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By Gabriele Meiselwitz, Brian Wentz, and Jonathan Lazar

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Universal Usability: Past, Present, and Future

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Abstract

Computers are used all over the world in a variety of contexts by users with all levels of technical experience. This includes users such as kindergarteners, older users, people with various impairments, people who are busy doing other tasks (such as driving a car), and users with differing levels of education, literacy, and socio-economic means. The concept of computer interfaces that will be easy to use, for all of these users, in all of these different situations, is known as "universal usability." Making progress toward this goal requires innovations in techniques for gathering and understanding requirements, designing and developing interfaces, evaluation and assessment, development

and use of standards, and public policy, and much work in this field remains to be done. This monograph will present an overview of universal usability as it currently exists in the human–computer interaction literature, and will also present some future directions for work in universal usability.

1

Introduction

Many people use computers to access information electronically, to accomplish a variety of tasks. Computers are integrated into daily life in many ways, such as booking vacations online, paying bills, using the Internet to research health information, or even to earn college degrees online. Users with all levels of training and education, users with disabilities, the very young, and the very mature are using computers for many different tasks. This diversity makes it challenging for information and communication system designers to provide systems which will be easy to use by all, everywhere. Universal usability addresses this challenge and has the goal to design systems which enable the largest possible group of users to successfully use Information and Communication Technology (ICT) [205, 335, 337, 384]. Ben Shneiderman, a pioneer in the field of universal usability, defines universal usability in a more formal way as "having more than 90% of all households as successful users of information and communication services at least once a week" [334].

Universal usability is a concept known in other settings, and technologies like phones, televisions, or automobiles are addressing universal usability. Remote controls, mobile phone operation, and GPS interfaces all have the goal to make people's lives easier; yet, many of these technologies have significant drawbacks. Response times can be slow, operating instructions and help functions are often unclear and not intuitive, and small buttons and screens can make operation difficult [220, 287, 289, 329]. Electronic voting machines, for example, are expected to simplify the voting process, but some studies have shown that error rates are higher when comparing voters using e-voting machines with voters using traditional voting recording methods. In addition, older users, users with disabilities, and users with low literacy levels frequently experience problems using e-voting machines. Security and privacy concerns compound the issue and make this a political as well as an international issue [44, 229, 270, 387].

Computer technology with its frequent changes, updates, and new products makes attaining the goal of universal usability more difficult [300, 320, 334]. Some critics caution that this goal may only be reached by designing for a lowest-common-denominator solution and by limiting high end innovations [149, 334, 384]. However, many examples document how special accommodations can benefit all users. The most popular example is the sidewalk curb-cut. Pieces of sidewalk were originally modified (cut-out) to provide access for wheelchair users, but it turned out to benefit many other groups like delivery personnel, people with strollers, bicyclists, and skateboarders [222, 337]. Universal usability not only benefits users with vision, hearing, or motor impairment, but also users with environmental constraints, such as users working in areas under poor lighting conditions. Another good illustration is speech-recognition software, which assists users with physical impairments, but is also valuable for users who are busy doing other tasks (like driving a car) or users with special ergonomic requirements as a result of repetitive strain injuries [170, 222, 334].

Designing for universal usability not only improves the user experience, but also has several advantages for the business community. Businesses, including e-businesses, can reach a larger audience, and are able to expand their market share. Service and non-profit organizations can experience an increased volume of visitors, as well as a more diverse group of visitors to their web sites, providing a more successful diffusion of information and better service to all [12, 222, 267, 285, 383, 406].

Researchers have identified three primary challenges in achieving universal usability: technology diversity, user diversity, and gaps in user knowledge [66, 334, 337]. Technology diversity addresses the need to support a broad range of hardware, software, and network access; user diversity focuses on accommodating users with different skills, knowledge, age, gender, disabilities, disabling conditions, literacy, socio-economic means, and others; and gaps in user knowledge refer to the need to bridge the gap between what users know and what they need to know. Addressing these challenges will improve usability for first-time, intermittent, and frequent users, and it will also stimulate innovation and promote quality [12, 205, 320, 334, 351].

2

History of Universal Usability (UU)

Information and communication technology experienced enormous growth with the appearance of personal computers and the availability of the Internet and World Wide Web. Users of computing technology evolved from only a few, trained professionals to an ever-growing, diverse user community with a variety of needs and requirements.

Early efforts toward universal usability mostly focused on universal access, especially users with disabilities [80, 131, 205, 222, 244, 386]. The goal was not ease of use, but rather, trying to find ways simply to make technologies work for people with disabilities, and trying to find ways to get the user's assistive technology to interface with standard devices. The Trace Research and Development Center at the University of Wisconsin was established in 1971, and was an early leader and innovator in the field of universal accessibility [371]. The center was a coordinator for a nationwide Industry-Government Initiative on Computer Accessibility, and developed the first set of web content accessibility guidelines, which was used as the basis for the World Wide Web Consortium's Web Content Accessibility Guidelines [371, 391]. Ben Shneiderman also provides a good history of universal usability in the preface of the book *Universal Usability* [222].

As computers and technology became more pervasive in the workplace and in personal lives, the scope of universal access expanded to not only make computers more accessible, but to also make them more usable for a larger community of users, including the very young, the very mature, users with varying degrees of skill, knowledge, literacy, and socio-economic status, users with cognitive impairments, as well as users with different cultural backgrounds [43, 77, 222, 259, 284, 334, 384].

This broadened scope was mainly addressed through the design process, by promoting the integration of universal design in technology [77, 139, 163, 206, 207, 284, 354]. At that time, universal design was already a known element in the physical world, focusing on designing products and environments that are usable by all people, to the greatest extent possible, without the need for adaptation or specialized design. Wide doors, height-adjustable soap dispensers and towel holders in public restrooms, or door handles that require no gripping or twisting can significantly improve life with as little cost as possible not only for persons with disabilities, but also for short people, tall people, children, and older people [247].

Applying this principle to the Information and Communication Technology (ICT) design process emphasized the need to incorporate diversity into the design process early on. In many cases, accessibility and usability were considered at the end of the design or development process — more like an afterthought rather than an approach to inclusive design, which would involve users in the process from the beginning [163, 206, 284]. Ideally, universal usability would provide a single user interface that can be used by a diverse user population. For example, a program would provide speech recognition as an integrated option for all users, rather than offering it as an additional program or feature that users would have to purchase separately [67, 129, 163, 180, 205, 207, 284, 351].

Early implementations of accessible technology and software for mainstream personal computers were often expensive and difficult to integrate. The first touch screens or pen-operated devices, for example, were costly, and often lacked the accuracy needed to provide a satisfactory user experience [154]. AccessDOS, although free of charge, was an additional program that had to be obtained and installed in addition to the regular operating system in the early 1990s. Most operating systems today have integrated accessibility tools, which is a major improvement compared to the early implementations of accessibility technology [385].

The goals of universal design were also addressed in work chaired by Constantine Stephanidis and Gavriel Salvendy, who were instrumental in supporting these efforts in the European Community, including involvement in policy development in Europe [317, 354, 355]. Research in usability began to focus increasingly on a design process which would be more inclusive, and led to efforts on merging accessibility efforts with usability efforts [77, 205, 259, 359, 365, 370].

Ben Shneiderman, a leader in user-centered design and an advocate for usable information and communication technology for all, coined the term "universal usability" in 2000, describing the need for quality online services and novel social, economic, and political programs to reach the goal of having over 90% of all households as successful technology users at least once a week [163, 222, 334]. He further envisioned a research agenda which would concentrate on the three major challenges to universal usability: technology variety, user diversity, and gaps in user knowledge [334].

Since the origination of Shneiderman's idea, continuing developments in technology provide the basis for a broader support of hardware, software, and network environments. Mobile computing and virtual environments are steadily gaining popularity, offering a wide range of options for a diverse user community [12, 22, 43, 86, 91, 340, 385]. Multimodal, multi-layered, and adaptive interfaces have become increasingly important and provide an improved user experience, and increased performance for users with or without disabilities [55, 69, 93, 106, 259, 323].

Although many advances have been made in increasing accessibility and usability, unfortunately, there are some tradeoffs to consider. The high cost of specialized assistive technology often limits the availability for users, especially when considering population groups who do not own their own computer and must access information on public computers [385]. In addition, inclusive design that serves everyone equally well may be challenging. Some researchers suggest that the approach to providing a product for a large range of users should consider a view of *user-sensitive inclusive design* rather than *user-centered design*. This underscores the extra levels of difficulty involved when the range of functionality and characteristics of user groups is so great that it is not easy to design a product that is truly accessible by all potential users [149, 206, 284, 283, 384, 419].

Many studies have shown usability engineering to yield a significant return on investment, and the same is true for moving interfaces toward improved accessibility and universal usability. For instance, the Legal and General Group (an insurance and financial company in the United Kingdom), recouped the costs of making their web site accessible within the first year, and then continued to have a larger number of customers on their web site [394]. However, due to the development and budget constraints, designing and developing for universal usability are sometimes also associated with increased cost and inappropriate compromises (for example, modifications are made to suit a new version rather than to improve the interface), which potentially could lead to an overall product that does not necessarily present the best possible solution for the user [283, 407].

The advance of universal usability has been supported by government initiatives worldwide. Many countries have laws addressing specific aspects of universal usability (primarily accessibility). Technology used by the U.S. government, for example, is required to be accessible for users with disabilities. Some countries (e.g., Canada or Belgium) also address language diversity and require that government web sites be made available in several languages (Canada's languages are French and English, Belgium's languages are Dutch, French, and German). Education, work-place training, banking, and obtaining critical information (such as health, tax, or social security information) all involve technology to some degree and must serve a diverse user base. With information and communication technology becoming an important aspect of economic, social, and health equity, universal usability is a significant public policy concern [53, 68, 207, 222].

Much progress has been made toward universal usability, and research is moving forward to address new challenges and reach the full potential of universal usability [67, 217, 283, 300, 318, 321]. Unified user interfaces, for example, address how user interfaces can be automatically adapted to individual end users and context in which they are used [47, 320, 321]. Increased efforts are also under way to improve the situation for users with a variety of cognitive impairments, especially the aging population. Not only are people getting older, but longevity is increasing, emphasizing the need to investigate and support the special requirements of this user group [43, 55, 67, 275, 285, 283, 419]. Ubiquitous computing, the integration of technology into everyday life and tasks, suggests a shift toward ubiquitous accessibility, which may involve “pluggable” user interfaces (interfaces that are integrated into the environment) as an option that could provide accessibility [43, 61, 324, 375, 385]. Novel approaches, such as user empowerment, holistic approaches looking beyond just sets of user characteristics, and the connection of communities through universal sociability, are all efforts supporting the exploration of innovative directions to enable the widest possible range of users to be successful users of information and communication technology in the broadest range of situations [86, 135, 140, 217, 222, 283, 303, 322, 363, 375].

3

Technological Diversity

A major challenge for universal usability is the rapid technological growth and increasing computerization of society. Technological diversity requires the support of a broad range of hardware, software, and network access, and one of the major challenges for developers is to keep up with the speed at which technology changes as well as the variety of equipment utilized in user environments [132, 214, 334, 344].

3.1 Hardware

Although innovations like the USB port foster standardization, the rapid pace with which changes occur limits the options for developers to maintain and improve their products [149, 150, 334]. Not only is the task of keeping up with rapid advances of technology a challenge in itself, it has the potential to produce products of lesser quality. Products are often simply "updated" to work with the latest version of newer mainstream technologies instead of developers trying to update major advances in features and functionality [352, 370, 385].

Much improvement has been made in the field of input and output devices. With keyboards as the traditional form of entry for original text-based computer systems, pointing devices became instrumental as graphical user interfaces (GUIs) became prevalent. Joysticks, touchpads, multi-touch screens, and other pen-operated devices now provide additional options to the standard keyboard and mouse pointing devices [154].

Another group of input devices provides input based on sensing and recognition-based technologies. Physical signals are converted into an electrical signal recognizable by a computing device, including technologies such as eye tracking, speech-recognition, gesture recognition, or brain interfaces. The increase in CPU power and storage capabilities enables support of more sophisticated modeling techniques used in interpreting sensor outputs. The growth in mobile computing and the shift toward ubiquitous computing increase the demand for sensor and recognition techniques, and show a trend toward systems supporting a variety of interaction styles, which could be increasingly integrated into the environment and be available on demand [77, 93, 244, 385, 408].

Output devices provide feedback to users employing input devices, and as such are inseparable from input devices [154]. Visual and auditory output devices are integrated into almost every computer on the market today, but mobile and ubiquitous computing environments have increased the interest in non-traditional output devices such as haptic or olfactory feedback devices [214].

Although the quality of input and output devices has dramatically increased over the last decade, hardware issues still impact universal usability. Many systems, such as haptic interfaces that generate feedback to skin and muscles, multimodal systems using two or more combined modes, or virtual environments immersing users into a realistic 3D world, use a combination of hardware and software where multiple types of hardware devices can affect the user interface [404].

Mobile computing devices with smaller displays and often lower resolution, present a new challenge, which is compounded by the problem that most World Wide Web applications are designed and optimized for larger screens [154, 220, 289]. Designing web sites that are optimized for or dedicated to mobile device use and scaled back on complex functionality can result in higher user success rate and user satisfaction. Clearly identified links, auto-sensing user devices, and auto-forwarding users to specially-designed mobile sites can help avoid user confusion on how to access these web sites, and should be considered by developers [289].

Although advances in designing and developing technologies that support universal usability have been made, it remains difficult to ensure that users, who would benefit from these technologies, have access to them. Cost for hardware technologies, especially assistive technologies, can vary greatly, and some assistive technology that works with newer, mainstream technologies is unfortunately out of financial reach for many users [53, 100, 220, 385].

3.2 Software

One of the main software challenges for universal usability is the need for software to convert interfaces and information across media or devices, and to establish interaction between users and computers [52, 182, 334]. Communication or interaction between humans and computers can be understood as a message conceived through a modality. A modality is a human sensory channel to send and receive messages. Current human–computer communication primarily occurs using the modalities of vision and speech-based techniques, however, as computing becomes increasingly mobile and ubiquitous, modalities such as haptic (touch), kinesthetic (body posture and balance), gustation (taste), and olfaction (smell) may be integrated [124, 156, 182, 214, 233, 313, 360].

3.2.1 Vision

Human–computer interfaces were originally text-based, highly limiting the modality (and accessibility and usability) of human–computer interaction. The original transformation from text-based interfaces to graphical user interfaces is often identified as the major change in user interfaces [337, 385]. GUI interfaces have become ubiquitous with the existence of laptop computers, personal digital assistants, and cellular phones. Based on its success, the GUI has become the standard paradigm for human–computer interaction output today [52, 170, 179, 214].

3.2.2 Speech-Based Technologies

Speech-based techniques have several advantages, such as the ability to provide input to a computer without having to use a keyboard or mouse. Auditory output, including speech-based as well as non-speech-based output, is often employed for users who are visually impaired, but also has many advantages for all users. Screen readers (often known as text-to-speech) can read the content of a computer screen to users who are visually impaired. Global positioning systems providing spoken information, e-mail programs reading e-mails or sending auditory notifications, and computer-based phone programs emulating human–human communication, all offer additional information channels to users who are busy doing other tasks, and can also provide notification and error states [154, 214]. Multimedia or multimodal output often includes speech or sound to provide a more holistic user experience [154].

Using speech-recognition input reduces the amount of time spent interacting with a computer — people often speak much faster than they can type. Speech-recognition has advantages for users with or without impairments. Able-bodied users can have their hands available to complete other tasks, and users with impairments who may be unable to operate the keyboard or mouse, may now be able to interact successfully with a computer [100, 326]. Unfortunately speech-recognition also has some disadvantages. Recognition errors, the ambiguity of human speech, the effort it takes to correct these errors, privacy (e.g., speaking a password into a microphone), and noisy environments can cause users to question or abandon speech-recognition software [100, 102, 202]. There may also be a significant amount of training time required.

3.2.3 Haptic

Haptic interfaces generate sensations to the skin and muscles, including a sense of touch and weight. While visual and audio sensations are restricted to specific organs (eye and ear), sensations of force can occur anywhere on the body, making it much more difficult to synthesize [182]. Haptic interfaces are usually a combination of software and hardware. Tangible sensations to a user can become possible by using haptic interfaces, and feedback that typically is simulated visually takes on actual physical properties, such as mass or texture [214]. Haptic technology has potential to improve system use for scientific visualization, visually impaired people, or people with motor and other impairments. One of the technical challenges of haptic systems is to provide a contact surface that successfully imitates the perceptual aspects of human skin [190].

Haptic feedback can also improve usability for cellular phones. In one project a phone was able to detect and analyze a user's grip pattern, enabling the phone to change the mode, such as turning the display off when the phone was held to the ear [234]. Haptic feedback has also been used in a variety of educational settings and has shown to be very beneficial (especially for children) [130, 249, 252, 312, 349]. Project "Chemieraum" (chemistry lab) is an award winning German project employing tangible chemistry (Figure 3.1). In this project, students interactively explore molecules and atoms using touch-based interfaces, and receive haptic and visual feedbacks, thus enhancing the learning experience [130].

3.2.4 Kinesthetic

Kinesthetic interaction involves the act of users carrying out physical activity, and it is often used in connection with haptic interfaces. A number of games, including educational games, have successfully implemented kinesthetic interfaces. Simpler characteristics of motion,

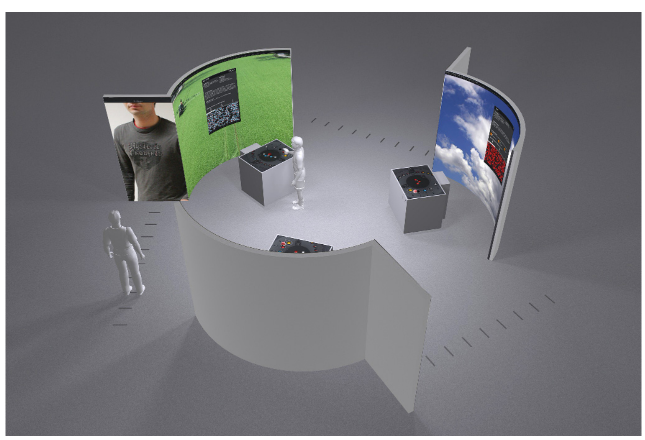

Fig. 3.1 Project Chemieraum showing wall projection, media table, and a puck with haptic feedback as an input device [115].

such as pressure sensors, are implemented in products like the Wii-fit balance board or dance music video games, which involve physical activity by the user [328, 402]. While most computer game and edutainment environments are geared toward visual and auditory users/learners, kinesthetic interfaces can significantly improve the user and learning experience by integrating physical interaction (especially for individuals who work or learn better using tactile and kinesthetic approaches) [269, 299, 328, 392].

3.2.5 Gustation and Olfaction

Gustation deals with the human sense of taste, and olfaction deals with the human sense of smell. Interfaces working with gustation and olfaction are often considered the last frontier in virtual reality [152, 417]. Currently, research regarding gustation and olfaction interfaces as output devices is an emerging area, and some studies are exploring the integration of these types of interfaces into the fields of human behavioral research and educational technology [183, 416]. Smell has been linked to memory and emotion, and showed potential in a study that used smell to trigger memory when recalling previously tagged photos. Although tagging with smell was less successful than tagging with text, performance with smell for participants was above random probability [36]. One study, involving olfactory interfaces, investigated whether the use of mint smell improved learning for a group of computer science students, and indicated that students who smelled the mint performed slightly better on educational activities [124, 125]. Whereas sensory interfaces are related to physical stimuli, gustation and olfaction are chemical senses. The difficulty in treating smell and taste interfaces in a similar manner to other sensory channels, and the difficulty in implementing unobtrusive devices limit the implementation of gustatory and olfactory interfaces, and suggest the need for longitudinal studies in this area [124, 177, 183, 416].

3.2.6 Multimedia

The functionality and usability of text-based user interfaces were first addressed by the introduction of multimedia to the user interface.

Multimedia interfaces integrate images, videos, sound, and speech, providing a richer representation of information and enabling a more diverse population to interact with information and communication devices. However, the rapid development of the World Wide Web, especially the number of diverse contributors to web content all over the world, makes providing universally usable multimedia content a challenge [217]. Web 2.0 technologies like JavaScript, CSS, or Ajax increase interaction and provide a more dynamic and rich web, yet they also increase complexity and present challenges to assistive technology [264].

A study investigating users with limited literacy and non-literate users showed that users strongly preferred a multimedia interface, and results of this study could have implications for pre-literate users (young children) or users with cognitive limitations [360, 260]. Gaming applications or cellular phones often successfully employ multimedia interfaces. In addition, situations that require a reduced cognitive load and distraction, such as driving a car or operating other machinery, could especially benefit from multimedia, but designers are encouraged to carefully consider the amount and diversity of multimedia to avoid problems with user comprehension and attention [7, 62, 192, 259, 419].

3.2.7 Multi-Layered

Multi-layered interfaces support strategies for increasing user control through sets of features being available to the interface at any moment. This approach could offer something such as a three-layer interface, where one layer is dedicated to novices working with the program, the second layer to intermediate users, and the third layer to expert users. Division into several layers has the potential to increase user acceptance and ease the learning process [13, 268, 336]. This multi-layered approach has been successfully used in games, where players encounter increased complexity as they move from beginner to expert level; or in search engines, where users are often provided the "quick search" and "advanced search" options; or in software where there is a "light" and a "professional" version available. Some of the difficulties with multi-layered interfaces include the complex task of defining what should be included in which layer, and the challenge of providing an easy and graceful way for users to move from layer to layer or between layers [109, 268, 336, 358].

3.2.8 Adaptable

Adaptable interfaces also increase user flexibility; they achieve this by providing interfaces with configurable options. These types of interfaces allow individual users to explicitly tailor the interface to their satisfaction [105, 189]. Personalizing web pages, creating home pages in social networking sites, and setting preferences in computer programs are all examples of adaptable interfaces. Adaptable interfaces are user-controlled, and increase usability by providing a familiar environment with user-selectable options. A simplified interaction process for individuals makes it easier to predict what will happen and comprehend how the system works [105, 133, 189, 196].

3.2.9 Multimodal

Humans use multiple sensory channels concurrently to interact with other humans and have a strong preference toward interaction that involves multiple sensory channels. This characteristic is represented in multimodal interfaces. Multimodal interfaces process two or more combined user input modes (e.g., speech, touch, gestures, body movements) in a coordinated manner. Multimodal systems also generally provide multimedia system output [295, 343]. Many cellular phones, PDAs, GPSs, and personal music and video players offer multimodal interfaces for users, including touch screens, speech recognition, traditional keyboard entry, and even haptic interfaces [39, 59, 197, 210]. A brain–computer interface using an electrode-studded cap and a keyboard represented on a computer screen was recently used to post on Twitter, and could be beneficial for individuals with locked-in syndrome, ALD, or spinal cord injury [372]. Multimodal input increases user flexibility by allowing users to select which modality (or combination of modalities) they prefer to use, and giving users the option to switch between them depending on the task to be completed, the environment, impairments, literacy level, or personal preference [20, 124, 295, 296].

3.2.10 Adaptive

The goal of increased flexibility for the user is also addressed in adaptive interface technology. Adaptive interfaces attempt to improve access to content and navigation for individual users; they can streamline menus, adjust e-mail spam filters, and aid in web search processes [58, 64, 107, 350]. This approach includes interactive systems that are able to adapt their behavior by involving some form of learning, inference, or decision making; however, they usually do so without users controlling the process. Adaptive menus in software applications (Figure 3.2), for example, can adapt to the most frequently used menu items by evaluating the frequency and duration of certain processes [52, 189].

It is important to contrast adaptable and adaptive interfaces. Adaptable interfaces are user-controlled, and they usually offer some selection of features that can be customized by the user. In contrast, adaptive interfaces are interactive systems that adjust to user behavior by applying deductions and conclusions. Adaptive interfaces often find application in complex interactive systems, diverse user populations, or diverse contexts, and can improve user performance and success [107, 189, 350, 364]. Older users looking to re-enter the workforce have been observed to overcome age-specific decreases in motor and cognitive activities, visual acuity, and short-term memory capacity, when aided by adaptive interfaces. Research that couples adaptive interfaces with

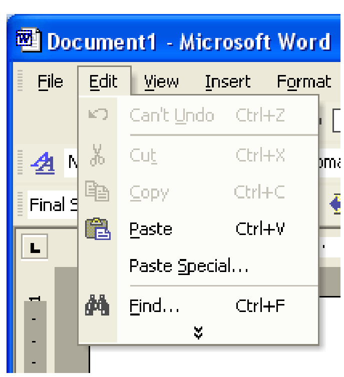

Fig. 3.2 Adaptive menu folding up menu choices that are infrequently used.

brain activity has successfully used these interfaces in the rehabilitation of users with neurological impairment due to brain injury [58, 133, 323].

3.2.11 Virtual Environments

Multimedia, multimodal, as well as adaptive interfaces are often employed in virtual environments (VE), including gaming environments where users experience immersion into a realistic setting. Virtual reality allows users to interact with a system in a natural way by hiding or helping users to ignore the computer, the interface, and other technologies [348]. Although originally more prevalent in the entertainment market, virtual environments are used for education and training (e.g., flight simulator, military training exercises) with great success and have applicability in physical and cognitive rehabilitation programs, nursing, and even virtual worlds [23, 25, 45, 172, 348, 374].

A study investigating the use of virtual nurses improved not only health care for patients; most patients also reported that they actually preferred receiving information through the virtual environment rather than through their doctor or nurse [25]. Furthermore, virtual worlds are experiencing a surge in the business world with the appearance of "Second Life" (Figure 3.3). Companies can create virtual representations of real business cultures, and users can participate in

Fig. 3.3 Second life avatar representing a user with visual impairment navigating virtual world, with seeing-eye dog.

the form of "avatars." Although these environments promote team building and company culture, there is also some skepticism about technical difficulties — especially graphical representation, motivation, and available appropriate activities [23, 122, 178, 282].

Virtual environments support interactive computing and often combine a multitude of input and output devices, making them ideal tools for supporting a range of tasks that improve performance [348]. However, this also creates some unique design challenges for virtual environments, such as navigational complexities, social implications, the consideration of the most appropriate modalities, and how users with a variety of abilities will access these modalities [348].

3.3 Network

Network access variety has been identified as a key challenge in technology diversity. Not only does access speed make a difference, but also the advent of wireless networking and increasingly multifunctional mobile devices require careful consideration of system components [30, 78, 334]. Some of the major user interface issues are response time, network availability and reliability. Users generally have little control over the networking process, status indicators do not always provide useful (or correct) information, and network delays are unpredictable [78, 185, 289, 368].

System response times are directly related to user productivity, error rates, and user satisfaction. Generally, shorter response times lead to higher productivity, reduced error rates, and higher user satisfaction. User frustration is also an increasing concern; and network disruptions, confusing error messages, viruses, and spam cause dissatisfaction in the Internet user community [54, 185, 309].

In addition to network connections, the increasing use of mobile devices presents a challenge to many users. Although in the USA, 78% of adults have a cell phone and 55% have broadband at home, a third of all individuals with either cell phones or Internet need help to set up or use new electronic devices [111, 161]. Average success rates of using web sites on mobile devices are reported at 59%, compared to 80% success rates when using web sites on a regular PC [289].

The main usability issues for mobile users are small screens, awkward input, and mis-designed sites. Often, web sites are designed for desktops and are simply displayed on mobile devices without offering a mobile version of the site [198]. Tests show that the user success rate is substantially higher (64%) when individuals access sites specifically designed for mobile devices. Higher device quality, such as larger screens, full keyboards, and touch screens, also significantly increase the user experience. GUIs and personalization of interfaces (as well as adaptive interfaces) further improve user interaction with mobile devices [198, 289, 306].

The trend toward ubiquitous computing and the demand of having computers readily available from any location have increased the consideration of wearable computers (Figure 3.4). The availability of wireless networks, and smaller, portable devices help to realize this goal. Wearable computers are found in a variety of settings and environments, and include smartwatches (wearable smartphones), health-monitoring and health-supporting devices, and gaming environments [148, 286, 298, 340].

Fig. 3.4 Golden-i® head-mounted wearable display by Kopin, including natural speech recognition interface for wireless remote control [213].

Future research in the field of technology diversity offers a wide range of options, including collaborative development of a common open-source technology core which could provide the basis for different types of assistive technology, pluggable interfaces on demand, sensors embedded into the environment, context-aware and adaptive systems, complex heterogeneous environments, and an increasing shift from a "one size fits all" mentality to computing devices individually tailored in a sophisticated way [150, 146, 154, 340, 385, 408].

4

User Diversity

User diversity is understood as supporting and accommodating the largest possible range of users, including users with a wide range of impairments (such as perceptual, motor, or cognitive impairments), users with learning disabilities, users with different skill-, knowledge-, or literacy-levels, users of different age, gender, socio-economic status, and from various cultures [79, 139, 222, 284, 300, 334, 384].

4.1 Impairments

An impairment refers to any loss, abnormality, or limitation of body structure or function, whereas a disability refers to difficulties that an individual may have in conducting a task or action; as such, impairments may cause a disability [184]. Functional impairments is a group of impairments that affect a person's ability to use a computer [204]. Within this group, perceptual impairments in universal usability often address the areas of visual and auditory impairment, since the majority of information and technology communication relies on this for successful interaction between users and technology [184, 325, 341]. However, motor impairments as well as cognitive impairments can also restrict the extent to which users can successfully interact with information and communication technology. Users with motor impairments may have difficulty operating a keyboard and mouse, and users with cognitive impairment may be hindered by the complexity of an interface or may have difficulty reading and comprehending information [204]. The following section will address these major impairment categories and their relationship to universal usability. Table 4.1 gives a brief overview of common issues facing users with impairments and was adapted from Keates [204]. The chapter will conclude with a table illustrating the cross-benefits of adopting universal usability for users with a variety of impairments.

4.1.1 Perceptual Visual

In any discussion of user diversity and impairments it is essential to emphasize the area of perceptual visual impairment due to its wide-reaching impact on individuals throughout the world. It is estimated that there are nearly 314 million individuals worldwide who are visually impaired, including 45 million who are blind, according to the World Health Organization which identifies four levels of visual function: normal vision, moderate visual impairment, severe visual impairment, and blindness [414]. In the USA, the terms blind and visually impaired are

Table 4.1. Common issues facing users with impairments.

Impairment	Issues
No Residual Vision	Cannot use mouse for input Cannot see screen
Low Vision	Difficulty with small characters Difficulty with contrast
Auditory	Cannot hear audio or video Cannot hear system alerts or alarms
Motor	Limited or no use of hands Tremors Limited range of movement Limited speed Limited strength
Cognitive	Difficulty reading information Difficulty comprehending information Difficulty writing

used interchangeably. Blind users face many unique challenges when using technology at home and in the workplace, including difficulties in accessing web sites and using corporate software, because computer interfaces are still primarily visual. To better understand the variety of issues that blind users face, it is important to first understand how a blind individual uses software.

Users who have low vision may simply approach that challenge through screen magnification, such as ZoomText [5], changing the color or font size of the web site or software that they are attempting to use, changing their operating system settings, customizing their software, or applying their own style sheet. This approach, of course, assumes that the technology in focus has the flexibility to allow a user to change the color or font size. Too often web sites are developed without significant effort to separate the presentation from the content so that the presentation can be easily modified to accommodate user needs [75]. Cascading style sheets provide the ability to offer presentation choices that separate from the actual content, and can make web site presentation much more flexible (Figure 4.1).

Screen magnifiers are built into current versions of popular operating systems (such as Linux, Mac OS, and Windows), and there are many other assistive technology products (including software and portable hardware devices) that can also provide more advanced magnification for screen content. One example of a portable hardware device for magnification would be the RUBY Handheld Magnifier from Freedom Scientific [118], and a simple example of a software device for screen magnification is the Magnifier tool built into the Windows operating system (Figure 4.2) [271].

```
p {font-face: arial; color:black}

th {background-color:#D3D3D3;}
td {background-color:#FFFAF0;}

a:link {color:#8A2BE2;text-decoration:none;}
a:hover {color:red;font-weight:bold;text-decoration:none;}
a:visited {text-decoration:none;}
```

Fig. 4.1 Cascading style sheet content, like the sample above, allows web site formatting aspects to be separated from web site content.

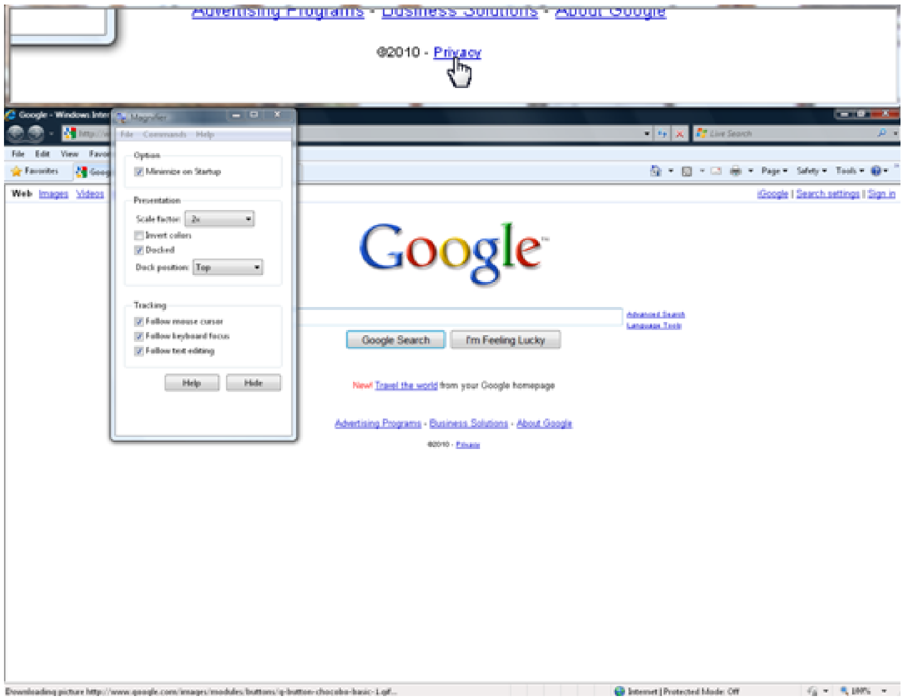

Fig. 4.2 The Magnifier tool is built into the Windows operating system.

Some type of assistive technology is necessary for blind users (with no residual vision) to use computer software. One approach for users who are completely blind would be through the use of Braille and Braille-supported devices. The primary challenge with relying on Braille devices to access and use technology is that they are often very expensive, and the rate of Braille literacy among blind users is very low [277]. The consumer cost of a Braille device can be from $1,500 to as much as $15,000 [119, 280]. There are many Braille-supported devices available today, including devices that work with computers, laptops, cell phones, and PDAs. One popular manufacturer of Braille devices is HumanWare. BrailleNote is a stand-alone device from HumanWare that attempts to provide accessible applications to blind users [173]. PAC Mate is a Pocket PC device from Freedom Scientific that can interface with a computer or laptop and uses a refreshable Braille display [117]. Refreshable Braille displays use pins that automatically protrude

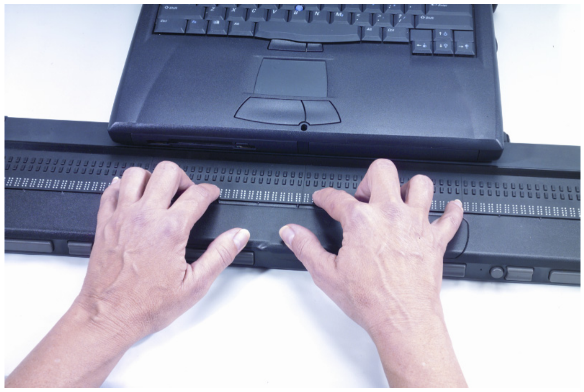

Fig. 4.3 Refreshable Braille displays like the Focus 80 from Freedom Scientific mechanically protrude and retract pins to form Braille characters.

and retract to form Braille characters which provide an output alternative to a visual display (Figure 4.3) [95].

Screen readers are one of the most common assistive technology tools used by blind users [224]. A screen reader is a software application that is used through a keyboard-based interface so that information that would otherwise be displayed to a visual output device (like a computer screen) can be translated to synthetic speech output so that a user can listen to the content (using headphones or speakers). Screen readers can be used with most common software applications, including office productivity software (such as MS-Word or Excel), and web browser software like Internet Explorer or Mozilla Firefox [95]. Two common examples of screen readers are JAWS from Freedom Scientific [116, 141] and Window-Eyes from GW Micro [141]. Besides low Braille literacy rates, other reasons for the widespread usage of screen reader software include the low learning curve, the fact that the software will work with existing standard computer hardware, and high cost of Braille displays [224].

HearSay, a non-visual web browser under development at Stony Brook University [28], and WebAnywhere, a portable screen reader developed at the University of Washington [26], are two examples of alternative approaches to screen readers such as JAWS and Window-Eyes. HearSay is designed to be a context-directed browser in that it allows a user to skip irrelevant content and easily navigate from one page to another. HearSay uses either words or sounds to help the user distinguish between various types of HTML elements as the user listens to a web page. WebAnywhere is a free, web-based screen reader that was designed to allow access to the Internet from any computer without the need for special software to be installed. Using server-side text-to-speech and a web proxy combined with client-side scripts, WebAnywhere provides an alternative solution to expensive screen reader software. The down-side of WebAnywhere is that unlike screen reader software, it only works with web-based applications and not with desktop applications. One of the goals of WebAnywhere is to lower software costs for those who might otherwise be unable to afford the cost of a screen reader to use web browsing software [26].

Software called iGraph-Lite was developed to provide better accessibility to graphs that are commonly presented in mainstream software applications such as Word, Excel, and PowerPoint as well as other forms of electronic media. While screen readers can read the text portions of a graph that has been properly labeled, complex graphs are often primarily inaccessible to blind users. The iGraph-Lite software tries to solve this inherent problem by analyzing and providing verbal descriptions of information contained in statistical graphs [103]. Another software package, aiBrowser, attempts to address the growing problem of inaccessible multimedia content embedded in many software applications and web sites as well as the shortcomings of popular screen reader software such as JAWS, by allowing the use of simple shortcut keys to control multimedia content (such as playing, pausing, and changing volume). When testing aiBrowser, users found that there was greater control over media settings as well as the requirement of fewer keystrokes [273].

Graphical user interfaces have provided many benefits to sighted users, but the use of graphical interfaces makes the use of technology more difficult for blind users. Only textually represented aspects of an interface can be represented for blind users by using Braille or speech output devices [81]. Some of the issues related to usability impact both blind and sighted users, but there are specific and unique problems that only affect blind users, including problems with assistive technology itself [302]. The linear nature of output from Braille and speech devices only allows a blind user to be able to focus on one specific part of screen at a particular time, in contrast to the visual overview and perspective that can be viewed by a sighted user [95]. Another challenge is that many web sites and software applications are not designed with the use of a screen reader in mind, and as such they do not always have equivalent textual content for the screen reader to use as it relays the information on a given screen [224].

Blind users also face many other accessibility and usability problems when using software and web sites. An example of the usability challenges that are faced by blind users is well illustrated in the Lazar et al. study on the frustrations that screen reader users experience on the web, which identified poorly labeled links and forms, missing or confusing alternate text for graphics, and problems with PDF files as being some of the challenges commonly faced by blind users on the web [230]. Computer frustrations that impact the ability to complete a work task have been shown to affect the mood of blind users [226]; and it is also known that blind users are more likely to avoid content when they are aware, in advance, that it will cause them accessibility problems such as the problems presented by dynamic web content [27]. Blind users are also often forced to discover some sort of workaround to complete a particular task [333].

Developments in technology have expanded the level of opportunity for blind users and have removed some of the physical limitations to various work tasks [126]. However, new technology is often inaccessible, and consequently, the usability of technology or the lack of it greatly determines the level of disadvantage for blind users [218]. Accessibility evaluation tools are essential for measuring technical compliance to standards such as WCAG and Section 508 (as illustrated in Section 9). As current and future technology products become more accessible, the available opportunities for blind users will increase. This should underscore the importance and urgency of universal usability.

4.1.2 Perceptual Auditory

Graphical user interfaces using mouse and keyboards as input devices have dominated computer technology, however, many interfaces are now offering multimedia and speech interfaces to support a larger range of users. While the integration of speech-based input and output can benefit some users, it can be a detriment to others. Sounds are being used in many systems as a form of alerts, such as notifications about incoming e-mails or errors. Sound is also an inherent component in video or movie clips (e.g., YouTube or online news channels).

Users with hearing impairments may be unable, or may have significant difficulty using speech-based technologies; often these users not only experience difficulty with sound, but also have difficulty with reading [144, 325, 327]. Multimedia interfaces can improve the situation for users with hearing impairments by providing captioning or signing [32, 35, 313]. Captioning presents a print alternative to the user in addition to speech and sound events; signing employs technologies representing signed languages on the computer. Sign language representation on computers ranges from fingerspelling (each letter is assigned a handshape), to live persons signing, or even to signing avatars using virtual reality techniques [92]. Of particular interest are signing interfaces which use sign recognition techniques as a subset of gesture recognition. These techniques involve multimodal input, and signers often employ haptic interfaces, such as specifically designed gloves or sensors, allowing a computer to track hand and arm movements [35, 92, 235, 388]. Although these technologies provide increased support to users with hearing impairments, it seems unlikely that all video content available on the Web will be available with captioning in the near future (especially considering the amount of user created video content such as video on YouTube) (Figure 4.4).

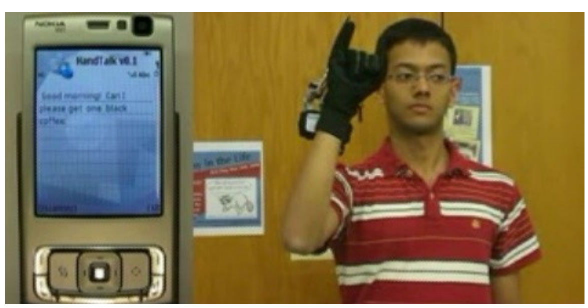

Fig. 4.4 HandTalk glove, developed by students at Carnegie Mellon, converts hand gestures such as sign language into spoken words [48].

As automatic speech recognition systems continue to mature, a number of applications have explored their capabilities for users with hearing impairments. One example is the Liberated Learning Project which uses speech recognition in the classroom. As a teacher speaks into a microphone, a transcript of the lecture appears in almost real time on a screen at the front of the classroom [17].

A recent project explored how to enhance the musical experience for the deaf. Using a haptic chair, sensory input (vibrations) was provided through touch, and a computer display of visual effects corresponded to the music [276].

Auditory input and feedback have also increased the performance of older adults when combined with other multimodal interfaces [93]. As a result, it is recommended for designers to offer flexibility of language, such as captioning or signing. At a minimum, designers should consider that any audible information, whether sound alert, speech prompt, or other auditory event, should have an equivalent visual counterpart [144, 327, 389].

4.1.3 Motor

One of the biggest challenges for users with motor impairments is the use of a conventional mouse and keyboard. Motor impairments can have a number of causes, such as cerebral palsy, Parkinson's disease, spinal cord injuries, arthritis, or repetitive strain injuries. The related technical challenges often include lack of sufficient mobility, dexterity, and endurance [147, 204, 325, 409]. Many users with motor impairments use input devices like joysticks, trackballs, or touchpads (often in combination with speech recognition), some of which are already integrated into other assistive devices like wheelchairs. In addition, special purpose keyboards with keys having a different order or with a keyboard that is shaped differently, soft keyboards operated by a stylus or pen, and accessibility software that controls keyboard and mouse behavior can address more specific impairment challenges [87, 196, 325]. Unfortunately, the appearance of mobile and/or handheld devices with their small keypads, non-traditional arrangement of keys, or interaction with a small stylus or pen provide new challenges for many users with motor impairments [154].

Motor impairments can vary greatly; while users with muscular dystrophy remain relatively accurate in fine motor skills, the operation of controls is often slow, and users tire easily. In comparison, users with cerebral palsy or Parkinson's disease often suffer from tremors, which impacts their fine motor skills [325]. Other users may have difficulties controlling voluntary movements, or experience pain or discomfort when operating certain computer controls. Some users with motor impairments also suffer from a limited ability to speak, which reduces the use of speech-based recognition systems [80, 325]. Dysarthria, a motor-speech disorder due to weakened muscles of the mouth, face, and respiratory system, often occurs in users with cerebral palsy [175]. Speech-based recognition systems on assistive devices are often limited, but recent research has successfully used an adaptive text-to-speech synthesizer to produce a personalized voice for users with this condition [195].

The integration of text entry into the operation of trackballs, joysticks, as well as touchpads could be of great assistance for a large range of users. Regardless of their specific motor impairment, users could "write" using a trackball, joystick, or touchpad [409, 410, 411].

Research has also investigated the use of eye gaze as an input modality, as well as software which can automatically identify and correct typing errors based on word frequency, keyboard layout, and typing error patterns [181, 248]. The use of the eye as an input device is essential for an individual having no other means of controlling an environment and can enhance the user experience in a variety of applications, such as gaming or attentive user interfaces, which behave according to the attentive state of the user. However, explicit control through eye tracking is difficult, and commercially available eye-tracking systems are relatively expensive, making them out of reach for many users [19, 181, 200, 248]. Again, adaptive interfaces have shown great promise to serve users with motor impairments, and test results have shown that users become faster, make fewer errors, and favor the adaptive interface over interfaces with set default features [120, 128, 199, 200].

4.1.4 Cognitive

Cognitive impairment refers to a limitation in cognitive ability, which applies to a large number of computer users. Almost all users experience some change in cognitive ability over time, and the process of aging can affect a large range of impairments. For some users, these cognitive impairments are very specific, but for others, they can be very vague [9, 208, 294]. Cognitive impairments can include a variety of factors, but are most often related to: (a) the limited ability to use selective attention, enabling users to focus on specific tasks and to ignore others; (b) memory loss and dementia, affecting the functions of memory; and (c) visuo-spatial, iconic, and verbal abilities, relating to difficulties decoding layouts, problems with GUIs, and comprehension of metaphors [239, 285].

Key concerns when developing interfaces for users with cognitive impairments are speed and complexity. Many users significantly increase their performance when interactions are carried out at the user's own pace. Often, increased time for processing is needed, not only for the actual cognitive processes but also for the sensory stimulus needed to trigger these processes [285]. Clear layout can significantly decrease time and increase successful interaction, benefiting not only users with cognitive impairment, but also users with limited literacy levels or users with specific learning difficulties. Clear layouts and reduced complexity have been shown to assist users with autism spectrum disorders, dyslexia, and older users with decreased cognitive ability [70, 285, 305, 401].

Recent research explores the option of adaptive displays in which interfaces can learn to predict information that users desire or need in different contexts. These interfaces are able to select information relevant to the situation, and use this information to decide when and how to update the display, or adjust menu functions, thus reducing the cognitive burden on the user [194, 239, 245, 361].

Users with cognitive impairments may also experience deficits in social skills, including social communication and interaction [101, 366]. Computer-mediated software or agents have shown to support language development and building of social skills for children with autism spectrum disorders (ASD) [311, 366]. Virtual peers, for example, have shown to be a useful intervention for children with autism. Participants in a study particularly improved in interaction relying on contingency and the ability to maintain, follow, and build on a conversation [367]. Robots have also shown the potential to improve social communication of children with autism. Children interacting with a humanoid robot demonstrated increased communicative competence after participating in social skill building activities such as imitation and role-playing [311].

Most importantly, it is essential for designers to become fully aware of the range of cognitive impairments and the changing nature of cognitive functionality. "Dynamic diversity" describes the reality that already diverse abilities grow more diverse dynamically as people age. It also highlights that abilities at any given time are subject to a wide variety of factors, such as environmental factors, fatigue, or time of day. As a result, interface design should be increasingly dynamic, providing a means for adapting to the changing needs of users [70, 77, 207, 285].

4.2 Learning Disabilities

Learning disabilities (sometimes also called learning difficulties or learning disorders) are neurological-based processing problems and can interfere with acquiring basic skills such as reading, writing, or math. Each individual with a learning disability is unique and shows a different combination and degree of difficulties (commonly with uneven areas of ability). For instance, a person with dyslexia who struggles with reading, writing, and spelling, may be very capable in math and science. Processing problems can be in either one or more of the following four areas: input (getting information into the brain), integration (making sense of information), memory (storing and retrieving information), and output (getting information back out) [232]. Two of the most common forms of learning disabilities are dyslexia (a language and reading disability) and dyscalculia (problems with math and math concepts) [79, 232, 283].

Research regarding learning disabilities is sometimes included in the area of cognitive impairment, and often users with learning disabilities face similar issues as those with cognitive impairment

[79, 232, 285]. The range and variety of symptoms of any one person with a learning disability are a major challenge for system developers; a single approach is not sufficient for the range of problems presented by the population of people with learning disabilities [138, 285, 419]. Some of those problems include readability levels of online information, disorientation during navigation and search processes, and deficiencies in metacognition (which supports strategic planning and monitoring processes) [139, 259].

Dyslexia is one of the most researched areas, and findings show that multi-sensory approaches, user-configurable systems providing alternative and personalized configuration, and integrated inclusive design approaches, can significantly improve the experience and success of users with this learning disability. Additional recommendations for designers include limiting user choices, minimizing screen clutter, and maintaining consistency in all aspects of the design [96, 139]. In principle, these approaches can also be applied to other groups, such as those with limiting cognitive conditions including Down syndrome, autism Spectrum disorders, and users with limited literacy levels. These approaches could also potentially benefit all users [8, 211, 285, 318].

4.3 Low Literacy Levels

World literacy statistics show that literacy rates vary greatly. Europe and the United States show low illiteracy rates of only approximately 10%, however, in some of the developing world countries illiteracy rates are much higher (30% to over 50%) [378]. However, even countries with high literacy rates can include people with low literacy levels. Low literacy levels affect a large number of Americans, and 50% of adults in the United States cannot read a book written at an eighth grade level. Almost half of Americans read so poorly that they cannot find a single piece of information when reading a short publication [90]. Low literacy levels cause children to drop out of school, and this can lead to unemployment or incomes at or below the poverty level [90].

Low literacy levels may also be related to learning disabilities, and children with a learning disability have a higher likelihood of becoming an adult operating at a low literacy level. However, other factors such as low educational attainment or social deprivation may also be involved in causing low literacy levels. With the ubiquitous nature of information technology, low literacy levels are becoming a major barrier for many Americans as they compete for work or try to improve their quality of life [104, 139, 369, 393].

Designers could improve the current situation by considering the grade-readability of web sites during the design process. Successful interaction with government, insurance, education, or health-related sites can be greatly improved by keeping the readability level at or below an eighth grade level. In 2008, only 13% of evaluated U.S. government web sites were at an eighth grade reading level or below, which is a considerable problem [18, 288, 400].

Support for multimedia output has shown to be beneficial for users with low literacy levels. However, designers should consider multimedia integration carefully; multimedia can also cause user confusion, especially when other learning disabilities or cognitive impairments are present [139]. Best results are achieved when output is repeatable, and the pace is under the control of the user. Additional recommendations for designers regarding low literacy levels include chunking of information, presenting content in sequence, repeating information from screen to screen, and maintaining consistency in language and procedures [96, 139, 308].

Redundant coding can also play a role in improving interfaces for users with cognitive disabilities, visual impairments, learning disabilities, or low literacy levels. The concept of redundant coding involves the representation of information in multiple ways so that a user who may otherwise not understand or access the information will have an increased opportunity to comprehend it [382]. Practical examples of redundant coding include providing navigational links in multiple formats so that all users can access the links, and using more than just color to highlight important items on an interface. An example of using redundant coding on an interface is well-illustrated in the Federal Aviation Agency's online Human Factors manual (Figure 4.5) which shows an illustration of using shape and color on a visual display [99].

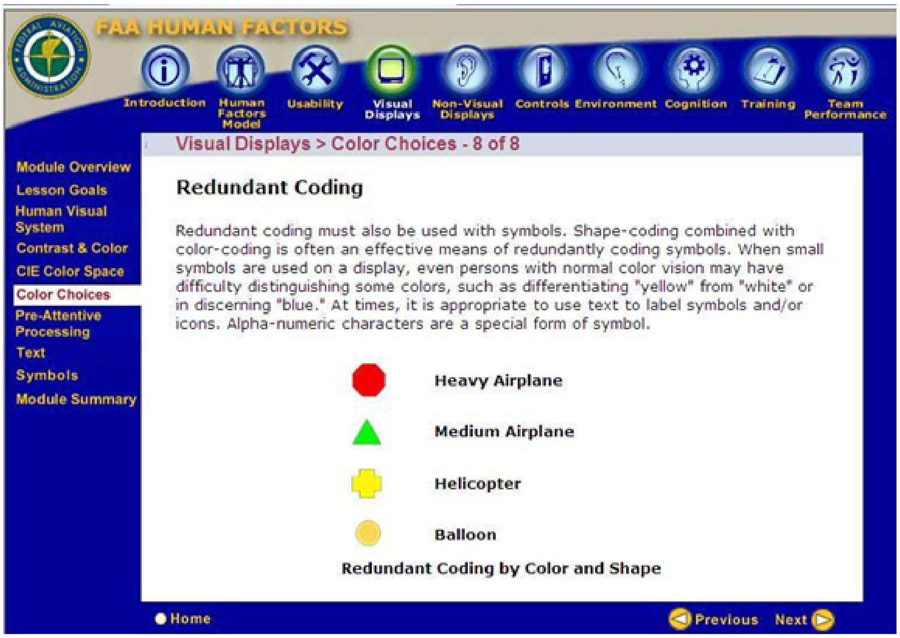

Fig. 4.5 FAA human factors illustration of redundant coding [99].

4.4 Age

Internet users span a wide range of age groups, and although the Web is more frequented by younger age groups, larger percentages of older generations are online now than in the past. While the most popular Internet tasks for the younger generation are entertainment and communicating with friends and family through social networking sites and blogs, older generations primarily use the Internet for e-mail, shopping, banking, and as a tool for research. Older users also outpace the younger generations when it comes to online health information, government web sites, and religious information [112].

4.4.1 Older Users

Considering the aging population and increasing longevity, issues on how to design and develop for this population are extremely important. Many technology products are not easily usable by older people, which is largely attributed to designers being unaware of the needs of users with varying abilities and how to accommodate them [67, 77, 207, 284, 288].

Moreover, cognitive, perceptual, and motor abilities decline with age and have negative effects on performing many tasks, including basic pointing and selection tasks that are commonly required to use graphical user interfaces [55, 66, 274, 413]. Studies indicate that older adults often experience usability problems relating to search performance and the complexity of the user interface. Older adults use less efficient strategies, make more errors, and have more difficulty recovering from these errors; however, with training, practice, and support, older adults can successfully complete their tasks and report a positive user experience [67, 93, 291, 405].

The challenge for interface designers is the fact that aging is a very individualized process. Abilities, skills, and experiences vary considerably within this group of older adults, and chronological age alone is not a predictor for a particular behavior or condition [66, 67]. Changes in cognition, such as declines in memory, spatial cognition, or processing speed, may make it difficult for an older user to locate information on web sites, manipulate images or patterns, or perform tasks at the same rate as younger users. The aptitude for learning generally also declines; however, knowledge acquired through education and experience usually remains stable [58, 66, 67, 291].

Since these cognitive abilities have an impact on technology-based tasks as well as technology adoption, there are a number of implications for system designers. Design changes such as highlighting relevant information, reducing complexity, and reducing demands on working memory have shown to produce a reduction in error rates and faster performance. Increased support and training such as special training programs for adults, or tailored online help systems, have also shown to be beneficial for older adults [66, 108, 149, 155, 186, 291, 342].

Figure 4.6a and 4.6b show the NIH Senior Health web site, which was developed as a joint project by the National Institute on Aging and the National Library of Medicine. The site provides three methods of addressing visual limitation in older users: text size, contrast, and a speech interface [151].

Fig. 4.6a NIH Senior Health web site controls addressing visual limitation in older users: text size, contrast, and a speech interface [151].

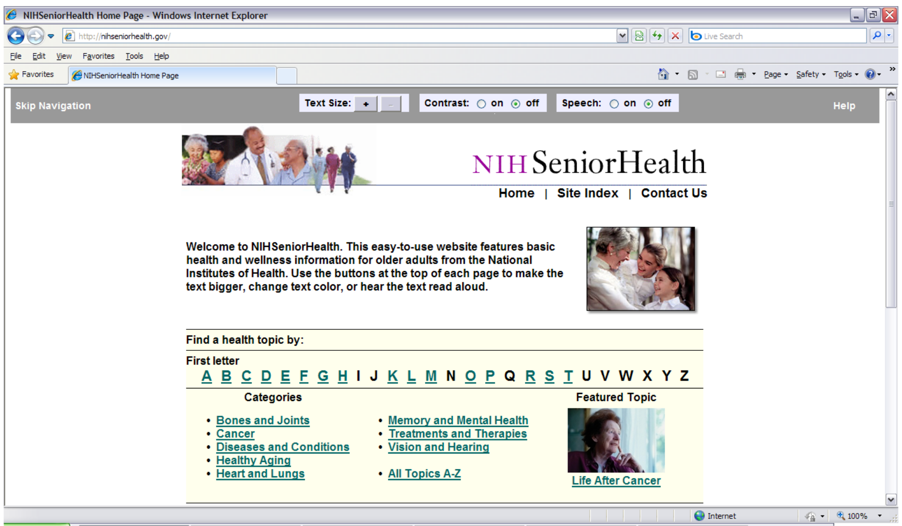

Fig. 4.6b NIH Senior Health web site.

4.4.2 Younger Users

Younger Internet users are often called "digital natives" or the "net generation", and in the age group of teens, over 90% are using the Internet [112]. One of the largest groups of Internet users is elementary-age children, and households with children are more likely to have computers and Internet access [10, 145, 176]. Young and old users develop in different ways; however, they have in common, that the process of growing up is just as individual a process as is the process of aging, and the development process is different for each individual.

As humans develop from infants to adults, their physical and cognitive abilities increase over time [40, 145, 176]. In their early years (2–7 years), children's attention spans are limited, they have limited reading skills, and they usually have difficulty operating a keyboard and mouse, especially when selecting and clicking targets, causing them to click inaccurately [166]. During the stage between 7 and 11 years children begin maturing toward adult cognitive abilities, and children of age 11 are generally assumed to have cognitive abilities similar to those of adults [40]. Since much of online information is text-based, it is necessary to provide other media forms for all text-based communication with preliterate children; however, this can increase development time and cost [176].

Knowledge builds over time by learning and experience, and naturally, very young children tend to have little background knowledge. Children are less likely to be familiar with adult concepts like file folders or recycling bins, and it is beneficial to younger users when designers use metaphors that children are familiar with [40]. Children's interaction and communication style should also be considered when developing interfaces, because their methods for finding information and interacting with web sites are distinctly different than those of adults. Children often react to visual and audio clues, instead of following task-based procedures. Strategies like reducing complexity and keeping the interface as simple as possible will benefit young children [22, 40, 86, 145, 174].

It is especially noteworthy that younger Internet and computer users enjoy working in collaborative environments (like entertainment and communication); an astonishing 97% of users between 12 and 17 years of age play online games, often with multiple users, and 55% of this group use social networking web sites [237, 238]. This preference for collaborative work could be a great benefit in learning environments where learning and knowledge building is a social process. Environments like Wikis or Second Life have been very successful in applying the collaborative principle to information and communication technology and are now integrated in a variety of learning environments [40, 307]. Several recent research projects have used Wikis in an educational context. One project created a science research resource for high school students by supporting collective knowledge construction and knowledge building and evaluating the success of collaborative environments in young adults [41, 89, 110].

4.5 Gender

Men dominated the Internet in its early days, but recent studies show that the proportion of women online is now nearly equal to that of men in the United States. Overall, slightly more men (68%) are online than women (66%), but this trend is reversed in the younger generation; young women (86%) are more likely to be online than young men (80%) [98].

Although on the surface gender access appears to be equally divided, underlying issues reveal a gender gap. When investigating the reaction to technology, women usually show higher levels of anxiety, less comfort, and less ability and excitement to learn; this happens across generations from young children to college students, the workplace, and retirees [63].

Stereotypes about gender, individuals, and groups exist, and can have a significant impact on how males and females respond to information and communication technology; this becomes especially important when designing software for both genders. Many edutainment products, for example, use features appealing to boys, causing girls to be less motivated and less responsive to the content. For example, boys have shown to prefer hand–eye coordination, competition, and feedback in the form of flashing lights, loud sounds, and explosions. Girls often dislike competitive programs, prefer frequent and clear feedback and characters they can identify with, and this emphasizes the need for social context [13, 63, 180, 191, 240, 376].

Moreover, differences in attribution for success and failure compound the gender problem. Where males often relate problems and errors in technology to failures in hardware or software, females are more likely to relate these problems and errors to their own ability, causing them to feel poorly about their performance and to lower their expectations for future computer tasks [63, 76]. Designing programs for both genders is a first step in improving the situation. Systems that incorporate features highlighted by female users (such as communications, supportive social networks, and social interaction), and allow all users to benefit from their success without attributional filters can significantly reduce the gender divide [63, 191, 376].

4.6 Socio-economic Status

The digital divide is often referred to as the gap between individuals and communities that have, or do not have, access to computers and information technology. Recent surveys indicate that this gap is continuously shrinking. Access to the Internet at home continues to grow (although at a slower pace than in previous years), and the number of households with high-speed Internet connections has significantly increased worldwide [162, 396]. In addition, wireless Internet access is becoming more popular. In the United States, the majority of Americans (56%) are accessing, or have accessed, the Internet wirelessly on a laptop, cell phone, MP3 player, or game console [162, 379].

Unfortunately, there is still some disparity in overall access, and lower income families still have less Internet access. Only 38% users in households with family incomes below $25,000 have Internet access, compared to 71% users in households with family income over $50,000 [379].

In addition to limited access, users with a low socio-economic background have less computer experience and more computer anxiety (even when accounting for other control variables such as access), often causing these users to limit computer use [31].

Several initiatives address this socio-economic disadvantage, and one such example is the "Creating Community Connections Project". This project has successfully transformed a low-income housing development through community networks, community network centers, and community content. It is all available to residents at little or no cost and targets community building, empowerment, and self-sufficiency in a low-income community [304].

Another example is the One Laptop per Child (OLPC) Foundation. The foundation's goal is to provide children in the developing world with free laptops, empowering children by giving them the opportunity to learn, access vast amounts of information, and connect with other users beyond their local limitations [292]. Results from a study with OLPC in Uruguay showed that, although the computers have a very positive impact and transform the way children learn, some challenges also surfaced. Inaccurate input devices caused pointing and clicking problems for the children, and poor network connectivity as well as lack of localization compromised usability and user experience [167].

Unfortunately, the situation for users with low socio-economic status is compounded by the connection between learning disabilities and low income populations. Over 62% of students with a learning disability were unemployed one year after graduation, and the number of families reporting a family member with a learning disability is twice as high in the group with annual incomes below $25,000 than in other groups. This emphasizes a critical need to provide accessible and usable information and communication technology that provides the special requirements related to the possible learning disabilities of this group [232].

4.7 Cultures

Cultural diversity refers to religious, historical, linguistic, aesthetic, and other more humanistic issues of groups, often within countries or across national borders. Increasing globalization impacts user interfaces, and to be globally successful, interfaces must consider general, universal solutions, as well as unique, local solutions [113, 253, 267, 354].

The business advantage is obvious; localization attracts and retains customers, while globalization expands the customer base. The user experience becomes more meaningful, effective, and satisfying when users encounter familiar structures, metaphors, navigation, interaction, and appearance. Targeting the global market has the potential to increase market share, however, achieving globalization (also known as internationalization) is a complex goal, and unfortunately, there is rarely a one-size-fits-all solution. This is why interfaces should be localized [72, 113, 158, 212].

Differences relating to cultural issues range from simple formatting issues (e.g., number and date/time formats) and the meaning of colors, to miscommunication with disastrous outcomes, such as brand names or slogans that refer to something completely different. Pepsi encountered a problem when translating their slogan “Come Alive with the Pepsi Generation” into Taiwanese as “Pepsi brings your ancestors back from the dead” [65]. Windows operating system Vista, for example, translates into “frumpy woman” for PC users in Latvia [94].

In addition to translation problems, gender roles, work tasks, family, or age distinctions can also vary greatly among cultures. Cultures are often not easily identifiable, and moreover, cultures may be different within countries (e.g., religious groups within a country). Cultural borders are fluid, and cultures may even impact each other [113, 253, 255].

There are many examples of increased globalization and localization. A large number of web sites today are offered in various languages, many programs offer translation services, images are adapted to local cultures, and layouts are adjusted for varying directions and size of text [253, 254]. Google and Microsoft search engines, as well as the online encyclopedia Wikipedia all offer interfaces in the major languages of the world (Figure 4.7).

When designing for culturally diverse environments, motivational factors and interaction style should also be examined. Do users respond to money, fame or achievement as a motivating tool? How formal should the interaction be? [253]. Design recommendations for culturally diverse environments include consideration of user demographics, metaphors, mental models, navigation, interaction, or general appearance. In addition, testing with culturally diverse users, testing in the

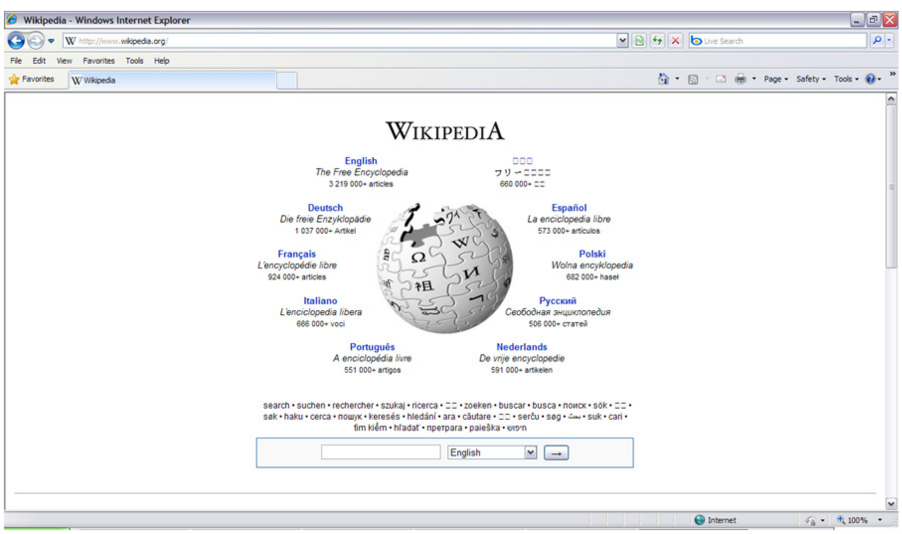

Fig. 4.7 Wikipedia main page with language selections.

actual environment using focus-group techniques, and collaboration suitable for the cultures involved could be a first step toward achieving culturally diverse environments [113, 167, 250, 253, 267, 297].

In summary, many of the strategies and technologies that integrate universal usability have benefits beyond the user group and intention that they were originally designed for, and increase successful user interaction with information and communication technology for a wide, diverse group of users. The following table provides a summary of the cross-benefits of integrating interface features that improve universal usability (Table 4.2).

Table 4.2. Cross-benefits of integrating universal usability.

Solutions	Visual Imp.	Auditory Imp.	Motor Imp.	Cognitive Imp.	Learning Disab.	Age
Screen readers/voice output	x			x	x	x
Screen magnifiers	x			x		x
Captioning		x			x	x
Signing		x				
Speech recognition	x		x	x	x	x
Multi-sensory interfaces	x	x	x	x	x	x
Adaptive interfaces	x	x	x	x	x	x
On-screen keyboards			x	x	x	x
Self-paced interaction	x	x	x	x	x	x
Reduced complexity			x	x	x	x

5

Bridging Gaps in User Knowledge

Many users have to learn how to use interfaces without any prior training, and may encounter roadblocks or situations requiring special attention. Users are often confused about the multitude of options to select, what to do in the event of a problem, or where to look or ask for help. Universal usability can be seriously hindered by complex systems with inadequate interfaces, leading to potential user confusion, frustration, and even failure [50]. These "gaps in user knowledge" are where users need help systems, clear error messages, documentation, "live" help, and other assistance to be successful users of information and communication technology [334].

Users come with a variety of skills, motivation, or abilities; tasks that can be easily mastered by one user may be extremely difficult for another user. Many learning or help constructs concentrate primarily on learner tasks and immediate task outcomes, but often do not consider other elements of learning, such as learner background and knowledge, multiple intelligences, social dynamics, or learning environment and tools [127, 262, 266, 318, 330, 334].

However, learning is a complex process, and it is different for every individual. Cognitive information-processed learning involves several stages of information–human interaction: the information and comprehension, representation and integration with existing and available knowledge, the retrieval and development of new connections, and the construction and elaboration toward a deeper understanding [263].

There often are situations where users may not need to use advanced features of an interface, and having novice users attempt to use those advanced features is a recipe for disaster. Classic papers in research literature such as minimalist design [49] and a "training wheels" interface [50] have built the foundation for understanding different designs for different levels of user experience. When information needs to be made available to people with varying levels of background expertise in the task domain, a technique called audience-splitting is often used. For instance, healthcare web sites often need to provide medical content at multiple levels: for doctors and nurses, for those who are going through medical treatment for a disease, for those who are new to a medical topic, and so on. There is no automated method for translating content from advanced level to basic level, and no guidelines from human–computer interaction will help with that. Further complicating this issue is the fact that while users may need content written at different levels, they often feel insulted and do not like the fact that they are receiving different information than what is received by another group of users [221]. Designing for diversity in domain knowledge is beyond simple audience-splitting in an interface. Audience-splitting refers to presentation of an interface that is maximized for the use of a group of users with similar interests [221]. The goal of an audience-splitting interface is to get people to the categories of information that interest them, as fast as possible. They can easily understand the information presented to others, but it is not the content that they are looking for. Using this approach, the gap between what users know and what users need to know is bridged by lowering the amount that users need to know, so that it matches what users already know.

In most cases, it would not be practical to have 20 versions of every web site and every application. Aside from being a non-elegant and impractical solution, there is a bigger reason to not have 20 different versions of an interface: not all of them will continue to be updated and supported. Who would want to use the "disabled" version of an interface? That would be demeaning. The goal should be to have one version of an interface, which can be “plastic” or flexible, and appear differently to different users in different situations. In short, this is a very high level description of what most universal usability-related guidelines state. It is better to offer simple content on the home screens of an interface, and then offer advanced content, noting that it might only work with some devices, or noting that there will be a long download time for those not using broadband. Guidelines such as the guidelines for Accessible Rich Internet Applications (ARIA) are helpful to ensure that dynamic web pages can serve multiple user groups at the same time, changing what is presented to the user depending on their needs, but coming from the same, up-to-date source of content.

But just offering plastic, flexible interfaces, and lowering the threshold for what users need to know is not sufficient. Users will continue to find themselves in situations in which they need assistance. Training approaches that prepare users to respond to errors are often not offered or are not effective [228]. Features like online help and keyword searches provide users with information relevant to their task in context, and can reduce task complexity and cognitive workload [42, 256]. User-produced technical writings involve other users in the training process and users provide helpful information about the task to be accomplished. Frequently asked questions (FAQs), blogs, and user communities are examples of user-produced technical writing, where users provide other users with basic information, strategies, walkthroughs, and help them solve problems [16, 331].

Users need to seek out online help, help wizards, and technical writings. But what is more commonly provided to users, without their asking, when they run into problematic situations? Error messages. They are often the “first line of defense” when users run into trouble, and they are a necessity for bridging that gap between what users actually know and what they need to know. When designing error messages, there must be specificity as to what occurred (in non-technical language that the user can understand), positive wording (not use words like fatal or illegal), and suggestions on how to respond [338]. In addition, it may be helpful to provide multiple levels of information, such as one level of information for novice, less-technical users, and a “click here for more detail" option that provides more technical data about the error [338].

Recent learning theories increasingly emphasize constructivist learning environments, where learning is understood as a complex process and occurs in social context as a knowledge building process. This type of learning is learner-centered and learner-controlled, and such learning environments consider an individual user experience [38, 193, 219, 263, 314]. Higher level solutions addressing situational learning to address gaps in user knowledge are more complex, but can also provide a deeper involvement of the learner into the learning process, fostering increased learning outcomes, including long-term strategies and mental models [127, 219, 263, 314, 334]. Increasingly, constructivist approaches are used in user workplace training and have been successful in increasing the skills of inexperienced operators [356].

Multi-layered, multimedia, multimodal, and adaptive interfaces all support increased user flexibility and reduced task complexity; they integrate consideration of multiple user learning styles into the task, and as a result support a more diverse user population.

Multi-layered interfaces support several levels of user interaction, such as novice, intermediate, advanced; multimedia interfaces support several forms of media, such as text, images, video, or audio; multimodal interfaces support two or more modes of input/output, adaptive interfaces adjust to user behavior by making some deductions and conclusions (see Section 3.2).

Multi-layer interfaces, for example, can support a variety of skill levels. One layer could provide a simplified interface for novices, the next layer could provide more functionality for the intermediate user, and another layer could provide a comprehensive interface at the expert level. Integration of adaptable interfaces can allow users to individually configure tasks and interfaces, can adjust default values and settings, configure the interface according to their preferences, and change or modify these settings on demand. With the option of allowing some user configuration and consideration of individual user differences, both multi-layered and adaptable interfaces support the demand for increased learner-centered and learner-controlled environments [109, 268, 336].

Multimedia, as well as multimodal, interfaces provide features to integrate support for multiple intelligences, and offer users options for interaction modalities. Users can communicate according to what works best for them, and they can select visual or audio clues, or use haptic interfaces, that allow them to work with tangible devices [62, 127].

Users without impairments benefit as well as users with impairments. Mobile phones, for example, when programmed with different operation modes (e.g., picture mode or text mode), enable mobile technology for users with cognitive impairment, a user group that otherwise would be unable to use this technology [329]. At the same time, these phones can be used by non-impaired users, allowing users to share phones. This principle is also applicable to other user groups, for example inter-generational design, making phones usable for younger as well as older users [86, 329].

However, in an individualized learning process, the use of multimedia or multimodal interfaces is never a "one size fits all" solution, and designers are encouraged to evaluate the appropriateness and potential overuse of multimedia and multimodal interfaces when integrating them into the learning process [7, 127, 259, 265].

Adaptive environments take the learning environment even a step further, by observing and analyzing user behavior and actions, and then adjusting the interface accordingly. Users with limited motor and cognitive activities, or visual acuity, for example, have shown to especially benefit from adaptive interfaces [133, 323]. Often users are not fully aware of possible limitations concerning their own physical and mental abilities, and in these cases, adaptive interfaces can increase the quality, and at the same time limit the complexity of the interface [29, 106, 189].

Adaptive interfaces have also shown benefits for mobile computing; adaptive features and menus can increase usability on small screen devices. However, studies have also pointed out the difficulty that, in adaptive interfaces, users may have limited awareness of the fully available set of options, which could limit their performance, effectiveness, and learning, suggesting that more research in this area is needed [106, 121, 258].

Software systems today are complex systems with a complex functionality, making learning about these systems a challenge for many users. Multimedia, adaptable, and adaptive interfaces, which can be customized for what users need to know, can aid users in learning about, and learning how to master, technology. However, learning is a highly individualized process and requires consideration not only of a user's prior knowledge and the task at hand, but also consideration of user background, intelligences, context of learning, and context of the task.

6

Context-Aware Computing and Contextual Design

6.1 Context-Aware Computing

Context-aware computing is based on the idea that user environments, including who the users are, who they are with, and what they are doing, influence the computing process, and moreover, can even inform computing devices [43, 56, 69, 159, 180]. Considering context, information could be made available to the user depending upon specific environmental factors, such as location, time, device type, and the user's current cognitive or psychological state. Further, systems can include information about social navigation, such as collective knowledge of previous users, or communication with other users [43, 69, 180, 189].

Often these situations involve dynamic tasks, which require rapid selection among multiple information sources, and require sophisticated technology, including wireless technology and devices, large databases, and intelligent systems based on complex rules and machine learning [245, 241, 347].

Individuals with cognitive or other impairments also benefit from context-aware computing. An early application, the "Aware System" integrated environment controls and communication devices into a power wheelchair to assist users with Locked-in syndrome [3]. Guidance and navigational systems like GPS, wireless devices informing about objects or persons in the area, or systems detecting obstacles or limitations due to environmental constraints affect user interaction in different contexts, and can increase usability for all [56, 69, 236].

Although context-aware systems are primarily intended to reduce user cognitive load, some important concerns include system intelligibility and user control in these systems. These systems often employ adaptive interfaces, which are interactive systems that adjust to user behavior by applying deductions and conclusions (see Section 3.2.10). Often users are frustrated because they have little control over this adaptive process, and do not understand how or why a system arrives at certain decisions, which can result in reduced user satisfaction and acceptance of a product. Interface designers can assist users by incorporating user help, making the decision process more transparent for the user, and by integrating as much user control as possible [43, 56, 74, 241].

6.2 Contextual Design

Creating products with the goal of making these products usable for the largest possible user population in a variety of contexts should naturally involve users in the design process at some point. Traditionally, users are involved in the design process toward the end of the process, to see whether they like a product or not. The contextual design approach, a form of user-centered design, strives to not only integrate the user into the design process at some point, its goal is for users to drive the design process, emphasizing the user, the environment, and the team, thus accommodating diverse user environments, and integrating user as well as contextual diversity into the design process. Contextual design involves users who will work with the product, and it gathers data significant to the design process, making this data the base criteria for deciding what the system should do, and how it should be structured [24, 203].

The complete process involving contextual inquiry and user-centered design can be quite complex and time consuming, so there is an increased interest in a streamlined process. Traditional competitive corporate design environments, for example, are interested in infusing contextual design (or contextual design elements) without the need to add significant time to the overall design process.

Additionally, organizations often also have existing procedures and would like user-centered design to fit into these processes. Rapid contextual design offers a design process on several levels, enabling organizations to infuse the benefits of contextual design into the traditional design process, even if they may have limited time or resources. These methods often limit the scope — for example, the number of users to interview could be reduced, and the data to be collected or the testing process could be limited [24, 73, 159, 160].

The idea of contextual design has found a variety of successful applications, and many of them are used in mobile or web development. One example is contextual web searches built on user data. These applications collect, build, and evaluate user web searches in context, by supporting a more efficient search process and reducing cognitive load on the user [261, 412].

7

Tools and Frameworks for UU

There are a wide range of software tools and frameworks for usability that have been developed and used over the past few decades. Many of these tools also have application to universal usability. As the understanding of universal usability evolves and product design changes, new tools and frameworks for usable design will continue to emerge. Some tools were created for the explicit testing and structure that is often required to implement and examine product usability (which is one aspect of universal usability). Other tools very specifically focus on accessibility, a part of universal usability which often receives the most attention due to legal requirements for accessibility. Table 7.1 attempts to categorize the types of tools that could apply to universal usability.

7.1 The Use of Tools for Universal Usability

The following discussion represents a sampling of tools developed to address particular usability and accessibility problems, and as such they address the granular components that often need to be examined in order to accomplish successful universal usability testing.

Table 7.1. Types of tools for universal usability.

Category	Simulation	Content Conversion	Evaluation
Description	This type of tool attempts to simulate a product experience when having a particular disability	This type of tool modifies content to conform to more accessible usage	This type of tool evaluates an interface against a standard (or even customizable) set of guidelines
Examples	• Accessibility Designer [310] • Lynx Viewer [246] • Vischek [83]	• Adobe PDF Conversion Tool [4] • Daltonize [82]	• InfoScent [73] • SUIT [11] • Wave [397]
Benefits	• Informative for designers and stakeholders • Quickly identifies more obvious problems	• Quickly modifies content for novice users • Better than the scenario of doing nothing	• Informative for designers not familiar with guidelines • Creates a good starting point for universal usability evaluation
Drawbacks	• Simulation cannot replace the value of designing and testing interfaces in conjunction with users with those disabilities	• Cannot correct or modify all content	• Simple conformance to accessibility guidelines does not always indicate actual usability, and results are often misleading

7.1.1 Simulation Tools

The Accessibility Designer visualization tool allows designers to understand the weak points of their designs and understand how their web pages may be lacking usability [362]. With this tool, the time to reach each part of a page is illustrated with certain colors, accessible and inaccessible areas of a web page are denoted with color-filling, and the text information that is read to a user through a screen reader is also revealed. These features are intended to give the designer a visual concept of what a blind user would experience when using web content.

Lynx viewer is a text-based web browser that was developed in the early 1990s and re-emerged in popularity due to its application as a simulation tool to test the usability and accessibility of web site

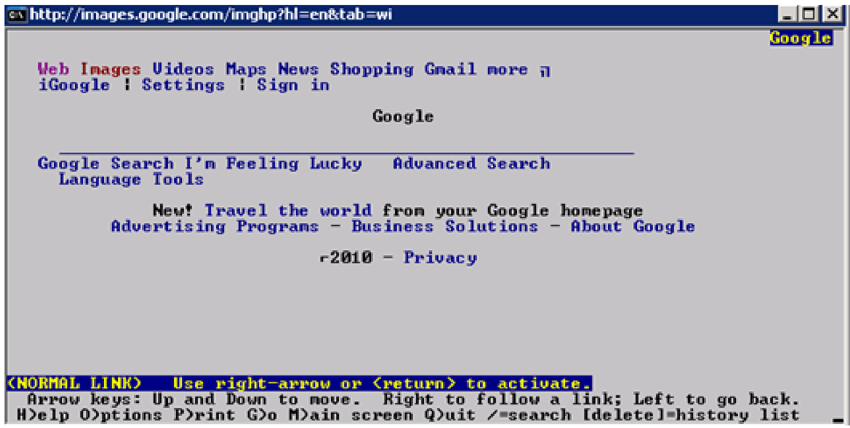

Fig. 7.1 The Lynx browser allows an evaluator to visualize and navigate a web site with a keyboard in its text-only format.

content [159]. By providing only access to web site text, Lynx allows the evaluator to assess the accessibility of non-text content as well as determine site usability when using only a keyboard for navigation (Figure 7.1).

Vischek allows designers to simulate the usability of a web site for someone who is color blind. Image files can be uploaded for evaluation or the tool can be run on the content of a web page. This tool uses a three-step modeling process to simulate all the components of human vision [241].

7.1.2 Content Conversion Tools

The web-based Adobe PDF conversion tool is a good example of a content conversion tool that can be applied to universal usability. This tool takes an uploaded or web-based PDF and attempts to convert it to HTML or plain-text format. Since PDF and similar document formats can often present accessibility problems when created incorrectly, such tools may benefit those wishing to create universally usable alternatives to often inaccessible file content. The presence of a tool such as this does not correct all PDF accessibility issues, nor does it remove the responsibility for creating accessible PDF documents from the author/creator of the document.

Fig. 7.2 Daltonize can be used to modify an image to account for daltonism.

Daltonize is a web-based service that uses image processing algorithms to correct common problems with images that create difficulties for users with daltonism (daltonism is another name for color blindness). Red/green color dimensions in images are shifted to light/dark and blue/yellow dimensions in an effort to create more distinguishable images for affected users. The suggested uses for Daltonize (Figure 7.2) include modifying images for computer display as well as modifying images before they are printed [24].

7.1.3 Evaluation Tools

With the navigation of web sites presenting a primary issue for universal usability, Chi et al. (Palo Alto Research Center) developed a tool called the "InfoScent Bloodhound Simulator" which was designed to measure the navigability of a web site by computing the probability of a user being able to reach a particular destination on the site [57]. The basis of whether a user will decide a link is worth clicking on is determined by the items (or cues) surrounding the link. This tool attempts to relate user behavior to the context of the link and it was tested by generating automated usability reports for several web sites as well as with extensive user studies to determine how accurately the tool simulates actual users. The results of both testing processes were recorded and correlated in order to determine whether comparable results can be derived. After testing, the results confirmed that this tool reasonably represented actual users and could attain its goal of reducing the cost of efforts to discover navigational usability problems on web sites. The navigability of web sites and other software can produce or prohibit the goal of universal usability and as such holds a direct correlation.

In 2006, Carmelo Ardito et al. (Università di Bari) introduced a web-based usability inspection tool to analyze the usability of software. Systematic Usability Inspection Tool (or SUIT) is a web-based tool that allows the tester to identify specific usability objectives and implement suggestive actions when a usability problem is highlighted. The tool is based on evaluation patterns called Abstract Tasks which guide the evaluator by describing in detail what to look for and evaluate during the inspection process. This is noted to be a change from generic heuristic inspection which may be dependent on the skill and experience of the usability tester [11]. Apart from the ability to conduct focused testing, the web-based nature of SUIT would appear to be well-suited for remote collaboration on software projects. Reports from all evaluators who are involved in a usability test with this tool are combined so that the results can be compared and discussed in order to find solutions to any problems discovered. SUIT is a good example of how the dynamics of usability testing tools have changed significantly over recent years (as opposed to earlier dependence on heuristic inspections) and since the evaluation objectives and specified actions can be adjusted and customized by the evaluator, it is a tool which could help an evaluator assess the universal usability of a product.

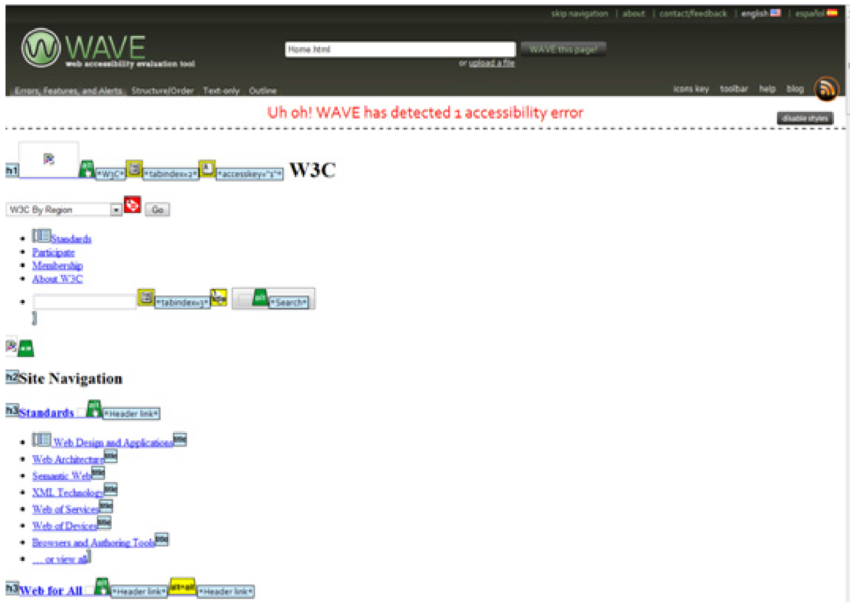

Fig. 7.3 WAVE attempts to automatically evaluate the accessibility of a web page.

The Web Accessibility Initiative maintains a web page repository of various automated web accessibility tools. This is an excellent point of reference for designers and professionals who are beginning to acquire or wish to enhance their knowledge of the available tools for universal usability [390]. One such example of these tools is WAVE tool which can be used to evaluate web accessibility (Figure 7.3) [74].

The drawback of automated accessibility evaluation tools is that there are instances during the accessibility inspection process in which human judgment is required (as illustrated by the fact that some of the standards specified in legislation such as Section 508 cannot be automatically measured and verified) [398]. The primary objective of universal usability tools should be to collect data from a usability testing process in order to record and analyze it in a way that will ultimately affect the design process [169].

7.2 Usability Frameworks

In their book, *Designing the User Interface*, Ben Shneiderman and Catherine Plaisant identify six foundational approaches to usability evaluation: expert reviews, usability testing, survey instruments, acceptance tests, evaluation during active use, and controlled psychologically oriented experiments [339]. Expert reviews comprise methods such as heuristic evaluations, consistency inspections, and formal usability inspections. Usability testing implies a lab setting with careful planning and step-by-step testing. Survey instruments would include online and written surveys of large numbers of participants using carefully prepared survey questions. Acceptance tests involve pilot testing a product or interface to measure whether it meets an acceptable level of usability from the user and developer standpoints. Evaluation during active use is dependent on interviews, focus groups, and other ongoing means (including automated processes) to obtain user feedback about a particular product. Controlled psychologically-oriented experiments are methods of replicating similar tasks, participants, and conditions to obtain reliable and valid results concerning cognitive tasks [339]. Approaching universal usability from a similar methodology that assumes multifaceted evaluation would conceivably be an appropriate framework from which to begin.

In 2006, Jonathan Howarth at Virginia Tech introduced a tool called Wizard, with the purpose of enabling usability engineers to identify the "immediate intention" of the user. "Immediate intention" refers to the sensory, cognitive, or physical action that was engaged in by the user when a usability problem is encountered [168]. The rationale behind the Wizard tool is that many tools which support a traditional usability engineering process do not have a method of reporting the results of the user intention on a more specific (micro) scale at a point in the process that enables a usability engineer to obtain additional information from the specific participant(s) involved. Because of this problem, Howarth suggested a new framework called the User Action Framework (UAF) which contains the planning, translation, physical actions, outcome and system functionality, assessment and overall stages of the user interaction cycle. The framework uses a "tree" layout which enables a usability engineer to follow a path that enables a complete description of (and possibly solutions for) specific usability problems [168]. During the two formal studies of the Wizard tool, Howarth determined that the tool and framework were successful in identifying immediate user intention.

The purpose of identifying this intention is to produce a focus that provides an improvement in the quality of data that is gathered during the usability testing process. The User Action Framework could definitely be an asset to any designer attempting to produce a product that is universally usable.

The "usability perspective" framework was introduced in 2008 by Tobias Uldall-Espersen (University of Copenhagen) in order to create a practical tool for use in software development. At the core of the usability perspective framework are five usability perspectives, three cross-perspective themes, and 18 key questions that associate the usability perspectives to the themes [377]. The usability perspectives were defined as the following:

- The interaction object usability perspective
- The task usability perspective
- The product usability perspective
- The context of use usability perspective
- The enterprise usability perspective.

The three themes are summarized as consistency, coherence, and fitness, and each theme is related to some of the 18 key questions [377]. The authors noted that the 18 key questions were based on observations and experiences (both research and personal) and are continuing to be developed. The usability perspective framework was published as a work that is still being developed, so studies of this new framework in practice will need to validate its relevance. This model does attempt to look at usability from all aspects of a product in its environment, which increases the likelihood of achieving universal usability for a product.

Ultimately a framework for universal usability should be able to support or produce a usability design or testing process that will be able to incorporate new or existing tools. Such a model should also assist designers and evaluators in the various aspects of developing technology that is universally usable. The lack of specific frameworks for universal usability should emphasize the need for research in this area.

8

Design Processes for UU

Pursuant to the lack of specific design processes for universal usability, the following discussion of design processes highlights a sampling of processes that have applicability. While there are many different approaches to usable design processes, most share basic core principles such as giving control to the user, approaching consistency, providing feedback, and supporting the user's memory [88]. Constantine Stephanidis has been involved in many studies relating to accessibility and usability. In 1999, Akoumianakis and Stephanidis noted that accessibility design guidelines are often seen as an afterthought and are more of a reactive than proactive approach [6]. The same can be said for many approaches to universal usability. Often usability is addressed after a product is designed rather than as an integral step in the design process. Savidis and Stephanidis proposed (in 2002), that there is a need to have a systematic process for alternative design decisions, and they related this directly to the need to design universally accessible interfaces [319]. Universal usability should also be approached as a systematic process as products are being designed.

Sousa and Furtado (University of Fortaleza) presented a design process in 2005 that attempted to enable the design of user interfaces based on identifying functional and usable tasks during the elicitation component of the system requirements identification process [346]. They proposed this design process after recognizing the minor (and often treated as optional) attention that usability is given during the design process for many user interfaces. According to Sousa and Furtado, the six "best practices" proposed to be included in the design process included the following [346]:

- Develop the product incrementally and present each result to users in order to correct possible misunderstanding and inconsistencies in a timely and efficient manner.
- Control changes to requirements as they appear throughout the life cycle in order to satisfy users' changing needs.
- Define the system architecture considering usability.
- Define the system structure and behavior with visual models that can be understood by users.
- Constantly evaluate the system through users.
- Control the evolution of requirements through the maintenance of the product and its elements.

A case study of a Brazilian digital TV system was used to illustrate how this approach to usable design would work. During the requirements definition process, task models relating to usability were detailed and usability patterns to address the system requirements were selected through the recommendation of a group of participants (in a usability workshop). From these pattern recommendations, the user interface prototypes were developed. A second usability workshop was then used to evaluate the prototypes and suggest any additional changes. Finally, usability tests with system users were conducted to validate the success of the design process [346]. The conclusion of Sousa and Furtado was that their proposed design process avoids a singular perspective of usability and provides for multiple perspectives of usability based upon usability patterns and embedded user participation. Just as a universal usability framework must be multi-faceted, universal design must also include a broad perspective.

A good design process has the potential to form the foundation for a usable product and as such also becomes a major focus during the universal usability testing process. It is important for designers to formulate and adhere to usable design processes and guidelines throughout the entire cycle of development so that the product or service is accessible and universally usable for all [353].

9

Standards and Guidelines for Universal Usability

It is never sufficient to tell project managers, webmasters, designers, and technical professionals to "make something universally usable." The first question will be "HOW do I make it universally usable?" A general direction is not enough; there must be specific details on how to reach that goal (especially since universal usability often is not a central concern). Details on how to make an interface universally usable often take the form of guidelines. Interface guidelines are not the same as coding standards. While coding standards are important to follow, simply following standards of coding will not ensure that an interface is universally usable (or even marginally usable). Often, coding standards will ensure that software can be used from a variety of platforms (browsers, platforms, and operating systems), but will in no way address user diversity. While coding standards are encouraged to avoid proprietary technology, they will not ensure universally usable interfaces.

There are a number of terms that are often used in conjunction with guidelines, such as standards, laws, recommendations, and policies. All of these provide design advice, although often standards are more specific and detail-oriented than guidelines. Guidelines are often developed from research literature, while standards are more specific guidelines that are adopted by large organizations or international bodies. Laws (or regulations) are standards that have been maximized for legal enforcement. The root concept is the same, but the goal and level of detail for guidelines, standards, and laws are different. All groups involved in interface design need guidelines for design advice. Guidelines form the core of the field of human–computer interaction, as they are a method to convert past insight and expertise into improvements in current and future interfaces [338].

It would be very helpful to have one set of interface guidelines, which would be appropriate for all types of software applications, and all types of users, therefore meeting the goal of universal usability. Such a set of guidelines do not exist. The complexities of the various types of applications, technologies, devices, and user groups make creating one set of guidelines for all nearly impossible. What becomes more possible is coming up with guidelines that address a large portion of universal usability for certain categories of applications. What becomes very possible is creating guidelines that maximize the user experience for specific groups of users in specific types of applications. The more specific the user population, the more specific the type of application, the easier it is to have concrete, specific, easy-to-implement guidelines.

Guidelines can be used in conjunction with other approaches to move toward more universally usable interfaces. Some of these approaches already exist in current interfaces. For instance, many current interfaces already address the novice/expert user diversity by offering differing paths to the same task goals. In a typical user interface, novice users may choose to use menus or wizards to reach their task goals. Expert users may utilize keyboard shortcuts (CNTRL-F7 or CNTRL-S) or command lines to reach their task goals. Interfaces may also be adaptive, where the software monitors user actions, and adds or removes choices based on frequency of use or problems that occur [336]. Just as interfaces have scrollbar controls for different levels of security, interfaces can also have scrollbar controls to set a “level of experience” so that by self-identifying a level of expertise with the software, an appropriate complexity level can be offered to the user.

The novice/expert continuum, technology diversity, and domain knowledge are not the areas in which guidelines are most effective. The areas in which guidelines are most effective are in dealing with user diversity related to age and impairment. The reality is, when "universal usability" is discussed, it tends to be more focused on impairment and age diversity, anyway. Furthermore, there is not enough background research in areas such as low-literacy users, gender differences in interfaces, and users with cognitive impairment, to present good quality guidelines that would meet their needs. There is a much longer history of research in user interface design for children, older adults, and people with perceptual and motor impairment. While guidelines for older adults are now starting to appear, there is no well-accepted set of interface guidelines for children. There is an extensive base of literature on interaction design and children ([165] is a thorough review), but no single set of guidelines would work well. "Children" as a group are very diverse. The different age levels, different cultural backgrounds, preferences, abilities, and forms of schooling mean that no one set of interface design guidelines would ever be appropriate [85]. Even development methodologies and usability testing methods can differ depending on the age [84, 143]. There might be a few generalizations that could be made regarding children (e.g., younger children may need larger clickable objects than older children [164]), but there is not enough data to result in specific guidelines.

Due to the large number of guidelines relating to user diversity, it is impractical to mention every set of guidelines in this article, but some of the best known guidelines related to universal usability will be mentioned in Table 9.1. Some of them (such as WCAG and Section 508) are not only guidelines, but well-vetted standards. It is no surprise that the only well-known standards are those related to users with impairments. There is a reason for that: only users with impairment have the legal right, in many countries, to have interfaces work for them. Older users, younger users, low literacy users — none of these groups have the legal right to have interfaces work for them. It is important to note that the United States Section 508 regulations were included in this table, while regulations from other national governments were not included, because (1) most other governments hold more closely to

Table 9.1. Well-known guidelines related to universal usability.

Name of Guidelines	Comments
Web Content Accessibility Guidelines 1.0 http://www.w3.org/WAI/intro/wcag.php	The original and best-known guidelines for web content, many laws are still based on WCAG 1.0 **International standard**
Web Content Accessibility Guidelines 2.0 http://www.w3.org/WAI/intro/wcag.php	The current version of WCAG countries are slowly adopting these **International standard**
Authoring Tool Accessibility Guidelines 1.0 http://www.w3.org/WAI/intro/atag.php	Guidelines for developing accessible development tools (such as web development applications and content management systems) **International standard**
User Agent Accessibility Guidelines http://www.w3.org/WAI/intro/uaag.php	Guidelines for developing accessible user tools, such as web browsers, media players, and plug-ins **International standard**
Accessible Rich Internet Applications Suite http://www.w3.org/WAI/intro/aria.php	Guidelines for developing accessible web applications using technologies such as AJAX and Javascript **International standard**
United States Section 508 Guidelines http://www.section508.gov	Guidelines cover not only web sites, but also hardware, operating systems, and devices **US Regulations**
National Institutes on Aging Guidelines for Making your web site Senior Friendly http://www.nia.nih.gov/HealthInformation/Publications/website.htm	Guidelines, based on existing research, for making web content accessible for older adults
Guidelines for making Usable web sites for blind screen reader users [370]	32 Guidelines for web sites, based on observing 16 blind screen reader users
Research-derived web design guidelines for older people [216]	A summary of guidelines from the literature, selected based on focus groups and usability testing with older users
Research-Based Web Design and Usability Guidelines http://www.usability.gov/guidelines/index.html	Large detailed set of guidelines for web design which indicate the strength of the evidence for the guideline, from the research literature
IBM Accessibility Center Guidelines http://www-03.ibm.com/able/guidelines/	Sets of accessibility checklists for software, hardware, web sites, and documentation

WCAG than the US government does; and (2) Section 508 is more than just a modified version of the Web Content Accessibility Guidelines, as it covers other types of technologies. While one portion of Section 508 (1194.22) focuses on web accessibility and is based upon WCAG 1.0, other sections of Section 508 focus on the accessibility of software applications and operating systems (1194.21), telecommunications products (1194.23), and desktop and portable computers (1194.26). Therefore, Section 508 is unique in providing accessibility guidelines for many different types of technology — not only web sites.

Guidelines need to be specific enough that they can be easily understood and implemented. General guidelines can be created to cover all user groups, and all technologies (e.g., "make sure that interfaces are flexible and plastic", "ensure that a web page can appear properly regardless of the user or technology accessing it"), but they will be too broad and vague to provide specific advice, and they can easily be misunderstood or applied. One of the best-known guidelines for interfaces is the Web Content Accessibility Guidelines version 1.0. It was approved by the World Wide Web Consortium in 1999. But some of the guidelines have been perceived to be vague, easily misunderstood, misinterpreted, or difficult to apply [209]. When guidelines are broad, they are more inclusive and cover more situations and applications and usage, but they do not provide enough detail on how to make particular technologies, in specific situations, usable for specific user groups [209]. Often, developers want guidelines that are technology-specific, such as accessibility advice for Adobe PDF files [209].

While most governments around the world based their web accessibility standards on WCAG 1.0 (see Section 10 for more information on public policy), governments often modified the WCAG guidelines to make them less subjective, easier to test and implement, and provided specific coding examples [310]. It does not help developers if each country has a separate set of legal requirements for interfaces, all of which must be met by interface developers. One of the stated goals of the newest version of WCAG, version 2.0, was to make sure that all of the guidelines can be easily understood, tested, and applied, so that governments can adopt the guidelines as standards (or regulations) without any modifications [310]. This is also known as harmonization, where many governments and organizations adopt the same set of international standards [395]. Having harmonization of standards certainly would encourage the development of better software tools for developers, would encourage developers to learn the standards, and would encourage educators to include the standards in curriculum models. In the meantime, most legal guidelines are based on WCAG 1.0, and are starting to move toward WCAG 2.0 (see Section 10 on legal guidelines). Unfortunately, in current draft form (April 2010), the new version of US Section 508 regulations again fails to harmonize with WCAG 2.0 guidelines, but at least do cite portions of WCAG 2.0.

While the WCAG are probably the best-known guidelines related to universal usability for interfaces, there are also other guidelines that come from the same source, the Web Accessibility Initiative. These guidelines include the User Agent Accessibility Guidelines, and the Authoring Tools Accessibility Guidelines. The User Agent Accessibility Guidelines cover how to make web browsers, assistive technologies, and other user tools accessible. The Authoring Tools Accessibility Guidelines cover web development software, content management systems, and multimedia design tools for the web. There is also an existing draft of guidelines for Accessible Rich Internet Applications (ARIA) that, according to the Web Accessibility Initiative web site, is moving toward an approved standard (http://www.w3.org/wai).

While web content gets most of the attention, authoring tools and user agents must also be accessible for web sites to work properly for people with disabilities [209]. There is a logical reason for having attention on web content: very few individuals and companies develop assistive technologies, web browsers, or web development tools. Millions of companies develop web sites. The biggest challenge is to reach every single web developer and every web design company in the world and make them aware of web accessibility. Accessible content is not enough; the user tools and the web developer tools must also support accessibility. While research is starting to appear about users with cognitive impairment, and while WCAG 2.0 includes some guidelines to assist users with cognitive impairment, the WAI guidelines (and government regulations) still focus primarily on perceptual and motor impairment.

Guidelines often form the backbone of automated usability testing applications. Many software applications claim to test web sites for compliance with accessibility guidelines, and they also may help make repairs, once interface problems are identified [1]. Most of these software tools are focused specifically on users with impairments (http://www.w3.org/WAI/ER/tools/complete), while other tools focus on older users, such as Dottie [21]. These tools generally check a series of interfaces (web pages or screens) for compliance against a set of guidelines related to user diversity. While they are often used in accessibility evaluations, there is evidence that human inspections using guidelines are far more effective than automated software evaluations, [251, 187]. It may be suggested then, that these automated tools may give misleading results on identifying the problems themselves, but if humans can identify the problems, the automated tools are very good at guiding developers through the process of fixing problems [1]. In addition, because the guidelines are frequently vague and open to interpretation by different developers, the automated tools, while performing imperfect accessibility evaluations, can provide a level of consistency in evaluations across interfaces and limit difference in how humans interpret the guidelines [34].

It is questionable whether there will ever be one set of practical guidelines for universal usability. The guidelines for groups of diverse users that now exist are a good start, but more work needs to be done. Specifically, the guidelines must be constantly kept up-to-date to relate to new technology, and must be continuously improved so that they are easy to understand and implement. The guidelines must be developed and modified so that they can be effectively used in real-world development, with support from developers themselves. In addition, the guidelines must be created and modified in such a manner that government policymakers can adopt the guidelines with only minor or no changes.

10

Public Policy and UU

One of the reasons why universal usability often gains attention is because of public policies. Policies, either from non-governmental organizations, or government requirements, bring attention to the topic of universal usability. Policies come in many different forms, and often the policies, in the form of guidelines and standards from non-governmental organizations, eventually become the core of governmental policies [157].

However, public policy does not enforce or even encourage true universal usability. True universal usability is defined by user diversity, technical diversity, and bridging the gaps between what users know and what they need to know [334]. Public policies related to interfaces usually focus on the rights of people with impairments. An argument could be made that people with impairments are a form of technical diversity (since those users are trying to access information using specialized assistive technologies), but the reality is, their diverse access technologies are not the root of public policies, rather the impairment is. An example of this is that people who use different technologies (e.g., Blackberries vs. iPhones) do not receive any attention in public policies.

Net neutrality could be considered as technical diversity. Net neutrality is the idea that the bandwidth, the connections, the network, should be neutral as it relates to users or applications. So, e-mail traffic should not receive priority over video or music downloads, and certain user groups or customers of certain Internet providers should not receive priority over other user groups in the traffic queue. A real-world example of this is that only customers of certain Internet service providers can receive access to the web content on ESPN360.com. Supporting net neutrality could be seen as a form of universal usability policy. However, net neutrality is not often supported by public policies. A recent court ruling in the United States actually limited the ability to enforce any policies related to net neutrality.

The only portions of universal usability that tend to be covered by public policies are user diversity. The user diversity component of universal usability includes younger users, older users, users with low literacy or education, and users with impairments. Public policies often focus on making sure that information is technically accessible for diverse user populations, but often do not consider usability for diverse user populations. Some government policies have encouraged technical access to the Internet for organizations such as public schools, libraries, and hospitals. For instance, in the United States, a program called the e-rate, mandated by the Telecommunications Act of 1996, provides discounts to schools, libraries, and hospitals, on technology and telecommunications services. The level of discount is related to the level of poverty, and whether the organization is in a rural or urban area [171]. The majority of funding for this initiative has gone to schools, rather than libraries [188]. In addition, community technology centers, also known as community access centers or telecenters, are popular around the world and provide Internet access for the general public, often assisting those who have low levels of education or low socio-economic status [293]. These policies are all focused on having access to computers and the Internet, but not usability.

For an example of an "access to technology" project from a non-governmental organization, focusing on access to technology without considering ease of use, the "One Laptop per Child" project (sponsored by a non-governmental organization) has the stated goal of providing a laptop to every child around the world, for use in education (www.laptop.org). While there are features in the XO laptop that are related to ease of use (such as the touch pad, and the multiple display settings for indoor and outdoor use), these were not the results of any public policies, governmental or non-governmental [215]. Public policies tend not to focus on interface usability for older or younger users (only access to technology), with a few notable exceptions, such as the "Making your web site senior friendly" guidelines from the U.S. National Institute on Aging [279].

Public policies related to universal usability do not focus on technology diversity, older users, younger users, low literacy, low education, or low socio-economic status. What public policy on universal usability does focus on are users with impairments, and there is a good reason for that. While public policy in general has not focused on interfaces, there is a long history of public policies, in many different countries, protecting the rights of people with impairments [187]. Note that many countries also use different terminology to describe these groups: people with disabilities, people with impairments, and then specific labels such as blind people, deaf people, or physically challenged people. In reality, public policy does not even focus on true usability for people with impairments; it focuses more on technical functionality for people with impairments [370]. The result is that public policy on universal usability only focuses on technical accessibility for people with impairments. Generally, the policies only apply to government technology, through the use of interface design guidelines.

In previous sections of this monograph, the Web Content Accessibility Guidelines (WCAG) were discussed. While there are other guidelines (for user agents and authoring tools), the guidelines for web content are the ones that are the most prevalent, since there are a very large number of people designing web sites, whereas there are a very small number of people designing user agents or authoring tools. When the WCAG 1.0 was approved by the World Wide Web consortium in 1999, it became the backbone for a number of different government policies around the world. In many ways, these guidelines spurred the development of government policies. One of the earliest countries to require accessible government web sites was Portugal, in

1999 [136]. While a new version of WCAG, version 2.0, was approved in 2008, the majority of government policies around the world are based on WCAG 1.0, and most countries have regulations based only on web content, not web authoring tools or user agents. It may take a few years for the government policies to catch up. Canada's guidelines are based on WCAG 1.0 [373], and Australia's guidelines are also based on WCAG 1.0, but their Human Rights Commission notes that they are currently working on evaluating how to implement WCAG 2.0 [15]. The revised version of Section 508 in the United States (known as the 508 refresh) is currently undergoing review, and the advisory council's report utilizes WCAG 2.0 as the core of the new 508 guidelines [381]. The draft version of the new regulations was released in March, 2010 (http://www.access-board.gov/508.htm). Countries that have only recently become involved in accessibility may base their first guidelines directly on WCAG 2.0, which is what has happened in Thailand [272].

Government policies related to web accessibility generally cover only web sites sponsored by governmental agencies, or computer equipment purchased by governmental agencies, or technology that is somehow funded by the government. In the United States, Section 508 requires that all federally funded technology be accessible for people with impairments (web sites, operating systems, application software, and hardware). The Disability Discrimination Act in the United Kingdom covers government technology. As primary, secondary, and higher education increasingly utilize online learning tools, these laws are starting to cover instructional technology in education. Sometimes the coverage of accessible educational technology is implied, but not explicit. A potential reason for this is that earlier laws from the mid-1990s covered education but not specifically instructional technology. It could also be that education is often managed at the state or regional level, rather than at a national level, where most laws related to accessibility are implemented. Sometimes, specific, focused regulations for accessibility of online education are put into place, even if the deadlines and goals are modified over time, such as in the California State University system [46]. Without statutory laws in place, the public policy on interface accessibility is often decided by lawsuits in the court system.

In general, government policies relating to accessibility do not cover private companies unless, of course, those companies are selling technology products or developing software or web sites for the government. But there are exceptions — for instance, Australian law states that “This [accessibility] requirement applies to any individual or organisation developing a Worldwide Web page in Australia, or placing or maintaining a Web page on an Australian server” [15]. A lawsuit in the United States, National Federation of the Blind vs. Target, investigated whether disability laws which apply to private companies (i.e., the Americans with Disabilities Act) also apply to web sites. There were some preliminary court rulings that established that web sites are an extension of a physical location, and if the physical location is covered by the Americans with Disabilities Act as a public accommodation, then the web site is also a public accommodation, and is therefore covered by the law [278]. However, these rulings were settled out of court, so there was no final conclusive ruling as to whether private web sites must be accessible in the United States.

There are also computing resources that are owned by private companies, but could be considered “public” technology, such as automated teller machines, airline web sites, and kiosks. There was a lawsuit in 2000 against the Sydney Organising Committee for the Olympic Games for having an inaccessible web site [14]. While that committee receives substantial public funding, it was not a government agency. In the United States, while the Department of Transportation, the Federal Aviation Administration, and the Transportation Security Administration manage the air flight infrastructure, private airlines actually run the flights. So, those private airlines are not covered by government rules such as Section 508. However, the U.S. Department of Transportation has rules (since 2009) saying that if an airline has an inaccessible web site, they must allow citizens to call the telephone center for the airline, receive the same low fare as on the web site, and not be charged higher prices for calling the telephone center [380]. However, the U.S. Department of Transportation has not decided yet how to handle the extensive use of kiosks in airports, which are rarely accessible for people with impairments [380].

Government policies can be complex. While a government policy may require that a certain action takes place, in reality, that action may not takes place. Although many government policies may require accessibility for a certain category of interfaces (such as government web sites), that does not necessarily mean that those sites ARE accessible. It is well-documented that having a government policy does not mean that the policy is followed. Even government web sites which are clearly covered by laws are often inaccessible [97, 134, 187, 231, 357].

While many national, governmental policies may take years to be put in place (and then more years to become effective), policies within organizations can often be somewhat effective in moving toward more universally usable interfaces. Training web developers and web managers on how to design universally usable interfaces is a good first step [225]. Providing developers with resources that are tailored for them and their processes and that are well-documented, and easy to use, without requiring a substantial background in universal usability, can also be helpful [60]. Having either downloadable page design templates, or full content management systems, can help ensure that basic interface design guidelines are followed (e.g., using CSS instead of hard-coding font styles and sizes) [123, 243]. An example of this might be a content management system that requires content developers to enter alternative text for graphics or images.

11

Cost-Justifying Universal Usability

If universal usability is so wonderful, why do not all developers, all designers, and all companies practice it? Often, companies perceive the costs of universal usability as being prohibitive. If not done properly and early in a development life cycle, there WILL be major costs associated with making computer interfaces universally usable. The earlier in a development life cycle that these universal usability design concepts are included, the lower the cost. The reality is that we cannot make interfaces work for 100% of all users, but that should not deter trying to make interfaces more universally usable.

In the case of a physical home that is being built, if universal design concepts are included from the conception of the project, it does not actually cost any more to make the doorways wide enough for a wheelchair, and it costs very little to add ramps to the design, and to add levers instead of doorknobs. After a home has already been built, the tasks of retro-fitting an existing home are labor-intensive, and the costs are then enormous to retrofit doorways and add ramps. In a similar vein, if universal usability concepts are included from the inception of an interface design project, the costs are negligible, but if an interface must be retro-fitted, the costs can be much higher.

Many companies perceive universal usability as an extra cost or an extra feature. But if universal usability concepts are included in the inception of the interface design project, the added costs are minor [332]. For corporations to achieve more universally usable interfaces, they must view universal usability as a part of a process, not a specific goal that they must reach, with specific costs [33]. This is especially true since most interfaces are modified on a regular basis. While web sites might be modified on a daily or weekly basis, even operating systems and applications may have upgraded interfaces every 2–3 years. There is always an opportunity to include universal usability, in the NEXT design life cycle. Since web design is a process, not a goal, universal usability must be viewed in the same manner. While a minor amount of additional resources may need to be given to ensure universal usability in design and re-design, it often results in higher-quality interfaces [332]. It is important to get universal usability concepts included in the re-design development process cycle. Unfortunately, this often is not the case: over time, web sites seem to have an increasing number of universal usability problems [142, 227].

Often, companies are more interested in moving toward universally usable interfaces when one of two situations is present: (1) there is an internal champion, someone inside the organization who really brings these topics to the forefront; or (2) the company views its focus on universal usability as a competitive advantage — a strategy for being profitable [281]. Unfortunately, misperceptions often stop companies from moving toward universally usable interfaces.

One misperception in the design world is that making a universally usable interface means making an interface that is text-only, with no graphics [225]. This is simply not true, and a universally usable interface can have graphics and many advanced features. What makes an interface universally usable is that it has features that allow for ease of use by multiple user groups. You cannot examine an interface and immediately say that it is universally usable. The appearance does not change; instead, the flexibility of the interface, the multiple paths or approaches available to users — that is what changes. Another misperception is that making interfaces universally usable is prohibitively expensive. But the technical resources needed to make universally usable interfaces are in the public domain. Current interface development tools include features for making interfaces work for diverse user populations. While a company could purchase stand-alone testing tools or assistive technologies, such as screen readers, the costs for these are relatively low for most businesses [223]. Screen reader software often costs under 1,000 U.S. dollars, and there are many screen reader tools on the web, either for free (such as WebAnywhere), or for use as a demo version for a short period of time. There are a number of web sites that provide simulations (at no charge) to check how interfaces will appear given certain visual limitations (such as color blindness) to help determine the reading level of text and interface appropriateness for older users. There are other web-based tools that allow developers to test how screens will appear in different operating systems and browsers. A quick and inexpensive way to start checking for accessibility is to attempt to use a software application by using only a keyboard and without a pointing device, since pointing devices often cannot be used by users with visual or motor impairments. Hardware costs to develop universally usable interfaces are often minimal.

The greatest costs in developing universally usable interfaces are human costs, not technical costs. The best way to develop interfaces that meet the needs of diverse users is to involve the users themselves in the development process. That is where the costs are — the costs of developer time, and the cost of involving diverse users. While users should be compensated when they take part in usability testing, often, users take part in other user-centered design activities for the enjoyment of it (and out of frustration with previous software), without any payment. And while software developers do spend time modifying interfaces to make them universally usable, at an organizational level, those costs are usually exceeded by the increased amount of productivity, sales, or revenue that an organization receives from having a universally usable interface. The perception of the costs involved is usually higher than the actual costs. One estimate, which is a decade old and probably now out of date, is that making a web site accessible adds only a few percentage points to the cost of initial design [51]. However, the important consideration is how much the cost of moving toward universally usable interfaces is exceeded by the benefit to be gained.

A preliminary cost–benefit analysis is often helpful. It is true that more developer time, more testing, and more attention to detail will be needed. For instance, an organization may need to pay additional diverse users to perform usability testing. A publication by [37] provides good detail on how to calculate the actual cost of moving interfaces toward universal usability. There is not one specific cost per project. The costs depend on how large the interface is (5 screens vs. 10,000 web pages vs. a database-driven web site), how many new sets of design guidelines are being addressed (a proxy for which user groups are being included), and how involved the user testing will be (how many diverse user representatives will be included) [37]. It is also realistic to expect that the specific interface screens that have the most impact (the home page, the shopping cart check-out, the help screen) should be the first to receive attention [37]. Universal usability is a process, so it is necessary to triage and begin with the interfaces that impact user experience the most.

If a company views universal usability as an important part of customer service, such as one of the core concepts in an interface design, it is not an extra feature; it is just a standard part of development. Sometimes, a company may decide to focus on universally usable interfaces because of the belief that it will give a public perception of being a good corporate citizen [281]. This can positively influence how all consumers perceive the organization, and improve customer loyalty [301]. The flip side of this is that one big reason why companies actually focus on making their interfaces universally usable is the threat of lawsuits [114]. While most individuals do not have a standing to sue, since individuals with impairments have protections under the law, for many companies, the lawsuit described in Section 10 was a big wake-up call, and forced those companies to change their design patterns and move toward making their interfaces more universally usable [114].

Another reason to focus on universally usable interfaces is that doing so increases the number of consumers to which a company can sell [37]. One recent estimate is that over 50 million people in the United States, and over 600 million people worldwide have some form of disability, and all of these are potential consumers who are often not the focus of technology companies [242]. Very often, individuals with impairments have challenges with transportation, and therefore, are more likely to shop online. Imagine that even minor changes were made to a web site design so that the site subsequently worked for people who were blind; that would immediately add millions of potential consumers. This is only addressing people with disabilities; there are many diverse user populations that are not being served with appropriate, universal technology, such as older people. There are simply many potential consumer markets that remain untapped as a result. Most video game systems are inaccessible for people with impairments [137]. However, as gaming systems are increasingly used for skill development, there is a significant market demand for universally usable games. One illustration of this is that accessible versions of popular games like Guitar Hero have been created [418]. Making interfaces and products universally usable increases the number of people who are potential customers. When interfaces are universally usable, it not only benefits the various diverse user populations, but also users with different technologies. A good illustration of this is that users of smart phones, PDAs, and handheld devices all benefit from web interfaces that are universally usable. Similarly, when interfaces that are universally usable become less so, there is a drop-off in the number of potential customers. For instance, in mid-2009, when the web site CDBaby changed their design so that it was no longer usable for people with various impairments, they lost a large number of their customers [153]. Previous customers who wanted to purchase CDs were unable to do so, and at publication time, the interface still had not been fixed [153]. Just as interfaces that are not universally usable lose potential customers, when interfaces that have been universally usable become less usable, they may lose a lot of their existing customers. Perhaps the development costs are slightly higher for a universally usable interface, but the potential customer base is also higher.

Finally, there is the reality of the situation: it is impossible to make all interfaces 100% universally usable for all user populations [37]. There is not enough design guidance or research available to even know how to design for every user group. That should not, however, prevent the move of interface design toward a higher level of universal usability. Consider how the Web Content Accessibility (WCAG) 1.0 guidelines focused on users with perceptual and motor impairment, but not cognitive impairment. While WCAG 2.0 did include design aspects for people with cognitive impairment, a number of governmental groups (such as the advisory board for the Section 508 refresh) have already decided not to include those specific guidelines dealing with cognitive impairment. As such, there is precedent for deciding to improve interfaces for certain user groups first and continuing the process from that point. Of course, due to the public policies in place (see Section 10), user groups that receive attention first are users with perceptual and motor impairment. While all interfaces may never be 100% universally usable, that should not stop companies and organizations from making improvements in their interface usability to reach new user populations, and for this it would be cost-justifiable.

12

Security/Privacy and Universal Usability

Computers are firmly integrated into daily life and store an immense amount of information. Users trust that these systems are secure, and that the data is protected from misuse [257]. Unfortunately, system and infrastructure vulnerabilities as well as malware are major threats to security and privacy; and the protection of information is a very important concern for all users [201]. Security requirements for computing traditionally address the components of confidentiality, integrity, and availability. Confidentiality ensures that information is shared only among users with appropriate access, integrity ensures that the information has not been altered or manipulated, and availability ensures that the information is available when and where users need it [345]. In addition to security, users also have an expectation of privacy, which can be understood as an individual's capability to control personal information in particular social situations, highlighting that privacy is subject to individual user expectations and the context in which technology is used [2].

Many mechanisms are in place today to support the goals of security and privacy, and while most users are familiar with the concept of passwords, encryption, human interaction proofs (such as CAPTCHAs), and account personalization, there are many challenges in providing universally usable security and privacy options for all users. Password authentication, for example, generally assumes that a user can type in a text entry, and applications increasingly require users to choose complex passwords consisting of text characters, special characters, and numbers. Moreover, many applications force users to change passwords frequently, increasing the number of passwords users have to memorize [415]. Password authentication presents a number of challenges for universal usability, which are common in security and privacy mechanisms: the entry mode is limited (often to keyboard and text entry), a certain cognitive ability is required of the user (often to ensure memorability and construction of security tokens, logins, or passwords), and user control of the authentication process is limited (there are few or no alternatives provided for the user) [257, 264, 415].

Alternatives to traditional password authentication exist; they can overcome some of these limitations and improve security mechanisms not only for users with impairments, but also for many other user groups. Methods such as biometric authentication, graphical passwords, speech-based authentication, or suggestions to increasing the transparency of the process (for example, by unmasking the password) have been successfully implemented and can increase security and privacy [71, 290, 399, 420]. Graphical passwords can improve authentication for users with motor impairments as well as for users with cognitive impairments, or users with limited literacy or language skills (such as non-native language users or very young users) [403]. However, graphical passwords clearly pose a problem for users with partial vision or no residual vision.

Existing security mechanisms pose a problem for many diverse user groups. For instance, while blind users have no trouble with passwords and security questions, human interaction proofs (such as CAPTCHAs) are a very big problem [316]. Visual CAPTCHAs do not work at all for these users, and existing audio CAPTCHAs have only a 50% task success rate [315]. The high rate of distortion in CAPTCHAs is needed to protect against automated attacks, but it makes the CAPTCHAs incredibly difficult to use. Newer techniques, which do not use distortion as the primary technique for security, are far superior for blind users

[316]. Biometrics, such as fingerprints and voice recognition, are usable for blind users, as long as the prompts (about what to say and where to place the finger) are accessible. Iris or retina scanning may not be effective for blind users, since there may be deformities and/or atrophy in the eye, or there may be a glass eye. One further concern is that anti-virus software is often inaccessible, meaning that blind users may not have the most up-to-date protection against viruses and bots.

Users with motor impairments (such as spinal cord injuries, arthritis, or repetitive strain injuries) often use either modified keyboards, or some alternative input devices, such as speech recognition, eye tracking, head tracking, or electrophysiological solutions. This may lead to increased errors when typing in passwords. It is questionable whether techniques such as speech recognition (in which the user speaks out loud) can be used for traditional passwords or for security questions. Human interaction proof concepts may not be problematic, but users with motor impairments may have a slower input rate, and therefore, automatic timeouts or logouts (where the user must enter a password or the response to an HIP within a limited amount of time) may be problematic. Biometrics such as finger or retina scanning may also cause difficulty, since users may not be able to move that part of their body to the appropriate location.

Cognitive impairments vary widely, and often, the severity of the impairment may differ from user to user. As such, the challenges are more specific to individuals rather than to cognitive impairments in general. For instance, passwords may not be problematic for users with Down Syndrome or Autism, but may be a great problem for users with Dementia, Amnesia, or Traumatic Brain Injuries. The same holds true for security questions — users with types of cognitive impairments that impact memory may not be able to use them, but users with other types of cognitive impairments may be able to respond to security questions without difficulty. Biometrics, such as fingerprint recognition and iris scanning may be useful for people with cognitive impairments, but with some cognitive impairments (such as Aphasia, Down Syndrome, or Alzheimer's Disease), speech may be impacted; therefore, voice recognition may not be appropriate. There is not any published research yet that examines how people with cognitive impairments might interact with human interaction proofs, but it is assumed that it might be challenging. It is suggested that the reader consults the web site http://triton.towson.edu/∼uaia/uaia/ which has a set of notes and teaching materials related to users with disabilities and online security.

Security and privacy present unique challenges when integrating universal usability, and recommendations include involving different user groups with different skill sets and abilities within the development process, increasing the transparency of the process, reducing the complexity of security and privacy mechanisms, and providing the ability to update security and privacy solutions easily and frequently to accommodate changes in legislation and regulations [201].

13

Summary/Future Directions

Computers are used by many people all over the world to access information electronically in order to accomplish a variety of tasks. Users with all levels of technical experience, training and education, users with disabilities, older users, young users, users with differing levels of socio-economic means, and users who are busy doing other tasks build a very diverse user base for interface designers today. Universal usability has the goal to design systems, which are easy to use, for all of these users, in a wide range of different situations, to make all people successful users of information and communication services.

Computer technology with its frequent changes, updates, and new products makes reaching this goal more difficult. Technology diversity, such as the variety of hardware, software, and network technologies, presents developers with a major task — the challenge is to keep up with the speed at which technology changes and the variety of equipment employed in user environments. Although progress toward the goal of universal usability has been made, some tradeoffs remain. Specialized assistive technology is often in a high price category, and not always affordable for the users who need it. Creating products for a large range of functionality and characteristics of user groups and serving everyone equally well, can be very difficult. Communication between users and computers is possible not only using the traditional sensory channels of vision and hearing; recent research has also addressed other modalities in the form of haptic, kinesthetic, gustatory, or olfactory interfaces.

User diversity includes users with a wide range of abilities and backgrounds. Originally, most of the early research concentrated on users with disabilities and a wide range of impairments, such as perceptual and motor impairments. However, today's research in universal usability focuses on the support and accommodation of the largest possible range of users. It also addresses users with various education levels and learning disabilities, users of different age, gender, or socio-economic status, and users from various cultures.

User interfaces have to bridge the gap between what users already know, and what users need to know to use interfaces and technology. Users have a variety of skill levels, motivations, and abilities, and often users encounter roadblocks that require special attention. Addressing this problem of learning while in the process of communicating with a system is a particular challenge. Just-in-time training includes features like online help and keyword searches, but bridging the knowledge gap increasingly includes higher-level learning solutions that consider the context of the user and the task. Supporting the complex process of learning enables users to not only master the task at hand, but it also supports knowledge building and provides users with long-term strategies and mental models that are necessary for the operation of complex systems with complex functionality.

Contextual diversity addresses supporting users in a variety of situations, and requires attention especially due to the tendency toward ubiquitous computing and the integration of technology into everyday life and tasks. Computing that is context-aware can provide users with environmental factors or social navigation, often involving large databases and some form of system learning or artificial intelligence. Environmental factors can include location, time, device type, or even the user's current cognitive or psychological state. Social navigation can integrate information through the collective knowledge of previous users or communication with other users.

Research is moving forward to address new challenges and to reach the full potential of universal usability. Technological advances and global networking provide the basis for many new developments. A recent trend in universal usability is the movement toward convergence. Devices have become smaller, systems have become more complex, and more functionality is included in a single device, enabling users to often use one device for a variety of tasks. A smart phone, for example, allows users not only to make and receive calls, but it can also serve as a GPS device, show movies on demand, or connect to the Internet using a wireless connection.

Adaptive interfaces also find increased application in a variety of settings for diverse users, especially in complex systems. These interfaces can reduce the cognitive load for the user as they adjust to user behavior and/or environmental conditions by applying deductions and conclusions, usually in the form of artificial intelligence. Users with low literacy levels, small children, and users with cognitive or other impairments can all benefit from adaptive technology. Recent research has coupled adaptive interfaces with brain activity and offers new perspectives for users with impairments due to brain injury. In the context of adaptive interfaces, however, there is also the demand for more user control and transparency of systems.

Another recent development addresses the situation of universal sociability. A large number of computer users participate in some form in social and professional networking, such as Facebook, Twitter, or LinkedIn. Social networking based on collective user networks and user and community knowledge building like Wikipedia are also frequented by very diverse user groups, and many users connect to these services from a variety of devices, including mobile devices. These types of networks highlight the demand to support the broadest range of users, in the broadest range of tasks and environments, including community, cultural, and social considerations.

Design and development increasingly work toward inclusive approaches, so that users can be served through one device and one interface. More work remains on the specific approaches used in the development and design processes to reach universal usability. If the concept is not included in the development process, it is highly unlikely that the resulting interface will be universally usable. Therefore, existing development approaches must be better documented and new development life cycles and techniques (which move toward universal usability and at the same time and are simple, inexpensive, and easy to implement) need to come to the forefront. Table 13.1 provides a list of some potential strategies to move toward universal usability in specific interface projects. Emphasis is on the fact that these inclusive solutions should not offer a simple one-size-fits-all solution but rather a solution that is individually tailorable and serves diverse user groups and environments equally well. This may possibly include solutions

Table 13.1. Strategies for moving toward universal usability in a specific interface project.

Planning for development:
If an interface is not universally usable in its current form, push hard to include universal usability in the next development life cycle for the interface
Verify that the scope of user and technology diversity is well-documented... when you talk about UU for this project; specifically, what users and what technologies are you talking about?
Do any laws related to accessibility apply to your project?
What level of expertise on UU exists among the members of the project team? What user representatives do you need to bring into the development process?
Early design:
In early design stages, make sure that scenarios/use cases and personas represent user diversity
Be certain that early low-fidelity mock-ups are developed in consideration of user diversity
Usability evaluation:
Use free and low cost tools available on the web (such as screen readers, impairment simulators, and reading comprehension estimators)
Have developers attempt to use an interface using only a keyboard, with no pointing device
Involve users from diverse user populations in usability testing, even if it's as few as three or four users
Implementation:
Measure the usage by diverse user groups and technologies. These metrics will be important to collect, in order to convince of the importance of UU in the NEXT development life cycle
If certain user diversity or technology groups were not addressed in design, document why they were not included and how they should be included in the next design life cycle

that are built into infrastructure, such as sensor-based interfaces or pluggable interfaces. This concept is becoming particularly important when considering ubiquitous computer use (the integration of computing into everyday tasks in a variety of contexts and environments). Making computers and interfaces context-aware requires holistic approaches and evaluations, taking interfaces beyond designs that are simply looking at sets of user characteristics. Table 13.1 summarizes strategies for integrating universal usability into the design and development process.

The main focus of universal usability, however, remains to enable users to be successful users of information and communication technology, and the goals of supporting user flexibility, user control, system transparency, availability, and accessibility will always be the key considerations in universal usability.

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