INTRODUCTION

Traditionally, human interactions with computers has relied most heavily on visual perception and motor ability. Graphical user interfaces (GUIs) have dominated computer displays, both large and small, while mouse and keyboard devices have dominated computer input. Increasingly, however, newer interfaces are using sound and speech. The use of attention-grabbing multimedia computer presentations plus the increasing use of conversational speech interfaces are examples.

As exciting as these new technologies may be, they have the potential to disenfranchise deaf and hard of hearing users. This chapter will discuss interface technologies as they relate to the needs of users unable to hear auditory information. In addition, language considerations associated with limited hearing will be discussed.

This chapter begins with a discussion of hearing loss, followed by issues of language acquisition as they relate to hearing loss. Auditory user interfaces that present difficulties will be discussed next, along with information about interface alternatives that enable access for deaf and hard of hearing users. The chapter will conclude with a brief overview of technologies that have been developed to assist with communication.

HEARING LOSS

According to the National Institute on Deafness and Other Communication Disorders (NIDCD), about 28 million people in the United States have some degree of hearing loss (National Institutes of Health [NIH], 2004; see also, Mitchell, 2005, 2006). This is a sizable population to be considered in the design of computer interfaces. Numbers alone, however, obscure some significant differences among the individuals who experience hearing loss. Degree and type of loss, age of onset of loss, as well as family, educational, and societal influences will all contribute to the experience and abilities of an individual who has a functional hearing loss.

Some individuals will have relatively little hearing loss, while others will experience a profound loss. Individuals who are hard of hearing will generally have some hearing. The ability that an individual user will have to make use of their residual hearing, however, is not a straightforward calculation of dB loss. People with hearing loss will experience difficulty with pitch, timbre, and loudness, but, critically, will also experience difficulty with speech perception. Factors such as type of loss (e.g., conductive, sensorineural, mixed, or central) will have a major effect on the user experience. People with sensorineural hearing loss (such as resulting from lengthy exposure to loud noises or as a result of aging) generally will have more difficulty perceiving speech than people with conductive hearing losses that result from difficulties in middle ear functioning. The extent to which an individual makes use of this hearing for communication and whether the individual can hear computer sounds, however, varies greatly.

In addition, the way in which an individual having a hearing loss interacts with their environment may also be influenced by societal factors. Whether individuals identify themselves as Deaf (with an uppercase “D” as a member of the Deaf Community), deaf, or hard of hearing is indicative of cultural identity (Lane, 1992; Padden & Humphries, 1988, 2005). Membership in the Deaf Community is determined more by shared language and worldviews rather than by results of audiometric tests. For example, people may lose their hearing with age. These people, while deaf by the audiometric definition, would not share the culture of the Deaf Community.

In the United States, the language of the Deaf Community is American Sign Language (ASL). Other countries and locales have their own native sign languages shared by members of Deaf Communities in those areas. Interestingly, these signed languages are not based on the spoken languages of the region. People are often surprised to learn that ASL is more similar to French Sign Language, from which it originated (Lane, 1984), than it is to British Sign Language. Beginning with the seminal work of Ursula Bellugi and colleagues in the 1970s, linguists, cognitive psychologists, and brain researchers have studied native sign languages and their users for clues as to the origin of language and the biological nature of language (Emmorey & Lane, 2000; Klima & Bellugi, 1979; Erard, 2005).

Cochlear implants are a medical intervention that has received much attention in the last couple of decades. The decision as to whether or not to have a cochlear implant is often a complex one, as was explored in the movie Sound and Fury (Aronson, 2000; see also Hyde & Power, 2006). From the standpoint of a user, an implant is not the same as perfect hearing, but does allow the user to hear sounds and, with training, may greatly aid in the perception of speech (Chorost, 2005).

HEARING AND LANGUAGE

Some, but not all, deaf and hard of hearing individuals use sign language. The type of signed language depends on the user’s life experiences. Deaf children born to deaf parents, regardless of severity of hearing loss, will generally acquire a sign language, such as ASL, natively as hearing children of hearing parents acquire spoken language. People who lose their hearing late in life generally will not master a sign language. In between, there are many variations. Deaf signers may be exposed to a native sign language as adults and as a result, may only acquire partial mastery (Newport, 1990). Other deaf signers will be exposed primarily to manual forms of English (or other spoken languages), rather than natural sign languages. Many schools that use sign

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1Terms such as hearing-impaired and deaf-mute are generally considered to have negative connotations. For a discussion of this, see “What is Wrong with the Use of these Terms: ‘Deaf-mute,’ ‘Deaf and dumb,’ or ‘Hearing-impaired?’” by the National Association of the Deaf. (Available at http://www.nad.org/site/pp.asp?c=foINQJMBF&bk=103786). The style manual of the American Psychological Association (APA) recommends use of nondiscriminatory language in all publications (see http://www.apastyle.org/disabilities.html ).
language in the classroom do not use a natural sign language, but rather a representation of the spoken language that is signed. Forms of signed English borrow signs from ASL, but these signs are produced in English word order rather than using ASL sentence structures (for an extended discussion, see Lane, Hoffmeister, & Bahan, 1996). Children attending schools that use some form of signed English may not be exposed to ASL. Moreover, schools that educate students using an oral approach, in which speech is the primary means of communication in the classroom, also may not be exposed to ASL.

A person who is profoundly deaf from birth may have difficulty acquiring mastery of the spoken language, he presented auditorily or in print. It is not surprising that someone who has never heard speech will have difficulty perceiving or producing it. In a large-scale study of deaf and hard of hearing children attending schools using an oral approach to education, Conrad (1979) reported that profoundly deaf children rarely acquired sufficient lipreading skills to allow easy participation in conversations. He found, on average, that these children (with hearing loss greater than 85 dB) could only comprehend about 25% to 28% of the words through lipreading that they could comprehend through reading. Even among these orally educated students, fewer than 20% had speech that was rated even fairly easy to understand. While the statistics are better for hard of hearing children, Conrad found that even these students (with hearing loss less than 65 dB) could only comprehend about 36% of the words through lipreading that they could comprehend through reading. Nearly 85% of these hard of hearing students, however, had speech that was rated at least fairly easy to understand.

Perhaps more surprising may be the fact that many deaf and hard of hearing individuals have difficulty with reading (Conrad, 1979; Hanson, 1989). In the case of deaf readers, however, it can be assumed that reading will build on a firm un-derstanding of grammar and text comprehension. Learning to read is generally considered to be learning to map the print onto the spoken language the person already knows (Brady & Shankweiler, 1991). In addition, speech plays a critical role in the short-term memory processes that serve understanding of grammar and text comprehension (Lichtenstein, 1998). In the case of deaf readers, however, it cannot be taken for granted that reading will build on a firm understanding of the structure of the spoken language, but there are some absolutes. Some prelinguistically, profoundly deaf children become excellent readers, while some with lesser degrees of hearing loss do not (Conrad, 1979; Hanson, 1989).

Interestingly, research has recently turned to an examination of signed languages as an influencer in the development of skilled reading. It has long been known that deaf children of deaf parents, on average, acquire greater mastery of reading and writing than deaf children of hearing parents. Is this due to early exposure to sign language? While a number of both intellectual and societal factors have been considered as contributors to this disparity, interest has focused on the issue of language. Evidence is now emerging as to the important role that early mastery of a sign language can have on second language learning for deaf students as they acquire reading and writing skill (Padden & Hixon, 2000; Padden & Ramsey, 2000).

In short, for any deaf or hard of hearing individual, language experience cannot be assumed. That individual may or may not sign, speak clearly or lipread well, or have reading skills consistent with those of the hearing population. This knowledge has implications for designers who seek to address the needs of deaf and hard of hearing users.

DISPLAY TECHNOLOGIES

In many ways, computers and other technologies have proven to be of great benefit to deaf and hard of hearing users. The largely visual nature of information on the Internet makes this information accessible to deaf and hard of hearing users. Instant messaging and e-mail facilitate communication with deaf and hearing family, friends, and coworkers, while network-connected wireless devices such as PDAs and pagers are used in place of cell phones. As would be suspected from the previous discussion, however, effective interfaces for these and other technologies for use by deaf and hard of hearing individuals must take into account both sensory and language considerations. In particular, the increasing reliance on sound and speech interfaces to convey information can have serious consequences for individuals who have a hearing loss.

Audible Signals

Sounds have become increasingly popular in computer interfaces. They have long been used to convey information about new messages and have become popular as problem alerts, such as when an error has been committed. These sound events are considered attention-grabbing events for users whose visual attention may otherwise be engaged. For any user who has a hearing loss, however, sounds will be a problem.

A number of considerations can help provide the necessary visual support for a user who is deaf or hard of hearing (Vanderheiden, 1994). It is necessary to provide visual forms for all auditory information. Critically, these visual cues should be sufficiently noticeable so that they catch the attention of a person who may not be looking directly at the computer screen. Operating systems have features that can provide such visual alerts. For example, Windows® has accessibility features that allow users to set up their system to have captions or visual warnings displayed for sound events. These are helpful, although they may not give the full range of information carried by a sound event. For example, the meaning of a sound event may differ based on the tone of the signal or when the sound is produced. While visual captions and warnings may alert a deaf user that a sound event has occurred, they will be unable to convey these more subtle distinctions. It is important for designers to give careful consideration to sound events to ensure that crucial information is available by a nonauditory means for deaf and hard of hearing users.

Multimodal interfaces, as the name implies, are designed to support a range of perceptual capabilities. In theory, this would
seem ideal for users who are deaf or hard of hearing as visual alternatives to auditory materials should be available. Multimodal interfaces, however, do to always present all information on both modalities. The emphasis in many multimodal interfaces is representing information via speech that would otherwise be conveyed by print or some other visual means. To the detriment of deaf and hard of hearing users, often, less attention is given to ensuring that all auditory material be visually conveyed as well.

Multimedia Interfaces

Multimedia uses a combination of text, sound, pictures, animation, and video to present information (see Sutcliffe, chapter 20). “Multimedia User Interface Design,” this volume). Traditionally, games and educational software have exploited the richness of multimedia, but the advent of high-speed Internet communications has enabled the use of multimedia for a number of engaging applications on the web. For the present discussion, consideration will be given to multimedia presentations as they may impact access for deaf and hard of hearing users.

Multimedia material is inherently sensory. The technology offers eye-catching visual displays and attention-grabbing sound effects. To the extent that the information conveyed visually and auditorily is the same, information can be reinforced for users who have both channels available to them. To the extent that different information is presented in the two channels, however, users who have a functional loss of one of the channels will not have full access to that information. As it relates to the present discussion, this means that any information that is carried solely by sound or speech will be unavailable to deaf and hard of hearing users. Accessibility guidelines for multimedia products and web pages require equivalent visual presentations (e.g., see Brewer & Dardailler, 1999; U.S. General Services Administration, n.d.).

Consider the growing popularity of video on the web. Video material is an extremely effective way to convey information and younger generations of computer users have come to expect video to be part of their computer experience. For deaf and hard of hearing users, the voice-over that is common in video will be inaccessible. Words spoken by persons in view of the camera also are largely inaccessible. Even people skilled at lipreading cannot lipread video conversations that have poor lighting or poor resolution, or speakers who turn away from the camera. Additionally, the video may present music or sound events (e.g., doorbells or animal noises) that contribute significantly to events on the video. These, too, are unavailable to deaf and hard of hearing users. Technologies such as captioning and sign-language translation exist to provide alternative presentations of sound events and speech. Designers wishing to make their applications universally accessible should consider these alternatives and incorporate them into their applications.

Captioning. Captioning provides a print alternative to speech and sound events. It is much like substituting, except that it is specifically designed for deaf and hard of hearing users and, thus, will include comments in the captioning about sounds (e.g., "<music playing>" or "<sounds of child crying>") that may not be included in subtitles of foreign language videos. Captioning of certain television programming is mandated in the United States by the Federal Communications Commission and is considered to be beneficial to large number of users, not only those with hearing loss. It has been shown, for example, to improve reading abilities of children and to benefit second language learners. Designers who use multimedia materials have an obligation to their full audience to provide captioning of audio and video materials. The listing of a number of resources for captioning software is available at the Closed Captioning website (n.d.).

As might be anticipated from the previous review of reading levels of deaf and hard of hearing users, there has been some controversy about what language level should be used for captioning. Simply put, the issue revolves around the question of whether captions should be verbatim transcripts or simplified captioning should be presented. Verbatim captioning is generally preferred by users themselves (NIH, 2002) and is often cited as having the potential to improve reading skills (Steinfeld, 2001).

Signing. For sign language users, there are sign language alternatives to captioning. These sign interfaces have been defined as ways of representing signed languages on a computer such that signing can be stored, displayed, and manipulated to facilitate computer interaction (Frischberg, Corazza, Day, Wilcox, & Schulmeister, 1993). It should be noted that these interfaces have often been employed not only for making audio and speech materials accessible to deaf and hard of hearing users, but they have also been used for language learning by both deaf and hearing people. A number of software applications have been developed that use sign language as a means of teaching reading skills and writing to deaf signers or teaching sign language skills to individuals wishing to learn to sign.

Importantly, software applications that purport to use “sign language” or ASL differ in significant ways in the language that is being used. Notably, many of these applications use fingerspelling. Fingerspelling is not a natural signed language, but rather is a derivative of print. Specifically, in fingerspelling, there is one handshape for each letter of the alphabet and words are spelled out letter by letter on the hands. Thus, the word “language” would be spelled out by eight distinct handshapes spelling L-A-N-G-U-A-G-E. Other sign language interfaces use a form of signed English, rather than the native sign language. For young children and others not fluent in English, interfaces that use fingerspelling or signed English transliterations of text may not meet their needs.

In many cases, the goal when using sign interfaces is to provide ASL translations. Given the present state of the art, automatic translation from English to ASL is not possible; however, many current efforts are directed at facilitating this translation, acknowledging the need for translation into ASL. In what follows, a few of the options for sign language presentation of audio and multimedia will be discussed.

Ideal in many respects would be to have a live person signing an ASL version of print and multimedia materials. Hanson and Padden (1989, 1990) used videodisc technology in the earliest computer-based attempt at a bilingual ASL/English approach to reading and writing instruction for signing children. The work combined ASL video and the translated English text on one
screen. In this and other language learning situations where the users are young children still developing both ASL and English skills, this use of live signing has been particularly effective (Frishberg et al., 1993).

The advent of high-speed networks and Internet video has created opportunities for web applications that use live signing interfaces. For example, classroom applications have been developed (e.g., see King, 2000; Laurent Clerc National Deaf Education Center, n.d.; for a demo, see “Sample Web Page,” Gallaudet University, n.d.). Additionally, video blogs have created the opportunity for blogs to be signed by the blogger, rather than written (Lamberton, 2005), and video e-mail allows signers to communicate through signing by creating video recordings to be transmitted as e-mail messages (e.g., see “Road Runner Video Mail,” n.d.; also, “Vibe Video Mail,” n.d.).

Although ideal from the language perspective, other constraints may argue against the use of live signing in an interface. Lack of access to high-speed networks for video transmission may be an issue, but often the problem is the desire for automatic translation of software and web content that live signing does not provide. Live signing requires the prior recording of the signed material. Once recorded, changes to the video require a new recording. Because of this, live signing is not practical in applications that require that sign versions of audio or multimedia be created in real time. Short of having an interpreter doing the translations, live signing is not possible in these situations.

One approach to automatic sign presentation is what might be called “concatenated signing” (e.g., see “iCommunicator,” n.d.; “Signtel,” n.d.). With this, a software program is used to create word strings or sentences by concatenating signs produced by a live signer. The program starts with a vocabulary of stored individual signs. These signs can be strung together to form phrases and sentences. To prevent a jerky appearance that would occur through the simple production of a list of signs, algorithms are used to smooth the transitions between these signs. While these transitions are not as natural as live signing, the signing is legible and suggests an interesting approach to sign language interfaces.

A technique that has generated much interest in recent years is signing avatars (e.g., see Cox et al., 2002; Karpouzis, Caridakis, Fotinea, & Efthimiou, in press; Kennaway, 2002; Sims, 2004). These avatars use virtual-reality techniques to produce animated signing. The specific techniques differ for the various avatars, but central to all is that they display computer generated signing. Some systems are able to display not just hands, but full signers, so that facial expressions as well as hand movements are shown. See, for example, the SigningAvatar® shown in Fig. 45.1 that illustrates the sophistication of these animations.

Signing avatars have been used in education and have potential for applications such as translation of web pages, television programs, and conversational dialog. Chief among the virtues is that, unlike natural (live) sign language applications that are limited to prerecorded materials, avatars can generate signed versions of English words “on the fly.” They also have the advantage of not requiring large downloads for web usage.

While the avatars can sign ASL when preprogrammed, the language translation work needed for automatic translation into

FIGURE 45.1. An ASL sign avatar. The full animation of this avatar can be viewed on http://www.vcom3d.com/ASL.htm. © Vcom3D, Inc., 2004. All rights reserved.

ASL (or other signed language) is not ready to support this rendering on the fly. A current research focus in avatar work is on natural language translation and exploring techniques to display native sign languages by avatars (e.g., see Huenerfauth, 2005).

INPUT TECHNOLOGIES

Standard keyboard and mouse input technologies offer no barriers to users who have a hearing loss. The emergence of new interfaces, however, presents alternatives that will impact the way in which we are able to interact with computers. We consider here both speech and gestural interfaces as they may influence interactions for deaf and hard of hearing users.

Speech Interfaces

Conversational speech interfaces have appeal as a natural means of interacting with computers (see Karat, Vergo, Nahmoo, Lai, & Yankelovich, chapter 19, “Conversational Speech Interfaces and Technologies,” this volume). These interactions can range from simple, even one-word commands to full dictation of documents and user collaborations. For deaf and hard of hearing individuals, such interactions require consideration of user needs. First, these interactions can involve speech output which, as already discussed, requires a visual display alternative. Second are problems with speech input. Some deaf and hard of hearing individuals utilize speech and would be interested in taking advantage of speech input. Speech recognition, however, may be more problematic for these speakers than for hearing speakers.

As mentioned briefly in the previous paragraph, the speech of deaf and hard of hearing individuals is not always highly intelligible to hearing listeners. Since speech recognition engines can be trained to the voice and pronunciations of an individual speaker, however, couldn’t a recognizer be trained to understand the speech of an individual deaf speaker, even if the
speech is not completely intelligible to listeners? The difficulty is that recognizers require consistent speech. Research has shown that the speech of deaf and hard of hearing speakers often is more variable than the speech of hearing speakers (McGarr, 1987; McGarr & Lofqvist, 1988). For example, there is more acoustic variation in the pronunciation of a single phoneme by a deaf or hard of hearing speaker than there is in the pronunciation of that phoneme by a hearing speaker. Hearing listeners are very tolerant of this variability; speech recognizers are less so. Thus, deaf and hard of hearing users who may wish to use their speech for input may well find recognition less accurate than it is for hearing speakers.

Speech interfaces are often seen as useful alternatives to visual interfaces in situations when computers or keyboards are not available (see Karat et al., chapter 19, “Conversational Speech Interfaces and Technologies,” this volume). For hearing users, this alternative of a speech interface may be highly desirable. Many deaf and hard of hearing users, however, will not be interested in speech interfaces; others may experience difficulties in using them. Although situational demands may sometimes dictate the use of conversational interfaces, care must be taken that outside of the situational context, there exists a means for deaf and hard of hearing users to access the same information that hearing users access.

Sign Interfaces

Designed specifically for deaf and hard of hearing users, sign recognition is a specific and complex subset of gesture recognition technologies having the goal of automatically converting signed language to text or speech. These technologies have been investigated for a number of years, primarily to address the need to facilitate communication between signers and nonsigners. They also have the potential to provide an alternative means of natural language input to computers.

The task of recognizing full ASL or other natural sign languages is a difficult problem. The first reason is that an individual sign varies depending upon its context. Take, for example, the sign for the word GIVE. This sign has a specific shape combined with a variable movement. The movement reflects who is giving and to whom. I GIVE-TO YOU, YOU GIVE-TO ME, I GIVE-TO HIM, HE GIVES-TO ME, and I GIVE-TO ALL-OF-YOU each have a different movement that indicates subject and object. A second reason for difficulty in sign-language recognition is that several pieces of linguistic information are produced in parallel. For example, facial expression carries critical grammatical information. Thus, a full language recognizer needs to recognize not only the hand gestures of ASL, but must also recognize certain facial information relevant to the grammar. Such facial elements include eyebrow position, eye gaze, and mouth movements.

As with interfaces that produce signs, many systems that purport to perform sign-language recognition deal with recognition of fingerspelling handshapes rather than recognition of ASL sentences or even ASL signs. Using fingerspelling handshapes rather than ASL signs certainly constrains the size of the problem. Because there are only 26 handshapes in the English alphabet, this represents a much more manageable problem space than the recognition of full ASL signing. While it presents an alternative to keyboard typing of words, it doesn’t provide the type of natural language interaction with computers that is afforded by speech interfaces.

Technologies for recognizing signs have tended to use either instruments worn by the signer or computer vision techniques. The first if these approaches has the signer wear a specially designed glove or sensors placed on their joints that allow a computer to track movement (e.g., see Braffort, 1996; Fang, Gao, & Zhao, 2003; Hernandez-Rebollar, Lindeman, & Kyriakopoulos, 2002; Kadous, 1996; Wang, Gao, & Ma, 2002). In contrast, computer vision techniques use cameras to provide input to a computer about a signer’s movements and facial gestures (e.g., see Brashear, Starner, Lukowicz, & Junker, 2003; Kadous, 1996; Lee, et al., 2005; Vogler & Metaxas, 2001). These inputs are then analyzed using a variety of techniques such as neural networks or Hidden Markov Models that then recognize the sign.

Critically, however, this recognition does not do language translation. Thus, the output will be a one-to-one mapping of a sign into print or speech. As mentioned with the avatar work presented earlier, the ASL/English rules that would be needed for such translation are not developed to a state where automatic translation can occur; however, advances are being made. Recently, for example, Hernandez-Rebollar (2005) presented work designed to translate signed input into English phrases. In that work, the translation was enabled by having a limited number of phrases that the system could recognize, thus constraining the problem space.

The current state of the art for sign recognition is not as advanced as speech recognition. As researchers continue to work on the problem, however, advances can be expected. For signers, it might be the case that conversational sign interactions will one day be possible, much as speech recognition now allows speakers to benefit from conversational speech interactions.

**TECHNOLOGY AND COMMUNICATION**

Deaf and hard of hearing individuals have difficulties not only with computer interfaces, but also experience significant difficulties in certain communication situations. Telephone conversations, as well as one-on-one conversations, group discussions, and presentations or classroom lectures, are all problematic. No discussion of HCI for deaf and hard of hearing individuals would be complete without at least a brief mention of technologies that have been developed to aid in these situations.

Telephones have long been a source of difficulty for deaf and hard of hearing people. Alexander Graham Bell was a teacher of deaf students and was married to a woman who was deaf. His interest in finding improved ways to communicate with deaf speakers lead to his invention of the telephone. Ironically, however, over the years, telephones created a number of barriers for deaf and hard of hearing individuals in the workplace and other situations. To overcome these barriers, a number of assistive devices have been developed (Lazzaro, 1993). Amplification and adapters exist for many phones that will allow hard of hearing individuals or people with cochlear implants to hear phone conversations. Teletype devices (TTYs and TDDs) as well as some
computer applications allow deaf users to type conversations that are carried over phone lines.

Operator-assisted relay services have been established to enable conversations between deaf and hearing individuals. The relay personnel serve as a bridge between the two conversation participants, translating typed information into speech for the hearing participant and translating speech into written text for the deaf participant. Hard of hearing speakers can speak directly with others using a captioning service that provides, nearly in real time, a printed transcript of the conversation to support hard of hearing users (CapTel, 2005). Various means of enabling signed conversations over the telephone have been explored over the years, but the advent of video phones has now made feasible the option of signed phone conversations.

The current prevalence of conference calls in the workplace has created a new set of problems for deaf and hard of hearing workers. Similarly, classroom situations or lecture presentations also create significant difficulties for deaf and hard of hearing attendees. Even individuals skilled in lipreading have difficulty in these situations because the speaker’s face is rarely visible with sufficient resolution for lipreading. Sign language interpreting and captioning are two means of providing accommodation for participants unable to hear or understand the speech in these situations.

Sign language interpreters allow signers to participate in meetings by providing real-time translation of the spoken conversation into sign. This is a two-way translation service, such that the signing participant is also able to participate by having the interpreter speak their signed utterances. Remote interpreting is a technology that addresses the problem of a shortage of skilled interpreters, particularly in some locations. The interesting aspect of this is that the interpreter need not be present at the location of any of the conference participants. The deaf or hard of hearing participant views the remotely located interpreter on a computer display or TV screen. The interpreter listens to hearing participants by telephone and provides sign-language interpreting for the deaf participant. The interpreter also voices what the deaf person signs for hearing participants. This remote interpreting can be used similar to the telephone relay service, with participants in different locations (Video Relay Service, or VRS), or in situations where the participants are located in the same room (Video Relay Interpreting, or VRI).

Communication Access Real-time Translation (CART) provides real-time captioning, enabling discussions and presentations to be transcribed into text for deaf and hard of hearing participants. Typically, this is done by a person who creates the captions. As with sign language interpreting, the captioner can be physically present or remotely located, listening to the conversation by phone and transmitting the text via a network to a computer screen or projected display. The deaf participant types their questions or comments. That input is then read aloud for the other participants, either by a captioner or using computer text-to-speech technology (e.g., see Caption First, n.d.; Viable Technologies, n.d.)

The ability to automatically transcribe speech was envisioned more than 100 years ago as a technology that held great promise for deaf and hard of hearing people, even though such technology was hardly imaginable at the time (Fay, 1883). As speech-recognition systems have matured over the last quarter century, a number of applications designed for deaf users have been explored (Bain, Basson, Faisman, & Kanevsky, 2005; Stinson & Stuckless, 1998).

The Liberated Learning Project is one example of using automatic speech recognition in the classroom (Bain, Basson, & Wald, 2002). In this effort, the classroom teacher speaks into a microphone that transmits his or her speech to a computer to perform the recognition. The transcript of the lecture is displayed in close to real time on a screen at the front of the classroom. Shown in Fig. 45.2 is a classroom situation for the Liberated Learning Project.
While recognition technologies have improved over the years, they still do not attain 100% correct performance for dictation. To provide students with accurate transcripts for lecture notes, the professors who participate in the Liberated Learning Project review the transcript for inaccuracies and make corrections after a lecture is completed. The corrected transcripts are then made available to students (Bain et al., 2002). Other efforts that use automatic speech recognition for captioning use different methods for correcting errors in transcripts. These other methods include having a trained speaker “shadow” the speech to produce more reliable recognition, and/or having a person correcting errors in real time (e.g., see Bain et al., 2005; Robson, 2001; Viable Technologies, n.d.).

CONCLUSIONS

Computer technologies are very important in the lives of many deaf and hard of hearing people. These technologies can ease communication between coworkers, friends, family members, neighbors, and a variety of services. These technologies have also provided access for deaf students, employees, and individuals to have full access to rich multimedia services, shopping, news, and general information. In short, barriers long encountered by deaf and hard of hearing people are now being overcome through the use technology.

Deaf and heard of hearing users represent a population that, in itself, is diverse in both hearing and language experiences and skills. Applications that offer flexibility of language (e.g., captioning, signed English, or ASL) will be most accessible to users who have a hearing loss. At a minimum, however, developers and designers need to ensure that information is not carried by the auditory channel alone. Paramount is the need to ensure that any audible information, be it a sound alert, speech prompt, or other auditory event, have a visual counterpart. Such considerations are not only good design, but are also mandated by a growing number of regulations worldwide. The ability of everyone to participate in our increasingly technological society is crucial.

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