
Hearing Impairments

Anna Cavender¹ and Richard E. Ladner²

¹ Computer Science and Engineering, University of Washington
cavender@cs.washington.edu

² Computer Science and Engineering, University of Washington
ladner@cs.washington.edu

1 Abstract

For many people with hearing impairments, the degree of hearing loss is only a small aspect of their disability and does not necessarily determine the types of accessibility solutions or accommodations that may be required. For some people, the ability to adjust the audio volume may be sufficient. For others, translation to a signed language may be more appropriate. For others still, access to text alternatives may be the best solution. Because of these differences, it is important for researchers in Web accessibility to understand that people with hearing impairments may have very different cultural-linguistic traditions and personal backgrounds.

Key words: hearing impaired, deaf, hard of hearing, web accessibility, American Sign Language, sign language recognition, sign language avatars, captioning

2 Introduction

People with hearing impairments form a disability group very different than other disability groups. Because a large segment uses signed languages which are distinct from the spoken language used around them, the accessibility needs of this group involves language translation. In this section, we provide basic information about those who are hearing impaired and the distinct sub-groups of deaf and hard of hearing.

2.1 Models of Hearing Impairment

The hearing impaired disability group is very diverse and not necessarily of one mind. It helps to think of the three models of disability: (i) *medical model*, (ii) *rehabilitation model*, and (iii) *social model* (Oliver 1990).

In the medical model a person who is hearing impaired is thought to be broken, in need of repair to restore hearing. The ideal is a complete cure, but any step toward better hearing is an achievement. Hearing-aids and cochlear implants may partially restore hearing, but are not considered to be cures for deafness.

In the rehabilitation model a person who is hearing impaired is viewed to be in need of assistance to carry on a more independent life. In this model, sign language interpreters or real-time captioning are provided. Closed captioned television has become a standard in many parts of the world. There is a focus on lip-reading and speech training to help the person interact with hearing people without assistance.

In the social model a hearing impaired person is viewed to be part of a community or culture. The group of hearing impaired people who share a common language, such as American Sign Language (ASL), Japanese Sign Language (JSL) or British Sign Language (BSL), appear to be a distinct subculture with their own language and customs. In the United States, members of this group call themselves “Deaf” with a capital “D” and a certain degree of pride. Indeed, this group is uncomfortable with the term “hearing impaired” as it appears to accentuate something that is lacking and is not a term that they chose for themselves. In a similar way, another group in the United States prefers to call themselves “Black”, and rejects terms that were chosen by others.

In the United States, among those who are hearing impaired there is a large group who prefer to be called “hard of hearing” rather than deaf or hearing impaired. Again, the term hearing impaired is rejected because it was chosen by others. They recognize that the term “deaf” does not fit them well because they primarily rely on their residual hearing and speech, rather than on sign language.

An individual hearing impaired person may choose at different times to be viewed within any of these models. Those of us who are working in the accessibility field must recognize that we are essentially viewing hearing impaired people in the rehabilitation model. Nonetheless, it is important to recognize that there are other views that must be respected. An elderly person who has lost her hearing is likely not to know sign language and does not identify with Deaf Culture. A hearing impaired young man may have been brought up with hearing parents who tried everything to make him as “hearing” as possible, giving him a cochlear implant and extensive lip reading and speech training at an early age. Later in life, the young man may disable his implant, refuse to speak, and instead choose to be Deaf with a capital “D”. He rejects the medical model and the part of the rehabilitation model that tries to define him as hearing. He never felt fully included in the hearing world. However, it is likely that he accepts the part of the rehabilitation model that supports sign language interpreting and captioning, as neither of these has a focus on correcting his hearing.

From a strictly audiological point of view there are several ways to quantify hearing loss. The most common metric is the degree of loss in decibels (dB) from mild loss (25 to 40 dB) to profound loss (90 dB or greater). There is also a distinction between pre- and post-lingual deafness, meaning the deafness occurred before spoken language acquisition or after, respectively. With post-lingual deafness, speech training is much easier and often successful while with pre-lingual deafness, speech training is much more difficult and often unsuccessful. In either case, excellence at lip reading is not common. Interestingly, a person's identification as either deaf or hard of hearing is not a function of the degree and onset of hearing loss, rather, it is a personal choice of what the person feels comfortable calling him- or herself and with which group the person most identifies.

2.2 Demographics on Hearing Impairments

The World Health Organization estimates that in 2005 the number of people in the world with hearing impairments is 278 million, or about 4.3% of the world's population (WHO 2005). According to the National Center for Health Statistics, in 1994, there were 20,295,000 (8.6%) hearing impaired people in the United States and about .5 million of these cannot hear or understand speech (Holt et al. 1994). There appears to be no accurate statistics on the number of people in the U.S. who are fluent in ASL. It would appear that a large majority of those considered hearing impaired are not part of the Deaf Community and do not know sign language. A significant segment of this group are elderly people who have lost some or all of their hearing.

2.3 Legal Perspective

In the United States, the Individuals with Disabilities Education Improvement Act of 2004 (IDEA) and the Americans with Disabilities Act of 1990 (ADA) benefit all disabled persons including those who are hearing impaired. There are many regulations and laws specifically related to deaf, hard of hearing, and hearing impaired people. The Television Decoder Circuitry Act of 1990 requires that all televisions, 13 inches or larger, must have built-in closed caption decoders. This law does not apply to computer equipment that is capable of delivering video or television programming. There are federal regulations that require phone companies to provide TTYs to their deaf customers free of charge. More recently those regulations have been expanded to require free access to Video Relay Services. Most states have laws that give a deaf person the right to have a sign language interpreter in certain situations such as legal proceedings. In many countries there are similar laws and regulations to those found in the United States regarding persons with hearing impairments.

3 Deaf People and Sign Language

In this section we focus on the subgroup of people with hearing impairments who identify themselves as deaf. This group uses signed languages and have a rich and interesting history and culture (Ladd 2003, Lane 1984, Padden and Humphries 2005).

3.1 Sign Language

In the 1960's linguists began the study of signed languages in earnest. They determined that signed languages have essentially all the properties of spoken languages, except that the hands, arms, body, and facial expressions are used instead of speech. Up until that time, it was generally believed that signed languages were just a system of gestures devoid of the linguistic features of spoken languages. Although a sign language may be influenced by the spoken language found in the same region, it is distinct, with its own grammar suitable for the efficient use of the body and eyes, and not the vocal/aural system.

Probably the most studied signed language is ASL, with a large body of literature. Individual signs in ASL are composed of hand shapes, location, and motions. In addition, subtle shifts of body positions and facial expressions can also contain information. An important grammatical component of ASL that does not occur in spoken languages, is the use of classifiers. A classifier is a specific hand shape that can represent a particular person or object. The classifier is then put into motion in an iconic way to make a sentence or part of a sentence. For example, one can say "My car raced down the street, careened to the left, then to the right, then turned over" by setting up the hand shape classifier for "vehicle" as my car, then putting the classifier in motion, showing spatially what the sentence says. In fact, the ASL version would contain even more information about the timing and severity of the motions. There is a grammatically correct way to use classifiers; the description of a rollover is not simply iconic gesturing. Because of the complexity of the ASL grammar and its essentially infinite way to modulate signs to change their meaning, there is no universally accepted written form of ASL or any other sign language (Baker-Shenk and Cokely 1991).

3.2 Historical Perspective - Education

Schools for the deaf have played a pivotal role in the history of the deaf (Lane 1984). Perhaps the first significant such school was founded in Paris in the middle of the eighteenth century by Abbé Charles Michel de l'Épée. Although there was likely a signing community in Paris at the time, the bringing together of many deaf signers and the natural human propensity for language allowed the French Sign Language to flourish at the school. In the early nineteenth century Thomas Hopkins Gallaudet, at the behest of the father of a deaf child, was sent to Europe from the United States to research what was

known about educating deaf children. He brought back a French educator of the deaf, Laurent Clerc, who was also deaf. Gallaudet formed what is now called the American School for the Deaf in West Hartford, Connecticut with Clerc as its first teacher. The American School and many others that were founded in the United States accepted sign language both in and out of the classroom. At the time that the American School was founded, schools for the deaf in much of Europe had adopted a very different philosophy, stressing the oral method that promoted lip reading and speech, to the exclusion of sign language. The Congress on the Education of the Deaf held in Milan in 1880 passed a resolution that essentially stated that the oral method was superior to any other method and that sign language should be banned from education of the deaf. Only two countries voted against the resolution, the United States and Great Britain.

As a result of the oral movement, many schools for the deaf, even in the United States, were converted to oral schools. In spite of this effort to banish sign language, it did not die. Students would sign with each other in bathrooms and at night when they could not be observed. When they left school as adults they would congregate together at deaf clubs and at social events. Naturally, there were some students who were “oral successes” who never joined the Deaf Community after leaving school. Others who mastered lip reading and speech to some degree would join the Deaf Community for recreation and emotional support, but would join the hearing world for work and other needs.

In the United States, and in most parts of the world, there is now a recognition that oralism alone is not a satisfactory solution for deaf education. Educational philosophies such as “Total Communication” encourage the development of oral skills at the same time allowing students and teachers to use sign language in the educational process. The “Simultaneous Method” encourages teachers both sign and speak at the same time. Some schools promote teaching in “Signed English” where students are taught to speak with their hands in English language structure, borrowing signs from ASL. Some schools for the deaf offer “Bilingual Bicultural” education where ASL is promoted as a first language and English is taught as a second language.

In spite of the oral movement and numerous educational approaches, deaf people tend to eventually learn their indigenous sign language and choose to socialize with each other. When outside the Deaf Community, deaf people may choose to use the oral skills they have gained in school or abandon those skills altogether, instead relying on writing and sign language interpreters.

Regardless of what educational philosophy a deaf person is exposed to, it is not uncommon for an individual deaf person to struggle with the indigenous spoken language in both spoken and written form. For example, many deaf people educated in the United States have difficulties with English. Hearing people learn their native spoken language without actually being taught. Language comes naturally. They may have difficulty with the written form of the language, but not in speaking it. Those deaf people who have deaf parents (which is less than 10%) also learn their signed languages naturally. However,

over 90% of deaf children have hearing parents who do not know any signed language. Many of these children are not exposed to any language in a natural way during those early critical years of language acquisition. Oral training is not really a substitute for almost effortless natural language acquisition. This lack of early exposure to any language may be the reason so many deaf people have difficulty with written language.

3.3 Historical Perspective - Technology

There is another driving force in deaf history: technology. From primitive hearing aids in the shape of horns to modern high tech hearing aids to cochlear implants, there has been a desire to improve hearing. Modern cochlear implants can improve hearing considerably and can be beneficial for many, but they should not be considered a cure. The cochlear implant industry is growing at a rapid pace, especially since 2000 when the Federal Drug Administration (FDA) lowered the age to 12 months for implantation. There is concern within the Deaf Community that a new oral movement will start again, where implanted children are not allowed an opportunity to learn sign language because of the fear by some that oral skills will suffer from such exposure.

While medical advances have affected the Deaf Community, so too have advances in entertainment and communication technology. The Deaf Community was sad to see the demise of the silent movies in the late 1920s, but closed captioned television and subtitled movies introduced in the 1970s have opened television and reopened movies to deaf audiences. Until the 1960s the telephone was inaccessible. The invention of the acoustic modem in 1964 by a deaf physicist, Robert Weitbrecht, allowed surplused Western Union teletypewriters (TTY) to communicate with each other over phone lines. Modern portable TTYs became very popular in the 1980s. TTY relay services flourished in the 1990s allowing deaf people to communicate with hearing people through intermediaries who voice what is typed and type what is spoken.

As the popularity of e-mail, instant messaging, and text messaging have grown in the general population, the Deaf Community has rapidly adopted this ubiquitous technology, making TTYs essentially obsolete. The fastest growing new technology is the Internet-based video phone. Video phones allow deaf people to use sign language instead of text to communicate. This allows for a more natural conversation than can be achieved through a text approach. Video relay services, similar to TTY relay services, are also growing in popularity. The use of vlogs (video web logs) is a relatively recent phenomenon within the Deaf Community that allows for blogging in sign language. Vlogs are so popular that even Robert Davila, the president of Gallaudet, maintains a weekly vlog (Davila 2007). In Europe, Japan, and other countries with 3G networks, video phone calls can be made from cell phones.

The growth and popularity of the Web has further enabled deaf and hard of hearing people to participate mostly on an equal basis as hearing people.

Although there is a growing amount of multimedia on the Web, most information on the Web is still visually oriented. Whether or not we are in the “silent movie era” of the Web is yet to be seen. If so and audio and multimedia become dominant on the Web, then there may be trouble ahead.

4 Current Web Access Technology

Current and future research on Web accessibility for deaf people and people with hearing impairments has and will likely continue to focus on providing alternative or augmented visual information for inaccessible auditory information. This visual information can take the form of captions, transcripts, or sign language synthesis.

4.1 Embedded Video and Captioning

Captions provide accessible text versions of video and audio in real-time. While this access is essential for people with hearing impairments, it also benefits people who do not have speakers, people in noisy places, and people in noise-minimizing environments such as libraries and cubicle offices. In the case of vlogs discussed in section 3.3, captions or equivalent text transcripts can ensure accessibility for people who do not know the signed language. Captioning provides an alternative channel of information that may make content more understandable for people with learning disabilities and people learning a new language. Also, adding text to video and audio content makes it more searchable and indexable, which allows more people to discover and access those materials.

Common Web accessibility guidelines recommend that captions be both equivalent to the audio and synchronized with the audio. At a minimum, an equivalent transcript of the audio should be provided, even if it cannot be synchronized. Transcripts can also be useful to people who do not have the required video or audio player or who do not want to download the entire video or audio file. Either way, the captioning should be readily accessible through an easy to find link and/or instructions on how to enable the captioning.

There are two different types of captions: closed and open. Closed captions give the user the option to display or hide the captions and require a compatible decoder to process and display the caption data. The decoder determines the way in which closed captions are displayed; typically they appear as white text on black background toward the bottom of the screen. Open captions are incorporated into the video itself and cannot be hidden. But, because they were designed with the video, they can be placed in visually convenient locations on the screen and with appropriate colors and backgrounds. Designing open captioned video often requires expensive and time consuming video editing tools. The more common approach is to utilize closed captioning functionality within multimedia players such as Microsoft’s

Windows Media Player, Apple's Quicktime, RealNetwork's RealPlayer, and Macromedia's Flash. Each of these media players handles captions differently. Detailed technical instructions for including captions in Web videos can be found on the WebAIM website (WebAIM 2007).

Websites that allow users to upload and share personal videos are becoming more and more popular. YouTube and Google Video (both owned by Google) are two examples. Google Video supports closed captioning by allowing users to upload a file containing timestamped text to be played back with the video (Google Video 2007).

Several video editing software packages contain features for adding captions to videos. MAGPie, an authoring tool for assisting Web designers in creating captions and audio transcriptions, was developed by the National Center for Access Media (NCAM) at WGBH (MAGPie 2007).

4.2 Captioning Services

Several closed captioning and real-time transcription services such as Automatic Sync, Viable Technologies, and the Media Access Group at WGBH have been established to provide Web video accessibility service. Automatic Sync offers an automated Web-based service for captioning that parses text from voice into appropriate captions, synchronizes them with the audio, and formats the output for Webcasts, DVDs, and/or videotapes (Automatic Sync Technologies 2007). For on-line classrooms, Viable Technologies offers a captioning service using remote voice operators (Viable Technology 2007). The Media Access Group at WGBH can supply closed captions for media players when provided a television video with existing closed captions. They can also provide real-time captions for live Web events and Web conferencing (Media Access Group at WGBH 2007). These are just a few examples of services that can help Web designers to more easily ensure accessibility of both static and streaming video.

4.3 Access using Sign Language

As computer vision and computer graphics techniques have improved in recent years, progress has been made both in sign language recognition and sign language synthesis with the pursuit of automatically translating between written or spoken languages (such as English) and signed languages (such as ASL).

Sign language recognition uses computer vision techniques to convert sign language videos into written or spoken language (Ong and Ranganath 2005). Beyond video, sensors may be placed on the arms, hand, and/or face of the signer or data gloves may be used to assist in tracking the movements. Even the best recognition systems still use very limited word sets (under 100 words) to increase the probability that the movements detected are correctly matched with a word or sentence.

Sign language synthesis, or signing avatars, are systems that use complex translation systems to convert written or spoken languages to video sign language using human-like graphics. Some projects focus on translation challenges by attempting to formalize a grammar for sign languages (Zhao et al. 2000). Other projects (Toro et al. 2001, Vcom3D 2007) focus on graphics challenges by allowing the user to explicitly select hand shapes, hand positions, and whole words. The TESSA system (Cox et al. 2002) avoids some of the grammatical challenges by constraining the language to a specific domain (common phrases used in the post office) to aid in the communication between a deaf person and a clerk at a post office. Here, voice recognition software matches sentences spoken by the clerk to a limited set of pre-defined phrases that the graphics avatar is then capable of signing.

Translation is a difficult task overall for three reasons. First, computer vision techniques continue to struggle with real-world situations such as natural lighting and human skin. Second, synthesized human graphics that produce realistic sign language is still an open problem. And third, automatic translation between languages is already difficult in general, perhaps more so for sign language due to its lack of a written form. For example, computationally expressing the modulation techniques and classifiers discussed in Section 3 is problematic.

While sign language recognition may one day contribute to better communication between hearing and hearing impaired people, avatars may be more applicable to Web accessibility. Avatars could help create more accessible Web pages for people who consider ASL their primary language (see Section 3.2).

5 Future Research Directions

With extensive training on a single speaker, voice recognition can be very effective, and such systems are used real-time, automatic generation of captions. For example, many real-time television broadcasts use trained operators who repeat words voiced by actors and news and sports reporters into a voice recognition system. Voice recognition is not perfect. For example, it lacks punctuation, has poor accuracy, and is less reliable for multiple speakers. Highly accurate, speaker-independent voice recognition is still an open problem. Thus, increasing the accuracy and feasibility of voice recognition technology for many different situations is an important area for future research.

Given the imperfections of voice recognition, better interfaces for allowing voice captioners to quickly modify and correct the output is a high-need research area. Similarly, better interfaces for designers to choose good placement and timing for both real-time and non-real-time captions would also be interesting and useful future research.

Translation between written/spoken language and signed language continues to be a hot topic in research as working models still need consider-

able improvement. Current signing avatars are improving, but are a long way from being satisfactory. A different type of translation problem, yet equally challenging, would be converting linguistically complex language into a more universally accessible form. Such a system would benefit anyone whose primary language is not English (or the language being translated). For example, translation of legal documents to a widely understandable form would be a boon for everyone.

As the area of Human Computer Interaction (HCI) incorporates the concept of universal design, there is a growing need to include persons with disabilities on research teams, not just as test subjects. This is complicated somewhat with the deaf and hard of hearing group because of the potential language barrier. Nonetheless, with sign language interpreters and real-time captioning such participation is possible and will enhance the research.

6 Authors' Opinion of the Field

Communication technology developments in the last 40 years have opened up the world to the once sheltered Deaf Community. The technology has enabled deaf people to communicate remotely with each other, thereby keeping the community alive and vibrant. At the same time, it has enabled individual deaf people to communicate with more ease with hearing individuals. Medical advances are pushing the greater society to believe that deafness has been or soon will be cured. Hence, there is a constant or even increasing tension between those who love and cherish the Deaf Community and its unique language and those who believe that it is an anachronism that will soon disappear because of medical advances in technology. Unfortunately, most of those in the latter camp have never bothered to learn sign language and get to know deaf people on their terms.

Those persons with hearing impairments, especially those in the aging population, have benefited from advances in technology that improve hearing and support texting of any kind.

Automated captioning is improving, while language translation between spoken and signed languages is far from ideal. Including captions and language translation for Web accessibility is still basically up to the Web designers.

The amount of multimedia on the Web is growing rapidly. Currently, information on the Web is still visually oriented, but we may be in the "silent movie era" of the Web. Should multimedia become dominant on the Web, automated ways to achieve accessibility for people with hearing impairments becomes an imperative.

Acknowledgements

Thanks to Rob Roth for reading a preliminary version of this chapter and providing valuable suggestions.

References

- Automatic Sync Technologies. Captionsync. In *Automatic Sync Technologies*, 2007. <http://www.automaticsync.com/>.
- C. Baker-Shenk and D. Cokely. *American Sign Language: A Teacher's Resource Text on Grammar and Culture*. Gallaudet University Press, 1991.
- S. Cox, M. Lincoln, J. Tryggvason, M. Nakisa, M. Wells, M. Tutt, and S. Abbott. Tessa, a system to aid communication with deaf people. In *ACM SIGACCESS Accessibility and Computing*, pages 205–212, 2002.
- R. R. Davila. Bob's vlogs. In *Gallaudet University Web Site*, 2007. <http://www.gallaudet.edu/x3603.xml>.
- Google Video. Google video help center for captions. In *Google*, 2007. <http://video.google.com/support/bin/answer.py?answer=26577>.
- J. Holt, S. Hotto, and K. Cole. Demographic aspects of hearing impairment: Question and answers, third edition. In *Center for Assessment and Demographic Studies, Gallaudet University*, 1994. <http://gri.gallaudet.edu/Demographics/factsheet.html>.
- P. Ladd. *Understanding Deaf Culture: In Search of Deafhood*. Multilingual Matters, Clevedon, 2003.
- H. Lane. *When the Mind Hears: A History of the Deaf*. Random House, 1984.
- MAGPie. Media access generator. In *National Center for Access Media (NCAM) at WGBH*, 2007. <http://ncam.wgbh.org/webaccess/magpie/>.
- Media Access Group at WGBH. Media access group. In *WGBH*, 2007. <http://main.wgbh.org/wgbh/access/access.html>.
- M. Oliver. *The Politics of Disablement*. Palgrave Macmillan, 1990.
- S. C. Ong and S. Ranganath. Automatic sign language analysis: A survey and the future beyond lexical meaning. In *IEEE Transactions on Pattern Analysis and Machine Intelligence*, pages 873–891, 2005.
- C. Padden and T. Humphries. *Inside Deaf Culture*. Harvard University Press, 2005.
- J. Toro, J. Furst, K. Alkoby, R. Carter, J. Christopher, B. Craft, M. J. Davidson, D. Hinkle, G. Lancaster, A. Morris, J. McDonald, E. Sedgwick, and R. Wolfe. An improved graphical environment for transcription and display of American Sign Language. In *Information 4*, pages 533–539, 2001.
- Vcom3D. Vcommunicator signing avatar. In *Vcom3D*, 2007. <http://www.vcom3d.com/>.
- Viable Technology. Remote realtime transcription. In *Viable Technologies, Inc.*, 2007. <http://www.viabletechnologies.com/>.
- WebAIM. Web accessibility in mind. In *Center for Persons with Disabilities, Utah State University*, 2007. <http://www.webaim.org/techniques/captions/>.
- WHO. Deafness and hearing impairment. In *World Health Organization*, 2005. <http://www.who.int/mediacentre/factsheets/fs300/en/index.html>.
- L. Zhao, K. Kipper, W. Schuler, C. Vogler, N. Badler, and M. Palmer. A machine translation system from English to American Sign Language. In

Proceedings of the Association for Machine Translation in the Americas,
pages 54–67, 2000.