selection set of a standard keyboard, which consists of all the letters and function keys. Another individual who is working on developing language and communication skills may have a selection set consisting of only two picture symbol choices displayed on a lap tray.

### Selection Methods

There are two basic **selection methods** that an individual with a disability can use to make selections with a control interface: **direct selection** and **indirect selection**. Direct selection methods generally have one interface for each selection that can be made. For example, each letter on a keyboard has a separate key. Indirect selection methods include **scanning**, **directed scanning**, and coded access. Typically, with indirect selection there are fewer interfaces than the number of possible selections (e.g., with one switch, the user makes the selection when the letter he wants is highlighted by an automatic system that scans through the alphabet).

## DIRECT SELECTION

**Direct selection** allows the individual to use the control interface to choose any item in the selection set. The person indicates her choice by using voice, finger, hand, eye, or other body movement. In this method of selection, the user identifies a target and goes directly to it (Smith, 1991). At any one time, all of the elements of the selection set are equally available for selecting. Typing on a keyboard or picking a flower from the garden is direct selection. Direct selection is the most demanding method physically because it requires refined, controlled movements. Because there is an immediate, direct result from the selection made, it is intuitive and easy to understand, and the cognitive demands are not great. Fig. 7.1 shows the input that is made using direct selection to obtain the letter *S*.

### Indirect Selection

When an individual's physical control does not support direct selection, indirect selection methods are considered. **Indirect selection** involves intermediary steps to make a selection. The most common indirect selection methods are scanning, directed scanning, and coded access.

### Scanning

With scanning, the selection set is presented on a display, and each item in the selection set is sequentially lit or indicated by sound or speech. When the particular element that the individual wishes to choose is presented, the user activates a control interface to select that item. The control interface used for scanning is typically a single switch or an array of two or more switches. Scanning requires good visual tracking skills, a high degree of attention, and the ability to sequence. The advantage of scanning is that it requires very little motor control to make a selection. Depending on the needs of the user, scanning can vary in the format (type of symbols and the way they are presented), and the way that the control interface signal is used to make the selection.

## SELECTION FORMATS FOR SCANNING

There are a number of formats in which the items in the selection set can be presented to the user for selection in scanning (Box 7.1). In **a linear scanning** format, as shown in Fig. 7.2, the items in the selection set are presented in a vertical or horizontal line and scanned one at a time until the desired selection is highlighted and selected by the user. Circular or **rotary scanning** (Fig. 7.3) presents the items in a circle and scans them one at a time.

To increase the rate of selection during scanning, **group-item scanning** can replace the singular-item scan. In this case, there are several items in a group, and the groups are sequentially scanned. The individual first selects the group that has

**BOX 7.1 Scanning Formats**

Selection Set Formats
- Linear
- Circular
- Matrix

Adaptations to Formats for Increasing Rate of Selection
- Group item
- Row–column
- Halving
- Quartering
- Frequency of use placement

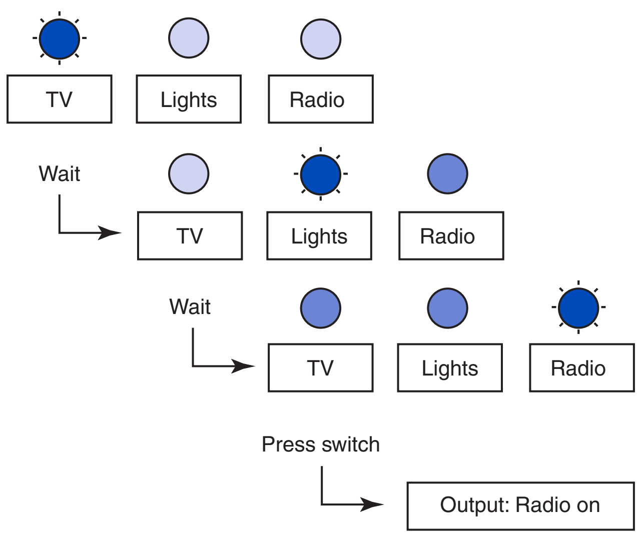



**Fig. 7.2** In linear scanning, choices are presented vertically or horizontally one at a time.

the desired element. After the group has been selected, the individual items in that group are scanned until the desired item is reached. When there are a large number of items, a *matrix* scan can be used. In this type of scanning, the *group* is a row of items and the *items* are located in columns, and it is called **row-column scanning**. In row-column scanning, there may be several rows of items, and each complete row is highlighted sequentially. The row with the desired item is selected; then each column in that row lights up until the desired item is selected. Fig. 7.4 shows the input required using a single switch with row–column scanning to produce the letter *S*.

There are other ways that scanning formats can be adapted to increase the user's rate of selection. *Halving* is a group-item approach in which the total array is divided in halves. Each half is scanned until the user selects the desired half. The scanning then proceeds in a row–column format as described until the desired item is reached. This same concept can be used in a *quartering format* in which the array is divided into fourths.

Another method used to increase rate of selection is to place the selection set elements in the scanning array according to their frequency of use. For example, if letters are being used as the selection set, placement of *E, T, A, O, N,* and *I* (the most frequently used letters) in the upper left positions of the scanning array results in an increase in rate of selection (Simpson, 2013). The application of these principles to augmentative communication is discussed in Chapter 18.

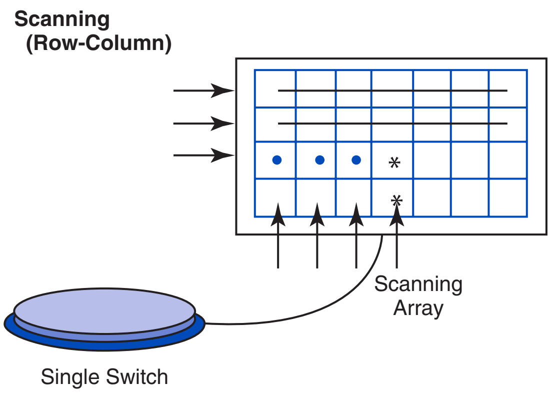
**Fig. 7.3** In rotary scanning, choices are presented one at a time in a circle. Here a child is choosing the color she wants to use by pressing her switch when the pointer is aimed at her choice.

## SELECTION TECHNIQUES FOR SCANNING

The action required by the user to activate the control interface to make a selection during scanning usually can be varied to accommodate the user's skills.

**Automatic scanning** presents items in sequence from which the user may choose. The rate of presentation (scan rate) can be set and adjusted according to how fast the user can respond. When the desired selection is presented, the user selects the choice by activating the control interface and stopping the scan. Automatic scanning requires a high degree of motor skill by the user to wait for the desired selection and to activate the control interface in the given time frame. It also requires a high degree of sensory and cognitive vigilance for attending to and tracking the cursor on the display.

In **step scanning**, the user activates the control interface once for each item to advance through the choices in the selection set. When the user comes to the desired choice, there are two possibilities for selecting it. Either an additional control interface is used to give a signal to select that choice or an **acceptance time** is used. The acceptance time is a slight delay between the time the selection is made and the time it is sent to the device. It allows the user to make a choice by merely waiting for the acceptance time to expire, upon which the selected item is sent to the device. Step scanning allows the user to control the speed at which the items are presented. The ability to wait or pause is not required for the scan, but it may be for the acceptance of the selection. The ability to activate the control interface repeatedly, however, is important for step scanning. Motor fatigue can be high because of repeated control interface activation.




| Input | Output |
|---|---|
| Press Switch | S |
| Wait | |
| Wait | |
| Press Switch | |
| Wait | |
| Wait | |
| Wait | |
| Press Switch | |

**Fig. 7.4** Row–column scanning showing the input required for selecting the letter *S*. The rows are first scanned and the user selects the row with the desired item. Then each item in that row is scanned until the desired item is selected. (From Smith RO: Technological approaches to performance enhancement. In Christiansen C, Baum C, editors: *Occupational therapy: Overcoming human performance deficits,* Thorofare, NJ: SLACK, 1991.)

**TABLE 7.1 Selection Techniques for Scanning and Directed Scanning**

| | Automatic Scanning | Step Scanning | Inverse Scanning |
|---|---|---|---|
| Wait | High | Low | Medium |
| Activate | High | Medium | Low |
| Hold | Low | Low | High |
| Release | Low | Medium | High |
| Motor fatigue | Low | High | Low |
| Sensory/cognitive vigilance | High | Low | High |

Modified from Beukelman D, Mirenda P: *Augmentative and alternative communication,* ed 3, Baltimore: Paul H. Brookes, 2013, p. 151.

**Inverse scanning** is initiated by the individual activating and holding the control interface closed (e.g., keeping a switch pressed). As long as the control interface is held down, the items are scanned. When the desired choice appears, the individual releases the control interface to make the selection. Inverse scanning requires holding the control interface and releasing it at the proper time. Inverse scanning may be easier for some people than automatic scanning, which requires activation of the control interface within a specified time frame. For individuals who require lots of time to initiate and follow through with movement, inverse scanning can be helpful. Similar to automatic scanning, motor fatigue is reduced over step scanning because of fewer control interface activations; however, sensory and cognitive fatigue are higher because of the vigilance required to attend to the display.

Table 7.1 lists the three scanning techniques and the level of motor skill required for each. This table is helpful in matching the scanning technique to the user's skills. For example, some techniques depend more on the ability to react quickly to activate a switch. Others require vigilance and the ability to wait until a choice appears. Still others require the user to hold a switch until the choice appears and then release. Users have varying levels of skill in these areas.

## Choosing Scanning Setups for Individual Users

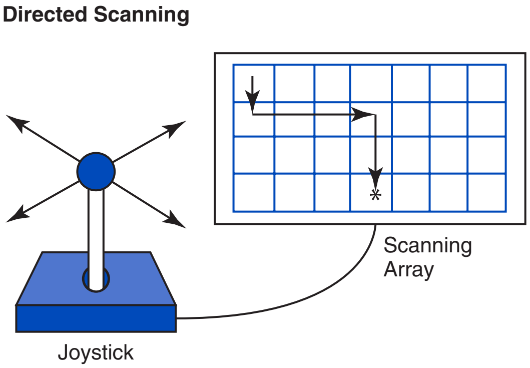
Scanning involves a number of variables that can affect user performance (see Table 7.1). A major challenge in scanning is optimizing the scan rate. If the rate is too fast, users will not be able to make accurate selections because they cannot respond fast enough. If the rate is too slow, the text entry rate (TER) will be slower than necessary and cause the user to be slower at generating input than is necessary. A reliable and systematic method for selecting the most appropriate scan rate for single-switch scanning that avoids excessive trial and error is provided by the "0.65 rule" (Simpson et al., 2006). The 0.65 rule is based on data showing that the ratio between a user's reaction time and an appropriate scan rate for that user is approximately 0.65. The clinical implication is that if the consumer's reaction time can be measured, then dividing this number by 0.65 will give a scanning rate in scan per seconds that is likely to be the optimal rate for that person. For example, if the reaction time is 1 second, then the scan rate would be 1/0.65, which equals about 1.5 scan steps per second. Although it is not terribly precise, the easiest way to measure reaction time is with a stop watch.

Other scanning options include the arrangement of the selection set and the choice of selection method. If a trial and error approach is used, it can be very difficult to obtain a configuration that yields optimal performance. Simpson and colleagues summarized the competing factors, "Often, so much time is spent just identifying a reliable switch site and a basic scan layout appropriate for the user's needs that very little time is left to properly adjust the remaining options" (Simpson et al., 2011, p. 2).

Models that predict performance under different configurations provide one way to choose the most appropriate configuration for a particular client (Bhattacharya et al., 2008; Simpson et al., 2011). Most of the models that have been developed assume error-free performance by the user (e.g., Bhattacharya et al., 2008). These models do not generally provide predictive performance that is closely matched to actual user results in clinical trials. Simpson et al. (2011) developed an approach that models errors and includes several types of error correction commonly applied in scanning systems when an incorrect switch activation is made by the user. The error correction methods evaluated by Simpson et al. included (1) setting a fixed number of times for the scanning to loop through the row or column or the array before starting over at the beginning (fixed loop count), (2) a "stop scanning" selection at the end of each row, (3) activating the switch for an extended time, and (4) selecting an (incorrect) item within the row. In addition to these errors of commission, there is the error of omission in which the user fails to make a choice in a row. Two methods of correcting for this type of error were modeled by Simpson and colleagues: (1) a fixed-loop count as earlier and (2) a "continue scanning" item at the end of the row that is selected to restart the scanning through the row.

Using configuration options from 16 commercially available scanning systems, Simpson et al. (2011) modeled performance with varying probabilities of errors for each type described earlier. Based on their model results, they concluded that the best approach for clinicians is to: (1) use a frequency-arranged matrix, (2) avoid extra "bells and whistles" such as "stop scanning" or "reverse scanning" items, and (3) keep error rates as low as possible by focusing on development of switch skill as we describe later in this chapter.

Mankowski et al. (2013) carried out a clinical trial with five users of scanning systems to validate the error-free model developed by Simpson et al. (2011). There were five participants who were all single-switch scanning users. Scanning rate was selected using the 0.65 rule compared with the participant's current scan rate. The Simpson et al. model was used to calculate the projected TER, and this was compared with the actual TER obtained by the users transcribing a set of sentences. Alphabetic and frequency of occurrence scanning arrays were used by all participants. The predicted and actual TERs were within 10.49% averaged over all participants. For a model assuming error-free




| Input | Output |
|---|---|
| Move Joystick:<br>Down<br>Right<br>Right<br>Right<br>Down | S |

Fig. 7.5 Directed scanning showing the input required to select the letter *S*. The user selects the direction of the scan, and the items in the selection set are scanned sequentially by the device. When the desired item is reached, the user makes the selection. (From Smith RO: Technological approaches to performance enhancement. In Christiansen C, Baum C, editors: *Occupational therapy: Overcoming human performance deficits,* Thorofare, NJ: SLACK, 1991.)

performance, the model error was 79.7%. Mankowski et al. discuss clinical applications of this model that allow consideration of factors that will increase TER while also minimizing the chance of error.

## Directed Scanning

**Directed scanning** is a hybrid approach in which the user activates the control interface to select the direction of the scan, vertically or horizontally. There is typically one switch for each direction of movement, usually four directions, but it can be as many as eight (cardinal and intercardinal directions). The user first selects the direction in which he wishes to scan. The cursor continues to move in the selected direction by the user holding down the switch. When the switch is released, the cursor stops, and the user either waits for an acceptance time interval or hits an additional switch.

A joystick or an array of switches (two to eight switches) is the control interface used with directed scanning. Fig. 7.5 gives an example of the input required to select the letter *S* using directed scanning with a four-position joystick. Directed scanning is slower than direct selection but requires fewer steps (less selection time) than single-switch scanning. The user needs to be able to activate and hold the control interface and to release it at the appropriate time. If the individual can produce the movements required to use this method, the outcome is faster entry of the desired selections into the device.

## Coded Access

Another form of indirect selection is **coded access** in which the individual uses a distinct sequence of movements to input a code for each item in the selection set. Similar to the other two methods of indirect selection, intermediate steps are required for making a selection.

The control interface used is a single switch or an array of switches configured to match the code. Morse code is one example of coded access wherein the selection set is the alphabet, but an intermediate step is necessary in order to obtain a letter. Each letter in the alphabet has a code consisting of short (dot) or long (dash) entries.

| Input | Morse code | Output |
|---|---|---|
| Press Switch 1 | — | |
| Press Switch 2 | • | |
| Press Switch 1 | — | |
| Press Switch 2 | • | C |

Fig. 7.6 The input required for selecting the letter *C* using Morse code.

In single-switch Morse code, the system is configured so that a quick activation and release of the switch results in a dot, and holding the switch closed for a longer period before releasing it results in a dash. Letter boundaries are distinguished by a slightly longer pause than between dots and dashes within one letter. As long as the user holds one of the switches, it continues to send dots or dashes. In two-switch Morse code, one switch is configured to represent a dot and the other switch a dash. This can make the entry of codes much faster, but it requires motor control sufficient to activate and release a switch quickly enough to avoid extraneous dots or dashes to be entered. The rate at which dots or dashes are repeated is usually adjustable. The computer automatically interprets the code as a letter or other character and treats it as if it had been typed. Fig. 7.6 shows the steps required for obtaining the letter *C* (dash, dot, dash, dot) using two-switch Morse code.

The user must enter a series of long or short switch presses to access a letter or other keyboard entry (e.g., space bar, number, special symbol such as $ or #). Morse code was developed to be very efficient by assigning the most frequently used letters the shortest codes, (e.g., *E* is one dot, *T* is one dash). Fig. 7.7 shows the symbols for international Morse code. This efficiency can be useful in written or conversational communication. In addition, Morse code does not require that a selection set be displayed as in scanning. The codes are usually memorized, although visual displays, diagrams, or charts can be used to aid in recalling the codes (Fig. 7.8).

Like scanning, coded access requires less physical skill than direct selection. The advantage of coded access over

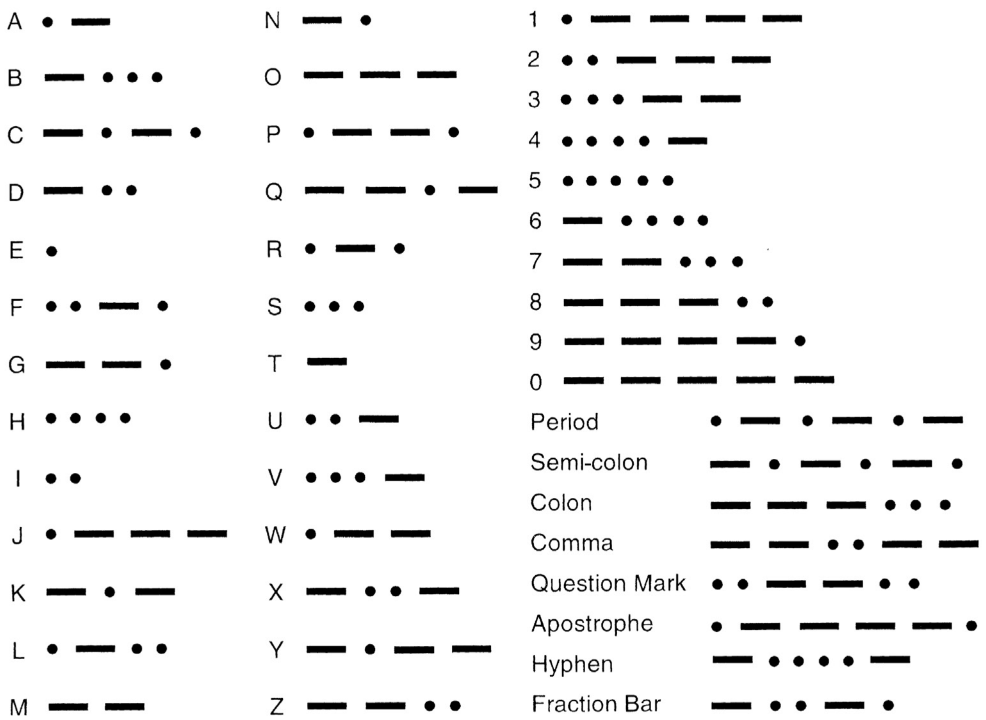



**Fig. 7.7** International Morse code.

scanning, however, is that the timing of the input is under the control of the user and is not dependent on the device. For example, the user decides how long a dot and dash last and thus how long to hold the switch to generate each one for Morse code, but in scanning, she has to wait for the correct choice to be presented, so the device controls the timing. The disadvantage is that coded access takes more cognitive skill, especially memory and sequencing, than direct selection.

Because codes are typically memory based, they do not require a selection display (a set of characters on the screen) as is needed for an on-screen keyboard or scanning array. This method allows the entire screen to be used for the application software being run. It can also be used by people who have visual impairments.

Original Morse code (letters and numbers only) did not include other computer items such as ESC or RETURN keys or characters such as punctuation or \ /@#$%. The absence of standardized codes for anything other than alphanumeric characters has resulted in different AT Morse code systems having different codes for these characters. Note that, after one set of codes is learned and the motor patterns developed, it is very difficult to change to a new set of codes, and changing from one system to another can be both time consuming and frustrating for the consumer. There is commercially available software that allows text entry by Morse code using mouse buttons.

## RATE ENHANCEMENT

*Rate enhancement* refers to all approaches that result in the number of characters generated being greater than the number of selections the individual makes. For example, using "ASAP[space]" for "As soon as possible [space]" saves 16 keystrokes. Because an increased level of efficiency is obtained, the user has to make fewer entries, and the overall rate is increased. Rate enhancement goals and approaches differ for direct selection and scanning. In direct selection, the goal is to reduce the number of keystrokes while increasing the amount of information selected with each keystroke. In scanning, the goal is to optimize the scanning array to reduce the time required to make a desired selection. Specific approaches are discussed later in this section. Rate enhancement is used for many electronic AT applications, including augmentative communication (see Chapter 18), computer access (this chapter), cell phone access (Chapter 9), and EADLs (see Chapter 14). Many mainstream software applications use some form of rate enhancement, also called autocorrect or **word completion**. Similar functionality is present in many phones and tablets.

Effective rate enhancement requires that the motor task become automatic (Blackstone, 1990). Motor patterns become more automatic as they are practiced. One familiar motor pattern is that of entering the door lock code to enter your apartment building or office. Sometimes we cannot actually remember the digits of the number, but we can enter it just by the stored motor pattern (e.g., remembering the number by looking at the keypad).

As the skills improve, motor and cognitive tasks become more automatic, and the user becomes an expert. As Blackstone (1990) points out, after these motor patterns are established, even small changes in the task may result in dramatic *decreases* in rate. This effect on efficiency is why it is important to keep menu items or selection set items in the same place even as new items are added.

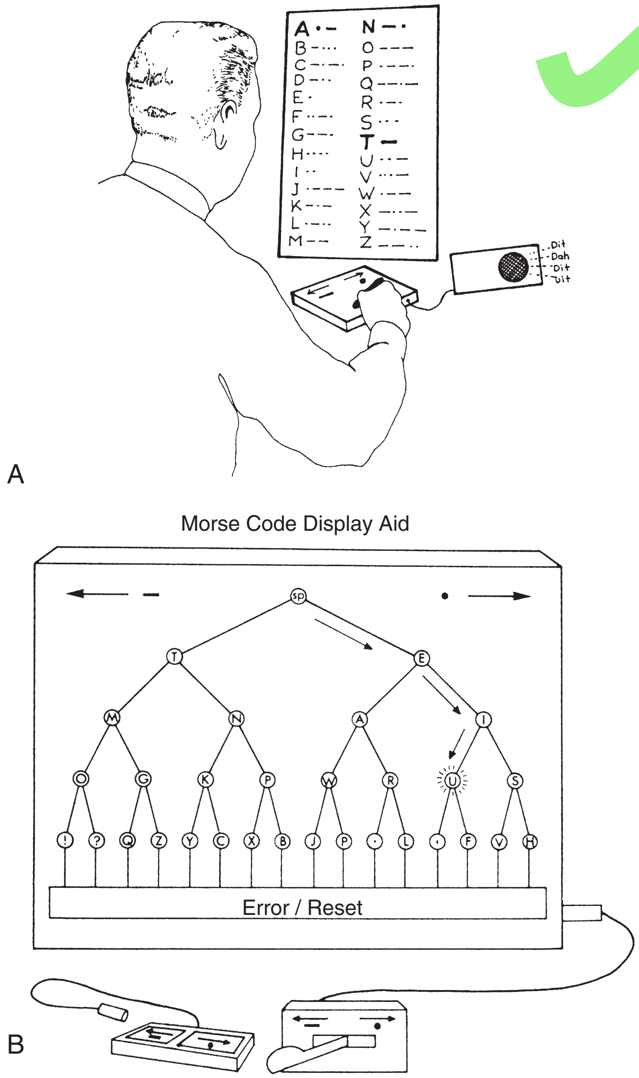



**Fig. 7.8** Encoding systems may be either chart based (A) or display based (B). (From Blackstone S: *Augmentative communication*, Rockville, MD: American Speech Language Hearing Association, 1986.)

Rate enhancement techniques fall into two broad categories: (1) encoding techniques and (2) prediction techniques. Vanderheiden and Lloyd (1986) distinguish three basic types of codes: memory based, chart based, and display based. These are compared in Table 7.2.

A memory-based technique requires that both the user and his partner know the codes by memory or that the user has the codes memorized for entry into his device. Chart-based techniques are those that have an index of the codes and their corresponding vocabulary items. This can be a simple paper list attached to an electronic device or a chart on the wall (e.g., two eye blinks = "call nurse"; three eye blinks = "please turn me"; eyes up = "yes"; eyes down = "no"). Fig. 7.8 illustrates both a chart-based and display-based approach for Morse code (Vanderheiden & Lloyd, 1986).

**Word prediction** or **word completion** approaches use a window on the screen that displays an ordered list of the most likely words based on the letters entered. In word completion, the user selects the desired word, if any, by entering its code (e.g., a number listed next to the word) or continuing to enter letters if the desired word is not displayed (Case Study 7.2). Desired word choices can also be made by mouse click or touching the screen on some devices. Word prediction devices offer a menu of words based on previous words entered. (e.g., *computer* leads to list of *software, system, program,* and *keyboard*). The most important advantage of this approach is that the user needs only recognition memory, not recall. It also eliminates the need for memorizing codes. Word prediction (or completion) approaches require that the user redirects the gaze from the input (keyboard keys or scanning array) to a list of words after each entry to check for the presence of the desired word, which can reduce the item selection rate compared with letter-by-letter typing. This reduction in selection rate is due to an increased cognitive or perceptual load that can offset the benefits achieved in keystroke savings and result in an overall decrease in text generation rate (Hortsman and Levine, 1989). There are also cognitive demands placed on the user by the way in which the rate enhancement is implemented.

If the word lists are placed on the screen at the point in the document where the typed letters appear, then the user does not need to redirect his gaze to check the word list while typing. This approach can result in significantly fewer control interface activations in scanning. One application of this approach, called Smart Lists (Applied Human Factors, Helotes, TX, http://www.ahf-net.com), can be used with either keyboard or scanning entry. With Smart Keys (also Applied Human Factors), after each entry, only the keys that contain a prediction based on that entry are left on the on-screen keyboard, which can make scanning significantly faster because only the relevant keys need to be scanned.

Predictive approaches may be fixed or adaptive. Fixed types have a stored word list based on frequency of use that

**TABLE 7.2 Modes (Memory, Chart, Display) of Presentation of Codes to the User**

| Type | Memory-Based | Chart-Based | Display-Based |
|---|---|---|---|
| Memory required | Recall | Recognition | Recognition |
| Advantages | Can be used by those with visual limitations | Can be seen by both user and partner | Can be updated (dynamic display), giving many stored items |
| Disadvantages | Limited to 200 to 300 items for most people | Must have chart in visual field; chart can become separated from device | Requires attention to display; can slow down text selection because of split attention |

never changes. This method is anticipated and consistent for the user and can help in the development of motor and cognitive patterns for retrieval. These vocabularies are often used in electronic aids to daily living. Adaptive vocabularies change the ordering of words in the dictionary list by keeping track of the words used by the person. The words are always listed in frequency-of-use order customized to the individual user and are more directly matched to the user's needs and recent usage.

### CASE STUDY 7.2 Word Prediction Vocabularies

Assume that one college student is taking a course in assistive technologies and another student is taking a course in world religions. If both students have word completion/prediction systems, compare the word lists you might expect to be used for writing homework assignments for each course. Would most words be the same, or would they be different for the two applications? How would the word lists vary in (1) an adaptive system and (2) a nonadaptive system? What words would you start with as a basic vocabulary in each case?

Current technologies (e.g., phones) may include combinations of abbreviation expansion and word prediction. **Abbreviation expansion** is a technique in which a shortened form of a word or phrase (the abbreviation) stands for the entire word or phrase (the expansion). The abbreviations are automatically expanded by the device into the desired word or phrase. Abbreviations are more direct because the user can merely enter the code and immediately get the desired word, and they allow complete phrases and sentences. Predictions are easier to use because they do not require memorization of codes.

## Speech: A Human/Technology Interface Output

Speech is the auditory form of language; electronic ATs that provide language output rely on artificial speech. The three major AT applications are screen readers and print-material reading machines for persons who are blind (see Chapter 16), voice output augmentative communication devices (see Chapter 18), and alternative reading formats for persons with cognitive disabilities (see Chapter 17). Issues unique to these applications are discussed in the relevant chapters. Speech output is also used in many mainstream technologies (see Chapter 9). The two types of speech output are **digital recording** and **speech synthesis.** They differ in how the speech is electronically produced. Table 7.3 lists the features and the typical AT applications for the two approaches.

## DIGITAL RECORDING

**Digital recording** stores human speech in electronic memory circuits so it can be retrieved later. The speech to be stored can be entered at any time by just speaking into a built-in microphone. Even a few seconds of speech takes a great deal of memory. For example, 16 seconds of speech may take up to 1 megabyte of memory for storage without signal processing and compression. Current memory technologies are similar to those used for audio music and speech recordings, and they can store large amounts of vocabulary. The major advantage of digital recording of speech is that it allows any voice to be easily stored in the device and played back. For example, if the person who is using the AAC system (see Chapter 17) that uses digital recording is a young girl, we can use another young girl's voice to store the required messages.

## SPEECH SYNTHESIS

**Speech synthesis** generates the speech electronically instead of storing the entire signal. This approach reduces the amount of memory required. Speech output can be created from any electronic text, including that sent to the screen of a computer or mobile device. A mathematical model of the human vocal system is used to synthesize the speech. There are two types of sounds in speech, voiced and unvoiced (a hissing sound similar to unvoiced sounds such as *s* or *f*), and both these types of speech sounds must be included in the vocal tract model. These signals are then fed into a model of the vocal tract that is varied to produce the speech in a manner similar to the variation of the tongue, teeth, lips, and throat during human

**TABLE 7.3 Types of Speech Output Used in Assistive Technologies**

| Type of Speech Output | Major Features | Typical Assistive Technology Applications |
|---|---|---|
| Digital recording | Uses actual voice and can easily be child, male, or female<br>Speech is limited to what is stored<br>Relatively low cost | Augmentative communication |
| Speech synthesis | Very high quality for single words or complete phrases<br>Intelligibility decreases for unlimited vocabulary with text to speech<br>Unlimited vocabulary with text to speech<br>Moderate intelligibility with letter-to-sound rules only<br>Highly intelligible with morphonemic rules<br>Cost depends on text-to-speech approach | Speech output for electronic aids to daily living<br>Augmentative communication<br>Screen readers for blind users<br>Speech output for users with learning disabilities<br>Speech output for phone communication by persons who are deaf |

speech. Speech synthesizers can generate any word if the correct codes are sent to them in the correct order.

**Prosodic features**, which give speech its human quality, are generated by changes in three parameters: (1) amplitude, (2) pitch, and (3) duration of the spoken utterance. Human speech consists of both these basic or segmental sounds and prosodic or suprasegmental features. These features allow us to stress a phrase or word, to emphasize a point, or to generate an utterance that portrays a mood (e.g., angry, polite, or happy). They are also responsible for the inflection changes that distinguish a yes/no question (rising pitch at the end of the sentence) from a statement (falling pitch at the end). For example, the statement "He is going to dinner" has a falling inflection at the end. However, the inflection in the sentence "Is he going to dinner?" rises at the end.

## TEXT-TO-SPEECH PROGRAMS

The smallest meaningful units of language are called morphemes. Free morphemes are complete words that may stand alone (e.g., run); bound morphemes must be coupled to another morpheme (e.g., -ing) to form a complete word. Words are articulated sounds or series of sounds that are used alone as units of language; they symbolize, communicate, and have meaning. In computer use, words consist of text characters (one per letter), each of which has a specific numeric code. **Text-to-speech programs** convert text characters into the codes required by the speech synthesizer by analyzing a word or sentence. When the speech synthesizer receives these codes, they are combined phonetically into the word the user wants to say. Several approaches can be taken to generate speech from text input; modern techniques use artificial intelligence (AI) algorithms. Major software engineering companies such as Google, Microsoft, or Apple provide text-to-speech applications, many already included in mainstream technologies.

Most AAC devices (see Chapter 18) and screen readers for the blind (see Chapter 16) use DECTalk, Vocalizer (Nuance, Peabody, MA; http://www.nuance.com/index.htm#eti), IVONA (http://www.ivona.com/us/), Acapela (http://www.acapela-group.com), or a proprietary text-to-speech system. Aaron et al. (2005) provide an excellent tutorial on speech synthesis. Another is Nexmo (https://www.nexmo.com).

## AUDIO CONSIDERATIONS

The intelligibility and sound quality of any speech synthesis system are dramatically affected by the quality of the amplifier and speaker used to provide the final speech output. Many commercial systems use low-power amplifiers and small, low-fidelity speakers. This technology can reduce the quality of the sound and therefore make it more difficult to understand. However, in most AAC applications, the speech synthesis system must be portable. Higher-power output amplifiers require larger batteries, and larger speakers that have greater fidelity are heavier than lower-quality speakers. Both of these factors affect weight and, therefore, portability. The most important rule that applies here is that you don't get something for nothing; higher quality in speech sound output is obtained only at the cost of increased weight and reduced portability.

## CONTEXT

Three contexts affect the HTI as we have described in this chapter. In the social context, the use of ATs can be stigmatizing for the individual using it. It is possible that some control schemes will lead to greater stigma than others. For example, the use of scanning can significantly increase the time it takes to make choices, control a device such as a phone or tablet, or create an utterance on a communication device. The slow speed may significantly change the social interaction a person has. It can also make it difficult to effectively use system features, including mainstream applications such as texting or internet access. These limitations can call attention to the individual's disability rather than facilitating his or her participation.

Artificial speech can also be stigmatizing. Synthetic speech can sound robotic or cartoon-like. The sound can bring unwanted attention to the user of systems that use such speech, especially in public environments such as restaurants.

In the institutional context, HTI devices can be expensive, and the process of obtaining funding can be complex. Often significant paperwork is required, and delays of weeks or months may occur between assessment and actual delivery of the required technology.

The physical context can also provide challenges. All selection systems that rely on visual displays are sensitive to ambient light conditions, especially bright sunlight.

Speech output devices are harder to understand in noisy environments. The physical space and ability of the space to support proper positioning for access is another physical context issue. Educational and work settings do not always have sufficient space to locate the system nor do they have a support surface that facilitates access to it. All these factors must be taken into account before a device is recommended for an individual user.

## ASSESSMENT

Here we discuss the assessment for control sites. Guidelines for assessment for control interfaces can be found in Chapter 8, and for selection sets and methods in Chapter 18.

The control sites that can potentially be used by the consumer to operate a device are shown in Fig. 7.9. The various movements that each control site is capable of performing were described earlier in this chapter.

## FUNCTIONAL MOVEMENT EVALUATION

The overall goal of the physical skills evaluation is to determine the most functional position for the individual and evaluate his or her ability to access a device physically. At a very basic level, physical skills include range of motion, muscle

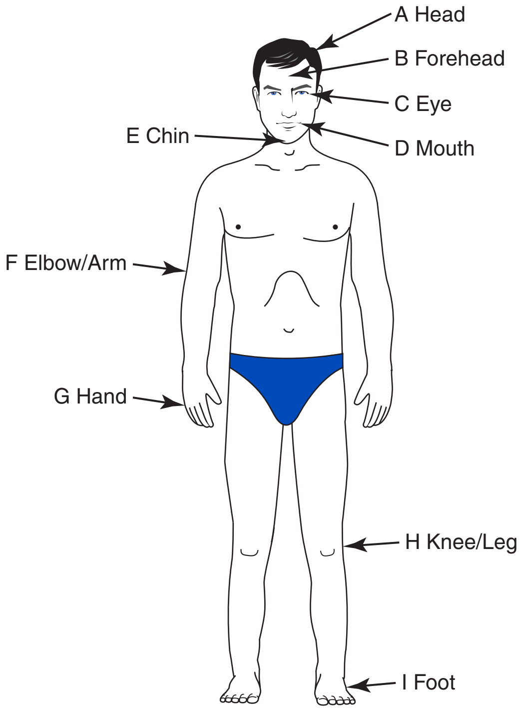



**Fig. 7.9** Anatomic sites commonly used for control of assistive technologies. (From Webster JW, Cook AM, Tompkins WJ, Vanderheiden GC: *Electronic devices for rehabilitation,* New York, 1985, John Wiley and Sons, p. 207.)

**Fig. 7.10** A proper sitting posture can promote independence and allow the person to function efficiently in the manipulation of objects or the activation of switches. (Courtesy www.Lburkhart.com.)

strength and endurance, muscle tone, and the presence of primitive reflexes and reactions. Many protocols exist for evaluation of range of motion (Latella and Meriano, 2003). Both passive and active ranges of motion are assessed. Range of motion is important in consideration of positioning needs for function (see Chapter 10 for a discussion of seating and positioning) and the amount of movement available to access a device or perform a task.

Related to range of motion is muscle strength. Again, many protocols are available for testing muscle strength. It is graded in a range from unable to move independently to moves with gravity eliminated, able to move against gravity, and moves against different degrees of resistance. It is important to note that the presence of a neurologic disorder such as CP, stroke, or traumatic brain injury (TBI) will affect both range of motion and muscle strength. Typical protocols for testing these components are not generally useful for these populations because the position of the individual affects muscle tone and subsequently range of motion and muscle strength. For example, a child with CP may seem to have limited flexion range of motion in the lower extremities when lying in supine. However, when turned on the side, flexing the legs is much easier. In supine, the influence of the tonic labyrinthine reflex increases extensor tone. This influence is not present in side lying, making flexion much easier (Nichols, 2005).

Muscle tone and the presence of obligatory movements are important considerations for individuals with neurologic disorders. The position of the individual affects the available movement. Muscle tone is assessed in various functional positions, particularly prone, supine, sitting, and standing. Obligatory movements, or reflexes, are assessed to determine how they might affect function. Key reflexes or obligatory movements include the asymmetrical and symmetrical tonic neck reflexes, tonic labyrinthine, extensor thrust, bite, and grasp reflexes. The ability to right the head when moved out of a vertical alignment, either lateral or in the anterior-posterior plane, is another component. Postural control is a related component that refers to the ability to maintain the trunk in a vertical alignment. When completing an assessment to determine function in various positions, it is important to handle the client and to challenge his or her balance and postural control to determine the degree of support she will need to work in a given position and the movement available in that position. Fig. 7.10 illustrates proper positioning for use of a keyboard. Sitting and standing balance are additional considerations (see Chapter 10).

It is important to assess aspects of motor skills and control mentioned in the previous paragraph as well as more complex gross and fine motor skills. Relevant gross motor skills to assess include balancing on one foot; performing symmetrical and asymmetrical movements of the upper and lower extremities; coordinating one side of the body; lifting and carrying objects; rapidly alternating movements; and running, skipping, and hopping. Fine motor assessment includes rapidly alternating finger movements, performance of isolated finger movements, manipulation of objects of different sizes, and performance of specific fine motor tasks. The Bruininks-Oseretsky Test of Motor Proficiency (Bruininks and Bruininks, 2005) and the Movement ABC (Henderson, Sugden, & Barnett, 2007) are two examples of comprehensive motor evaluations appropriate for children; however, they are not appropriate for children with neurological disorders. The Gross Motor Function Measure (GMFM) (Russell et al., 2013) is designed specifically for children with neurological impairments. Again, if a neurologic condition is present, it is important to remember that function depends on the client's position.

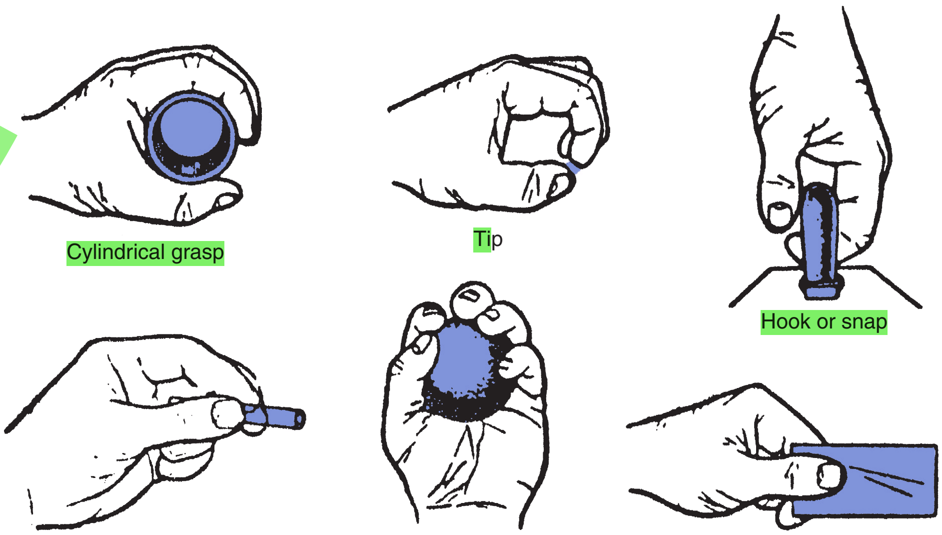



**Fig. 7.11** Functional grasp patterns for evaluating hand use.

Simulation of functional tasks is used to evaluate the types and quality of movement an individual possesses. Functional tasks are chosen for evaluation because they are often more meaningful to the consumer than physical performance components such as strength and joint range of motion. They also provide the clinician with an opportunity to gather qualitative information regarding the consumer's movements, and results of such tasks are more likely to reflect the consumer's true abilities.

## A Clinically Based Framework for Determining Optimal Anatomic Sites for Accessing a Control Interface

The hands, being the control site of choice, are the first to be assessed. Basic hand function can be observed by using a grasp module (Fig. 7.11) that includes a total of six functional grasp patterns. Notations are also made regarding how the consumer completed the movement and the factors that made it successful or not. For example, did the object need to be positioned in a particular way for the consumer to grasp it? Was there a delay in initiating the movement? Did the consumer have difficulty releasing the object? Was the movement pattern isolated or synergistic in nature? Did the consumer appear to have problems with depth perception when reaching for the object?

If the consumer has the potential for reliable hand use, it is then necessary to determine the minimal and maximal arm range within a workspace and the resolution in hitting a target. A range and resolution board, as shown in Fig. 7.12, can be used to measure both of these. This is an example of how to determine the person's ability to hit a target as well as the range of his reach. If possible, the consumer is asked to use the thumb or a finger to point to each corner of each numbered square. If the consumer is unable to point to the corners, he or she is asked to touch each square with the whole hand. This provides information regarding the approximate size of the workspace and the best locations for a control interface and a rough measure of accuracy of movement. Both arms are evaluated as appropriate.

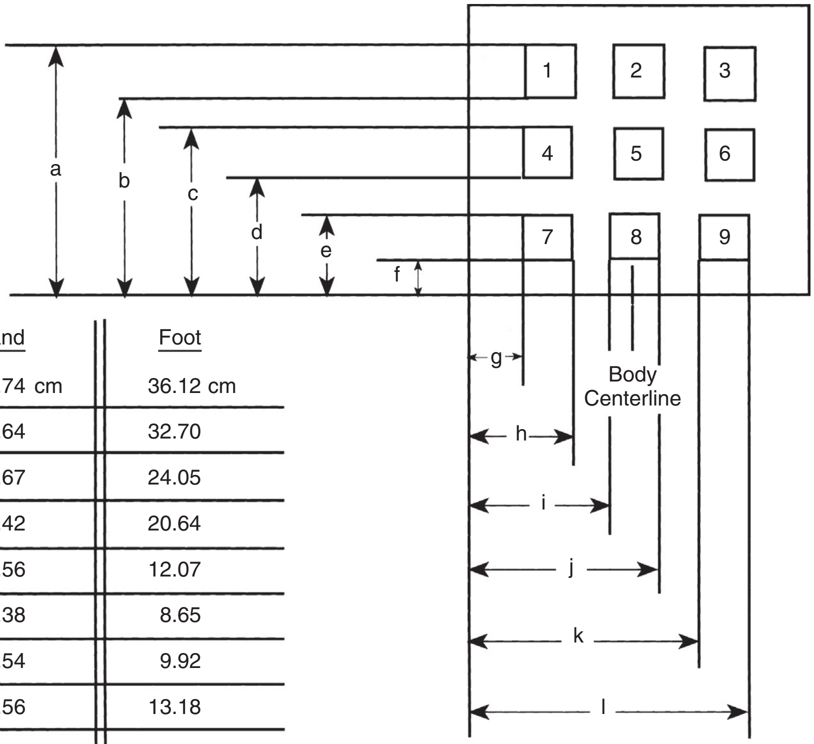
If the hands are eliminated as a control site, other anatomic sites must be considered. For example, we can also measure range and resolution for the foot and head. With a range and resolution board of smaller dimensions, the same task can be used to evaluate foot range and targeting skills and the consumer's range and resolution with a mouth stick, light pointer, or head pointer. After completion of this component of the skills evaluation, the clinician should have a good idea of the user's physical skills and the anatomic sites that can best be used to control an interface.

# OUTCOMES

## Optimal Control Sites

The outcome of the assessment process will be a determination of the possible control sites for an individual. There may be several or only one, depending on the motor capability of the individual. The initial evaluation may only indicate potential control sites that may be developed with practice or anatomic sites that are easily controlled without additional training and practice. Because it is also possible that the person's skills may decrease over time in the short term during the day because of fatigue or in the longer term because of a degenerative disease, identifying a back-up control site is a useful strategy when possible.

In most cases, control of individual sites will improve because of repetition of any motor act. It is possible that the quality and speed of movement may improve, and even the number of movement patterns (e.g., head movement and hand movement) available may increase.




| | Hand | Foot |
|---|---|---|
| a | 48.74 cm | 36.12 cm |
| b | 40.64 | 32.70 |
| c | 31.67 | 24.05 |
| d | 23.42 | 20.64 |
| e | 15.56 | 12.07 |
| f | 7.38 | 8.65 |
| g | 7.54 | 9.92 |
| h | 15.56 | 13.18 |
| i | 31.43 | 10.81 |
| j | 39.69 | 29.45 |
| k | 55.40 | 42.86 |
| l | 63.66 | 46.04 |

Notes:
1. All squares are 8.26 or 3.33 cm on a side.
2. Material is 1/8" thick cardboard.
3. Cover with clear contact paper to protect surface.

**Fig. 7.12** Range and resolution board used for evaluating the ability to hit a target using a given control site

## Development of Skills for the Use of Control Interfaces

Assistive technology provides many individuals who have physical disabilities with their first opportunity to perform a motor act to access communication, mobility, and environmental control or perform cognitive functions. Without these technological options, individuals with severe physical disabilities had few or no opportunities to use their existing motor movement. For this reason, there are many instances in which an individual may have a control site and the ability to activate a single switch, but the ability to activate this control interface is not consistent enough to justify the purchase of an assistive device such as a wheelchair, computer, or augmentative communication system. The intervention then becomes one of improving the individual's motor control, so she will be able to reliably activate the control interface.

Skill development varies greatly across different input devices depending on cognitive load, mastery, speed, and user characteristic. The results obtained by Cress and French (1994) (see Box 7.5) led Li-Tsang et al. (2005) to state:

> *This study showed that the IT [Information Technology] competency of people with ID [Intellectual Disability] was poor and that there is a barrier for people with ID to get into the world of IT. Intensive, organized, systematic training seems to be the way forward. This study has shed light on how to set training goals for people with ID for learning IT. A number of limiting factors regarding access to technology were found for people with ID. If people with ID could have access to modern technology, this would hopefully enhance their quality of life. (p. 133)*

Selection of control interfaces for a given individual depends on cognitive and motor requirements presented by a particular interface as well as the skills of the individual in these areas. Extrapolation from successful use by adults without disabilities or typically developing children to children with disabilities is not appropriate. The amount of training required for successful use is also generally greater for children who have disabilities than it is for typically developing children or adults.

Findlater et al. (2013) and Ng, Tao, and Calvin (2013) compared performance between older adults and younger adults using four desktop and touch screen tasks: pointing, dragging, crossing and steering, and pinch to zoom (touch screen only). Age and input device type both had significant effects on both speed and number of errors. Older adults were generally slower than younger adults, but the gap was less using the touch screen than for the mouse, and the error rate was also less (Findlater et al., 2013). However, older users preferred a trackball to either the touch screen or mouse, and age-related performance differences were not completely compensated for by the use of the touch screen (Ng et al., 2013).

**TABLE 7.4 Sequential Steps in Motor Training for Switch Use**

| Goal | Tools Used to Accomplish Goal |
|---|---|
| 1. Time-independent switch used to develop cause and effect | Appliances (fan, blender)<br>Battery-operated toys or radio<br>Software that produces a result whenever the switch is pressed |
| 2. Time-dependent switch used to develop switch use at the right time | Software that requires a response at a specific time to obtain a graphic or sound result |
| 3. Switch within specified window to develop multichoice scanning | Software requiring a response in a time window |
| 4. Symbolic choice making | Simple scanning communication device<br>Software allowing time-dependent choice making that has a symbolic label and communicative output |

A graded approach using technology as one of the modalities for improving the individual's motor skills should be implemented. Table 7.4 illustrates some general steps and tools involved in such an approach. The technology then becomes a tool to meet short-term objectives aimed at reaching the long-term goal of participation in an activity using AT. It is important that this goal be kept in mind so that the clinician reevaluates the individual at periodic intervals and allows her to move beyond the use of this technology as a tool into functional device use.

## Training and Practice to Develop Motor Control

When an individual has limited upper extremity fine motor control, it is necessary to use alternative anatomic sites such as head movement or gross arm, hand, or leg movements. The efficient use of a control interface requires the equivalent of fine motor control regardless of the anatomic site. Because these alternative sites have not been used for fine motor control, a combination of training and practice is required to develop the necessary skills. The initial choice of the best control site and method for an individual may not necessarily remain constant over time as skills change.

An individual may have the prerequisite motor skills to use a specific anatomic site but lack sufficient skill to control the recommended control interface. She will require training to refine her skills. Refining these motor skills may result in an increased rate of input, fewer errors, or increased endurance for using the control. For example, a person may be able to select directly but need training to learn to use a specific keyboard layout to reduce fatigue or increase speed (Case Study 7.3).

**CASE STUDY 7.3 Motor Training to Enhance Function**

Mrs. Bennett is a patient at the skilled nursing facility where you work. She sustained a stroke and has recently been transferred to your facility. To get her involved in using her right side, you have been asked to develop a motor training program that will engage her in using a joystick. How would you proceed?

**Fig. 7.13** For assistance with painting in art class, we can attach the paintbrush to a head-pointing stick or baseball cap. The type of activity can help children develop motor skills for head pointing.

Refinement of motor skills for mouse use, especially if an anatomic site other than the hand and fingers is used, will also require training and practice. Many software programs and apps are available that have been developed to gradually improve a person's ability to use a mouse or an alternative pointing device, including the gestures required for tablets and phones (e.g., swipe, pinch, tap). These programs include activities for developing targeting skills and mastering point-and-click and click-and-drag skills.

Use of mechanical and electronic pointers worn on the head typically requires substantial training to gradually build the consumer's tolerance. Activities such as painting using a brush attached to a head pointer (Fig. 7.13) add enjoyment to the task of developing a motor skill. Effectiveness in using control enhancers such as a typing stick, key guards, and mouth sticks (see Chapter 8) also requires practice. Similarly, strengthening of the person's existing neck, facial, and oral musculature and a gradual development of tolerance for the mouth stick should take place before having him perform tasks such as writing or typing. Playing simple board games, painting, or batting a balloon are examples of activities that can be used to develop skills for mouth stick or head pointer use. Many games can also be adapted so that a person using a light pointer practices using the interface through play activities. For example, a game of tag in which tagging is getting hit with the light from the pointer can make learning to use the light pointer more fun. Cautions for use of laser pointers are described in Box 8-1.

The development of motor skill for the operation of one or more control interfaces can also have carryover into more general motor skill development. Three outcomes can be achieved by a motor training and practice program: (1) the individual can broaden his repertoire of motor capabilities and the number and type of inputs that can be accessed; (2) the individual can refine the motor skills she has in using an interface to increase speed, endurance, or accuracy; and (3) the individual who lacks the motor skill to use any interface functionally can develop these skills.

A multiple baseline study with two participants, age 1 year 10 months and age 5 years, taught children with severe multiple disabilities switching skills in different environments (multiple sensory room and home) (Moir, 2010). The participant's frequency of switching (number of times in each session that the participant activated the switch), response to stimuli, communication via eye gaze, and vocalization all improved over time. Three questions were asked of parents: (1) Has the switching activity made any difference to your child? (2) Has the switching made any difference to you and your family? and (3) How important has it been for your child to participate in the switching program? Parental responses indicated significant changes to the child's behaviour that also produced a positive effect on the families. This limited sample study supports some interesting results in terms of related psychosocial performance that supports future investigation in this area.

## Developing Scanning Skills

Table 7.4 lists four steps that can be used to develop motor skill sufficient for scanning control of a device (e.g., a phone, tablet, communication device, computer access, EADL). The steps in Table 7.4 are only strategies intended to meet short-term objectives. The long-term goal is participation in an activity. Research on scanning has resulted in useful information regarding training and practice (Box 7.2).

Hussey et al. (1992) documented the progress of two young women after the implementation of a motor training program like the one described in Table 7.4. Initially, both Janice and Marge lacked the head control to activate even a single switch. After extensive training, they both were able to directly select choices on an augmentative communication device using a light pointer worn on the head. These two cases illustrate that individuals can gain motor skills for a functional activity from a systematic training program.

Scanning requires cognitive skills that are not intuitive, especially for a person with significant motor limitations. The cognitive skills required are causality, ability to wait, vigilance to the task to be ready when the desired choice is presented, and reaction time to respond quickly enough to select the desired item. If an individual has difficulty with scanning, it can be challenging to determine if the difficulty is due to motor limitations or cognitive understanding of the task. A systematic approach (see Table 7.4) starts with evaluating *causal understanding* (sometimes called cause and effect) and providing training at that level as needed. Causal understanding refers to the ability of the individual to understand that he can control things in his environment and can make something happen (den Ouden et al., 2005). It encompasses the prerequisite skills of attention and object permanence. The individual must be able to attend to and be aware of his environment and the

### BOX 7.2 Tips for Teaching Scanning

Piché and Reichle (1991) identified these steps for teaching scanning in either manual (i.e., no-tech) or technologically assisted systems:

- Selecting a signaling response
- Learning to use the signaling response conditionally (i.e., to indicate an item)
- Learning to use the signaling response with a larger array of items
- Learning to use the signaling response in different types of array (e.g., vertical, horizontal, row–column, circular)

Jones and Stewart (2004) surveyed 56 OTs and SLPs who were experienced in teaching scanning to determine how they carried out this training. This study yielded four themes:

- The process of training scanning is progressive and parallel.
- Clients must be considered on an individual basis when developing a training program. Training scanning is inextricably linked to functional goals.
- It is important to train both the child and the primary caregivers using a collaborative approach.

They also found that:

- Parallel training with the OT using scanning games on the computer and other activities and the SLP developing scanning skill on an AAC device was often used. This is especially true when a new mode or device is added to an existing, effective mode.
- A general progression from linear to row column takes place by using branching arrays.
- OTs were involved in all phases of scanning training with the SLPs being more involved in later stages.

The following tips can be used while teaching early switch control to emerging communicators:

- Cues to the AAC user should always be natural environmental cues (e.g., silence in the middle of a song). Using explicit commands, such as saying "Hit the switch," will keep the learner dependent on that prompt and impede learning.
- The learner must not repeatedly or continuously activate the switch in anticipation of the right moment. This would prevent him or her from learning to wait for the right moment (and later the cursor in scanning).
- It is unfair to expect communicative use of the switch or selection method before ensuring that the individual has reliable control (operational competence) over the interface itself.

*AAC,* Augmentative and alternative communication; *OT,* occupational therapist; *SLP,* speech-language pathologist.
Adapted from Dowden P, Cook AM: Choosing effective selection techniques for beginning communicators. In Reichle J, Beukelman D, Light J, editors: *Exemplary practices for beginning communicators,* Baltimore: Paul H. Brookes, 2002, pp. 395-432.

## BOX 7.3 Tips for Preparing a Learner for Motor Skill Development

Before engaging the learner in early scanning activities, make sure there is:

- At least one comfortable position for an engaging activity
- An appropriate control site and switch has been identified for learner's motor control
- A well-positioned and stable switch
- Movement to activate the switch is easy for the learner
- Nearly 100% accuracy in the learner's switch activation upon stimulus or cue without scanning
- The scanning method matches the learner's motor ability (see Table 7.1)

Investigators have discovered that the ratio between a user's reaction time and an appropriate scan rate for that user is approximately 0.65, which we refer to as the "0.65 rule" (Lesher et al., 2000; Simpson et al., 2006).

The learner is not rewarded for inappropriate activations (e.g., during stimulus)

- There are empty spaces (foils) in the scanning array in addition to targets.
- The scanning pattern is simple: linear or circular.
- The presentation of the options is highly salient to the learner (McCarthy et al., 2006).
- The cue or stimulus should be in the same modality as the selection set items (e.g., for visual scanning, the cue should be visual, and for auditory scanning, the stimulus should be audible).
- Use natural cues and prompts such as "Which toy do you want" rather than unnatural ones such as "Hit the switch now."
- For visual scanning, be sure the learner is able to look at the display continuously.
- The feedback upon selection is salient and reinforcing (McCarthy et al., 2006).

Adapted from Dowden P, Cook AM: Choosing effective selection techniques for beginning communicators. In Reichle J, Beukelman D, Light J, editors: *Exemplary practices for beginning communicators,* Baltimore: Paul H. Brookes, 2002, pp. 395-432.

permanence of objects in that environment. Information can be gathered on the individual's ability to understand cause and effect through the use of a single switch.

Some tips for preparing for this type of training are shown in Box 7.3. At the first step in Table 7.4, the goal related to AT use is for the individual to be able to activate the switch at any given time and associate the switch activation with a result. The individual is asked to use a control site to activate a single switch that is connected to some type of reinforcer. Caregivers and those working with the individual can provide initial information on what the individual enjoys and finds reinforcing. Objects that can be adapted for switch input that may be of interest include battery-operated toys, a radio, a blender, or a fan. The person shown in Fig. 7.14 is using a switch with a battery-operated toy as the reinforcer. Typically, the individual who is aware that she has generated an effect will show some type of response, such as smiling, crying, or looking toward the reinforcer.

**Fig. 7.14** Child using a single switch with a battery-operated toy as a reinforcer.

If there is success with these activities, computer software programs can be used as an alternative type of reinforcement. These programs provide interesting graphics, animation, and auditory feedback each time the switch is activated. Individuals of all age groups find the programs enjoyable. Data can be collected for each switch activation, including (1) time from prompt to activation, (2) whether the individual activates the switch independently or whether verbal or physical prompting was needed, and (3) the consumer's attention to the result. There are several companies that sell software programs to be used at the different stages described in this section[1].

At the second step in Table 7.4, the goal is for the individual to activate his switch consistently at a specific time. Vigilance, ability to wait, and the ability to activate the switch at the correct time are important at this step. With some computer games, the individual needs to activate the switch for an object to move or to carry out an action such as shooting a basket, hitting a target, and so on. With some programs, as long as the individual successfully activates the switch, the movement of objects on the screen speeds up.

This approach can also be considered one-choice scanning, in which the switch is either hit or not—choice making at its most fundamental level. For example, with some computer games, the individual needs to activate the switch for an object to move or to carry out an action such as shooting a basket, hitting a target, and so on. With some programs, as long as the individual successfully activates the switch, the movement of objects on the screen speeds up. Any data provided by the program (e.g., speed, number of correct hits, errors) and data regarding the individual's success in activating the switch at the correct time and whether prompts have been needed are recorded.

[1]https://www.helpkidzlearn.com/;http://www.judylynn.com/. Most are games that are designed to be one or two switches accessible. The Grid software https://thinksmartbox.com/product/grid-3/) also contains games for teaching scanning skills.

Linda Burkhart has many suggestions for computer-based and non–computer-based activities and resource materials that can be used for motor training (see http://lburkhart.com/). One suggestion for a non–computer-based activity is to use a battery-operated toy fireman that climbs a ladder as long as the switch is activated. To make this a time-dependent activity, a picture of a reinforcer can be attached somewhere along the ladder, and the individual is asked to release the switch to stop the fireman at the picture and receive the reinforcement.

The third step of the scanning training program adds a time window, and the individual is asked to use the switch to choose from two or more options. The skills involved at this stage include vigilance, waiting, and reaction time as in step two. The additional required skill is the understanding that a choice is only available during a window in which the item to be selected is highlighted. Toys, appliances, and computer software programs can also be used at this stage.

The goal is to gradually increase the number of choices from which the individual is to select. The increase in the number of choices is important if scanning is to be used for communication, text entry, or environmental control. One approach is to highlight locations on the screen in sequence. When the switch is hit on a highlighted item, the program provides an interesting result. In some programs, the highlighted areas can be limited so that only one is correct, which helps the consumer develop scanning selection skills in the absence of language-based tasks. In addition to the data that have been collected in the previous stages, data on the minimal scan rate the individual can successfully use are recorded.

If the need is for power mobility, then the next step is to use software specifically designed for developing skills in using a joystick. Alternatively, scanning training software aimed at single-switch or dual-switch wheelchair use can be used for training at this stage.

The final training phase shown in Table 7.4 is intended to add communicative intent to the task. At this stage, the cognitive skill of symbolic representation is added to the choice making. Development of the individual's language skills may have been taking place in parallel with the motor skills training (Box 7.2), and this linguistic step may follow naturally. The amount of training required for successful use is also generally greater for children who have disabilities than it is for typically developing children or adults. A summary of research that is relevant to the development of motor skills for AT use is shown in Box 7.4.

## BOX 7.4 Research on Developing Motor Skills for Assistive Technology Use

What Does the Research Say?: Developing Skills with Switches and Other Control Interfaces

Jagacinski and Monk (1985) evaluated the use of joysticks and head pointers by young nondisabled adults. The task involved moving from a center point to one of eight lighted targets as fast as possible. The skill in using these devices for this task was acquired with some difficulty over many trials. Based on a criterion of less than 3% improvement in speed over 4 consecutive days, proficient joystick use required 6 to 18 days, and head pointer use required 7 to 29 days of practice for nondisabled, young, highly motor-skilled participants.

Angelo (2000) reported 11 essential elements of a single-switch assessment as identified by experienced OT: reliability of movement, volitional nature of movement, safety, easily performed movement, use of activities in which learners participate regularly, efficiency of movement, previous successful movements, ability to perform a timed response within a time frame, and time required between switch activations is appropriate to child's reaction or response time.

Cress and French (1994) found that skill development varies greatly across different input devices (touch screen, trackball, mouse, locking trackball, and keyboard).

- Three groups: adults without disabilities, typically developing children between 2.5 and 5.0 years, and children with intellectual disabilities (mental age 2.5 to 5.0)
- Adults without disabilities mastered all of the devices without training.
- About 50% of typically developing children were able to master all devices except the locking trackball without training.
- After training, 80% of the typically developing children mastered all devices. The trackball was the easiest to master.
- Children with intellectual disabilities averaged between 0% and 46% mastery (depending on the device) without training and less than 75% mastery with training. The locking trackball was significantly more difficult to master than the other devices.
- Adults were able to use the devices faster than the children, and the typically developing children used most devices slower than the children with intellectual disabilities (probably related to the greater chronological age of the children with intellectual disabilities).
- Performance by typically developing children was related to age and gross motor abilities.
- Performance of children with intellectual disabilities was also related to pattern analysis skills, and the individual input devices showed distinctly different relationships to cognitive and motor development than for the typically developing children.
- Selection of control interfaces for a given individual depends on cognitive and motor requirements presented by a particular interface as well as the skills of the individual in these areas.
- Extrapolation from successful use by adults without disabilities or typically developing children to children with disabilities is not appropriate.

*OT,* Occupational therapist; *SLP,* speech-language pathologist.

Adapted from Dowden P, Cook AM: Choosing effective selection techniques for beginning communicators. In Reichle J, Beukelman D, Light J, editors: *Exemplary practices for beginning communicators,* Baltimore: Paul H. Brookes, 2002, pp. 395-432.

Selection of symbol systems is discussed in Chapter 18. Through this phase, the individual makes the transition from object manipulation (environmental control) to concept manipulation (communication). Greater resources are available at this stage to convey needs, wants, and other information. Simple scanning communication devices or multiple-choice computer programs can also be used for further skill development as a precursor to a scanning communication device.

Integration of the selection set into daily activities can be evaluated in a number of ways. Goal attainment scaling (GAS), a criterion-referenced, individualized objective measure (King et al., 1999), can be as used to evaluate the effectiveness of a training program. For example, Cook et al. (2005) used GAS to identify individualized goals for children using a set of switches to control a robot in a functional task.

Individualized goals were developed for switch-controlled operation of the robot for each child in the study. For each individual goal set for the child, a scoring hierarchy is established in which a score of zero indicates achievement of the goals. Negative scores of −1 or −2 indicate degrees of failing to achieve the goal. Scores of +1 or +2 indicate that the child exceeded the goal. For each of the five scores, a task is described. For the robot task, typical goals were based on the number of prompts required (Cook et al., 2005). A score of zero meant that the switches were successfully hit without prompting. Scores above zero indicated successful completion of increasingly complicated tasks. Scores below zero indicated that either hand-over-hand (−2) or verbal (−1) prompting levels were required. There are also standardized outcome measures that are described in Chapter 6. For example, the Psychosocial Impact of Assistive Devices Scale (PIADS) and Quebec User Evaluation of Satisfaction with Assistive Technology (QUEST) can be used to evaluate outcomes for individuals using particular selection methods.

## SUMMARY

In this chapter, we have defined the elements of the HTI and their relationship to the other components of AT. The elements of the HTI include the control interface, the selection method, and the selection set. The selection set encompasses the items in the array from which the user can choose. There are two basic methods by which the user makes selections: direct selection or indirect selection. Indirect selection encompasses a subset of selection methods known as scanning, directed scanning, and coded access. Each selection method applies to a different set of consumer skills. The development of motor and cognitive skills for scanning requires a thoughtful and well-designed approach.

## STUDY QUESTIONS

1. Define the elements of the HTI and how they are related to the processor and the output.
2. What are the major anatomic sites that are used for control of ATs?
3. Describe the available movements for each anatomic site.
4. What is the order of preference in considering alternative anatomic sites? Why is this order used?
5. What are the major challenges for a person using head control for a fine motor task such as typing?
6. What is a selection set?
7. What is a control interface?
8. What are the two basic selection methods used with control interfaces?
9. What are the scanning formats that can be used to accelerate scanning?
10. What is directed scanning? Why is it useful?
11. Why is coded access an indirect selection method? What is the selection set for Morse code?
12. Describe the three different selection techniques used with scanning and directed scanning. Which one provides the user with more control and why?
13. What are the relative advantages and disadvantages of the three common scanning methods? Select a client profile that would benefit from each type.
14. What are the cognitive skills necessary to use scanning?
15. What does *rate enhancement* mean? What are the two main types?
16. What memory skills does a person need to use word prediction or word completion?
17. What is abbreviation expansion? What cognitive skills are required to use it?
18. What outcomes can be achieved through the implementation of training programs for the development of motor skills?
19. Describe the steps taken in a training program to develop motor control.
20. Why is it recommended that selection skill (e.g., scanning) be developed with games or other activities before the person uses it for a functional task?
21. Assume that you are asked to train a person to use scanning. How would your approach differ for:
    a. A 60-year-old man who has recently sustained a stroke
    b. A 5-year-old child with cerebral palsy
    c. A 45-year-old woman with multiple sclerosis