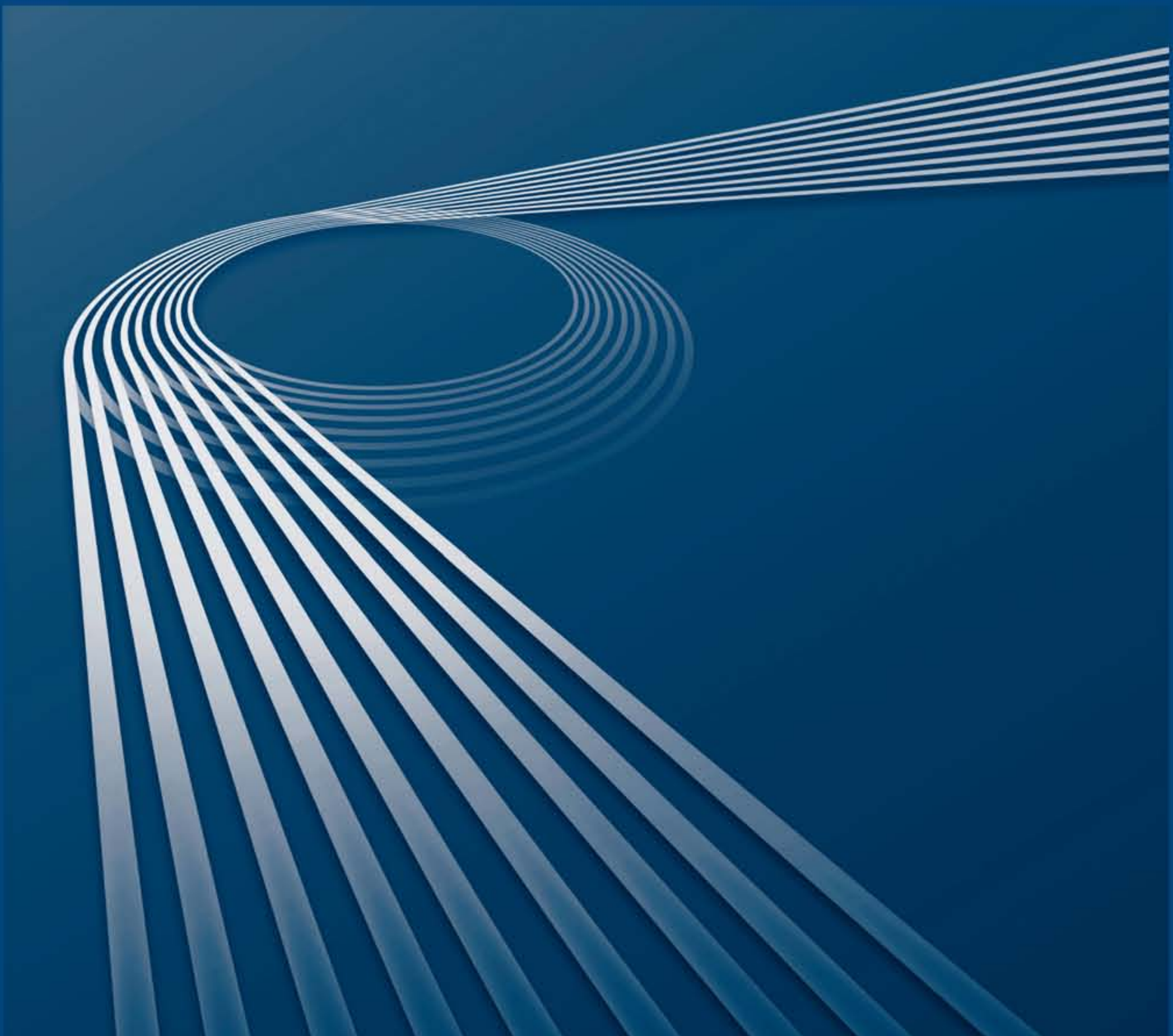
The Universal Access Handbook



Constantine Stephanidis

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The Universal Access Handbook

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To those who care

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Foreword

This new volume in the Human Factors and Ergonomics series represents the current state-of-the-art in a young but rapidly developing and maturing scientific domain—universal access—which addresses principles, methods, and tools to develop interactive technologies that are accessible and usable by all citizens in the information society.

The Universal Access Handbook follows the 2001 publication of the first book dedicated to design for all in human-computer interaction (HCI), *User Interfaces for All: Concepts, Methods, and Tools*.

Since then, the scope of investigation in universal access has broadened, more systematic investigations of users, contexts, and technology diversity in the information society have been carried out, new methodological approaches have been elaborated upon, existing approaches have been embedded in the development of support tools, a wide variety of novel interaction techniques have emerged for supporting user diversity, and a plethora of applications and case studies putting to practice all of these issues have become available. Additionally, awareness and policy have also progressed to the point that now accessibility to the basic technological infrastructure has been recognized as a fundamental human right by many countries in the world and by the United Nations.

This handbook reflects all these recent developments in an effort to consolidate present knowledge in the field of universal access and to open new perspectives for the future. It provides a structured guide to professionals and practitioners working in the field, a comprehensive and interrelated collection of reference articles for academics and researchers, an indispensable source of information for interdisciplinary and cross-thematic study, an important educational tool in an increasingly globalized research and development environment, and a base line for future in-depth studies in the subject matter.

It contains 61 chapters covering the breadth and depth of the subject area, written by 96 authors from 14 countries. Of these individuals, 60 come from academia, 22 from research institutions, and 14 from industry. The book includes 381 figures, 87 tables, and 3575 references.

In summary, this handbook provides a great contribution toward further advancing the concepts and principles of universal access for the benefit of all citizens in the emerging information society. For this, I express my appreciation and extend my congratulations to the editor and the authors of *The Universal Access Handbook*.

Gavriel Salvendy
Series Editor

Preface

Since the 2001 publication of the volume *User Interfaces for All: Concepts, Methods, and Tools,* which was the first and so far unique attempt to edit a book dedicated to a comprehensive and multidisciplinary view of design for all in human-computer interaction (HCI), the field of universal access has made significant progress toward consolidating theoretical approaches, methods, and technologies, as well as exploring new application domains. Universal access refers to the conscious and systematic effort to proactively apply principles, methods, and tools of universal design, in order to develop information society technologies that are accessible and usable by all citizens, including the very young and the elderly, as well as people with different types of disabilities, thus avoiding the need for *a posteriori* adaptations or specialized design. The requirement for universal access stems from the growing impact of the fusion of the emerging technologies, and from the different dimensions of diversity, which are intrinsic to the emergence of the information society. These dimensions become evident when, for example, considering the broad range of user characteristics, the changing nature of human activities, the variety of contexts of use, the increasing availability and diversification of information and knowledge sources and services, and the proliferation of technological platforms.

The Universal Access Handbook is intended to provide a comprehensive and multidisciplinary overview of the field of universal access. It is a collection of 61 chapters, structured into nine parts, written by leading international authorities, affiliated with academic, research, and industrial organizations. The nine parts of this handbook holistically address all major dimensions of universal access, unfolding:

- The historical roots of universal access through the progressive elaboration of diverse and complementary approaches to the accessibility of interactive applications and services
- Current perspectives and trends in the field
- The various dimensions of diversity in the user population, including, but not limited to, various forms of disability
- The various dimensions of diversity in the technological platforms and contexts of use, including trends toward mobile interaction
- The implications of universal access on the development life cycle of interactive applications and services
- The implications of universal access on user-interface architectures and related components
- Required and available support tools for the development of universally accessible applications and services
- Alternative new and emerging interaction techniques and devices to support diversity in user interaction
- Examples, case studies, and best practices of universal access in new and emerging application domains
- Nontechnological issues related to universal access practice, demand, offer, management, and acceptance
- Future perspectives, with emphasis on the role and impact of universal access in the context of ambient intelligence environments

The handbook is targeted to a broad readership, including HCI researchers, user-interface designers, computer scientists, software engineers, ergonomists and usability engineers, human factors researchers and practitioners, organizational psychologists, system/product designers, sociologists, policy and decision makers, scientists in government, industry, and education, and assistive technology and rehabilitation experts, as well as undergraduate and postgraduate students reading in the various relevant scientific fields.

Constantine Stephanidis
Editor

Acknowledgments

This handbook would not have been possible without the dedicated commitment of many people whom I would like to thank. The authors of all chapters are congratulated for their dedicated efforts and collaborative attitude throughout the long process of editing and publishing this volume. My appreciation goes to the book series editor, Prof. Gavriel Salvendy, and the advisory board of this handbook, who have greatly contributed to the highest quality standards of this volume. My sincere appreciation for all their efforts and dedication also goes to the reviewers of the chapters, who are listed below.

At base camp, my gratitude goes to Dr. Margherita Antona for her unwavering dedication to the cause of this project, and for her prominent and unwearied support role throughout the long and demanding editing process. Maria Pitsoulaki deserves a singular mention of appreciation for her commitment and assistance, down to the last detail, during the editing process.

Finally, I express my appreciation to Cindy Carelli and Marsha Pronin of CRC Press/Taylor & Francis, who have supported and facilitated the editorial work during the preparation of this volume.

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Constantine Stephanidis is a professor in the Department of Computer Science[1] at the University of Crete,[2] Director of the Institute of Computer Science[3]–FORTH,[4] and head of the Human-Computer Interaction Laboratory,[5] the Centre for Universal Access and Assistive Technologies,[6] and the Ambient Intelligence Programme.[7] He is currently a member of the National Advisory Council for Research and Technology of the Hellenic Ministry of Development and president of the Board of Directors of the Science and Technology Park of Crete.[8]

Over the past 25 years, Prof. Stephanidis has been engaged as the Scientific Responsible in more than 40 European Commission and nationally funded projects in the fields of human-computer interaction, universal access, and assistive technologies. In the beginning of the 1990s, he introduced the concept and principles of design for all in human-computer interaction and for universal access to the evolving information society technologies. He has published more than 350 technical papers[9] in scientific archival journals, proceedings of international conferences, and workshops related to his fields of expertise. He is editor-in-chief of the Springer international journal *Universal Access in the Information Society.*[10] He is editor and (co-)author of many chapters of the book *User Interfaces for All: Concepts, Methods, and Tools*,[11] published by Lawrence Erlbaum Associates (2001). From 1995–2006 he was the founding chair of the ERCIM working group “User Interfaces for All”[12] and general chair of its nine international workshops. From 1997–2000 he was the founding chair of the International Scientific Forum “Towards an Information Society for All,”[13] in the context of which he edited two white papers[14] concerning the roadmap and R&D agenda. Since 2001 he has been the founding chair of the International Conference Universal Access in Human-Computer Interaction,[15] and since 2007 he has been the general chair of the HCI International Conference[16] series.

Since the late 1980s, Prof. Stephanidis has been actively involved in activities contributing to the European Commission R&D Policy on Information Society. More recently, he was a member of the FP6 Information Society Technologies Management Committee (2002–2006) and the eAccessibility Expert Group (2002–2005). Since 2006 he has been a member of the eInclusion Group of the i2010 Initiative and the Management Board of the European Network and Information Security Agency (ENISA),[17] having worked tirelessly for the hosting of the European Agency in Heraklion since 2002. He is also a cofounder, in 2004, of the European Design for All

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2 http://www.uoc.gr/About/index.html.
3 http://www.ics.forth.gr.
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15 http://www.hcii2009.org/thematic_view.php?thematic_id=5.
16 http://www.hci-international.org.
17 http://www.enisa.europa.eu.

e-Accessibility Network (EDeAN)[18] and founder of the GR-DeAN,[19]the corresponding national network. Prof. Stephanidis is senior editor of the EDeAN White Paper,[20] outlining a roadmap for future European initiatives in Design for All, e-Accessibility and e-Inclusion (published in 2006).

Prof. Stephanidis is the scientific coordinator of the European Commission Coordination Action InterLink[21] (2006–2009), which aims to identify and address basic, worldwide research problems in software-intensive systems and new computing paradigms, ambient computing and communication environments, and intelligent and cognitive systems under a human-centered perspective and to define joint basic research agendas for worldwide cooperation in these domains.

[18] http://www.e-accessibility.org.
[19] http://www.e-accessibility.gr.
[20] http://www.springerlink.com/link.asp?id=e31p27x51v0mt60w.
[21] http://interlink.ics.forth.gr.

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Introduction to Universal Access

1

Universal Access and Design for All in the Evolving Information Society

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Constantine Stephanidis

1.1 Introduction

The Universal Access Handbook aims at advancing the state of the art in universal access by providing a comprehensive and multidisciplinary overview of the field and unfolding its various dimensions. After some years from its first steps (Stephanidis et al., 1998, 1999), universal access is a continuously growing and dynamically evolving field that accompanies and fosters the evolution of the information society in its current and future advancement and develops and extends its methods, techniques, and tools accordingly. Within a decade, universal access has already scaled up to obtain international recognition, specific research agendas,[1] technical scientific and policy forums and networks,[2] international conferences,[3] and archival journals,[4] while the need is also rapidly emerging to further consolidate the field by establishing technology transfer as well as education and training practices. In such a context, this chapter offers some reflection on universal access as a field of inquiry by providing an overview of progress and achievements so far and discussing current status and perspectives. This chapter also offers an interpretative key to this handbook by guiding the reader through its 9 parts and 61 chapters in the light of the main dimensions and implications of universal access.

1.2 The Field of Universal Access

The origins of universal access are to be identified in approaches to accessibility mainly targeted toward providing access to computer-based applications by users with disabilities, as well as in human-centered approaches to human-computer interaction (Stephanidis and Emiliani, 1999). The main aim is to prevent the exclusion of users from the information society while at the same time increasing the quality and usability of products and services.

Transcending the traditional view of accessibility and usability, universal access embraces theoretical, methodological, and empirical research of both a technological and nontechnological nature that addresses accessibility, usability, and, ultimately, acceptability of information society technologies (IST) by anyone, anywhere, at any time, and through any media and device (Stephanidis, 2001a).

Universal access puts forward a novel conception of the information society (Stephanidis et al., 1998, 1999) founded on a novel way of addressing the relationship between *techne* and *politeia*, where, on the one hand, technological development highly affects the life of all citizens, and, on the other hand, there is an ethical but also business-driven methodological requirement of informing technological evolution to deeply human-centered

[1] See Stephanidis et al. (1998, 1999).

[2] International Scientific Forum "Towards an Information Society for All"—ISF-IS4ALL, 1997–2000, http://www.ui4all.gr/isf_is4all; ERCIM WG UI4ALL, 1995–2006, http://www.ui4all.gr; Thematic Network "Information Society for ALL"—IS4ALL (IST-IST-1999-14101), 2000–2003; European Design for All eAccessibility Network—EDeAN, 2002–present, http://www.edean.org.

[3] Universal Access in Human-Computer Interaction (UAHCI), http://www.hcii2009.org/thematic_view.php?thematic_id=5.

[4] International journal *Universal Access in the Information Society* (UAIS), http://www.springeronline.com/journal/10209/about.

principles. In these respects, the connotation, theoretical underpinnings, and practical results of universal access are informed by, but are also intended to inform, the evolution of the information society as a human, social, and technological construct. Universal access can therefore be viewed as a social-shaping approach in terms of philosophy of technology (MacKenzie and Wajcman, 1985), equally distant from the determinism of both technological enthusiasm and technological nightmare views. In this perspective, it is fundamental that different routes are available in the design of individual artifacts and systems and in the direction or trajectory of innovation programs, potentially leading to different technological outcomes. Significantly, these choices could have differing implications for society and for particular social groups (Williams and Edge, 1996).

Thus, while universal access is targeted to provide a technological substratum for eInclusion in the information society, it also recognizes that "the development of the information society is not likely to be characterized by a linear technological progression, but rather through the often competing forces of innovation, competitive advantage, human agency and social resistance" (Loader, 1998), and that " 'inclusion' must be a process which is the result of the 'human agency' of the many diverse individuals and cultural or national groups who should help shape and determine, and not merely 'access,' technological outcomes" (Henwood et al., 2000).

A direct consequence is the multidisciplinary nature of universal access, evident from the beginning of the field in its conscious effort to ensure a broad scope of research and development activities empowered with new concepts, tools, and techniques from diverse and in some cases dispersed scientific disciplines, technological strands, and socioeconomic and policy perspectives. At the scientific level, this amounts to a need for establishing cross-discipline collaborative views based on synergies among relevant disciplines to bring about a new conceptualization of computer-mediated human activities within the information society (Stephanidis, 2001a).

Another important aspect of universal access is its human-centeredness. In the context of universal access, the study of human characteristics and requirements in relation to the use of IST is of fundamental importance, thus necessitating the contribution of all related scientific disciplines. Universal access goes well beyond current approaches stating the centrality of the human element in the design and development process (Norman and Draper, 1986), as it introduces a new and challenging dimension—the consideration and valorization of human diversity. In the information society and for the vast majority of its applications (e.g., World Wide Web services), the set of users is unknowable (Olsen, 1999). Therefore, in universal access, the consideration of human diversity becomes a *conditio sine qua non*, and the traditional precept of "knowing the users" becomes "knowing diverse user groups and individual users."

The role of technology is equally critical in universal access, as technology is the fundamental provider of the required tools through which humans interact with information artifacts. All technological advances in computing platforms and environments, as well as advances in computing that give rise to new interaction possibilities (in terms of both interaction techniques and domains of application), are potentially relevant to universal access. However, universal access seeks to transcend specific technological manifestations, as the nature of interaction changes dramatically as time goes by and new technologies and trends emerge continuously in the information society. This is evident from the history of computing, which has started with command-line interfaces and has gone through many evolutions, including graphical user interfaces, mobile computing, virtual reality, ubiquitous computing, and ambient intelligence. Therefore, universal access needs to be prepared for new evolutions by elaborating innovative, more fundamental approaches to interaction.

Universal access has a focus on design, as it entails a forward-looking proactive attitude toward shaping new generations of technology rather than short- or medium-term interventions on the present technological and market situation (Stephanidis et al., 1998, 1999). Therefore, innovation in design is invested with a central role in terms of methodological frameworks, processes, techniques, tools, and outcomes. In the context of universal access, *design for all* in the information society has been defined as a general framework catering for conscious and systematic efforts to proactively apply principles, methods, and tools to develop IST products and services that are accessible and usable by all citizens, thus avoiding the need for *a posteriori* adaptations, or specialized design (Stephanidis et al., 1998). Design for all, or universal design, is well known in several engineering disciplines, such as, for example, civil engineering and architecture, with many applications in interior design, building, and road construction. In the context of universal access, design for all either subsumes, or is a synonym of, terms such as *accessible design*, *inclusive design*, *barrier-free design*, *universal design*, and so on, each highlighting different aspects of the concept. Through the years, the concept of design for all has assumed various main connotations:

- Design of interactive products, services, and applications that are suitable for most of the potential users without any modifications. Related efforts mainly aim to formulate accessibility guidelines and standards in the context of international collaborative initiatives.
- Design of products that have standardized interfaces capable of being accessed by specialized user-interaction devices (e.g., Zimmermann et al., 2002).
- Design of products that are easily adaptable to different users by incorporating adaptable or customizable user interfaces (Stephanidis, 2001b).

This last approach fosters a conscious and systematic effort to proactively apply principles and methods and employ appropriate tools to develop interactive products and services that are accessible and usable by all citizens in the information society, thus avoiding the need for *a posteriori* adaptations or specialized design. This entails an effort to build access features into a product starting from its conception and continuing throughout the entire development life cycle.

Finally, while efforts toward technological developments are clearly necessary, they do not constitute a sufficient condition for leading to an information society for all citizens. There are additional requirements for nontechnological measures to assess efficacy and ensure adoption, acceptance, and diffusion of technologies. Socioeconomic and policy issues are relevant to the extent to which they address research and development planning, industrial policy and innovation, assessment of the envisioned products and services, security and privacy, cost factors, diffusion and adoption patterns, standards, legislation, and technology transfer.

The aim of this handbook is to reflect to the largest possible extent the multidisciplinary nature of universal access and at the same time provide a structured path toward unfolding the role and contribution of different research, development, and policy areas in the context of universal access.

1.3 Universal Access Today: An Overview

This section offers an overview of the progress made in the field of universal access as it consolidates itself after some years of intensive efforts and increasing expansion and recognition. The underlying intent is to systematically address, as comprehensively as possible, the various dimensions of universal access, as they hold at present and are reflected in this handbook, and to point out main achievements and prospects.

1.3.1 Theoretical Background

As previously mentioned, universal access emerged through the progressive elaboration of diverse and complementary approaches to the accessibility of interactive applications and services (Stephanidis and Emiliani, 1999). Traditional efforts to provide accessibility for users with disabilities were based on the product-level- and environment-level adaptation of applications and services, originally developed for able-bodied users. These approaches have given rise to several methods, including techniques for the configuration of input/output at the level of the user interface and the provision of assistive technologies. Popular assistive technologies include screen readers and Braille displays for blind users, screen magnifiers for users with low vision, alternative input and output devices for motor-impaired users (e.g., adapted keyboards, mouse emulators, joysticks, and binary switches), specialized browsers, and text prediction systems. Despite progress, assistive technologies and dedicated design approaches have been criticized for their essentially reactive nature (Stephanidis and Emiliani, 1999). Therefore, the need for more systematic and proactive approaches to the provision of accessibility has emerged, leading to the concepts of universal access and design for all. In this context, accessibility refers to the extent to which the use of an application or service is affected by the user's particular functional limitations or abilities (permanent or temporary), as well as by other contextual factors (e.g., characteristics of the environment). This implies that for each user task of an application or service (and taking into account specific functional limitations and abilities and other relevant contextual factors), there is a sequence of input actions and associated feedback via accessible input/output devices that lead to successful task accomplishment (Savidis and Stephanidis, 2004). In this light, universal access also provides a clear answer to the debate on the relationships between accessibility and usability (see, e.g., Petrie and Kheir, 2007): accessibility becomes a fundamental prerequisite of usability, intended as the capability of all supported paths toward task accomplishment to "maximally fit" individual users' needs and requirements in the particular context and situation of use (Savidis and Stephanidis, 2004), since there may not be optimal interaction if there is no possibility of interaction in the first place.

Along these lines, the historical roots of universal access are addressed in the remaining two chapters of Part I of this handbook from both a European and American perspective. The transition from accessibility to universal access and design for all is illustrated in Chapter 2, "Perspectives on Accessibility: From Assistive Technologies to Universal Access and Design for All," by P. L. Emiliani, through a series of landmark research projects, funded by the European Commission, that have demonstrated the feasibility of the design for all approach in the information and communication technologies (ICT) field. Over the years, suitable technical approaches have been elaborated to design and implement universally accessible interfaces, services, and applications. Looking toward ongoing developments and the emergence of ambient intelligence environments while asking for a more general application of the design for all approach also favors its implementation by making available in the environment the necessary interaction means and intelligence.

New technological achievements will contribute to the blurring of the lines between assistive technologies and design for all in next-generation interfaces. Current dramatic changes in information technologies and human interfaces are creating both new challenges and new opportunities for developing mainstream products that are accessible to and usable by people with disabilities or functional impairments, but in principle also all users. These issues are addressed in Chapter 3, "Accessible and Usable Design of Information and Communication Technologies," by G. C. Vanderheiden.

1.3.2 Diversity in the User Population

In the context of the emerging distributed and communication-intensive information society, users are no longer the computer-literate, skilled, and able-bodied workers driven by performance-oriented motives. Additionally, users no longer constitute a homogeneous mass of actors with standard abilities, similar interests, and common preferences regarding information access and use. Instead, it becomes compelling that designers' conception of users accommodate all potential citizens, including residential users, as well as those with situational or permanent disabilities, but also people of different ages and with different experiences and cultural and educational backgrounds. Therefore, at the heart of universal access lies a deeply human-centered focus on human diversity in all its aspects related with access to and use of ICT. Main efforts in this direction are concerned with the identification and study of various nontraditional target user groups (e.g., disabled, elderly, novice users, etc.), as well as of their requirements for interaction, and of appropriate methods, tools, and interactive devices and techniques to address their needs. Much experimental work has been conducted in recent years to elaborate design guidelines for diverse user groups. Work in understanding human characteristics and needs in relation to interaction has also been facilitated by the functional approach of the International Classification of Functioning, Disability and Health (ICF) (World Health Organization, 2001), where the term *disability* is used to denote a multidimensional phenomenon resulting from the interaction between people and their physical and social environment. This allows grouping and analysis of limitations that are not only due to impairments but also, for example, to environmental reasons.

Part II of this handbook provides an overview of the main issues related to users' diversity in the context of universal access. A general introduction to this topic is provided in Chapter 4, "Dimensions of User Diversity," by M. Ashok and J. A. Jacko. Several dimensions of diversity are discussed, including disabilities and impairments, skill levels, cognitive factors, social issues, cultural and linguistic issues, age, and gender. Each diversity dimension is analyzed with a focus on how differences translate into variations in the use of technology, along with suggestions for how designers can be inclusive in their design by accounting for such differences.

In the subsequent chapters of Part II, various dimensions of user diversity are analyzed in more depth. An overview of the different types of motor impairments that may affect access to interactive technologies, their prevalence across the general population, and their interrelations with the aging process are provided in Chapter 5, "Motor Impairments and Universal Access," by S. Keates. This chapter also overviews common software and hardware solutions for improving access for motor-impaired users and analyzes in detail the effects of motor impairments on key pressing and cursor control.

Various sensory impairments also bring about diverse interaction requirements. Chapter 6, "Sensory Impairments," by E. Kinzel and J. A. Jacko, addresses the general structure and function of the primary human sensory systems—vision, hearing, and touch—that are vital to interaction with technology, as well as some examples of common sensory-specific impairments that may affect interaction. Some of the recent technological developments targeted to enhance the sensory experience of users with impairments are also discussed.

The diversity and complexity of cognitive differences, addressed in Chapter 7, "Cognitive Disabilities," by C. Lewis, also highly affect interaction, and many barriers for access arise for people with cognitive disabilities. Designing technology to reduce these barriers involves the combination of appropriate interface features, attention to configurability, and user testing.

The current demographic phenomena that lead to an aging society and the degenerative ability changes caused by age determine fundamental differences in the way older and younger persons use ICT. Chapter 8, "Age-Related Differences in the Interface Design Process," by S. Kurniawan, focuses on understanding these changes and accommodating them through aging-sensitive design to mediate differences and considerably improve the use of computers, the Internet, and mobile devices by older persons.

Finally, the linguistic and cultural dimensions of diversity acquire progressive importance as the information society becomes increasingly global. Chapter 9, "International and Intercultural User Interfaces," by A. Marcus and P-L. P. Rau, addresses these issues by proposing an approach to global user-interface design consisting of partially universal and partially local solutions to the design of metaphors, mental models, navigation, interaction, and appearance. By managing the user's experience of familiar structures and processes, user interface design can obtain more usable, useful, and appealing results for an international audience.

1.3.3 Technologies for Universal Access

In the information society, diversity concerns not only users, but also interaction environments and technologies, which are continuously developing and diversifying. The diffusion of the Internet and the proliferation of advanced interaction technologies (e.g., mobile devices, network-attachable equipment, virtual reality, agents, etc.) signify that many applications and services are no longer limited to the visual desktop but span over new realities and interaction environments. Overall, a wide variety of technological paradigms play a significant role in universal access either by providing new interaction platforms or by contributing at various levels to ensure and widen access. Part III of this handbook seeks to offer an overview of these issues.

The World Wide Web and its technologies are certainly a fundamental component of the information society. Chapter 10, "Accessing the Web," by V. L. Hanson, J. T. Richards, S. Harper, and S. Trewin, discusses various challenges and solutions to make the web accessible to all. In the context of the information society, the World Wide Web offers much for those who are able to access its content, but at the same time access is limited by serious barriers due to limitations of visual, motor, language, or cognitive abilities. Current approaches to web accessibility, and in particular guidelines for web and browsers' development, as well as current opportunities and obstacles toward further progress in this domain, are also reviewed.

Another very important and rapidly progressing technological advance is that of mobile computing. Mobile devices acquired an increasingly important role in everyday life, both as dedicated tools, such as media players, and multipurpose devices, such as personal digital assistants and mobile phones. Chapter 11, "Handheld Devices and Mobile Phones," by A. Kaikkonen,

E. Kaasinen, and P. Ketola, describes the specific characteristics of mobile contexts of use, mobile devices, mobile services, and mobile user interfaces and how those characteristics are affected by the demand for universal access. Guidelines for designing and evaluating mobile devices and services for universal access are also offered.

As the information society extends from the real to the virtual world, Chapter 12, "Virtual Reality," by D. Hughes, E. Smith, R. Shumaker, and C. Hughes, describes the basic concepts of virtual reality in terms of specific technologies, physical infrastructures, and applications for accessibility, assessment, and therapy. Included within the discussion are a range of virtual reality concepts, such as augmented reality and mixed reality. Additionally, auditory displays, haptics, and tracking technologies for virtual reality applications are discussed.

Security and integrity of data are of paramount importance in the context of universal access. Chapter 13, "Biometrics and Universal Access," by M. C. Fairhurst, focuses on biometric technologies as a means to verify user access rights. Some of the basic principles underlying the adoption of biometrics as a means of establishing or verifying personal identity are outlined, and approaches are discussed to enhance the reliability and flexibility of biometrics and to ensure their effective implementation.

Agents constitute another enabling technology of universal access. Chapter 14, "Interface Agents: Potential Benefits and Challenges for Universal Access," by E. André and M. Rehm, discusses the use of interface agents to enable a large variety of users to gain access to information technology. As mediators between users and a computer system, agents seem to be ideally suited to adapt to the different backgrounds of heterogeneous user groups. The technological requirements to be met for interface agents to satisfy the requirements for universal access are investigated.

1.3.4 Development Life Cycle of User Interfaces

The notion of universal access reflects the concept of an information society in which potentially anyone (i.e., any user) interacts with computing machines, at any time and any place (i.e., in any context of use) and for virtually anything (i.e., for any task). To reach a successful and cost-effective realization of this vision, it is critical to ensure that appropriate interface development methods and techniques are available. Traditional development processes, targeted toward the elusive "average case," are clearly inappropriate for the purposes of addressing the new demands for user and usage context diversity and for ensuring accessible and high-quality interactions (Stephanidis, 2001b). Under this perspective, universal access affects the entire development life cycle of interactive applications and services. Work in this area has therefore concentrated on design and development methodologies and frameworks that integrate and support design for all approaches, support user interface adaptation, and integrate the consideration of diversity throughout all development phases.

Part IV of this handbook unfolds several aspects of user interface development in a universal access perspective, including user requirements analysis, user interface design, software development requirements, and accessibility and usability evaluation.

Various user requirement analysis methods and techniques present both advantages and potential difficulties in the optimal involvement and usage for diverse user groups, including users with various types of disabilities or in different age ranges. Chapter 15, "User Requirements Elicitation for Universal Access," by M. Antona, S. Ntoa, I. Adami, and C. Stephanidis, provides an overview.

The requirements for designing diversity for end-users and contexts of use, which implies making alternative design decisions at various levels of the interaction design, inherently leading to diversity in the final design outcomes, are discussed in Chapter 16, "Unified Design for User Interface Adaptation," by A. Savidis and C. Stephanidis. To this end, traditional design methods are suboptimal, since they cannot accommodate for diversity. Therefore, there is a need for a systematic process in which alternative design decisions for different design parameters may be supported. Unified user interfaces constitute a theoretical platform for universally accessible interactions, characterized by the capability to self-adapt at run-time, according to the requirements of the individual user and the particular context of use. The unified interface design method is a process-oriented design method that enables the organization of diversity-based designs and encompasses a variety of techniques such as task analysis, abstract design, design polymorphism, and design rationale.

An instantiation of unified user interface design in the area of computer games is presented in Chapter 17, "Designing Universally Accessible Games," by D. Grammenos, A. Savidis, and C. Stephanidis, that discusses its adaptation to the specific domain and its practical application in two design cases.

The last decade has also witnessed the elaboration of a corpus of key development requirements for building universally accessible interactions. Such requirements have been consolidated from real practice in the course of six medium-to-large-scale research projects within a 10-year timeframe and are discussed in Chapter 18, "Software Requirements for Inclusive User Interfaces," by A. Savidis and C. Stephanidis.

In parallel, models for inclusive design processes, methods, and tools that can stimulate and manage the implementation of inclusive design and evaluation methods to support informed decision-making for inclusive design have also been elaborated, and are reported in Chapter 19, "Tools for Inclusive Design," by S. Waller and P. J. Clarkson.

Finally, the last chapter in this part, Chapter 20, "The Evaluation of Accessibility, Usability, and User Experience," by H. Petrie and N. Bevan, introduces a range of accessibility, usability, and user experience evaluation methods that assist developers in the creation of interactive electronic products, services, and environments (e-systems) that are both easy and pleasant to use for a broad target audience, including people with disabilities and older people. For each method, appropriate use, strengths, and weaknesses are outlined.

1.3.5 User Interface Development: Architectures, Components, and Support Tools

Another challenge of universal access concerns the development of methods and tools capable of making it not only technically feasible but also economically viable in the long-term (Stephanidis et al., 1998). In the past, the availability of techniques and tools was an indication of maturity of a sector and a critical factor for technological diffusion. As an example, graphical user interfaces became popular once tools for constructing them became available, either as libraries of reusable elements (e.g., toolkits), or as higher-level systems (e.g., user interface builders and user interface management systems). As development methods and techniques for addressing diversity are anticipated to involve complex processes and have a higher entrance barrier with respect to more traditional means, the provision of appropriate tools can help overcome some of the difficulties that hinder the wider adoption of design methods and techniques appropriate for universal access, both in terms of quality and cost, by making the complex development process less resource-demanding and better at supporting reuse. To support a universal access development life cycle as sketched in Part IV of this handbook, purposeful software architectures, user interface toolkits, representation languages, and support tools have been elaborated, tested, and applied, with the underlying objective to facilitate the adoption and application of universal access approaches and improve ease of development and cost justification. Main achievements in this area are addressed in Part V of this handbook.

A software architecture that supports run-time self-adaptation behavior in the framework of unified user interfaces is presented in Chapter 21, "A Unified Software Architecture for User Interface Adaptation," by A. Savidis and C. Stephanidis. The software engineering of automatic interface adaptability entails the storage and processing of user and usage context profiles, the design and implementation of alternative interface components, and run-time decision making to choose on the fly the most appropriate alternative interface component given a particular user and context profile.

Chapter 22, "A Decision-Making Specification Language for User Interface Adaptation," by A. Savidis and C. Stephanidis, focuses on the decision-making process according to diverse profiles of individual end-users and usage contexts in automatic user interface adaptation. A verifiable language is proposed that is particularly suited for the specification of adaptation-oriented decision-making logic, while also being easily deployable and usable by interface designers.

A novel approach to the development of inclusive web-based interfaces (web content) capable of adapting to multiple and significantly different profiles of users and contexts of use is introduced in Chapter 23, "Methods and Tools for the Development of Unified Web-Based User Interfaces," by C. Doulgeraki, N. Partarakis, A. Mourouzis, and C. Stephanidis. The unified web interfaces method, building on the unified user interfaces development method, is proposed as an alternative approach to the design and development of web-based applications. An advanced toolkit has also been developed as a means to facilitate web developers in producing adaptable web interfaces following the proposed method.

User modeling is another important area that provides the foundations for design for all, personalization, and adaptation of user interfaces. Chapter 24, "User Modeling: A Universal Access Perspective," by R. Adams, outlines various approaches, implications, and practical applications of user modeling along with the basis for a toolkit of concepts, methods, and technologies that support them. These are discussed in relation to unified user interfaces as an emerging design methodology for universal access.

Model-based approaches are considered very promising in the context of universal access, as they can potentially reduce the complexity of design for all tasks while also facilitating development. As model-based tools capture design inputs and specifications and support their refinement to the implementation level, they can be used along the various phases of development and allow the specification of highly adaptable user interfaces, which are considered key for universal access. Chapter 25, "Model-Based Tools: A User-Centered Design for All Approach," by C. Stary, focuses on model-based tools that support design for all and take into account both user tasks and needs, as well as software engineering principles.

Design for all knowledge also needs to be represented and codified. Chapter 26, "Markup Languages in Human-Computer Interaction," by F. Paternó and C. Santoro, discusses the importance of formalizing interaction-related knowledge in such a way that it can be easily specified and processed and proposes markup languages as an appropriate instrument in this respect. Chapter 26 analyzes how various markup languages are used to represent the relevant knowledge and how such information can be exploited in the design, user interface generation, evaluation, and run-time support phases.

Finally, Chapter 27, "Abstract Interaction Objects in User Interface Programming Languages," by A. Savidis, presents a subset of a user interface programming language that provides programming facilities for the definition of virtual interaction object classes and the specification of the mapping logic to physically instantiate virtual object classes across different target platforms. These constitute a significant step toward universal access, as virtual interaction objects play the role of abstractions over any particular physical realization or dialogue metaphor, thus facilitating the compact development of user interface adaptations.

1.3.6 Interaction Techniques and Devices

A very wide variety of alternative interaction techniques and devices have significant potential to serve and support diversity in user interaction, and recent advances in several domains are crucial to universal access. On the other hand, it is of paramount importance that diversity and human characteristics are taken into appropriate account while developing new interaction devices and techniques, so that diverse user groups and individual users can be provided with the most appropriate interaction means for each application and task. Part VI of this handbook is dedicated to an overview of recent major progress in interaction techniques and devices relevant for universal access, ranging from traditional assistive technologies to advanced perceptual interfaces.

Chapter 28, "Screen Readers," by C. Asakawa and B. Leporini, introduces screen readers as the main assistive technology used by people with little or no functional vision when interacting with a computer or mobile devices. A classification of screen readers is provided, and basic concepts of screen reading technology are described. Interaction using screen readers is described through practical examples. In particular, an overview of two main features is provided for visually impaired people that should be considered when designing user interfaces: user perception and user interaction.

The importance of text entry techniques and tools in the context of universal access is emphasized in Chapter 29, "Virtual Mouse and Keyboards for Text Entry," by G. Evreinov. In this area, the need emerges for elaborating interaction techniques for text entry that are adaptive to personal cognitive and sensory-motor abilities of the users. Progress in this area implies the design of a wide spectrum of text entry systems and the elaboration of novel algorithms to increase their efficiency. This chapter reviews different solutions and principles that have been proposed and implemented to improve the usability of text entry in human-computer interaction. Examples are the virtual mouse and onscreen keyboards.

Speech-based interaction is also a fundamental component of universal access, as it is one of the most natural forms of communication. Effective speech-based hands-free interaction has significant implications for users with physical disabilities, as well as users interacting in mobile environments. Chapter 30, "Speech Input to Support Universal Access," by J. Feng and A. Sears, focuses on the use of speech as input. Its advantages and limitations are discussed in relation to diverse user groups, including individuals with physical, cognitive, hearing, and language disabilities, as well as children. Guidelines for the design, evaluation, and dissemination of speech-based applications are reported.

Natural interaction is an approach to interface design that attempts to empower different users in various everyday situations by exploiting the strategies they have learned in human-human communication, with the ultimate aim of constructing intelligent and intuitive interfaces that are aware of the context and the user's individual needs. Chapter 31, "Natural Language and Dialogue Interfaces," by K. Jokinen, discusses natural language dialogue interfaces. In this context, the notion of natural interaction refers to the spoken dialogue system's ability to support functionality that the user finds intuitive and easy (i.e., the interface should afford natural interaction).

Nonspeech audio can offer an important design alternative or accompaniment to traditional visual displays and can contribute meeting universal access challenges by providing a means for creating more accessible and usable interfaces and offering an enhanced user experience. Chapter 32, "Auditory Interfaces and Sonification," by M. A. Nees and B. N. Walker, discusses the advantages and appropriate uses of sound in systems and presents a taxonomy of nonspeech auditory displays along with a number of important considerations for auditory interface design.

Haptic is another important nonvisual dimension of interaction. Chapter 33, "Haptic Interaction," by G. Jansson and R. Raisamo, provides an overview of basic issues within the area of haptic interaction. An extensive collection of low-tech, high-tech, and haptic displays is presented, with a special focus on haptic interaction for the visually impaired.

Computer vision has recently been employed as a sensing modality for developing perceptive user interfaces. Chapter 34, "Vision-Based Hand Gesture Recognition for Human-Computer Interaction," by X. Zabulis, H. Baltzakis, and A. Argyros, focuses on the vision-based recognition of hand gestures that are observed and recorded by typical video cameras. It provides an overview of the state of the art in this domain and covers a broad range of related issues ranging from low-level image analysis and feature extraction to higher-level interpretation techniques. Additionally, it presents a specific approach to gesture recognition intended to support natural interaction with autonomous robots that guide visitors in museums and exhibition centers.

Hierarchical scanning is an interaction technique specifically suited to people with motor disabilities, ensuring more rapid interaction and avoiding the time-consuming sequential access to all the interactive interface elements. Hierarchical scanning provides access to all the interactive interface elements of a window based on their place in the hierarchy by dynamically retrieving the window hierarchical structure through the use of binary switches as an alternative to traditional input devices (i.e., a keyboard or mouse). Chapter 35, "Automatic Hierarchical Scanning for Windows Applications," by S. Ntoa, A. Savidis, and C. Stephanidis, presents an advanced scanning method that enables motor-impaired users to work with any application running in Microsoft Windows without the need for further modifications.

Eye tracking is a technique-enabling control of a computer by eye movements alone or combined with other supporting modalities. Traditionally, eye control has been in use by a small group of people with severe motor disabilities, for whom eye control may be the only means of communication. However, recent advances in technology have considerably improved the quality of systems, such that a far broader group of people may now benefit from eye control technology. An overview of this technology is provided in Chapter 36, "Eye Tracking," by P. Majaranta, R. Bates, and M. Donegan, where the basic issues involved in eye control are introduced that consider the benefits and problems of using the eye as a means of control. A summary of key results from user trials is reported to show the potential benefits of eye control technology, with recommendations for its successful application.

Brain-body interfaces can be used for communicating, recreating, and controlling the environment by disabled individuals. Chapter 37, "Brain-Body Interfaces," by P. Gnanayutham and J. George, discusses how brain-body interfaces open up a spectrum of potential technologies particularly appropriate for people with traumatic brain injury and other motor impairments.

Significant advances have also been achieved recently in technologies capable of generating sign language animations and understanding sign language input in the context of information, communication, and software applications accessible to deaf signers. In Chapter 38, "Sign Language in the Interface: Access for Deaf Signers," by M. Huenerfauth and V. L. Hanson, challenges in the processing of sign languages are discussed, which arise from their specific linguistic and spatial characteristics that have no direct counterparts in spoken languages. Important design issues that arise when embedding sign language technologies in accessibility applications are also elaborated upon.

Chapter 39, "Visible Language for Global Mobile Communication: A Case Study of a Design Project in Progress," by A. Marcus, reports on long-term attempts to develop a universal visible language and discusses mobile computing and communication technology as a new platform for the use of such a language. The example is a report on the LoCoS language and its application as a usable, useful, and appealing basis for a mobile phone application that provides communication capabilities for people who do not share a spoken language.

Finally, multimodal interaction intrinsic in ambient intelligence is claimed to offer multiple benefits for promoting universal access. Chapter 40, "Contributions of 'Ambient' Multimodality to Universal Access," by N. Carbonell, presents recent advances in the processing of novel input modalities, such as speech, gestures, gaze, or haptics and synergistic combinations of modalities, all of which are currently viewed as appropriate substitutes for direct manipulation in situations where the use of a keyboard, mouse, and standard screen is awkward or impossible. A software architecture for multimodal user interfaces is proposed that takes into account the recent diversification of modalities and the emergence of context-aware systems distributed in the user's life environment.

1.3.7 Applications

Recent years have witnessed a wide variety of developments that exemplify the adoption of universal access and design for all principles and approaches in diverse new and emerging application domains. These developments demonstrate the centrality of the universal access concept toward technologically supported and enhanced everyday human activities in an inclusive information society. The experience accumulated through such concrete applications demonstrates that universal access is more of a challenge than it is a utopia. Part VII of this handbook represents a collection of some relevant case studies.

Digital libraries are crucial for access to information and knowledge as well as education and work in the information society. Chapter 41, "Vocal Interfaces in Supporting and Enhancing Accessibility in Digital Libraries," by T. Catarci, S. Kimani, Y. Dubinsky, and S. Gabrielli, focuses on the involvement of users, and in particular users with disabilities, in the systems development life cycle of digital libraries to support accessibility. A case study is presented that illustrates the use of vocal interfaces to enhance accessibility in digital libraries due to their usefulness in hands-busy, eyes-busy, mobility-required, and hostile/difficult settings, as well as their appropriateness for people who are blind or visually or physically impaired. The involvement of users in the development process has taken place through an integration of user-centered and agile methods.

Online communities have acquired increasing importance in recent years for various target user groups, and in particular for people with disabilities and the elderly. Chapter 42, "Theories and Methods for Studying Online Communities for People with Disabilities and Older People," by U. Pfeil and P. Zaphiris, highlights some of the key benefits of such applications for the disabled and the elderly and points to a number of weaknesses. The key theoretical foundations of computer-mediated communication are addressed, explaining how those could help in studying online social interaction.

Humans have individual cognitive, perceptual, and physical strengths and weaknesses, and universal access aims to build upon the respective user's strengths and to compensate for the weaknesses. Computer-supported cooperative work can contribute to bridging these domains in universal access for groups and communities, particularly toward bringing together users with heterogeneous cognitive, perceptual, and physical abilities. Chapter 43, "Computer-Supported Cooperative Work," by T. Gross and M. Fetter, provides an overview of the field of computer-supported cooperative work from a universal access perspective.

The emerging need for universal access design and implementation methods in the context of e-learning systems is put forward in Chapter 44, "Developing Inclusive e-Training," by A. Savidis and C. Stephanidis. This chapter reports on a consolidated development experience from the construction of training applications for hand-motor-impaired users and for people with cognitive disabilities. In this context, the primary emphasis is put on design and implementation aspects toward accessibility and usability for the addressed user groups.

Along the same lines, Chapter 45, "Training through Entertainment for Learning Difficulties," by A. Savidis, D. Grammenos, and C. Stephanidis, focuses on real-life training of people with learning difficulties. This is a highly challenging and demanding process that can be effectively improved with the deployment of special-purpose software instruments. The development and evaluation of two games are reported, with the main objective of investigating how playing games, and more generally, providing a pleasant and engaging interactive experience, can have a significant role on improving the training of people with learning difficulties.

Enriched documents (e.g., eBooks) that contain redundant alternative representations of the same information aim at meeting the needs of a heterogeneous range of readers. Chapter 46, "Universal Access to Multimedia Documents," by H. Petrie, G. Weber, and T. Völkel, presents a multimedia reading system that meets the needs of a number of print-disabled reader groups, including blind, partially sighted, deaf, hard of hearing, and dyslexic readers. The development of the system is described from an iterative user-centered design perspective, and a set of attributes is established for user personalization profiles that are needed for adapting content and presentation, as well as for adapting and customizing content, interaction, and navigation.

Augmentative and alternative communication supports interpersonal communication for individuals who are unable to speak. Chapter 47, "Interpersonal Communication," by A. Waller, provides an overview of this domain and introduces recent technological advances as examples of how natural language processing can be used to improve the quality of aided communication.

Public access terminals are also omnipresent in the information society. Chapter 48, "Universal Access in Public Terminals: Information Kiosks and ATMs," by G. Kouroupetroglou, examines current barriers in the use of public access terminals, along with user requirements for the elderly, the disabled (visually, aurally, intellectually, and physically), the temporarily or occasionally disabled, and foreigners. Available technologies (both software and hardware) to alleviate the barriers are also discussed, a range of accessibility strategies and prototype-accessible public terminals is presented, and an overview of available specific accessibility guidelines and standards is provided.

Information and communication technologies play an important role in enhancing and encouraging individual mobility in the physical environment. Chapter 49, "Intelligent Mobility and Transportation for All," by E. Bekiaris, M. Panou, E. Gaitanidou, A, Mourouzis, and B. Ringbauer, addresses major design issues emerging from the need to consider the individual and contextual requirements of a far more heterogeneous target group than in ordinary computing. A brief benchmarking of the issues that various population groups face in getting pre- and on-trip information, as well as in actually traveling via various transportation means, is presented. The involved issues are further highlighted by a series of best practice examples.

Chapter 50, "Electronic Educational Books for Blind Students," by D. Grammenos, A. Savidis, Y. Georgalis, T. Bourdenas, and C. Stephanidis, introduces a novel software platform for developing and interacting with multimodal interactive electronic textbooks that provide user interfaces concurrently accessible by both visually impaired and sighted persons. The platform comprises facilities for the authoring of electronic textbooks and for multimodal interaction with the created electronic textbooks. Key findings are consolidated, elaborating on prominent design issues, design rationale, and respective solutions and highlighting strengths and weaknesses.

Making mathematics accessible is also a significant challenge, due to its two-dimensional, spatial nature and the inherently linear nature of speech and Braille displays. Chapter 51, "Mathematics and Accessibility: A Survey," by E. Pontelli, A. I. Karshmer, and G. Gupta, reviews the state of the art in nonvisual accessibility of mathematics. Various approaches based on Braille codes and on aural rendering of mathematical expressions are discussed.

Cybertherapy and cyberpsychology emerge from the application of virtual reality techniques in psychological and psychiatric therapy. Chapter 52, "Cybertherapy, Cyberpsychology, and the Use of Virtual Reality in Mental Health," by P. Renaud, S. Bouchard, S. Chartier, and M-P. Bonin, presents cybertherapy and cyberpsychology through a universal access perspective. It describes the technologies involved and explains how clinical psychology is gaining from these technological progresses. Empirical data from clinical studies conducted with arachnophobic patients are presented.

1.3.8 Nontechnological Issues

As discussed in Section 1.2, universal access is not only a matter of technology. A large variety of nontechnological issues also affect the wider adoption and diffusion of universal access principles and methods in the mainstream, as the information society does not develop independently from the human society but needs to build upon it, while at the same time continuing to shape it. Nontechnological issues related to universal access practice, legislation, standardization, economics and management, ethical principles, and acceptance are addressed in Part VIII of this handbook.

Several frameworks for analyzing and assessing policies and legislation related to accessibility in Europe, the United States, and Japan, as well as the United Nations, are introduced in Chapter 53, "Policy and Legislation as a Framework of Accessibility," by E. Kemppainen, J. D. Kemp, and H. Yamada. Legislative areas that can promote equal opportunities and eAccessibility include nondiscrimination, ICT, privacy and transparency, product safety, public procurement, and assistive technology.

Standards and guidelines are important aspects of accessible design and take a wide variety of forms that serve diverse functions. Chapter 54, "Standards and Guidelines," by G. C. Vanderheiden, outlines the process for the creation of related standards, as well as their impact on developing products that will be usable by people with a wide range of abilities.

Chapter 55, "eAccessibility Standardization," by J. Engelen, continues the discussion of the standardization topic by sketching formal, ad hoc, company-driven, and informal standardization activities in universal design and assistive technology. Standards are intended in this context as a reference instrument for legislation in these domains.

Design for all management is intended as comprising all activities needed for planning, organizing, leading, motivating, coordinating, and controlling the processes associated with design for all. Chapter 56, "Management of Design for All," by

C. Bühler, reflects on management approaches from a business perspective. Particular focus centers on the product level, but the brand and company level need close attention as well. Key business motivations are competitiveness in the global market, shareholder value, and sometimes corporate social responsibility. From a more general perspective, political economics and social considerations are key elements.

Chapter 57, "Security and Privacy for Universal Access," by M. T. Maybury, provides an overview of the security and privacy requirements for universal access. These include confidentiality, integrity, and availability for all users, including those with disabilities and those in protected categories such as children or the elderly. The need for privacy is also addressed in its potential conflict with the need to represent and analyze detailed user properties and preferences to tailor information and interaction to enable universal access. Some important functional requirements to support universal access are reviewed, along with a discussion of the current international legal environment related to privacy.

Finally, Chapter 58, "Best Practice in Design for All," by K. Miesenberger, discusses best practice in design for all, focusing on the context-sensitive and process-oriented nature of design for all, which is often invisible in the final products. This makes the selection of single examples as demonstrators for best practice a difficult task, and the transfer into other contexts not straightforward. Therefore, best practice is outlined as dependent on specific contexts.

1.3.9 Future Perspectives

As the information society evolves continuously, universal access also evolves and expands to address the needs of new technological environments and contexts of use. As a result of the increasing demand for ubiquitous and continuous access to information and services, IST are anticipated to evolve in the years ahead toward the new computing paradigm of ambient intelligence. Ambient intelligence will have profound consequences on the type, content, and functionality of the emerging products and services, as well as on the way people will interact with them, bringing about multiple new requirements for the development of IST; universal access is critically important in addressing the related challenges. Part IX of this handbook looks into the future of universal access from an ambient intelligence perspective.

Implicit interaction, based on the fundamental concepts of perception and interpretation, is a novel paradigm in an "environment as interface" situation. Chapter 59, "Implicit Interaction," by A. Ferscha, overviews the technologies and approaches that make implicit interaction feasible in the near future and discusses application scenarios and their implications.

An overview of the basic concepts, trends, and perspectives of ambient intelligence is presented in Chapter 60, "Ambient Intelligence," by N. A. Streitz and G. Privat. In light of an overall technological frame of reference, a number of constituent ambient intelligence approaches are presented. Furthermore, alternatives are proposed and discussed that characterize the theoretical and practical challenges to be addressed in this field, and current trends and perspectives that may help overcome these alternatives are discussed.

Finally, Chapter 61, "Emerging Challenges," by C. Stephanidis, concludes the handbook by summarizing current and future challenges in ambient intelligence that emerge from the various universal access dimensions addressed in this handbook.

1.4 Conclusions

Universal access is a young and dynamic field of inquiry that involves, exploits, and affects the development of a very large part of IST and has so far witnessed significant advances in all its main dimensions, as they are presented in this handbook. Currently, universal access is rapidly progressing toward a higher level of maturity, where the consolidation of achieved results and the systematization of accumulated knowledge are of paramount importance for a variety of purposes.

First, as discussed in Section 1.3.9 and thoroughly elaborated upon in Part IX of this handbook, universal access needs to build upon its strength and further evolve to be able to address new challenges that arise as the information society develops and intelligent interactive environments are gradually being created. Second, stronger links between research and industry in the universal access domain need to be established. On the one hand, it is important to encourage industry to become more receptive to universal access and more involved in its adoption and diffusion; on the other hand, research must provide industry with suitable techniques and tools for addressing real practical problems emerging from the consideration of diversity in mainstream product development.

Another critical impediment to the adoption of universal access and design for all principles and methods in practice is the lack of qualified practitioners who understand diversity in the user target population, in the technology, and in the context of use and are able to integrate the related requirements in the development process. Therefore, the need for better preparing present and future generations of scientists, designers, developers, and stakeholders toward developing a more inclusive information society through both academic education and professional training in accessibility, design for all, and universal access is widely felt. Various initiatives are targeted to meet this objective in Europe (e.g., Weber and Abascal, 2006; Keith, 2008).

This handbook aims to establish an important landmark in universal access and provide a useful tool for addressing these challenges.

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2

Perspectives on Accessibility: From Assistive Technologies to Universal Access and Design for All

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Pier Luigi Emiliani

2.1 Introduction

From the perspective of people with disabilities, technological developments have always been concurrently perceived as a potential support to inclusion in society, but, at the same time, also as a challenge to their present situation. The personal computer, for example, was immediately considered as an invaluable new possibility for accessing information, but it needed adaptations for blind and motor-disabled people. Following the development of textual screen readers, the introduction of graphical user interface was considered by blind people as a threat to their recently acquired autonomy in reading and writing. In fact, they had to wait for the development of screen readers for the graphic interfaces to be able to access computers again.

Traditionally, this has been the situation of people with disabilities. They must wait for the technology, even if potentially very promising, to be adapted for their use. The living environment in general, including technology, was also normally designed for the average user and then adapted to the needs of people who are more or less far from "average." Architects then started to think that it might be possible to design public spaces and buildings that are accessible to everyone, even, for example, those who move about in a wheelchair. This approach (design for all, or universal design) resulted in successful designs for landscapes, which were subsequently documented as guidelines for accessible built environments. It took several years before the approach was able to gather the political support needed for practical application, but the main principles had been developed. Moreover, it turned out that the approach was invaluable not only for disabled people, but also for the population at large. It is only a pity that too many buildings and public spaces are constructed at present whose designers do not take these basic principles into consideration.

This chapter deals with how the concept of designing for all potential users can be generalized outside the original field of architecture, to become applicable and relevant to the information society (i.e., from physical spaces to conceptual spaces). It will be shown that, to design an information society accessible to all, the basic assumptions of design for all as developed in architecture must be reverted. While a single physical space can be designed to be available to all, information environments must be implemented in such a way to be automatically adaptable to each individual user. Therefore, the individual needs of all potential users must be taken into account in constructing the emerging telecommunications and information environment with an embedded intelligence sufficient for automatic self-adaptation to the individual users.

It will be also argued that design for all concepts must be revisited with the evolution of the information society. There is a difference between designing for all an interface with a computer or an application running on it and designing for all the information society as such. It is probably a problem of intelligence that is possible to embed in the system, but certainly it is not limited to only intelligence needed for self-adaptation to the individual users.

However, the design for all approach is not "against" assistive technology, the conceptual and technological environment in which adaptations and add-ons for people with disabilities have been traditionally developed. The variety and complexity of individual situations are such that, at least in the short-to-medium term, it will not be possible and/or economically viable to accommodate all necessary features within the adaptability space of a single product. What will probably be necessary is an expansion of the assistive technology sector toward the use of advanced technology, as was the case 20 years ago when new technology (e.g., voice synthesis and recognition) was primarily applied in the environment of rehabilitation, and a shift from the adaptation of products designed for an average user to an adaptability built in at design time. Probably, the transition from assistive technology to design for all will have to be established upon a careful trade-off between built-in adaptability and *a posteriori* adaptations on the basis of economic and functional criteria.

Even if, conceptually, these developments appear promising, there is limited interest at the level of end-users and also professionals working in sectors related to eInclusion. Probably, people with disabilities think that being embedded in the "for all" concept will reduce interest in their specific problems, while other users, who so far did not have accessibility problems with information and communication technologies (ICT), are not aware of the important changes that the emergence of the information society is bringing about. Professionals, who must cope with problems of users in their present situation, are traditionally suspicious of approaches that, even if interesting, are foreseen to give results in the medium-to-long-term. The main arguments of this chapter are that to guarantee an accessible information society to all users, the design for all approach is the only viable one, and that if needs, requirements, and preferences of all users are taken into account as far as possible in the specification of new technology and corresponding services and applications, this will bring about advantages for all citizens.

2.2 Accessibility versus Universal Access

Presently, there is a shift from accessibility, as traditionally defined in the assistive technology sector, to universal access, due to developments in technology and an increased social interest for people at risk of exclusion, including not only people with disabilities, but any person who may differ with respect to language, culture, computer literacy, and the like. This section deals with the foreseen changes in technology and in the organization of society, as well as with the rationale underlying the concept of universal access.

2.2.1 From Terminals and Computers to the Information Society

In ICT, the issue of accessibility was originally related to people with disabilities. When the interest in the use of information technology and telecommunications for people with disabilities started, the situation was relatively simple: the main service for interpersonal communication was the telephone, and information was distributed by means of radio and television. Computers were mainly stand-alone units used in closed and specialized communities (e.g., those of scientists and businessmen).

In principle, the telephone was a fundamental problem only for profoundly deaf people. For all other groups of people with disabilities, solutions were within the reach of relatively simple technological adaptations. The technology used for implementing the telephone lent itself to the possibility of capturing the signal (electromagnetic induction) and making it available for amplification for deaf people. Even the problems of profoundly deaf people were facilitated by the telephone system itself, when it was discovered that the telephone line could be used to transmit digital data (characters) with suitable interfaces (modems). Radio was an important medium for the diffusion of information. In principle, radio can represent a problem for deaf people. But since amplification is inherent in a radio system, problems occur again therefore only for profoundly deaf people. Television was the first example of a service that used a combination of the visual and acoustic modalities, not redundantly, but for conveying different types of information. Being more complex, television could create more difficulties for people with disabilities, but it had inherent capabilities for overcoming some of the problems. It is evident that television can create problems for blind, visually disabled, and deaf people. On the other hand, the fact that additional information can be transmitted by exploiting the available bandwidth enables support for people with disabilities to be added to the standard service. Therefore, programs can be subtitled for deaf people, and scenes without dialogue can be described verbally for blind people. In addition, text services can be set up (e.g., televideo, teletext), thus solving some of the problems related to the accessing of information by profoundly deaf people.

Television is a simple example of a general situation. An increase in the complexity of a system or service increases the number and extent of problems that such a system or service can create for people who have reduced abilities compared to the majority of the population. At the same time, technical complexity often implies additional features to recover from this unfortunate situation, as well as the possibility of using the same technology in an innovative way to solve problems that have not yet been addressed.

The situation started to change, thanks to the development of computers and technology able to increase the bandwidth of communications channels, which ultimately contributed to creating a completely new environment for communication and access to information, as will be briefly described in the following. From the perspective of the user, the first important innovation was brought about by the introduction of personal computers. Personal computers were immediately seen as a new and very important possibility for supporting people with disabilities in communication and providing access to information. Unfortunately, they were not directly accessible to some user groups, such as blind people and people with motor impairments of the upper limbs. However, the possibility of encoding information, instead of printing it on paper, was immediately perceived as being of paramount importance for blind people. Therefore, personal computers had to be made available to them. Adaptations were investigated, and through the synergy of new transduction technologies (mainly synthetic speech) and specialized software (screen readers), capable of "stealing" information from the screen and making it available to appropriate peripheral equipment, coded information was made available to blind people (Mynatt and Weber, 1994). Blind people could also read information retrieved from remote databases, and write and communicate using electronic mail systems. Adaptations for motor-disabled people (special keyboards, mouse emulators) and for other categories of disabled people were also made available.

It can therefore be concluded that, when the interest in accessibility by people with disabilities and elderly people became more widespread, the worldwide technological scene was dominated by a set of established systems and services. The situation required adaptations of existing systems, which slowly became available with long delays.

Today, after a period of relative stability, the developments in solid-state technology and optoelectronics, which made possible the increase of the available computational power, the integration of "intelligence" in all objects, and the availability of broadband links, and, particularly, the fusion between information technology, telecommunications, and media technologies and industry, are causing a revolution in the organization of society, leading from an industrial to an information society.

The emergence of the information society is associated with radical changes in both the demand and the supply of new products and services. The changing pattern in demand is due to a number of characteristics of the customer base, including (1) increasing number of users characterized by diverse abilities, requirements, and preferences; (2) product specialization to cope with the increasing variety of tasks to be performed, ranging from complex information-processing tasks to the control of appliances in the home environment; and (3) increasingly diverse contexts of use (e.g., business, residential, and nomadic).

On the other hand, one can clearly identify several trends in the supply of new products and services. These can be briefly summarized as follows: (1) increased scope of information content and supporting services; (2) emergence of novel interaction paradigms (e.g., virtual and augmented realities, ubiquitous computing); and (3) shift toward group-centered communication-, collaboration-, and cooperation-intensive computing.

This general trend is exemplified by the shift in paradigm in the use of computers, leading to the present situation made possible by the fusion between information technology and telecommunications (Figure 2.1). As suggested by Figure 2.1, from the early calculation-intensive nature of work that was prevalent in the early 1960s, computer-based systems are progressively becoming a tool for communication, collaboration, and social interaction, which are the main characteristics of the emerging intelligent information environment. From a specialist's device, the computer is being transformed into an information appliance for the citizen in the information society.

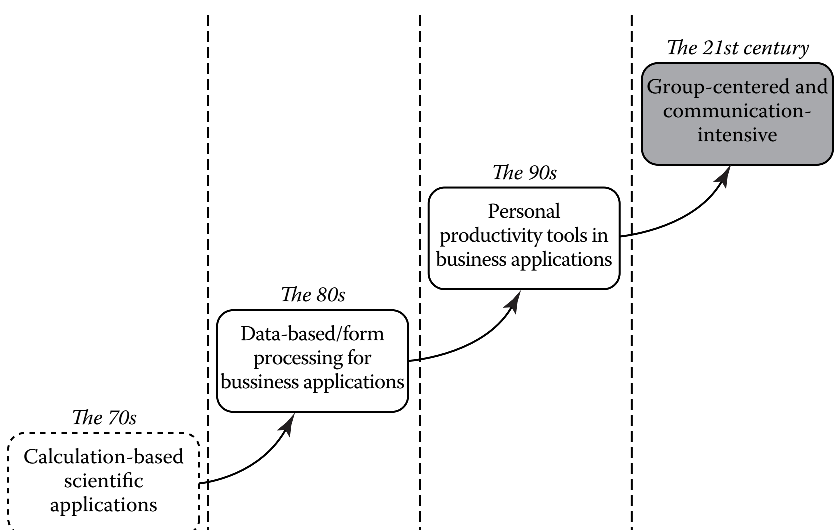

FIGURE 2.1 Paradigm shifts in the use of computers (From Stephanidis, C. and Emiliani, P. L., *Technology and Disability Journal*, 10, 21–44, 1999. With permission.)

To have a basis for discussion, let us consider a possible scenario for the further development of the information society. Almost all experts agree that the information society will not imply the use of an increased number of computers and terminals, such as the ones we are accustomed to use today, or at least this will occur only in small professional activity niches or only for few general activities. According to observatories around the world, the information society is foreseen to emerge and evolve as some form of "intelligent environment." This vision is present not only in Europe, but also worldwide (for example Australia, Japan, and the United States), both at an industrial (as, for example, at Rand, Xerox, Microsoft, IBM, Philips, Siemens, NEC, Fujitsu) and academic level (for example, MIT has an ambient intelligence laboratory and many research projects around it). Apparently, this idea is popular also in the research environment.

This will entail the emergence of a new environment where intelligence is a distributed function, that is, computers will behave as intelligent agents able to cooperate with other intelligent agents on distributed data. Wearable computers, disappearing computers, mobile systems, ambient intelligence, and a variety of technical platforms are some of the expressions emerging from technical discussions. The information society is expected to evolve in the direction of the proliferation of computational systems that integrate a range of networked interactive devices embedded into a physical context (in either indoor or outdoor spaces). These systems will provide hosting for a broad range of computer-mediated human activities and access to a multitude of services and applications. Such systems are based on the distribution of computers and networks in physical environments, and are expected to exhibit increasingly intelligent and context-sensitive behavior. On the user side, it is starting to become clear that the variety of users will increase to the point of including practically all people, since the entire society is supposed to become an "intelligent environment," with a variety of contexts of use, ranging from public spaces to professional environments, from entertainment activities to living environments.

The ambient intelligence (AmI) environment will be populated by a multitude of handheld and wearable "micro-devices," and computational power and interaction peripherals (e.g., embedded screens and speakers, ambient displays) will be distributed in the environment. Devices will range from personal (e.g., wristwatches, bracelets, personal mobile displays and notification systems, health monitors embedded in clothing), carrying individual and possibly private information, to public devices in the surrounding environment (e.g., wall-mounted displays). As technology disappears to humans both physically and mentally, devices will be no longer perceived as computers, but rather as augmented elements of the physical environment. Personal devices are likely to be equipped with facilities for multimodal interaction and alternative input/output (e.g., voice recognition and synthesis, pen-based pointing devices, vibration alerting, touch screens, input prediction, etc.), or with accessories that facilitate alternative ways of use (e.g., hands-free kits), thus addressing a wider range of user and context requirements than the traditional desktop computer. A variety of new products and services will be made possible by the emerging technological environment, including home networking and automation, mobile health management, interpersonal communication, and personalized information services. These applications will be characterized by increasing ubiquity, nomadism, and personalization, and are likely to pervade all daily human activities. They will have the potential to enhance security in the physical environment, save human time, augment human memory, and support people in daily routines and simple activities, as well as in complex tasks.

A general description of the direction of anticipated technological development can be found in the ISTAG[1] Scenarios (IST Advisory Group, 2003), where a vision of ambient intelligence is offered:

> The concept of Ambient Intelligence (AmI) provides a vision of the information society, where the emphasis is on greater user friendliness, more efficient services support, user empowerment, and support for human interactions. People are surrounded by intelligent intuitive interfaces that are embedded in all kinds of objects and an environment that is capable of recognizing and responding to the presence of different individuals in a seamless, unobtrusive, and often invisible way.

To have an idea of the type of technology, interactions, and services available in the information society, let us now summarize their main characteristics (IST Advisory Group, 2003). First of all the hardware is supposed to be *very unobtrusive*. Miniaturization is assumed to produce the necessary developments in micro and optical electronics, smart materials, and nanotechnologies, leading to self-generating power and micropower usage; breakthroughs in input/output systems, including new displays, smart surfaces, paints, and films that have smart properties; and sensors and actuators integrated with interface systems to respond to user senses, posture, and environment. Many technologies are conceived as handheld or wearable, taking advantage of the fact that intelligence can be embedded in the environment to support the individual personal system. This means being lightweight, but also readily available. It is taken for granted that people can have with them everything necessary for performing even complex tasks. For example the only communication item (sufficient, e.g., for carrying out navigation, environmental control, and communicating with other people) foreseen in the ISTAG scenarios is a personal communicator (P-Com). Its characteristics are not precisely defined. It does not have a specifically defined interface, but is a disembodied functionality supported by the AmI with different interfaces. It is adaptive and learns from user's interactions with the environment. It offers communication, processing, and decision-making functions. Finally, it must not necessarily be a highly sophisticated piece of equipment, whose performances are limited by size, weight, and

[1] IST Advisory Group.

power. The intelligence necessary to support the transduction of information necessary to address the different modalities and to support the user can be in the environment and in the network. In principle, the only limiting factor can be bandwidth.

Then a *seamless mobile/fixed web-based communications infrastructure* is supposed to be available. Complex heterogeneous networks need to function and to communicate in a seamless and interoperable way. This implies a complete integration of mobile and fixed networks, including ultrafast optical processing. These networks will have to be seamless and dynamically reconfigurable.

Dynamic and massively distributed device networks will be in place. The AmI landscape is a world in which there are almost uncountable interoperating devices. Some will be wired, some wireless, many will be mobile, many more will be fixed. The requirement will be that the networks should be configurable on an *ad hoc* basis according to a specific, perhaps short-lived, task, with variable actors and components.

Human interfaces will have to become *natural*. A central challenge of AmI is to create systems that are intuitive in use. This will need *artificial intelligence* techniques, especially dialogue-based and goal-orientated negotiation systems, as the basis for intelligent agents and intuitive human to machine interaction, which are supposed to be multimodal (multiuser, multilingual, multichannel, and multipurpose). It should also be adaptive to user requirements providing context-sensitive interfaces and information filtering and presentation.

Finally, the AmI world must be *safe, dependable, and secure*, considering all physical and psychological threats that the technologies might imply and giving important emphasis on the requirement for robust and dependable software systems components. Various aspects of AmI environments are discussed in Chapters 59 and 60 of this handbook.

2.2.2 From Accessibility to Universal Access

The previously discussed developments are expected to alter human interaction, individual behavior, and collective consciousness, as well as to have major economic and social effects. As with all major technological changes, this can have disadvantages and advantages. New opportunities are offered by the reduced need of mobility, due to the emergence of networked collaborative activities, and by the increased possibility of network-mediated interpersonal communications. However, difficulties may arise in accessing multimedia services and applications when users do not have sufficient motor or sensory abilities. The complexity of control of equipment, services, and applications, and the risk of information overload, may create additional problems.

The abovementioned problems are particularly relevant for people with disabilities, who have been traditionally underserved by technological evolution. Disabled and elderly people currently make up about 20% of the market in the European Union, and this proportion will grow with the aging of the population to an estimated 25% by the year 2030 (Vanderheiden, 1990; Gill, 1996). Not only is there a moral and legal obligation to include this part of the population in the emerging information society, but there is also a growing awareness in the industry that disabled and elderly people can no longer be considered insignificant in market terms. Instead, they represent a growing market to which new services can be provided. However, due to the foreseen increase of citizens who will need to interact with the emerging technological environment, accessibility can no longer be considered a specific problem of people with disabilities, but of the society at large, if suitable actions are not undertaken.

This final observation is very important—accessibility is not enough. The concept of universal access must be introduced and adaptations fully addressed as a real option for satisfying the eInclusion requirements. Design for all has been mainly introduced in human-computer interaction on the basis of serving a variety of users, that is, addressing users' diversity. The related line of reasoning is that since users are different, and they have different accessibility and usability requirements, it is necessary to take all of them into account in a user-centered design process. However, the emerging environment is much more complex and diversity must be considered from other perspectives. First of all, interaction no longer involved only computers and terminals, but the environment and the physical objects in it. Therefore, it will be necessary to consider a variety of interaction paradigms, metaphors, media, and modalities. Then customers will not have to cope with tasks determined by the used application, but with goals to reach in everyday life, which will be different in different environments and for different users. Additionally goals may be complex not only due to the foreseen merging of functions connected to access to information, interpersonal communication, and environmental control, but also because they may involve communities of users. Finally, the same goal must be reached in many different contexts of use. This gives an idea of the complexity of the involved problems, the limitation of the classical accessibility concepts, and the need for innovative approaches.

In this dynamically evolving technological environment, accessibility and usability of such complex systems by users with different characteristics and requirements cannot be addressed through *ad hoc* assistive technology solutions introduced after the main building components of the new environment are in place. Instead, there is a need for more proactive approaches, based on a design for all philosophy (Stephanidis et al., 1998, 1999), along with the requirement of redefining the role and scope of assistive technologies in the new environment. In such a context, the concepts of universal access and design for all acquire critical importance in facilitating the incorporation of accessibility in the new technological environment through generic solutions.

Universal access implies the accessibility and usability of information technologies by anyone at any place and at any time. Universal access aims to enable equitable access and active participation of potentially all people in existing and emerging computer-mediated human activities, by developing universally accessible and usable products and services. These products and services must be capable of accommodating individual user requirements in different contexts of use, independent of location, target machine, or run-time environment.

Therefore, the concept of accessibility as an approach aiming to grant the use of equipment or services is generalized, seeking to give access to the information society as such. Citizens are supposed to live in environments populated with intelligent objects, where the tasks to be performed and the way of performing them will be completely redefined, involving a combination of activities of access to information, interpersonal communication, and environmental control. Everybody must be given the possibility of carrying them out easily and pleasantly.

This also has an impact on the technological approach to the problem of accessibility. Universal access needs a conscious and systematic effort to proactively apply principles, methods, and tools of design for all to develop information society technologies that are accessible and usable by all citizens, including people who are very young, elderly people, and people with different types of disabilities, thus avoiding the need for *a posteriori* adaptations or specialized design.

2.3 From Reactive to Proactive Approaches

2.3.1 Reactive Approaches

The traditional approach to rendering applications and services accessible to people with disabilities is to adapt such products to the abilities and requirements of individual users. Typically, the results of adaptations involve the reconfiguration of the physical layer of interaction and, when necessary, the transduction of the visual interface manifestation to an alternative (e.g., auditory or tactile) modality.

Although it may be the only viable solution in certain cases (Vanderheiden, 1998), the reactive approach to accessibility suffers from some serious shortcomings. One of the most important is that by the time a particular access problem has been addressed, technology has advanced to a point where the same or a similar problem reoccurs. The typical example that illustrates this state of affairs is the case of blind people's access to computers. Each generation of technology (e.g., DOS environment, Windowing systems, and multimedia) caused a new wave of accessibility problems to blind users, addressed through dedicated techniques such as text translation to speech for the DOS environment, off-screen models, and filtering for the Windowing systems.

In some cases, adaptations may not be possible at all without loss of functionality. For example, in the early versions of Windowing systems, it was impossible for the programmer to obtain access to certain Window functions, such as Window management. In subsequent versions, this shortcoming was addressed by the vendors of such products, allowing certain adaptations (e.g., scanning) on interaction objects on the screen. Adaptations are programming intensive, which raises several considerations for the resulting products. Many of them bear a cost implication, which amounts to the fact that adaptations are difficult to implement and maintain. Minor changes in product configuration, or the user interface, may result in substantial resources being invested to rebuild the accessibility features. The situation is further complicated by the lack of tools to facilitate ease of "edit-evaluate-modify" development cycles (Stephanidis, et al., 1995). Moreover, reactive solutions typically provide limited and low-quality access. This is evident in the context of nonvisual interaction, where the need has been identified to provide nonvisual user interfaces that go beyond automatically generated adaptations of visual dialogues. Additionally, in some cases, adaptations may not be possible without loss of functionality.

Traditionally, two main technical approaches to adaptation have been followed: product-level adaptation and environment-level adaptation. The former involves treating each application separately and taking all the necessary implementation steps to arrive at an alternative accessible version. In practical terms, product-level adaptation practically often implies redevelopment from scratch. Due to the high costs associated with this strategy, it is considered the least favorable option for providing alternative access. The alternative involves intervening at the level of the particular interactive application environment (e.g., Microsoft Windows) to provide appropriate software and hardware technology to make that environment alternatively accessible. Environment-level adaptation extends the scope of accessibility to cover potentially all applications running under the same interactive environment, rather than a single application, and is therefore considered a superior strategy. In the past, the vast majority of approaches to environment-level adaptation have focused on access to graphical environments by blind users. Through such efforts, it became apparent that any approach to environment-level adaptation should be based on well-documented and operationally reliable software infrastructures, supporting effective and efficient extraction of dialogue primitives during user-computer interaction. Such dynamically extracted dialogue primitives are to be reproduced, at run-time, in alternative input/output (I/O) forms, directly supporting user access. Examples of software infrastructures that satisfy these requirements are the active accessibility technology from Microsoft Corporation, and the Java accessibility technology from Sun Microsystems.

2.3.2 Proactive Approaches

Due to the previously described shortcomings of the reactive approach to accessibility, there have been proposals and claims for proactive strategies, resulting in generic solutions to the problem of accessibility. Proactive strategies entail a purposeful effort to build access features into a product as early as possible (e.g., from its conception to design and release). Such an approach should aim to minimize the need for *a posteriori* adaptations and deliver products that can be tailored for use by the widest possible end-user population. In the context of human-computer interaction, such a proactive paradigm should address the fundamental issue of universal access to the user interface and services and applications, namely how it is possible to design systems that permit systematic and cost-effective approaches that accommodate all users.

Proactive approaches to accessibility are typically grounded on the notions of universal access and design for all. The term *design for all* (or *universal design*—the terms are used interchangeably) is not new. It is well known in several engineering disciplines, such as civil engineering and architecture, with many applications in interior design, building and road construction, and so on. However, while existing knowledge may be considered sufficient to address the accessibility of physical spaces, this is not the case with information society technologies, where universal design is still posing a major challenge. Universal access to computer-based applications and services implies more than direct access or access through add-on (assistive) technologies, since it emphasizes the principle that accessibility should be a design concern, as opposed to an afterthought. To this end, it is important that the needs of the broadest possible end-user population are taken into account in the early design phases of new products and services.

Unfortunately, in ICT there is not yet general consensus about what design for all is, and there is not yet enough knowledge and interest about developments in the information society (apart from what is directly testable in everyday present life). This is particularly strange because design for all by definition can be applicable only to products to be developed, that is, to the future. However, if the development is toward an agreed-upon model (ambient intelligence), since the new society will not materialize in a short time but there will be a (probably long) transition, it makes sense to try and find out the main characteristics of the future generations of technology and services and applications to influence them. This will bring advantages in the short and medium terms as a contribution to innovation in assistive technology, and will hopefully lead to the emergence of a more accessible information society in the long-term.

Some general investigations were carried out during a set of meetings of the International Scientific Forum "Towards an Information Society for All." The result of the activity of this international working group has been published in two white papers (Stephanidis et al., 1998, 1999), as a set of general recommendations and specific suggestions for research activities. An accurate report of the findings of the Scientific Forum, already reported in the white papers, is outside the scope of this chapter. However, a short summary is included that points out the main recommendations useful for the current discussion.

The first set of recommendations is related to the need to promote the development of environments of use, that is, integrated systems sharable by communities of users that allow for richer communications, and the progressive integration of the computing and telecommunications environments with the physical environment. This includes the study of the properties of environments of use, such as interoperability, adaptation, cooperation, intelligence, and so on; the identification of novel architectures for interactive systems for managing collective experiences, which can facilitate a wide range of computer-mediated human activities; the development of architectures for multiple metaphor environments, adapted to different user requirements and contexts of use; the introduction of multiagent systems and components for supporting cooperation and collaboration, and allowing more delegation-oriented activities; and the individualization and adaptation of user interfaces.

A second group of recommendations is related to the need for supporting communities of users, with emphasis on social interaction in virtual spaces, to enhance the currently prevailing interaction paradigms (e.g., graphical user interfaces [GUIs] and the World Wide Web) and to support the wide range of group-centric and communication-intensive computer-mediated human activities. This includes the study of individual/collective intelligence and community knowledge management; methodologies for collecting/analyzing requirements and understanding virtual communities; access to community-wide information resources; and social interaction among members of online communities.

A third set of general recommendations is connected with the integration of users in the design process and the evaluation of results. It is based on the concept of extending user-centered design to support new virtualities. Detailed recommendations include the identification of foundations for designing computer-mediated human activities, to apply, refine, and extend existing techniques and tools of user-centered design with concepts from the social sciences; metrics for important interaction quality attributes, for measuring different aspects of an interactive system, including additional quality attributes such as accessibility, adaptation, intelligence, and so on; computational tools for usability engineering to automate certain tasks, guide designers toward usability targets, or provide extensible environments for capturing, consolidating, and reusing previous experience; requirements for engineering methods to facilitate the elicitation of requirements in novel contexts of use and different user groups; and protocols for effective user participation in design activities.

A fourth set of recommendations deals with support actions as articulating demand for design for all, supporting the industry, as well as promoting awareness, knowledge dissemination, and technology transfer. These activities are of paramount importance to the real take-up of the technological developments that are needed for the creation of a truly accessible information society. However, their discussion is outside the scope of this chapter.

Technological developments that are considered necessary in contributing to the accessibility and usability of the emerging information society and a list of specific research topics are also reported in Stephanidis et al. (1999). These include suggestions on research activities on design process, methods and tools, user-oriented challenges, input/output technology, and user interface architectures. Even if the list included in the paper was not intended to be exhaustive, it gives a clear indication of the challenges and the complexity of the issues that need to be addressed by the research community to facilitate the development of an information society acceptable for all citizens.

2.4 The Design for All Approach

There are many definitions of design for all (or universal design). As a first definition, let us consider the one that is available in the web site of the Trace Center, a research organization devoted to making technologies accessible and usable: "The design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design" (Trace Center, 2008).

At an industrial level, Fujitsu has recently published an entire issue of their journal completely devoted to universal design, defined as: designing products, services, and environments so that as many people as possible can use them regardless of their age and physical characteristics (e.g., height, visual and hearing abilities, and arm mobility).

Finally, in the context of a series of European research efforts spanning over two decades, design for all in the information society has been defined as the conscious and systematic effort to proactively apply principles, methods, and tools to develop information technology and telecommunications (IT&T) products and services that are accessible and usable by all citizens, thus avoiding the need for *a posteriori* adaptations, or specialized design (Stephanidis et al., 1998).

These definitions are conceptually based on the same principle, that is, the recognition of the social role of the access to the information and telecommunication technologies, which leads to the need of design approaches based on the real needs, requirements, and preferences of all the citizens in the information society, the respect of the individuals willing to participate in social life, and their right of using systems/services/applications. Furthermore, computer accessibility is gradually being introduced in the legislation of several countries (see also Chapter 53, "Policy and Legislation as a Framework of Accessibility"). For example, in the United States, since 1998, Section 508 of the Rehabilitation Act (U.S. Code, 1998) requires that "any electronic information developed, procured, maintained, or used by the federal government be accessible to people with disabilities." In Europe, the eEurope 2005 (European Commission, 2002) and the i2010 action plans (Commission of the European Communities, 2005) commit the member states and European institutions to design public sector web sites and their content to be accessible, so that citizens with disabilities can access information and take full advantage of the information society. The legal obligation to provide accessible interactive products and services may contribute to the adoption of systematic design approaches under a design for all perspective.

The approach is also in line with the one at the basis of the preparation of the new World Health Organization (WHO) International Classification of Functioning, Disability and Health (ICF) (World Health Organization, 2001), where a balance is sought between a purely medical and a purely social approach to the identifications of problems and opportunities for people in their social integration. When dealing with the problems of people who experience some degree of activity limitation or participation restrictions, "ICF uses the term *disability* to denote a multidimensional phenomenon resulting from the interaction between people and their physical and social environment." This is very important, because it allows grouping and analysis of limitations that are not only due to impairments. For example, people are not able to see because they are blind, or have fixation problems due to spastic cerebral palsy, or are in a place with insufficient illumination, or are driving and therefore cannot use their eyes for interacting with an information system. People may have impairments, activity limitations, or participation restrictions that characterize their ability (capacity) to execute a task or an action (activity), but their performance is influenced by the current environment. The latter can increase the performance level over the capacity level (and therefore is considered a facilitator) or can reduce the performance below the capacity level (thus being considered a barrier). Here the emphasis is on the fact that all people, irrespective of their capacity of executing activities, may perform differently according to different contexts, and the environment must be designed to facilitate their performances.

Even if there is, apparently, a convergence on the conceptual definition of design for all, there is limited interest and sometimes skepticism about it among people working in the social integration of people with disabilities, where the related concepts were firstly explored in ICT. In particular, there is an argument that raises the concern that "many ideas that are supposed to be good for everybody aren't good for anybody" (Lewis and Rieman, 1994). However, design for all in the context of information technologies should not be conceived of as an effort to advance a single solution for everybody, but as a user-centered approach to providing products that can automatically address the possible range of human abilities, skills, requirements, and preferences. Consequently, the outcome of the design process is not intended to be a singular design, but a design space populated with appropriate alternatives, together with the rationale underlying each alternative, that is, the specific user and usage context characteristics for which each alternative has been designed.

If this is the case, then it is argued that this is clearly impossible or too difficult to be of practical interest. However, even if it is true that existing knowledge may be considered sufficient to address the accessibility of physical spaces, while this is not the case with information technologies where universal design is still posing a major challenge, important advances are being made in the development of concepts and technologies that are considered necessary for producing viable design for all approaches, as discussed in the previous section.

Apparently there is a conceptual confusion between the concepts of universal access and design for all (universal design). What is considered important, particularly in the field of disability, is granting people universal access. This is clearly right, but the claim that, therefore, everything that aims to give accessibility to all is design for all is conceptually misleading. Design for all is a well-defined approach, particularly promising due to the developments of the information society, which must coexist at least in the short and medium terms with assistive technology to serve all potential users of ICT systems, services, and applications.

Another common argument is that design for all is too costly (in the short term) for the benefits it offers. Though the field lacks substantial data and comparative assessments as to the costs of designing for the broadest possible population, it has been argued that (in the medium-to-long-term) the cost of inaccessible systems is comparatively much higher and is likely to increase even more, given the current statistics classifying the demand for accessible products (Vanderheiden, 1998).

The origins of the concept of universal access are to be identified in approaches to accessibility mainly targeted toward providing access to computer-based applications by users with disabilities. Today, universal access encompasses a number of complementary approaches, which address different levels of activities leading to the implementation of designed for all artifacts.

At the level of design specifications, for example, there are lines of work that aim to consolidate existing wisdom on accessibility, in the form of general guidelines or platform- or user-specific recommendations (e.g., for graphical user interfaces or the web). This approach consolidates the large body of knowledge regarding people with disabilities and alternative assistive technology access in an attempt to formulate ergonomic design guidelines that cover a wide range of disabilities. In recent years, there has also been a trend for major software vendors to provide accessibility guidance as part of their mainstream products and services. Moreover, with the advent of the World Wide Web, the issue of its accessibility recurred and was followed up by an effort undertaken in the context of the World Wide Web Consortium to provide a collection of accessibility guidelines for web-based products and services (W3C-WAI, 1999). The systematic collection, consolidation, and interpretation of guidelines are also pursued in the context of international collaborative and standardization initiatives. Another line of work relevant to universal access is user-centered design, which is often claimed to have an important contribution to make, as its human-centered protocols and tight design evaluation feedback loop replace technocentric practices with a focus on the human aspects of technology use.

At the level of implementation approaches, the proposed approach, which was first applied in the design of human-computer interfaces and then generalized to the implementation of complete applications, is based on the concepts of adaptability and adaptivity (Stephanidis, 2001a). The central idea is that the variety of possible users and contexts of use can be served only if the systems and services are able to adapt themselves automatically to the needs, requirements, and preferences of every single user. Adaptation must be guaranteed at run time (adaptability) and, dynamically, during interaction (adaptivity). Adaptation to users is now considered an important feature of all systems and services in ICT, even if in most cases this general claim is considered to be satisfied by introducing some form of personalization under the control of the user.

2.5 From Assistive Technology to Design for All: A Historical Perspective

After this general analysis let us now concentrate on an example of migration from assistive technology to design for all, following the evolution and achievements of a series of research projects, the majority of which were funded by European Commission Programs. This research line has spanned across almost two decades and has pursued an evolutionary path, initially adopting reactive, and subsequently advocating proactive, strategies to accessibility.

What is important to notice in this context is the progressive shift toward more generic solutions to accessibility. In fact, with the exception of early exploratory studies, which did not have an RTD development dimension, all remaining research efforts embodied both a reactive RTD component as well as a focus on proactive strategies and methods. The latter were initially oriented toward the formulation of principles, while later an emphasis was placed on the demonstration of technical feasibility.

2.5.1 Exploratory Activities

Early exploratory activities[2] have investigated the possibilities offered by the multimedia communication network environment, and in particular B-ISDN (broadband integrated services digital network), for the benefit of people with disabilities (Emiliani, 2001). To enable the accessibility of disabled people to the emerging telecommunications technology, it was considered essential that the designers and providers of the services and terminal equipment take explicitly into account, at a very early stage of design, their interaction requirements. Several barriers have been identified that prevent people with disabilities from having access to information available through the network. The identified barriers are related to accessibility of the terminal, accessibility of the anticipated services, and the perception of the service information.

To cope with these difficulties, different types of solutions have been proposed that address the specific user abilities and requirements at three different levels:

1. Adaptations within the user-to-terminal and the user-to-service interface, through the integration of additional input/output devices and the provision of appropriate interaction techniques, taking into account the abilities and requirements of the specific user group;
2. Service adaptations through the augmentation of the services with additional components capable of providing redundant or transduced information; and

[2] The IPSNI R1066 (Integration of People with Special Needs in IBC) project was partially funded by the RACE Program of the European Commission and lasted 36 months (January 1, 1989 to December 31, 1991).

3. Introduction of special services only in those cases where the application of the two previously mentioned types of adaptation are not possible or effective.

2.5.2 Adaptation of Telecommunication Terminals

Building on these results, the technical feasibility of providing access to multimedia services running over a broadband network to people with disabilities was subsequently demonstrated.[3] Adaptations of terminals and services were implemented and evaluated. In particular, two pairs of multimedia terminals (one UNIX/X-Windows based and one PC/MS-Windows based) were adapted according to the needs of the selected user groups. Special emphasis was placed on the adaptation of the user interfaces, and for this purpose, a user interface and construction tool was designed (Stephanidis and Mitsopoulos, 1995), which takes into account the interaction requirements of disabled users. The tool was built on the notion of separating an interactive system in two functional components, namely the application functional core and the user interface component, thus allowing the provision of multiple user interfaces to the same application functionality. However, for blind users who are not familiar with graphical environments, it was difficult to grasp the inherently visual concepts (e.g., the pop-up menu). Such an observation led to the realization that adaptations cannot provide an effective approach for a generic solution to the accessibility problems of blind users.

These efforts allowed an in-depth analysis of services and applications for the broadband telecommunications environment from the point of view of usability by disabled people, leading to the identification of testing of necessary adaptations and/or special solutions (Emiliani, 2001). This led to the conclusion that if emerging services, applications, and terminals were designed considering usability requirements of disabled users, many of their access problems would be automatically reduced with a negligible expense. One of the conclusions was that, as a minimum, sufficient modularity and flexibility should be the basis of product implementation to allow easy adaptability to the needs, capabilities, and requirements of an increasing number of users.

2.5.3 Adaptations of Graphical Interactive Environments

The subsequent research phase aimed to identify and provide the technological means to ensure continued access by blind users to the same computer-based interactive applications used by sighted users.[4] The short-term initial goal was to improve adaptation methodologies of existing GUIs. Specific developments were carried out through the implementation of appropriate demonstrators enabling access to MS-WINDOWS (PCs) and to interactive applications built on top of the X WINDOW SYSTEM (UNIX-based workstations). The adopted approach to interface adaptation for blind users was based on a transformation of the desktop metaphor to a nonvisual version combining Braille, speech, and non-speech audio. Access to basic graphical interaction objects (e.g., Windows, menus, buttons), utilization of the most important interaction methods, and extraction of internal information from the graphical environment were investigated.

Input operations (e.g., exploration/selection of menu options, etc.) can be performed either by means of standard devices (keyboard or mouse) or through special devices (i.e., mouse substitutes, touch pad and routing keys of Braille device). An important feature of the method is that the entire graphical screen is reproduced in a text-based form and simultaneously presented on a monochrome screen that can be explored by blind users by means of Braille and speech output. Additionally, sounds help navigation and provide spatial relationships between graphical objects. It is important to note that the text-based reproduction facilitates cooperation with sighted colleagues.

A variety of issues related to user interaction in a graphical environment were also investigated, particularly for blind users. For example, different input methods that can be used instead of the mouse were investigated. The problem of how blind users can efficiently locate the cursor on the screen, and issues related to combining spatially localized sounds (both speech and non-speech) and tactile information to present available information, were examined. Finally, the project addressed the design and implementation of real-world metaphors in a nonvisual form and the development of an optimal method to present graphical information from within applications.

In this context, a first step toward the development of tools aimed at the implementation of user interfaces for all was carried out. The goal of these efforts was the development of innovative user interface software technology to guarantee access to future computer-based interactive applications by blind users. In particular, these projects conceived, designed, and implemented a user interface management system as a tool for the efficient and modular development of user interfaces that are concurrently accessible by both blind and sighted users.

2.5.4 Dual User Interfaces

The concept of dual user interfaces (Savidis and Stephanidis, 1998) was proposed and defined as an appropriate basis for "integrating" blind and sighted users in the same working environment. Figure 2.2 shows the concept of dual user interfaces. A dual

[3] The IPSNI-II R2009 (Integration of People with Special Needs in IBC) project was partially funded by the RACE-II Program of the European Commission and lasted 48 months (January 1, 1992 to December 31, 1995).

[4] The GUIB TP103 (Textual and Graphical User Interfaces for Blind People) project was partially funded by the TIDE Program of the European Commission and lasted 18 months (December 1, 1991 to May 31, 1993). The GUIB-II TP215 (Textual and Graphical User Interfaces for Blind People) project was partially funded by the TIDE Program of the European Commission and lasted 18 months (June 1, 1993 to November 30, 1994).

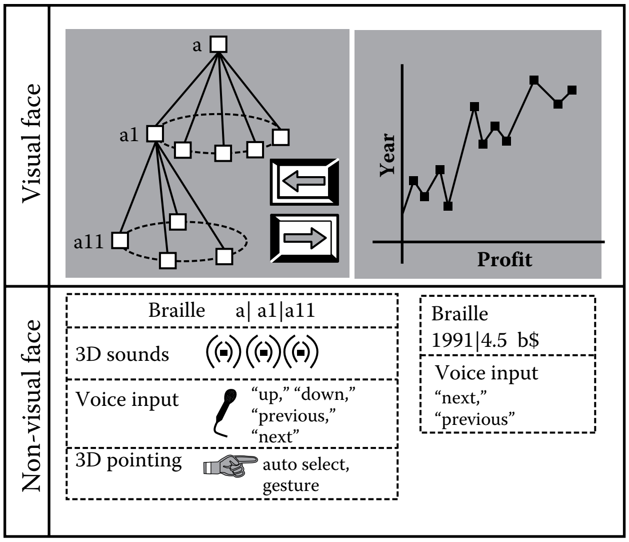

FIGURE 2.2 The concept of dual user interfaces (From Stephanidis, C. and Emiliani, P. L., *Technology and Disability Journal*, 10, 21–44, 1999. With permission.)

user interface is characterized by the following properties: (1) it is concurrently accessible by blind and sighted users; (2) the visual and nonvisual metaphors of interaction meet the specific needs of sighted and blind users respectively (they may differ, if required); (3) the visual and nonvisual syntactic and lexical structure meet the specific needs of sighted and blind users, respectively (they may differ, if required); (4) at any point in time, the same internal (semantic) functionality is made accessible to both user groups through the corresponding visual and nonvisual "faces" of the dual user interface; (5) at any point in time, the same semantic information is made accessible through the visual and nonvisual "faces" of the dual user interface, respectively.

The HOMER user interface management system (UIMS) (Savidis and Stephanidis, 1998) was developed to facilitate the design and implementation of dual interfaces. HOMER is based on a fourth-generation user interface specification language, which supports: (1) abstraction of interaction objects, for instance, representation of objects based on their abstract interaction roles and syntactic/constructional features, decoupled from physical presentation aspects; (2) concurrent management of at least two toolkits, so that any modifications effected on the interface by the user through the objects of one toolkit are concurrently depicted in the objects of the second toolkit; (3) metapolymorphic capability for abstract objects, for instance, abstract objects can be mapped to more than one toolkit, or to more than one object class within a specific toolkit; (4) unified object hierarchies supporting different physical hierarchies, so that alternative mappings of (portions of) the unified hierarchy to (portions of) physical hierarchies are possible; (5) ability to integrate different toolkits; (6) object-based and event-based model support for dialogue implementation, that is, the dialogue model can be defined either on the basis of the individual objects that participate in it, or on the basis of interaction events that originate from those objects; and (7) declarative asynchronous control models (e.g., preconditions, monitors, constraints), as opposed to syntax-oriented control models (e.g., task notations, action grammars), or alternative control techniques (e.g., event-based models and state-based methods); the rationale behind the adoption of declarative control models concerns the desired independence from specific syntactic models, which allows for differing models, supported by different toolkits, to be supported.

A nonvisual toolkit to support nonvisual interface development (Savidis and Stephanidis, 1998) was also developed and integrated within the HOMER UIMS. The toolkit was developed on the basis of a purposefully designed version of the rooms metaphor, an interaction metaphor based on the physical environment of a room, and whose interaction objects are floor, ceiling, front wall, back wall, and so on. The library provides efficient navigation facilities, through speech/Braille output and keyboard input. Two different nonvisual realizations of the rooms metaphor have been assembled: (1) a nonspatial realization, supporting Braille, speech, and nonspeech audio output with keyboard input; and (2) a direct-manipulation spatial realization, combining 3D audio (speech and nonspeech), 3D pointing via a glove and hand gestures, keyword speech recognition, and keyboard input. In both realizations, special sound effects accompany particular user actions such as selecting doors (e.g., "opening door" sound), selecting the lift (e.g., "lift" sound), pressing a button or a switch object, and so on.

The HOMER UIMS has been utilized for building various dual interactive applications such as a payroll management system, a personal organizer, and an electronic book with extensive graphical illustrations and descriptions.

2.5.5 User Interfaces for All and Unified User Interfaces

The concept of user interfaces for all (Stephanidis, 2001b) has been proposed, following the concept of design for all, as the vehicle to efficiently and effectively address the numerous and diverse accessibility problems. The underlying principle is to ensure accessibility at design time and to meet the individual needs, abilities, and preferences of the user population at large, including disabled and elderly people.

Collaborative research was conducted[5] to develop new technological solutions for supporting the concept of user interfaces for all (i.e., universal accessibility of computer-based applications), by facilitating the development of user interfaces automatically adaptable to individual user abilities, skills, requirements, and preferences. The problem was approached at two levels: (1) the development of appropriate methodologies and tools for the design and implementation of accessible and usable user interfaces; and (2) the validation of the approach through the design

[5] The ACCESS TP1001 (Development Platform for Unified ACCESS to Enabling Environments) project was partially funded by the TIDE Program of the European Commission, and lasted 36 months (January 1, 1994 to December 31, 1996).

and implementation of demonstrator applications in two application domains, namely interpersonal communication aids for speech-motor- and language-cognitive-impaired users, and hypermedia systems for blind users.

The concept of unified user interface development (Stephanidis, 2001a) was proposed with the objective of supporting platform independence and target user profile independence (i.e., the possibility of implementation in different platforms and adaptability to the requirements of individual users). Unified user interface development provides a vehicle for designing and implementing interfaces complying with the requirements of accessibility and high-quality interaction.

A unified user interface comprises a single (unified) interface specification, targeted to potentially all user categories. In practice, a unified user interface is defined as a hierarchical construction in which intermediate nodes represent abstract design patterns decoupled from the specific characteristics of the target user group and the underlying interface development toolkit, while the leaves depict concrete physical instantiations of the abstract design pattern. The unified user interface development method comprises design- and implementation-oriented techniques for accomplishing specific objectives. The design-oriented techniques (unified user interface design) aim toward the development of rationalized design spaces, while the implementation-oriented techniques (unified user interface implementation) provide a specifications-based framework for constructing interactive components and generating the run-time environment for a unified interface.

To achieve this, unified user interface design attempts to: (1) initially identify and enumerate possible design alternatives, suitable for different users and contexts of use, using techniques for analytical design (such as design scenarios, envisioning and ethnographic methods); (2) identify abstractions and fuse alternatives into abstract design patterns (i.e., abstract interface components that are decoupled from platform-, modality-, or metaphor-specific attributes); and (3) rationalize the design space by means of assigning criteria to alternatives and developing the relevant argumentation, so as to enable a context-sensitive mapping of an abstract design pattern onto a specific concrete instance.

The result of the design process is a unified user interface specification. Such a specification can be built using a dedicated, high-level programming language and results in a single implemented artifact that can instantiate alternative patterns of behavior, at either the physical, syntactic, or even semantic level of interaction. The unified implementation, which is produced by processing the interface specification, undertakes the mapping of abstract interaction patterns and elements to their concrete/physical counterparts.

Unified user interface development makes two claims that radically change the way in which interfaces are designed and developed, while having implications on both the cost and maintenance factors. The first claim is that interfaces may be generated from specifications, at the expense of an initial design effort required to generate them. The second claim relates to the capability of the unified user interface to be transformed, or adapted, so as to suit different contexts of use. For example, in the cases of blind and motor-impaired users, the problem of accessibility of the menu can be addressed through a sequence of steps, involving (1) the unification of alternative concrete design artifacts (such as the desktop menu, the 3D acoustic sphere likely for the nonvisual dialogue, etc.) into abstract design patterns or unified design artifacts (such as a generalized container); (2) a method to allow the instantiation of an abstract design pattern into the appropriate concrete physical artifact, based on knowledge about the user; and (3) the capacity to dynamically enhance interaction by interchanging or complementing multiple physical artifacts at run-time (see adaptivity examples in the AVANTI system, Section 2.6.1).

It follows, therefore, that unified user interface development results in a revised cost model for user interfaces, where there is an initial effort to design, while development cost of alternative versions of an interface and maintenance costs are minimized.

Unified user interfaces and the related design approach are discussed in depth in Chapters 16, 18, and 21 of this handbook.

2.6 Working Examples of Systems and Services Designed for All

The unified user interface design method has been applied and validated in large-scale applications, which have provided both interesting and challenging test beds for the method's application, as well as the opportunity to refine details of its representation, conduct, and outcomes. Two of these applications are briefly discussed in the following. Their main achievement is that they have demonstrated the technical feasibility of the design for all approach. In these projects, the integration of all users has been obtained by implementing systems and services that are adaptable (that is, automatically reconfigurable at run-time, according to knowledge about the user or the user group) and adaptive (that is, able to change their features as a consequence of the patterns of use).

2.6.1 The AVANTI System

The AVANTI system[6] put forward a conceptual framework for the construction of web-based information systems that support adaptability and adaptivity at both the content and the user interface levels (Stephanidis et al., 2001). The AVANTI framework comprises five main components (Figure 2.3):

1. A collection of multimedia databases, which contain the actual information and are accessed through a common communication interface (multimedia database interface, MDI);

[6] The AVANTI AC042 (Adaptable and Adaptive Interaction in Multimedia Telecommunications Applications) project was partially funded by the ACTS Program of the European Commission and lasted 36 months (September 1, 1995 to August 31, 1998).

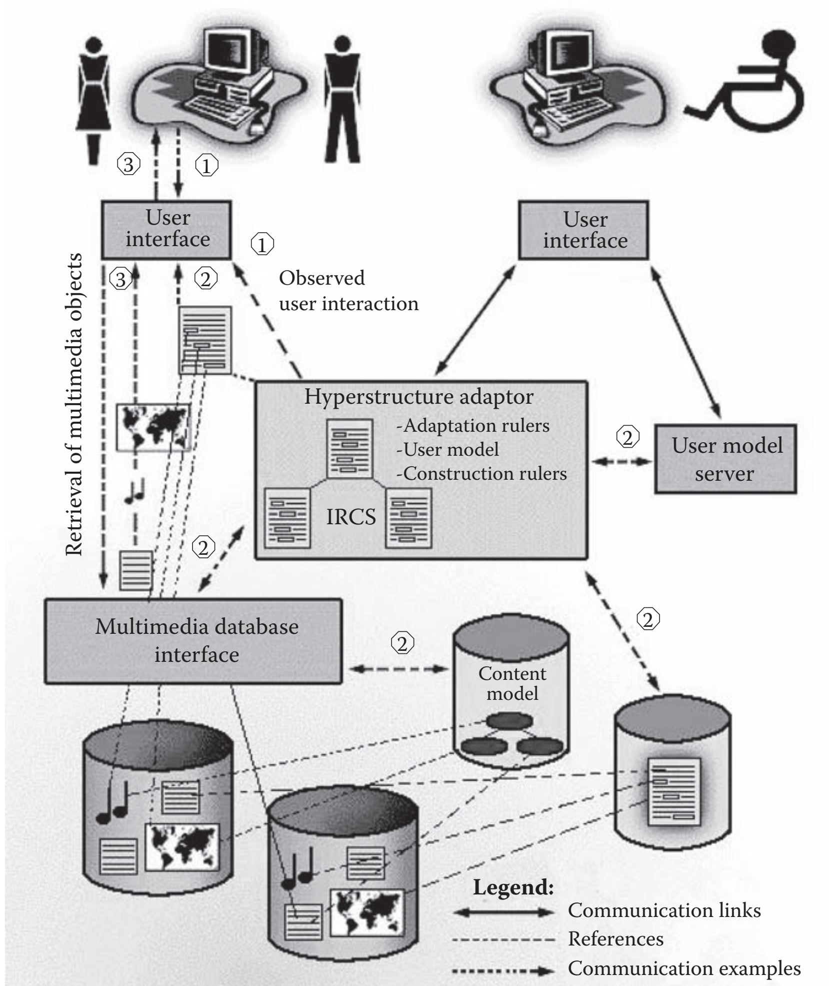

FIGURE 2.3 The AVANTI system architecture (From Emiliani, P. L., *Technology and Disability Journal*, 18, 19–29, 2001. With permission.)

2. A user modeling server (UMS), which maintains and updates individual user profiles, as well as user stereotypes;
3. The content model (CM), which retains a metadescription of the information available in the system;
4. The hyperstructure adaptor (HSA), which adapts the information content, according to user characteristics, preferences, and interests; and
5. The user interface (UI) component, which is also capable of adapting itself to the users' abilities, skills, and preferences, as well as to the current context of use.

Adaptations at the information-content level are supported in AVANTI through the HSA, which dynamically constructs adapted hypermedia documents for each particular user, based on assumptions about the user characteristics and the interaction situation provided by the user model server. The user characteristics that trigger appropriate adaptation types at the content level mainly concern the type of disability, the expertise, and the interests of the user. The resulting adaptations mostly concern: (1) alternative presentations using different media (e.g., text vs. graphics, alternative color schemes); (2) additional functionality (e.g., adaptive "shortcut" links to frequently visited portions of the system, and conditional presentation of technical details); and (3) different structures and different levels of detail in the information provided. The knowledge about the user and the interaction session is mostly based on information acquired dynamically during run-time (e.g., navigation monitoring, user selection, explicit user invocation), with the exception of the initial profile of the user, retrievable from the UMS, which is acquired through a short questionnaire session during the initiation of the interaction, or retrieved from a smart card if one is available.

The design and development of the AVANTI browser's user interface (which acted as the front-end to the AVANTI information systems) have followed the unified user interface design methodology. The resulting unified interface is a single artifact in which adaptability and adaptivity techniques are employed to suit the requirements of three user categories: able-bodied, blind, and motor-impaired people. Adaptations at the user

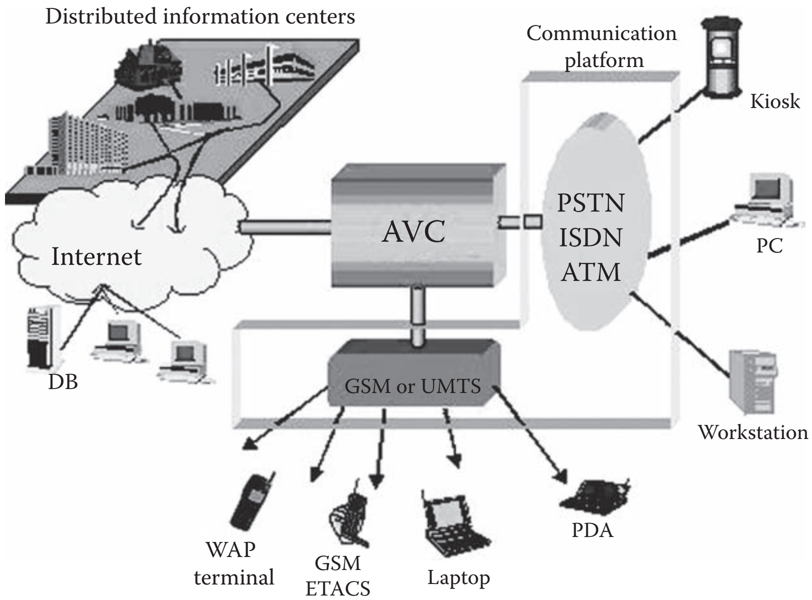

FIGURE 2.4 The PALIO information system (From Emiliani, P. L., *Technology and Disability Journal*, 18, 19–29, 2001. With permission.)

interface are supported through the cooperation of the browser and the user model server.

The categories of interface adaptation supported by the AVANTI UI include (Stephanidis et al., 2001) (1) support for different interaction modalities and input/output devices; (2) automatic adaptation of the presentation of interaction elements; (3) task-based adaptive assistance; (4) awareness prompting; (5) limited support for error prevention; and (6) limited support for metaphor-level adaptation. Additional features that have been included in the AVANTI browser to meet the requirements of the target user categories include adaptive support of multiple interaction metaphors (e.g., desktop application and an information kiosk metaphor), special I/O devices, and extended navigation functionality. Alternative metaphors have been designed for the different usage contexts of the AVANTI system. Furthermore, special-purpose input/output devices have been integrated into the system to support blind and motor-impaired individuals: binary switches, joysticks, touch screens and touch tablets, speech input and output, and Braille output.

2.6.2 The PALIO System

PALIO[7] (Stephanidis et al., 2004) is an open system for accessing and retrieving information without constraints and limitations imposed by space, time, access technology, and so on. Therefore, the system is modular and capable of interoperating with other existing information systems. Mobile communication systems play an essential role in this scenario, because they enable access to services from anywhere and at any time. One important aspect of the PALIO system is the support of a wide range of communication technologies (mobile or wired) for accessing services. In particular, it is possible for users equipped with either a common cellular phone or an advanced WAP phone to access services, wherever they are.

The PALIO system envisages the adaptation of both the information content and the way in which it is presented to the user, as a function of user characteristics (e.g., abilities, needs, requirements, interests); user location with the use of different modalities and granularities of the information contents; context of use; the current status of interaction (and previous history); and, lastly, the technology (e.g., communications technology, terminal characteristics, special peripherals) used.

The PALIO information system consists of the following three main elements (see Figure 2.4):

1. A communications platform that includes all network interfaces to interoperate with both wired and wireless networks;
2. The AVC center, which is composed of the main adaptation components, a service control center, and the communication layers to and from the user terminals and the information services; and
3. Distributed information centers in the territory, which provide a set of primary information services.

The AVC center is the architectural unit that manages diversity and implements the mechanisms for universal access. The AVC will be perceived by users as a system that groups together all information and services that are available in the city. It will serve as an augmented, virtual facilitation point from which

[7] The PALIO IST-1999-20656 Project (Personalized Access to Local Information and Services for Tourists) was partially funded by the EC 5th Framework Program and lasted 30 months (November 1, 2000 to April 30, 2003).

different types of information and services can be accessed. The context and location awareness, as well as the adaptation capabilities of the AVC, will enable users to experience their interaction with services as a form of contextually grounded dialogue: for example, the system always knows the user's location and can correctly infer what is near the user, without the user having to explicitly provide information to the system.

2.6.3 Recent Developments

In an AmI environment, applications are required to continuously follow end-users and provide high-quality interaction while migrating among different computing devices, and dynamically utilizing the available I/O resources of each device. An application experiment addressing these issues is reported in Stephanidis (2003). The developed experimental application is a nomadic music box for MP3 files, providing downloading from a server through the network, local storage, and decoding and playback functionality through a software/hardware player with typical audio control functionality. It exhibits elements of mobile, wearable, and wireless I/O resources, multiple I/O resources employed concurrently, and interface migration with state-persistent reactivation, ability to dynamically engage or disengage I/O resources as those become available or unavailable in mobile situations, and, finally, high-quality interface design to ensure interaction continuity in dynamic I/O resource control. The nomadic music box supports context awareness and adaptation to context, as well as adaptation to the (dynamically changing) available devices, addressing therefore diversity of contexts of use and technological platforms in the DC environment. Additionally, the adopted interface architecture and the dialogue design easily allow catering to additional target user groups (e.g., disabled users such as blind or motor-impaired users). Therefore, the nomadic music box constitutes a first example of prototype application addressing some of the issues raised by universal access in the context of AmI.

Furthermore, more recent developments of universally accessible systems based on design for all approaches and on the unified user interface development methodology are discussed in Chapter 23, "Methods and Tools for the Development of Unified Web-Based User Interfaces," which reports on a framework and the related toolkit for the development of web portals that integrate server-side adaptation capabilities, and Chapter 17, "Designing for Universally Accessible Games," which discusses the application of the unified user interface design method in the domain of electronic games, and presents examples of universally accessible games developed following such an approach.

2.7 Toward Intelligent Interactive Environments

The emergence of AmI environments (see Section 2.2 of this chapter and Chapter 60, "Ambient Intelligence") is likely to require a rethinking of design for all. In fact, in the context of AmI, the information society is no longer seen as a support to the execution of activities such as accessing and manipulating information or communicating with other people, but is supposed to have an impact on all aspects of social activities. This is clear if the sociopolitical factors at the basis of the deployment of the new technology and application environments as discussed in the ISTAG documents are considered.[8] According to ISTAG, AmI should (1) facilitate human contacts; (2) be oriented toward community and cultural enhancement; (3) help to build knowledge and skills for work, better quality of work, citizenship, and consumer choice; (4) inspire trust and confidence; (5) be consistent with long-term sustainability—personal, societal, and environmental—and with lifelong learning; and (6) be controllable by ordinary people. In essence, the challenge is to create an AmI landscape made up of "convivial technologies" that are easy to live with.

Accordingly, the main high-level design requirements of an AmI environment are that it must be unobtrusive (i.e. , many distributed devices are embedded in the environment, and do not intrude into our consciousness unless we need them), personalized (i.e., it can recognize the user, and its behavior can be tailored to the user's needs), adaptive (i.e., its behavior can change in response to a person's actions and environment), and anticipatory (i.e., it anticipates a person's desires and environment as much as possible without the need for mediation).

It is clear from the previous design requirements that design for all in the information society must provide much more than personalization (adaptability) and adaptivity, which nevertheless are among the required features of AmI. Smart devices and (complex) services are supposed to be embedded in the environment, and must be able to provide support to users only when they need them, anticipating their desires. Moreover, this must occur in any place and context of use and in any moment. This requires the deployment of an infrastructure for supporting ubiquitous connection and computational power, but also of intelligence for identifying the goals of the users and helping users in fulfilling them. Therefore, the environment must not only be filled with intelligent objects (that is, computer-based systems), but must also be able to reason with regard to the goals of the users and to optimize the support in accordance with the resources available.

While many problems related to interaction with the present information society are actually linked to a suitable structuring of information and an accessible human system interface, integration within the AmI environment is much more complex, due to the interplay of different levels (e.g., the physical level with a multiplicity and heterogeneity of intelligent objects in the environment and their need for a continuous and high-speed connection, the level of identification and consideration of the variety of contexts of use, and the level of elicitation of the diversity of user goals and help in their fulfilment).

The AmI environment must be able to seamlessly integrate these three levels. At the lower level, all objects in the

[8] See ISTAG online at http://cordis.europa.eu/ist/istag.htm.

environment must incorporate intelligence and must be interconnected and able to cooperate to support the goals of the user. Moreover, the environment must be reconfigurable in real time, to cater for the introduction or removal of components (e.g., objects that users entering the environment may have with them), by remodeling its support as a function of the available resources. This aspect of the intelligent environment is a prerequisite for its development, and the reconfiguration must take into account the variability of the contexts of use and the goals of the users.

At this level, artificial intelligence is crucial in supporting the development of basic technologies considered important in the implementation of AmI. For example, the ISTAG experts write that pattern recognition (including speech and gesture) is a key area of artificial intelligence that is already evolving rapidly. Speech recognition will have a big impact on the miniaturization of devices and the augmentation of objects allowing hands-free operation of personal ambient devices. In the scenarios, the use of voice, gesture, and automatic identification and localization are implicitly used to synchronize systems, so that services are available when people want them. The synchronization of systems is indeed a very important aspect. In the intelligent environment, there may be different users with goals that have different importance and criticality. AmI must be able to decide how to take care of potentially conflicting needs (from the perspective of resources).

At a higher level, the AmI environment must take care of the contexts of use considered as processes, which are defined by specific sets of situations, roles, relations, and entities (Coutaz et al., 2008). Recently, interest on the right definition and role of the contexts of use has grown, when dealing with both the development of user machine interfaces and with the organization and representation of information. For example, in connection with multimodality, it has been argued that the availability of different representations of the same information could be very interesting to avoid problems of context-related accessibility. Typical examples are car drivers who are functionally blind and motor disabled, meaning that they cannot interact with information and communication by using a screen and a pointer. But in AmI, the situation is more complex, because in the ubiquitous interaction with information and telecommunication systems the context of use may change continuously or abruptly, and the same systems or services may need to behave differently in different contexts. A clear example to be considered is the complexity of the situation where a user is carrying out some activity in a room (e.g., in the kitchen) and a second person enters the room. The system must reconfigure itself, not only due to the possible introduction of some additional intelligent component, but also because of the change in the context of use. The system must accommodate the original goals of two persons, and also take into account their interaction, which, for example, may redefine in real time some of their goals or change the time scale of different activities. This requires not only a complete configurability of the system and service at the level of interfaces and functionalities, but also the capacity of realizing changes in the environment and reasoning as to their impact on the context in which they are used.

When discussing the technology necessary for transforming the scenarios into reality, ISTAG experts (IST Advisory Group, 2003) make a list of its intelligent components. They are:

- Media management and handling, including presentation languages that support "produce once" and "present anywhere" methods and tools to analyze content and enrich it with metadata, and tools for exploiting the semantic web;
- Natural interaction that combines speech, vision, gesture, and facial expression into a truly integrated multimodal interaction concept that allows human beings to interact with virtual worlds through physical objects, and that enables people to navigate the seemingly infinite information which they will be able to access;
- Computational intelligence, including conversational search and dialogue systems, behavioral systems that can adapt to human behavior, and computational methods to support complex search and planning tasks;
- Contextual awareness, for instance, systems that support navigation in public environments, such as in traffic, in airports and in hospitals, service discovery systems that enhance the shopping experience, and context-aware control and surveillance systems; and
- Emotional computing that models or embodies emotions in the computer, and systems that can respond to or recognize the moods of their users, and systems that can express emotions.

These technologies are the necessary building blocks for implementing AmI environments populated by smart artifacts that can adapt to human behavior and to different contexts. The emerging question is whether the list is exhaustive and what the impact of (artificial) intelligence is in really meeting the design requirements. That is, creating an environment where people can reach their goals and in which they do not feel artificial does not create problems of information overload and confusion and is perceived as being worthy of trust and confidence.

Indeed, in addition to objects and contexts of use, there is a higher abstraction level to be considered. Most of the interaction with currently available systems is based on the performance of tasks in a set determined by the application used. In the intelligent environment, the goals of the user are the starting point. They must be inferred by the system and decomposed into tasks that are adapted to the preferences of the individual. This is really the level where intelligence plays a crucial role. The acceptability and uptake of the new paradigm will be essentially dependent on how smart the system is in inferring the goals of the users in the continuously varying contexts of use and in organizing the available resources (intelligent objects in the environment) to help users fulfil them. Moreover, this aspect is also very sensitive from a psychological perspective. For example, the system must be able to deal with the task of inferring the goals of the users without giving them the impression that the system is controlling them (Big Brother), and must be able to support the users without giving them the impression of force. It must "offer" possible solutions, not "impose" them. This requires a lot of ingenuity also on the part of human beings, and appears particularly difficult for a machine. However, it can also be argued that the intelligence in the system does not necessarily have to be artificial, but could and probably will also be in the network of interconnected and cooperating persons.

2.8 Conclusions

Due to the emergence of the information society, which is not conceived as an increased diffusion of computers and terminals as presently available, but as a space populated with interconnected intelligent objects offering people functionalities for communicating, controlling the environment, and accessing information, emphasis is being placed on the problem of granting universal access to the emerging information space, instead of providing accessibility to individual terminals and computers.

This is causing a revision of the traditional ways of using technology for the social inclusion of people with disabilities. In particular, due to the ongoing transition and the possible complexity of the resulting environment, it is commonly accepted that from reactive approaches to inclusion, based on the adaptation of available mainstream technologies with assistive technology, it is necessary to switch to proactive approaches, whereby the needs, requirements, and preferences of all potential users are integrated in the specifications for the design of new technology and its applications. This implies that assistive technology is no more "the technological solution" for inclusion, but one of its components.

This conceptual approach, known as design for all in Europe and universal design in the United States, is shifting the interest of designers from an artificial "average user" to real users in real contexts of use, aiming for an implementation of systems, services, and applications that are usable by all potential users without modifications. This concept, developed in architecture and industrial design, remains valid in the ICT environment, but the implementation strategy and the technical approach must be changed. As a matter of fact, design for all in the context of information technologies should not be conceived (as in architecture or industrial design) as an effort to advance a single solution for everybody, but as a user-centered approach to providing products that can automatically address the possible range of human abilities, skills, requirements, and preferences. Consequently, the outcome of the design process is not intended to be a singular design, but a design space populated with appropriate alternatives, together with the rationale underlying each alternative, that is, the specific user and usage context characteristics for which each alternative has been designed.

However, it is also necessary to define a technical approach for the practical implementation of this general strategy. A possible technical approach for the implementation of designed for all interfaces has been described in the chapter. The description starts from the initial difficulties found in exploratory activities concerned with the adaptation of telecom terminals and graphical interaction environments (GUIs), leading to the definition of a design for all technical approach based on the automatic initial adaptation of the interface when starting interaction (adaptability) and the continuous automatic adaptation as a function of the use (adaptivity), leading to the development, first, of the dual interface concept, and then of the unified user interface concept.

Then the feasibility of the approach is demonstrated through the application of the approach to the development of the interfaces of real web-based applications, both in the classical Internet environment (the AVANTI system) and in the emerging mobile environment (the PALIO system). Finally, its generalization outside the interface implementation to the automatic adaptation of the information contents of the web pages on which the services are based is also shown.

This approach appears particularly suitable in connection with foreseen technological developments. The emergence of ambient intelligence and the deployment of intelligent interactive environments will obviously be instrumental in making available the intelligence that is necessary to grant adaptability and adaptability in a way that is unobtrusive and anticipates the needs of the single user.

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3

Accessible and Usable Design of Information and Communication Technologies

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3.1 Introduction

Designing accessible information and communication technologies (ICT) has always been challenging. However, the dramatic changes in human interface that are now occurring are creating new challenges, some of which cannot be addressed with old approaches. New types of speech, gesture, and biosensor inputs are being developed. There are also new levels of intelligence, adaptation, and variation in the behavior of interfaces over time. Software is becoming virtual, as is computing. And the introduction of "pluggable user interfaces" changes the definition of "device user interface" from a physical-sensory form to a command and variable form (Vanderheiden and Zimmerman, 2005). About the only thing that is not changing is the human being and the range of abilities and limitations that humans present. However, with the possibility of direct brain interfaces and other direct neural interfaces, abilities and opportunities for human interfaces may be changing as well.

This chapter will negotiate the different facets of accessible interfaces to ICT in a layered fashion starting with user needs, then current techniques and strategies for addressing them. Approaches for addressing both single and multiple disabilities are covered. The chapter will cover access via assistive technologies, universal design, and pluggable user interfaces. It will also examine how these terms are blurring in ways that are changing them from categories to characteristics. That is, where it used to be possible to sort assistive technologies or techniques into these categories, most devices and technologies in the future will exhibit characteristics of all categories. This will provide advantages but may further complicate things as well, particularly around public policy. This chapter closes with a look at the future of interface as it relates to information and communication technologies, highlighting both the challenges and opportunities.

3.2 Needs of Individuals Experiencing Constraints

This chapter is primarily about individuals experiencing functional limitations due to disability, including those experienced during aging. However, most of the principles for making devices more accessible also solve problems of individuals who do not have disabilities, but who may be experiencing limitations due to some other factor. For instance, in a very noisy environment an individual who ordinarily has no trouble hearing may have great difficulty or find it impossible to hear the auditory output from a device such as a cell phone or ticket vending machine. While driving a car, one needs to operate devices without using vision. Others may find themselves in an environment where it is dark or may be without their glasses and unable to see controls or labels. Table 3.1 provides some parallels between individuals with disabilities and individuals without disabilities who may find themselves experiencing environmental or task-induced constraints. When all of these people are considered, as well as individuals experiencing a wide range of temporary disabilities, it is useful to note that "those with disabilities" are not such a small portion of the population. And when people are considered across their lifetime (rather than looking at a snapshot of the population at any point in time), the result is that most people will acquire disabilities if they live long enough.

Everybody hopes to live well into their sixties, and beyond. Unfortunately, as we age, an ever-increasing percentage of people will acquire functional limitations. In fact, all of us will acquire disabilities—unless we die first. Figure 3.1 provides a glimpse of this effect by plotting out the percentage of individuals with functional limitations as a function of age. If this series is continued, it will be moving toward unity as one increases in age. Figure 3.2 shows that these disabilities include physical, visual, and hearing. In addition, observing the percentages, it becomes clear that people acquire multiple disabilities as they age. Unfortunately, those who are designing the world in which people must live are usually the youngest, most able, and most technically oriented. Perhaps, as an ever-increasing percentage of the population falls in the upper age groups, market pressures may cause designs to take those with disabilities more into account to enable elders to remain productive and to live more independently for a greater portion of their lives.

3.2.1 Profile of User Interface Needs

There are many different ways of looking at user needs. One way is to explore the needs by disability. This is the approach originally taken in studying consumer product accessibility guidelines (Vanderheiden and Vanderheiden, 1992), Guide 71,[1] and many others that are organized by disability or limitations. However, a more useful approach to designers might be to examine user needs by interface component or interface dimension across disabilities. That is, examine the different parts or functions of the human interface individually and look at the impact or barriers experienced by individuals with different disabilities. Cross-disability interface strategies can then be described and understood more easily. Designers can both see aspects of design that would work for multiple disabilities, and identify those strategies that would not create barriers for one disability while solving another. This is particularly important for designing access into mainstream and public devices, where the interface must be usable by all. The Trace Center at the University of Wisconsin first began exploring this approach about 7 years ago and developed a user needs profile based on basic access/use essentials. It should be noted that these are not essentials for individuals who have disabilities, but essential components that must be there for anyone to be able to effectively use an interface. Everyone must be able to *perceive*, *operate,* and *understand* a product's interface to use the product. It must also be *compatible* with anything that is part of their person (glasses, clothes, or, for people with disabilities, any assistive technologies they must use while using the product). The basic essentials are:

1. Perceive
   To use a product, users:
   1a. Must be able to *perceive any information that is displayed*.
   - This includes information that is displayed passively (labels, instructions) or actively (on displays).
   - It includes both visually displayed information and information delivered in auditory form (usually speech).
   - Includes labels, signs, manuals, text on the product, and information conveyed by symbols on displays, alerts, alarms, and other output.

[1] ISO/IEC Guide 71:2001 guidelines for standards developers to address the needs of elderly persons and persons with disabilities.

TABLE 3.1 Parallel Chart: Disability vs. Situation

Requirement	Disability-Related Need	Situation-Related Need
Operable without vision	People who are ***blind***	People whose ***eyes are busy*** (e.g., driving a car or phone browsing) or who are ***in darkness***
Operable with low vision	People with ***visual impairment***	People using a ***small display*** or in a high-glare, ***dimly lit environment***
Operable with no hearing	People who are ***deaf***	People in ***very loud environments*** or whose ***ears are busy*** or are in ***forced silence*** (library or meeting)
Operable with limited hearing	People who are ***hard of hearing***	People in ***noisy environments***
Operable with limited manual dexterity	People with a ***physical disability***	People in a ***space suit*** or ***chemical suit*** or who are in a ***bouncing vehicle***
Operable with limited cognition	People with a ***cognitive disability***	People who are ***distracted***, ***panicked***, or under the ***influence of alcohol***
Operable without reading	People with a ***cognitive disability***	People who just ***have not learned to read a specific language***, people who are visitors, people who left reading glasses behind

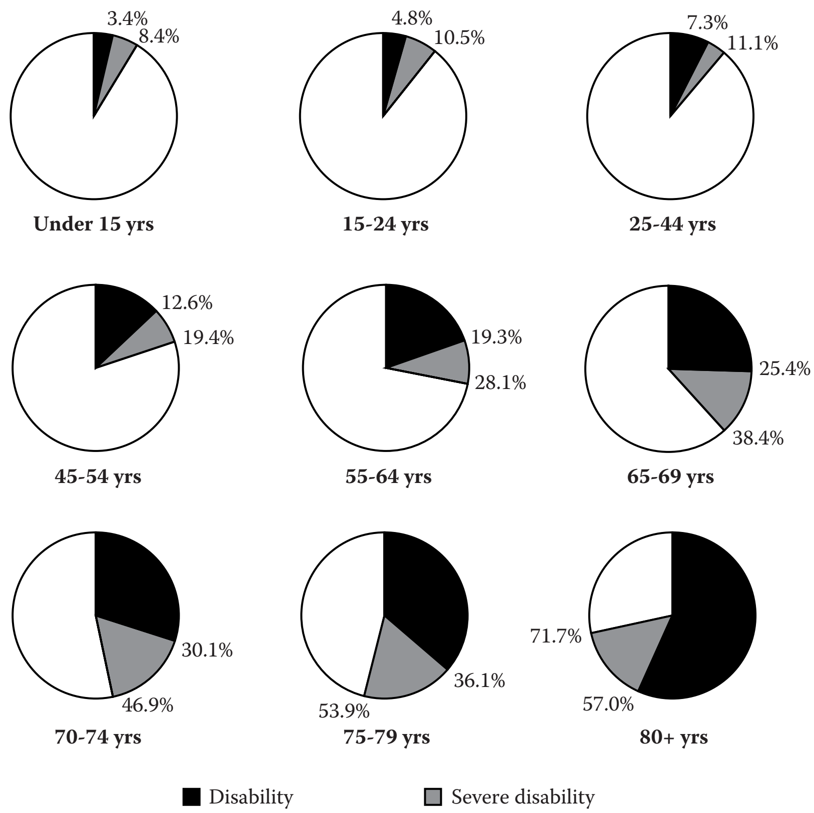

FIGURE 3.1 Prevalence of impairments by age. Pie charts show the percentage of people who have a disability as a function of age. From U.S. Department of Health and Human Services: 2006 National Health Interview Survey (http://www.cdc.gov/nchs/data/series/sr_10/sr10_235.pdf).

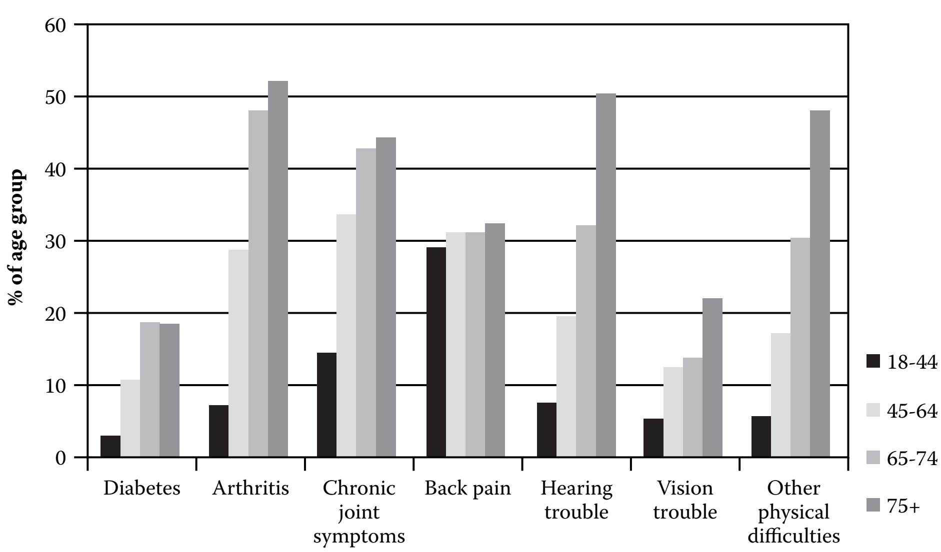

FIGURE 3.2 Disability as a function of age. Physical, sensory, and cognitive disabilities at different ages show that as we age physical, hearing, and visual disabilities rise sharply from small percentages to the 50% range. From U.S. Census Bureau, Survey of Income and Program Participation (June–September 2002).

1b. Must be able to *perceive the existence and location of actionable components*.
- Buttons, controls, latches, etc.
  - Must be able to find them and refind them easily.
  - Must be able to perceive the status of controls and indicators.
  - Includes progress indicators and the status of any switches, dials, or other controls, real or virtual.

1c. Must be able to *perceive any feedback* from operation.
- Includes not only programmed feedback, but natural feedback such as machine sounds that are important for safe and effective use of the device.

2. Operate

To use a product, users:

2a. Must be able to *invoke and carry out all functions* via at least one mode of operation.
- Including daily maintenance and set up expected of users.
- Preferably all of maintenance and set up.

2b. Must be able to *complete all actions and tasks within the time allowed*.
- To effectively compete in the workplace, meeting productivity requirements, etc.

2c. Must be able to *operate without accidentally activating actions*.

2d. Must be able to recover from errors.
- Physical or cognitive errors.

2e. Must have equivalent *security and privacy*.
- If alternate modes are needed, they need to provide equivalent security and privacy.

2f. Must be able to use *without causing* personal risk.
- e.g., seizures, physical injury, etc.

3. Understand

To use a product, users:

3a. Must be able to *understand how to use the product*.
- Including discovery and activation of any access features needed.

3b. Must be able to *understand the output* or displayed material.
- Even after they have perceived it accurately.

4. Compatible with personal technologies

To use a product, users:

4a. Must be able to *use the product in conjunction with any personal technologies*.
- e.g., glasses, wheelchairs, hearing aids, etc.
- For some it would be more efficient if they could use their own personal interface devices with the products they encountered.
- For others, the only way they would be able to use products would be to use specialized input devices that they would bring with them since it would be impractical to have them built into the products they encounter.

These basic principles were expanded into a profile, including the problems faced by individuals with different disabilities for each of these categories and specific user needs, as part of an online design tool under development at the Trace R&D Center (see Table 3.2 for current version).

In April 2005, these were submitted to the Joint Technical Committee, ISO-IEC Special Working Group on Accessibility (ISO/IEC JTC1 SWGA) where they underwent review, comment, and revision on their way to becoming a JTC1 technical report. The final version from JTC1 is scheduled for release in early 2009.

3.3 Strategies for Addressing User Needs

3.3.1 General Approaches

If someone is not able to use the environment and devices they encounter in daily life effectively, there are three approaches to intervention:

1. Change the individual, so that the person can use the world better as it is found.
2. Adapt the individual products encountered by the person to make them usable by the person.
3. Change the world, so that it is easier for people to use with the abilities they have.

The first approach, changing the individual, is based on a medical model and is a very important strategy. It seeks to increase the basic abilities of the individual through both medical and other rehabilitation strategies. It may include surgery and rehabilitation therapy, but also includes training, the learning of techniques from peers, and in many cases, equipping the individual with personal assistive technologies such as glasses, hearing aids, prostheses, splints, and wheelchairs. In the future, individuals (both with and without disabilities) may also carry around with them specialized interface technologies or devices that are tuned to the individual's need and could serve as personal interfaces to the devices around them (see the pluggable user interfaces discussion later in this chapter). These personal assistive technologies are thought of as extensions of the individual.

The second approach, adapt the individual products encountered, has been around as long as there have been inventive people with disabilities and their inventive friends. This approach basically focuses on adapting the devices around the individual so that they are operable by the individual. This includes, for example, adding tactile markings to a stove or microwave or putting grab bars near the toilet. Adaptations for information and communication technology include special keyboards, screen readers, and enlargers. This category includes products that are developed on a custom basis for individuals, as well as commercially available adaptive or assistive technologies (AT) used with mainstream products to make them more accessible and

TABLE 3.2 User Needs Summary: Trace Center, University of Wisconsin–Madison

Basic	Problems Using Products	User Needs
Users need to be able to PERCEIVE all information presented by the product, including:		

Perceive static displayed info
-Labels
-Signs
-Manuals
-Text
-Etc.
	People who are blind
	• Cannot see (to read)
	  ◦ Printed labels on keys, controls, slots, etc.
	  ◦ Printed signs near device or instructions printed on device
	  ◦ Manuals or other printed material provided with product
	• Cannot access information presented (only) via graphics
	• Cannot find public devices (cannot see where device is or see signs giving location)
	People with low vision
	• Cannot see (to read) signs and labels:
	  ◦ If text is too small for them
	  ◦ If contrast with background is too low
	  ◦ If text is presented as small raised letters (same color as background)
	  ◦ If information is coded with color only (color deficiency)
	  ◦ If there is glare (intensity); if they have light sensitivity
	  ◦ If there is surface (reflective) glare
	  ◦ (many problems same as blindness)
	People with physical disabilities
	• Often cannot reposition themselves to see information if not in easy sightline
	• May not be able to see due to glare/reflections (and cannot reposition enough)
		Some users with disabilities
		• Need to have all static text information required for use provided via speech output or large raised text
		  ◦ NOTE 1: Braille is also very useful to people who know it where it is practical to put it on the product, but it would be in addition to speech, not instead of, since most people who are blind do not know Braille, including those who acquire blindness late in life and those who have diabetes, which takes away sensation in the fingertips
		  ◦ NOTE 2: Speech output also important for those with cognitive disabilities (see “UNDERSTAND”)
		  ◦ NOTE 3: Raised text would need to be approx. 3/4 inch high
		• Need to have visual cues provided in auditory form
		• Need sufficient contrast between all printed information and its background
		• Need to have text presented in large easy-to-read fonts
		• Need to avoid surface (reflective) glare
		• Need to have information within viewable range of people in wheelchairs and those of short stature
		• Need to have any information presented in color be also presented in a way that does not depend on color perception

Perceive info presented via dynamic displays
-Screens
-Alerts
-Alarms
-Other output
	People who are blind
	• Cannot see what is displayed on visual display units (all types)
	• Cannot determine current function of soft keys (where key function is dynamic with label shown on dynamic display such as LCD)
	People with low vision
	• Same problems as static text (size, contrast, color) (see above)
	• Glare: from environment or too bright a screen
	• Miss information presented temporarily where they are not looking
	• Sometimes cannot track moving/scrolling text
	People who are deaf
	• Cannot hear information presented through:
	  ◦ Speech
	  ◦ Tones
	  ◦ Natural machine sounds
		Some users with disabilities
		• Need to have all DYNAMIC visual information required for use also provided via speech output
		  ◦ NOTE 1: Dynamic Braille displays are very expensive and impractical for inclusion in devices
		  ◦ NOTE 2: Speech output is also important for those with cognitive disabilities (see “UNDERSTAND” below)
		  ◦ NOTE 3: Raised text won’t work for dynamic information
		• Need a means for identifying all keys and controls via speech
		• Need sufficient contrast between all display information (audio or visual) and its background
		• Need to have text presented in large easy-to-read fonts
		• Need to avoid surface (reflective) glare
		• Need to avoid brightness glare
		• Need to have information within viewable range of people in wheelchairs and those of short stature
		• Need to have all auditory information required for use also available in visual and/or tactile form
		  ◦ NOTE 1: Tactile presentation only useful for products that will always be in contact with user’s body

(*Continued*)

TABLE 3.2 (*Continued*)

Basic	Problems Using Products	User Needs

	People who are hard of hearing
	• May miss any information presented auditorily because:
	  ◦ At a frequency they can't hear
	  ◦ Background noise blocks it or interferes with it (including echoes)
	  ◦ Too soft
	  ◦ Poor-quality speech
	  ◦ Speech too fast and user can't slow it down
	  ◦ Presented as two different tones that can't be distinguished
	  ◦ Information is presented that requires stereo hearing
	People with physical disabilities
	• Cannot maneuver to see display or avoid glare
	People with cognitive disabilities
	• Distracted by dynamic movements on screen
		• Need to have auditory events, alerts, etc., be multifrequency so that they can hear it
		• Need sufficient volume (preferably adjustable) for audio output
		• Need to have any information presented in color also presented in a way that does not depend on color perception
		• Need to be able to control the colors in which information is presented
		• Need to be able to control the pitch of information presented auditorily
		• Need to have audio information conveyed by sound pattern, not frequency
		• Need to have audio information conveyed by vibration to use patterns, not frequency or strength
		• Stereo information available in monaural form

Perceive existence and location of actionable components
-Buttons
-Controls
-Latches
-Etc.
(find them and refind them)
	People who are blind
	• Cannot determine number, size, location, or function of controls on
	  ◦ Touchscreens
	  ◦ Flat membrane keypads
	• Cannot find controls in a large featureless group; cannot be relocated easily even if known to be there
	• Switch or control in an obscure location may not be discoverable even if visible
	• Might touch tactilely sensitive controls while exploring with hands
	• Can be fooled by phantom buttons (tactile) (things that feel like buttons but are not, e.g., a logo, a round flat raised bolt head, a styling feature)
	• Cannot type on a non-touchtypeable keyboard
	People with low vision
	• Cannot find buttons that don't contrast with background (won't feel where nothing is visible or expected)
	• Phantom buttons (visual) (logos, styling that looks like button when blurred)
	• Cannot locate where the cursor is on the screen
	People with physical disabilities
	• Often cannot reposition themselves to see controls if not in easy sightline
	People with cognitive disabilities
	• Do not recognize stylized control as a control
		Some users with disabilities
		• Need a means to access all product functionality via tactilely discernable controls
		• Need controls to be locatable without activating control or nearby controls
		• Need sufficient landmarks (nibs, groupings, spacing) to be able to easily locate controls tactilely once they have identified them (per above)
		• Need to have controls visually contrast with their surroundings so they can be located with low vision
		• Need to have any keyboard be operable without sight
		• Need to have controls be in places where they can be easily found with poor or no sight
		• Need to have pointing cursors (on screen) be large enough to be visible with low vision
		• Need to have logos and other details not look like or feel like buttons or controls
		• Need to have controls where they can be seen by people of short stature and those using wheelchairs

Perceive status of controls and indicators (includes PROGRESS indicators)	**All disabilities** • Cannot tell state if the same alternative is provided for different signals **People who are blind** • Cannot tell status of visual indicators (LEDs, onscreen indicators, etc.) • Cannot tell the status of switches or controls that are not tactilely different in different states (or where tactile difference is too small)	**Some users with disabilities** • Need an auditory or tactile equivalent to any visual indicators or operational cues, manmade or natural • Need a visual or tactile indicator for any auditory indicators or operational cues, manmade or natural • Need visual or auditory alternative to any subtle tactile feedback • Need visual indicators to be visible with low vision

TABLE 3.2 (*Continued*)

Basic	Problems Using Products	User Needs
	People with low vision • Cannot read visual indicators with low vision if indicator is not bold • Cannot distinguish between some colors used to indicate status • Cannot see or read small icons for status • Cannot see cursors unless large, high contrast; static harder than dynamic to spot **People who are deaf** • Cannot hear audio indicators of status • Cannot hear natural sounds (e.g., machine running, stalled, busy, etc.) **People who are hard of hearing** • May not hear status sounds due to volume, frequency used, background noise, etc. **People with physical disabilities** • May not have good line of sight to indicators • May not have tactile sensitivity to detect tactile status indications **People with cognitive disabilities** • May not recognize or understand different indicators	• Need all indications that are encoded (or presented) with color to be encoded (marked) in some noncolor way as well • Need large high-contrast pointer cursors • Need sufficient volume and clarity for audio cues • Need alternatives that are different, when different signals are used (e.g., different ringtones, or tactile or visual indicators) • Need indicators and cues to be obvious or explained • Need to have controls and indicators located where they can be seen by people of short stature and those using wheelchairs

Perceive feedback from operation	**All disabilities**
	• Cannot tell state if the same alternative is provided for different signals
	People who are blind
	• Cannot see visual feedback of operation
	People with low vision
	• Cannot see visual feedback of operation unless large, bold
	  ◦ Often have hearing impairments as well so cannot always count on audio
	People who are deaf
	• Cannot hear auditory feedback of operation
	People who are hard of hearing
	• Often cannot hear auditory feedback of operation due to:
	  ◦ Volume
	  ◦ Frequency used
	  ◦ Background noise
	  ◦ Speech feedback not clear or repeatable
	People with physical disabilities
	• May not be able to feel tactile feedback due to insensitivity or impact of hand or use of artificial hand, stick, splint, etc. to operate the control
	People with cognitive disabilities
	• Feedback too subtle or not directly tied to action
		Some users with disabilities
		• Need visual feedback that is dramatic (visual from 10 ft)
		• While others need it to be audio or tactile feedback

(*Continued*)

TABLE 3.2 (*Continued*)

Basic	Problems Using Products	User Needs
Be able to OPERATE the product		

Be able to invoke and carry out all functions (via at least one method)	**People who are blind**
	• Cannot use controls that require eye-hand coordination
	  ◦ Pointing devices, including mice, trackballs, etc.
	  ◦ Touchscreens of any type
	• Cannot use devices with touch-activated controls (can't explore tactilely)
	• Cannot use products that require presence of iris or eyes (e.g., for identification)
	People with low vision
	• Difficult to use device with eye-hand coordination
	People who are deaf
	• Many cannot use if speech input is only way to do some functions
	• Cannot operate devices where actions are in response to speech (only)
	People with physical disabilities
	• Cannot operate devices if operation requires (i.e., no other way to do function):
	  ◦ Too much force
	  ◦ Too much reach
	  ◦ Too much stamina (including long operation of controls with arm extended or holding handset to head for long period unless able to prop or rest arm)
	  ◦ Contact with body (so that artificial hands, mouthsticks, etc., cannot be used)
	  ◦ Simultaneous operation of two parts (modifier keys, two latches, etc.)
	  ◦ Tight grasping
	  ◦ Pinching
	  ◦ Twisting of the wrist
	  ◦ Fine motor control or manipulations (i.e., can't operate with closed fist)
	  ◦ Cannot use products that require presence of fingerprints or other specific body parts or organs (e.g., for identification)
		Some users with disabilities
		• Need to be able to operate all functionality using only tactilely discernable controls coupled with audio or tactile feedback/display (no vision required)
		• Not requiring a pointing device
		• Need to not have touch-sensitive or very light touch controls where they would be touched while tactilely finding keys they must use to operate device
		• Need alternate identification means if biometrics are used for identification
		• Need alternate method to operate any speech-controlled functions
		• Need to be able to access all computer software functionality from the keyboard (or keyboard emulator)
		• Need method to operate product that does not require:
		  ◦ Simultaneous actions
		  ◦ Much force
		  ◦ Much reach
		  ◦ Much stamina
		  ◦ Tight grasping
		  ◦ Pinching
		  ◦ Twisting of the wrist or
		  ◦ Direct body contact

Be able to complete actions and tasks within the time allowed (by life, competition, productivity requirements, etc.)	**People who are blind**
	• Must use nonvisual techniques that are often slower, requiring more time than usual to read/listen to output, explore, and locate controls etc.
	People with low vision
	• Often take longer to read text and locate controls
	People who are deaf
	• May be reading information in a second language (sign language being first)
	• May be communicating (or operating phone system) through a relay/interpreter that introduces delays
	People who are hard of hearing
	• May have to listen more than once to get audio information
	People with physical disabilities
	• May take longer to read (due to head movement), to position themselves, to reach, or to operate controls
		Some users with disabilities
		• Need to have all messages either stay until dismissed or have a mechanism to keep message on screen or easily recall it
		• Need to have ability to either:
		  ◦ Have no timeouts, or
		  ◦ Have ability to turn off timeouts, or
		  ◦ Be able to set timeouts to 10 times default value, or
		  ◦ Be warned when timeout is coming and be provided with ability to extend timeouts except where it is impossible to do so
		• Need to have a way to turn off or freeze any moving text

TABLE 3.2 (*Continued*)

Basic	Problems Using Products	User Needs

	People with cognitive disabilities
	• May take longer to remember, to look things up, to figure out information, and to operate the controls, all of which can cause problems if:
	  ◦ Information or messages are displayed for a fixed period and then disappear
	  ◦ Users are only given a limited amount of time to operate device before it resets or moves on
	  ◦ Text moves on them while they are trying to read it	

Won't accidentally activate functions	**People who are blind** • Might touch "touch sensitive" controls or screen buttons while tactilely exploring • Might miss warning signs or icons that are presented visually • Might bump low-activation force switch(es) while tactilely exploring **People with low vision** • Might bump low-contrast switches/controls that they do not see **People who are deaf or hard of hearing** • May not detect alert tone and thus inadvertently operate device when unsafe **People with physical disabilities** • Might activate functions due to extra body movements (tremor, chorea) • Might activate functions when resting arm while reaching **People with cognitive disabilities** • Might not understand purpose of control (or control changes due to softkey)	**Some users with disabilities** • Need to have products designed so they can be tactilely explored without activation • Need products that can't cause injury with spasmodic movements • Need to have products that don't rely on users seeing hazards or warnings to use products safely • Need to have products that don't rely on users hearing hazards or warnings to use products safely • Need to have products where hazards are obvious and easy to avoid, hard to trigger
Be able to recover from errors (physical or cognitive errors)	**People who are blind or have low vision** • May not detect error if indication is visual • May not be able to perceive contextual cues (if visual only) to know they did something wrong or unintended (when not an "error" to the device) **People who are deaf** • Will not hear auditory "error" sounds **People who are hard of hearing** • May not hear auditory "error" sounds or be able to distinguish between them **ALL disabilities** • User may not be able to figure out how to go back and undo the error	**Some users with disabilities** • Need a mechanism to go back and undo the last thing(s) they did, unless impossible • Need good auditory and visual indications when things happen so that they can detect errors • Need to be notified if the product detects errors made by the user • Need clear unambiguous feedback when error is made and what to do to correct
Have equivalent, security, and privacy	**People with all disabilities** • Do not have privacy when human assistance is required **People who are blind** • Have more difficulty detecting people looking over shoulder • If no headphone or handset, information is broadcast to others via speaker **People with low vision** • Larger print makes it easier for others to look over shoulder	**Some users with disabilities** • Need ability to listen privately • Need to have product designed to help protect privacy and security of their information even if they are not able to do the "expected" things to protect it themselves

(*Continued*)

TABLE 3.2 (*Continued*)

Basic	Problems Using Products	User Needs
	People who are deaf • May not detect sensitive information being said aloud **People who are hard of hearing** • Louder volume may allow eavesdropping, even with headphones ◦ User may not realize volume of audio **People with physical disabilities** • In wheelchair, body doesn't block view of sensitive information like someone standing **People with cognitive disabilities** • Less able to determine when information should be kept private	
Not cause health risk (e.g., seizure, etc.)	**People who are blind** • Cannot see to avoid hazards that are visual • Cannot see warning signs, colors, markers, etc. • If using headphones, they are less aware of surroundings (and not used to it) **People who are deaf or hard of hearing** • May miss auditory warnings or sounds that indicate device failure **People with physical disabilities** • May hit objects harder than usual and cause injury • May not sense when they are injuring themselves **People with photosensitive epilepsy** • May have seizure triggered by provocative visual stimuli **People with allergies and other sensitivities** • May have adverse reactions to materials, electromagnetic emissions, fumes, and other adverse aspects of products they touch or are near	**Some users with disabilities** • Need products that don't assume body parts will never stray into openings or that only gentle body movements will occur around the products (unless required by task) • Need to have products that take into account their special visual, physical, chemical, etc., sensitivities so that they are not prevented from using products except when the nature of the product or task would prevent them (e.g., not by product design)
Be able to efficiently navigate product	**People who are blind** • Often have to wait for unnecessary audio before getting to desired information **People with low vision** • Have trouble tracking cursors on screen **People with physical disabilities** • Have trouble with navigation requiring many repeated actions to navigate **People with cognitive disabilities** • Have trouble with hierarchical structures	**Some users with disabilities** • Need to have alternate modes of operation that are efficient enough to allow them to be able to compete in education and employment settings • Need to control speech output rate • Need ability to preserve their access settings
Be able to UNDERSTAND		
Understand how to use product (including discovery and activation of any access features needed)	**ALL disabilities** • May have trouble understanding how to turn on special access features they need • May have trouble understanding how to operate it if different than standard users	**Some users with disabilities** • Need way to get overview and orient themselves to product and functions/parts without relying on visual presentation or markings on product • Need products to operate in predictable (standard or familiar) ways • Need way to understand product if they don't think hierarchically very well

TABLE 3.2 (*Continued*)

Basic	Problems Using Products	User Needs
	People who are blind (or have low vision) • Have a more difficult time getting general context for the operation of the product, since they cannot see the overall visual layout or organization • Complex layouts can behave like a maze for someone navigating with arrowkeys **People who are deaf** • English (or the spoken/written language used on the product) may be different from their natural (first) language (e.g., if it is sign language) **People with cognitive disabilities** • Have trouble remembering the organization of a product, its menus, etc. • Have a harder time with any hierarchical structures • Cannot read labels, signs, manuals, etc., due to reading limitations • May have trouble understanding directions, especially if printed • May have trouble remembering steps for use • May have trouble getting it turned on, and therefore active • May be confused by options, buttons, controls, that they do not need or use • Icons and symbols may not make sense to them, and they don't remember • Product may differ from real life experience enough to leave them at a loss • Might have trouble with products that operate in nonstandard ways	• Need to have clear and easy activation mechanisms for any access features • Need interfaces that minimize the need to remember • Need to have language used on products to be as easy to understand as possible given the device and task • Need to have printed text read aloud to them • Need to have steps for operation minimized and clearly described. • Need information and feedback to be "salient" and "specific" rather than subtle or abstract to understand it • Need keys that don't change function • Need cues to assist them in multistep operations • Need to have simple interfaces that only require them to deal with the controls they need (advanced or optional controls removed in some fashion)
Understand the output or displayed material (even after they perceive it accurately; see also **PERCEIVE** above)	**People who are blind** • Output often only makes sense visually. Reading it is confusing (e.g., "select item from list at the right" when they get to it by pressing down arrow) • Have difficulty with any simultaneous presentation of audio output and audio description of visual information (e.g., reading of screen information while playing audio) **People who are deaf** • Reading skills; English may not be primary language (ASL) • Can have difficulty with simultaneous presentation of visual information and (visual) captions of auditory information **People with cognitive disabilities** • May not be able to read information presented in text • Language may be too complex for them • Long or complex messages may tax their memory abilities • Use of idiom or jargon may make it hard to understand • Structures, tabular or hierarchical information may be difficult	**Some users with disabilities** • Need descriptions, instructions, and cues to match audio operation, not just visual operation • Need to have any printed material be worded as clearly and simply as possible • Need to have any printed material read to them • Need to have audio generated by access features not interfere with any other audio generated by device • Need to have visual information generated by access features (such as captions) not occur simultaneously with other visual information they must view (and then disappear before they can read the captions)

(*Continued*)

TABLE 3.2 (*Continued*)

Basic	Problems Using Products	User Needs
Be able to USE THEIR ASSISTIVE TECHNOLOGIES (in addition)		
Ability to use their AT to control the product (not always possible with public devices but common with personal or office workstation technologies) NOTE: To replace built-in access, AT must allow all of the above basics to be met.	**All disabilities** • Cannot use their AT to access products if: ◦ Product is in public and they will not have their technology with them ◦ They do not have permission to use their AT with the product • e.g., cannot install AT software on library systems **They are not able to connect their AT to it** • Cannot use their AT if the device interferes with it • Cannot use their AT if they are not easily able to find the connection mechanism given their disability • Need to have full functionality of the product available to them via their AT • AT is not available for new technologies when they come out **People who are blind** • Would need all visual information to be available to their AT in machine-readable form via a standard connection mechanism • Would need to be able to activate all functionality from their AT (or from tactile controls on the product) **People with low vision** • Would need all visual information to be available in machine-readable form to their AT via a standard connection mechanism so that the AT could enlarge it or read it **People who are deaf** • Would need all auditory information to be available to their AT in machine-readable form via a standard connection mechanism **People who are hard of hearing** • Would need all audio information to be available via a standard connection mechanism that is compatible with their assistive listening devices (ALDs) ◦ Need a standard audio connector to plug their ALD ◦ For something held up to the ear, it should be T-Coil compatible **People with physical disabilities** • Cannot use products that aren't fully operable with artificial hand, stick, stylus, etc. • Need connection point that allow operation of all controls **People with cognitive disabilities** • Would need all information to be available in machine-readable form to their AT via a standard connection mechanism	**Some users with disabilities** • Need to not have product interfere with their AT • Need to be able to connect their AT • Need to have full functionality of product available through their AT if they have to use their AT to access the product ◦ Need to have software use standard system-provided input and output methods ◦ Need to have all displayed text made available to their AT ◦ Need information about user interface elements including the identity, operation and state of the element to be available to assistive technology ◦ All controls need to be operable from AT • Need to be able to access all computer software functionality from the keyboard (or keyboard emulator) • Need to have all controls work with their manipulators, artificial hands, pointers, etc. • Need to have new technologies be compatible with their AT when the new technologies are released
Cross-cutting issues	**All disabilities** • Accessibility is not available in new technologies when they come out • Support services are not accessible (no training or proper communication equipment)	**Some users with disabilities** • Need to have new technologies be accessible when they are released • Need to have support and training services that are accessible

usable by individuals with particular disabilities. These bridging or adaptive technologies are especially important for individuals with severe or multiple disabilities, where building sufficient accessibility into mainstream products is not practical. It is also important in employment settings where the employee with a disability must be able to access a product and use it efficiently enough to be competitive and productive.

The third approach, changing the world, is commonly called universal design (UD) or design for all (DFA). It has also been called accessible design, barrier-free design, and inclusive design. The term universal design was originally coined by Ron Mace, an architect and director of the Center for Universal Design at North Carolina State University. He defined it as follows: "Universal design means simply designing all products, buildings and exterior spaces to be usable by all people to the greatest extent possible" (Mace, 1991).

This definition has served well as a reference point, but has raised concerns among some designers because it sets no practical limits. What is possible is not necessarily commercially viable. As universal design/design for all (UD/DFA) moved from a goal to appearing in social legislation, designers began to fear the implications of such an ideal goal (designing things that everyone can use) if the term was used in a requirements context. For example, building a $2,000 Braille display into every electronic device with a visual display is not generally practical. As a result, some designers began to fight the movement rather than embrace or explore the basic concept.

A debate also surfaced as to whether UD/DFA included compatibility with assistive technology, which many view as key to accessibility of mainstream technologies. This is particularly true with regard to personal assistive technologies, as discussed previously.

To address these issues and create a practitioner's definition of universal design (or design for all), a companion definition was proposed:

> The process of designing products so that they are usable by the widest range of people operating in the widest range of situations as is commercially practical. It includes making products directly accessible and usable (without the need for any assistive technology) and making products compatible with assistive technologies for those who require them for effective access. (Vanderheiden, 2000)

3.3.1.1 No Universal Designs, Only Universal Design

It is important to note the word *process* in the preceding definition. UD/DFA is a process, not an outcome. There are no universal designs. That is, there are no designs that can be used by everyone, no matter how many or how severe their disabilities. Universal design is not the process of creating products that *everyone* can use. It is a process of ensuring that designs can be used by as many people as is practical, and then constantly moving that line as new approaches are discovered and new technologies become available. For some products, this might result in a very narrow range of users, if it has extremely high user demands (e.g., jet fighters). For other products, it can have an extremely wide range of users. Fare machines, information kiosks, and even voting systems have been designed that can be used by individuals who have low vision, who are blind, who are hard of hearing or deaf, who have almost no reach, who cannot read, or who have various cognitive, language, and learning disabilities (Vanderheiden and Law, 2000; Vanderheiden, 2002). Moreover, they do not require multiple modes of operation, but rather options for operation in the same way that both the keyboard and mouse can be used to navigate windowing environments. Yet no matter how good the universal design, there are individuals who will not be able to operate products directly without the need for some type of assistive technology or alternate interface. Hence, the importance of compatibility with AT to complement direct access.

3.3.1.2 Pluggable User Interfaces

This whole area of personal assistive technologies and universal design has been made more interesting by the recent creation of international standards for pluggable user interfaces. A five-part ISO standard (ISO 24752, adopted in January 2008) describes a standard method for mainstream products to expose their functionality so that they can be directly controlled from personal alternate interface devices. This represents a breakthrough in the ability to design products that can be used by a much broader range of users as they encounter them.

Figure 3.3 shows the typical way an individual interacts with a product. The product has certain needs for information and/or commands from the user. A television, for example, needs to know the channel that the user wants to be watching, the volume that the user wants to set, the various color tints and settings to be selected, the source of the signal (cable, DVD, etc.), and so on. It does not care whether it gets the information by having the user push a button, turn a dial, or pick an item from a menu. However, the television comes with a built-in interface that takes its general device requirements (volume, channel, etc.) and changes them into specific actions that a user must perform. These actions may or may not be easy to perform for an individual with a disability.

Figure 3.4 shows the same device, except that an interface socket has been added that allows the individual to plug a different interface into the device to provide the television with the various types of information it needs, but this time using an interface of the user's choosing. An individual who is blind may choose an all-auditory interface; an individual with a physical disability may choose an interface that only requires sipping and puffing, etc.

The interface socket would provide all of the information necessary for the user's personal interface to be able to construct and present an interface to the user for each device encountered. Whenever the user encounters a device (that supports this standard) in the environment, the personal interface can discover it and download from it all of the information about the product's functions, and any commands or settings needed to operate the device. Optionally the device can also provide hints as to how an

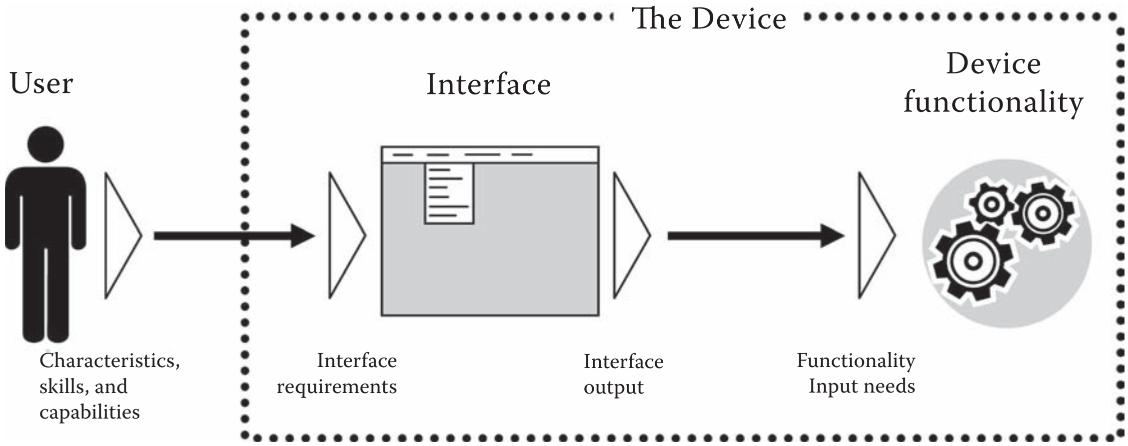

FIGURE 3.3 Typical interface where the only access to the device's functionality is through the interface built into the product with its particular assumptions and requirements regarding the user's abilities.

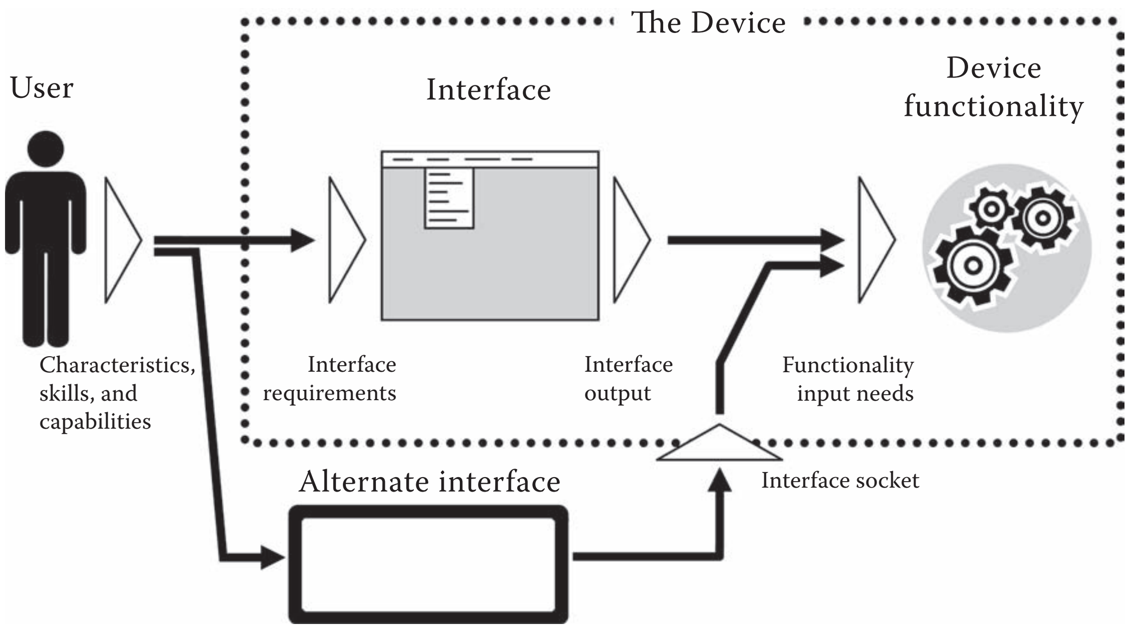

FIGURE 3.4 By adding an alternate interface connection point to the device in Figure 3.3, it is possible for users to connect an alternate interface that better matches their abilities.

interface should be structured. The user's personal interface can then construct an interface for the product that meets the user's needs. If he is blind, it might be auditory. If she has severe paralysis, it might be voice controlled. For a user who is deaf-blind, it might be a Braille-based interface. It should be noted that the pluggable user interface may connect to products without the need for any physical plug. Merely coming near a product may be all that is necessary for an alternate interface to link up to an interface socket on a product, allowing the individual to control the product using the alternate interface.

Key to this approach are the universal remote console (URC) standards (ANSI-INCIT 2005-389 to 393 and ISO-24752). Unlike products controlled by universal remote controls that need to be programmed, products implementing the URC standards would automatically provide all of the information needed by a URC to construct an interface for a user. In this way, an individual could approach an unknown device and the URC would be able to automatically construct an interface for this device that meets the user's needs and preferences.

Personal pluggable user interfaces like this that the user would carry about are examples of both type 1 (change the user) and type 3 (change the world) strategies working together. They could also be a type 2 strategy (adapt the individual products encountered by the person to make them usable to the person). That would be less common, since it is rarely possible for anyone besides the manufacturer to create an interface socket for a product. It can be seen, however, how the approaches are blending together as technologies advance.

3.3.1.3 Working Together, Blending Together

All of these techniques (change the person, adapt the environment, and change the environment) need to work together to accommodate individuals with the full range of abilities and limitations. In general, individuals with less severe disabilities can be accommodated through universal design/design for all. This includes a large percentage of individuals who are aging. For individuals with more severe or multiple disabilities, it may be more difficult to build interfaces into mainstream products that will work effectively for them. Either adaptive assistive technology, or perhaps personal assistive technology that connects through pluggable user interface sockets, may provide effective access.

More and more mainstream products are being developed that have interfaces that are more naturally flexible. Interface sockets are of interest to mainstream users as much as to people with disabilities. For example, many would like to be able to control their televisions and other devices in their house by simply pulling out their PDA or cell phone. With task-based control and continuing advances in voice recognition in constrained applications, it may soon be possible for mainstream users to control their television by simply telling it what they want to do, rather than having to navigate all of its menus, buttons, and features. ("Turn on *Masterpiece Theatre*"; "Record the 49ers game tomorrow"; "Show me the movies I have recorded"; "Play *Casablanca*"; "Play the DVD I just put in.") Moreover, since the intelligence is in the URC, the same commands would work on devices wherever they are encountered. Thus, changing TVs or changing environments, which can currently confuse many users, including many elders, may no longer be as much of a problem since these people could continue to use their familiar interface (on the URC) to control the new devices in the same manner as the old.

Thus, universal design can take many forms, including design of the main or default interface so that it is more usable, providing the ability to invoke interface modules that would increase the accessibility of the product, and options such as an interface socket to allow users to use alternate interfaces they carry with them. There is even research today looking at direct brain interfaces for both people with disabilities and those without (see Chapter 37, "Brain-Body Interfaces"). Combined with interface sockets, someday people may be interfacing with the devices around them without lifting a finger or having to carry physical interface devices (displays, keyboards, etc.) around with them.

Designing accessible products in the future therefore must look at all three approaches, since different users, environments, and tasks may require different approaches (built-in, adaptive, and alternate, pluggable accessible interfaces). Together with advances in technologies, the combination can provide new options for addressing the full range of functional limitations, including those not well addressed today.

3.3.2 Specific Strategies to Address Needs

There is an extremely wide range of specific techniques that can be used for addressing the needs outlined in Section 3.2. Table 3.3 provides a summary of the basic strategies organized in parallel with the essentials: perceivable, operable, understandable, and compatible. A more comprehensive list of strategies as well as specific techniques that can be useful when implementing them on different technologies can be found at http://www.trace.wisc.edu/resources.

As always, these strategies may be employed in the design of the mainstream product itself, or may be made possible by allowing the connection of adaptive assistive technologies or personal assistive technologies.

3.4 Priorities in Implementation

In looking at accessibility-usability features, it is important to prioritize because of the multidimensional nature of disability (vision, hearing, physical, cognitive) and the large number of individual design techniques or strategies that might be implemented for each dimension. Between 200 to 300 different strategies were identified in a number of design strategy collections for making products more accessible to people with disabilities (and this did not include the large number of different strategies documented in general usability literature). Without a means to prioritize, two behaviors have been observed in interactions with industry.

First, product designers become overwhelmed with the sheer number of different techniques and strategies. Just contemplating building over 100 different strategies into a product causes many to walk away or to approach feature selection (focusing of their efforts) in a somewhat random fashion. Usability tests by themselves are not a solution to the problem of being overwhelmed, since they quickly generate a long list of problems that, in turn, point back to the even longer list of potential solution strategies.

The second behavior observed is a poor prioritization in efforts where features that were first thought of or easiest to implement are chosen rather than strategies or features that are more important. The result is a product that has multiple low-priority features (which are helpful but not essential for access) while lacking key high-priority features that are needed to make the product (or key functions of the product) accessible for the same disability group. This is equivalent to changing the plush carpet in the entire building to a tighter nap to make it easier for wheelchairs to get around, but leaving the steps at the front door and having no elevators to get off of the ground floor.

TABLE 3.3 Basic Guidelines and Strategies for Access to Electronic Products and Documents (July 2001)

Basic Access Guideline	Why	How—General
Make **all information** (including status and labels for all keys and controls) **perceivable** • Without vision • With low vision and no hearing • With little or no tactile sensitivity • Without hearing • With impaired hearing • Without reading (due to low vision, learning disability, illiteracy, cognition, or other) • Without color perception • Without causing seizure • From different heights NOTE: Other aspects of cognition covered below	Information presented in a form that is only perceivable with a single sense (e.g., only vision or only hearing) is not accessible to people without that sense **NOTE**: This includes situations where some of the information is only presented in one form (e.g., visual) and other information is only presented in another (e.g., auditory) **In addition:** Information that cannot be presented in different modalities would not be accessible to those using mobile technologies, for example: • Visual-only information would not be usable by people using an auditory interface while driving a car • Auditory-only information would not be usable by people in noisy environment	**FOR INFORMATION:** Make all information available either in: a) **Presentation-independent form** (e.g., electronic text) that can be presented (rendered) in any sensory form (e.g., visual-print, auditory-speech, tactile-Braille) **OR** b) **Sensory parallel form** where redundant and complete forms of the information are provided for different sensory modalities (synchronized) (e.g., a captioned and described movie, including e-text of both) **FOR PRODUCTS:** Provide a mechanism for presenting all information (including labels) in visual, enlarged visual, auditory, enhanced auditory (louder and if possible better signal to noise ratio), and (where possible) tactile form **NOTE:** This includes any information (semantics or structure) that is presented via **text formatting or layout**
Provide **at least one mode (or set of different modes)** for **all product features** that **is operable**: • Without pointing • Without vision • Without requirement to respond quickly • Without fine motor movement • Without simultaneous action • Without speech • Without requiring presence or use of particular biological parts (touch, fingerprint, iris, etc.)	Interfaces that are input device- or technique-specific cannot be operated by individuals who cannot use that technique (e.g., a person who is blind cannot point to a target in an image map; some people cannot use pointing devices accurately) **In addition:** Technique-specific interfaces may not be accessible to users of mobile devices; for example, people using voice to navigate may not be able to "point" Many individuals will not be able to operate products, such as workstations, with sufficient efficiency to hold a competitive job if navigation is not efficient	**Provide at least one mode (set of modes) where…** a) All functions of the product are controllable via tactilely discernable controls and both visual and voice output is provided for any displayed information required for operation including labels **AND** b) There are no timeouts for input or displayed information, OR allow user to freeze timer or set it to long time (5 times default or range), OR offer extended time to user and allow 10 seconds to respond to offer **AND** c) All functions of the product operable with: • No simultaneous activations • No twisting motions • No fine motor control required • No biological contact required • No user speech required • No pointing motions required **AND** d) If biological techniques are used for security, have at least two alternatives with one preferably a nonbiological alternative unless biological-based security is required **AND** e) Allow users to jump over blocks of undesired information (e.g., repetitive info; or jump by sections if large document), especially if reading via sound or other serial presentation means. f) Make actions reversible or request confirmation
Facilitate understanding of operation and content • Without skill in the language used on the product (due to poor language skills or because it is a second language) • Without good concentration, processing • Without prior understanding of the content • Without good memory • Without background or experience with the topic	Many individuals will have trouble using a product (even with alternate access techniques) if the **layout/organization** of the information or product **is too difficult to understand** People with cognitive or language difficulties (or inexperienced users) may not be able to use devices or products with complex language	a) Make overall organization understandable (e.g., provide overview, table of contents, site maps, description of layout of device, etc.) b) Don't mislead/confuse (be consistent in use of icons or metaphors—don't ignore or misuse conventions) c) Consider having different navigation models for novice vs. expert users d) Use the simplest, easiest-to-understand language and structure/format as is appropriate for the material/site/situation e) Use graphics to supplement or provide alternate presentations of information f) If phrases from a different language (than the rest of the page) are used in a document, either identify the language used (to allow translation) or provide a translation to the document language

TABLE 3.3 (*Continued*)

Basic Access Guideline	Why	How—General
Provide compatibility with assistive technologies commonly used by people • With low vision • Without vision • Who are hard of hearing • Who are deaf • Without physical reach and manipulation • Who have cognitive or language disabilities	In many cases, a person coming up to a product will have assistive technologies with them; if the person cannot use the product directly, it is important that the product be designed to allow them to use their assistive technology to access the product **NOTE**: This also applies to users of mobile devices and people with glasses, gloves, or other extensions	a) Do not interfere with use of assistive technologies • Personal aids (e.g., hearing aids) • System-based technologies (e.g., OS features) b) Support standard connection points for: • Audio amplification devices • Alternate input and output devices (or software) c) Provide at least one mode where all functions of the product are controllable via human understandable input via an external port or via network connection

The purpose is to map out the dimensions of complexity involved and then to develop simplified and straightforward (as possible) techniques and procedures for addressing or accommodating them. The advice of Albert Einstein is appropriate to remember here: "Everything should be made as simple as possible. But no simpler." Hence the goal is to make this as simple as possible, but not to simplify where that leads to inaccuracy or poor decisions.

3.4.1 First Dimension for Prioritization: Accessibility/Usability

In looking at the usability of a product to different people, there is a continuous range that runs all the way from:

- People who have no problems at all in using all of the functions of a product (usually a small number of people)
- People who have little difficulty with all
- People who have difficulty with some features
- People who have trouble with most features
- People who are unable to use the product at all

Individual product features vary in importance to the overall use of the product. Some features are essential, while others are merely convenient.

The importance of product features, may be evaluated based on the following criteria:

- *Essential*—features that, if they have not been implemented, will cause a product to be unusable for certain groups or situations.
- *Important*—features that, if not implemented, will make the product very difficult to use for some groups or situations.
- *Improving usability*—features that, if they are implemented, will make the product easier to use but do not make a product usable or unusable (except for individuals who are on a margin due to other factors and this small amount of usability pushes them over the threshold).

In looking at this dimension, however, it is important to note that features that may merely improve the usability for some people may be essential to allow use by others. This is especially true for people with cognitive, language, and learning disabilities.

3.4.2 The Second Dimension Affecting Prioritization: Independence versus Reliance on Others

In addition to the accessibility/usability dimension, there is a second dimension that deals with independence versus reliance on others. Everybody depends upon others for some aspects of life. Few people know how to repair a car and television set. Some do not know how to change printer cartridges or clear paper jams or reformat hard drives. In daily life, there are some things people need to be able to do independently and some things that they can depend on others for. In setting usability priorities, this can be taken into account to facilitate decisions regarding expenditure of effort.

For example, it is more important that an individual be able to load their work into the input hopper on a copier and operate the controls to get the required number and type of copies than it is for them to be able to change the toner or clear a paper jam. In fact, in many offices only people trained in clearing paper jams are allowed to do so. Loading new reams of blank paper into the copier generally falls somewhere in between. Similarly, it is more important for an individual to be able to launch and operate programs than it is for him to be able to configure the modem settings. This importance stems not from the technical difficulty of the two tasks but from the fact that one is an activity that is required continuously as a part of daily operations, whereas the other is something that needs to be done only once or that can be planned for and scheduled when there is someone to assist.

Figure 3.5 shows a rough hierarchy based on the need for independence versus reliance on others. The exact order of the items will vary for different types of products and different environments (e.g., the availability of support personnel), but the general order can be seen. This can then be used to set priorities in a resource-constrained or time-constrained product design program.

Functions/features needed for basic use of the product

1. Unpredictable, but typically user-serviceable (by "average" user) maintenance or recovery operations
2. Unpredictable service, maintenance or recovery, typically corrected by support personnel
3. Predictable or schedulable maintenance that can be delegated to others
4. Unpacking and initial setup
5. Repair
Note: The location and availability of support personnel (e.g., in a home office) affect this dimension.

FIGURE 3.5 Priority based on the need for a person to be able to independently accomplish tasks.

3.4.3 A Third Dimension Affecting Prioritization: Efficiency and Urgency

A third dimension to prioritization deals with the need for *efficiency*. If a task is performed only once a day and there is no particular time constraint on its accomplishment (e.g., the person is not trying to disarm an alarm before it goes off), then the relative efficiency of operation is not as critical as in the case of a function that must be used continuously throughout the day. For example, if it takes an individual five times longer to operate the "on" switch on her computer than the average worker, it will not have a major impact on her productivity or effectiveness. In fact, activating the on switch is such a small part of booting a computer that the total time it takes for her to turn the computer on is likely to be only negligibly longer than the time for anyone else to boot her computer. If it takes an individual five times as long to type characters on his computer, however, and he spends the bulk of his day entering information into his computer, the difference in efficiency could be catastrophic. If it takes him five days to get an average day's worth of work done, it would be hard for him to compete in either an educational or work environment. Thus, for the on/off switch, level 1 accessibility may be all that is required. However, for data entry levels 1, 2, and 3 may all be critical on an individual's workstation.

A close parallel to efficiency is *urgency*. If there are situations where a user must do something within a particular time constraint to avoid an adverse situation, then, even if it is rarely done, it may be important to strive for level 2 or level 3 usability to allow the individual to be able to carry out the activity within the time allowed.

The importance that is attached to this dimension is the function of at least three factors.

1. The reversibility of the action
2. The severity of the consequence for failure
3. The ability of the person to adjust the time span to meet increased reaction times

Situations where the result is not reversible or is dire in nature and is also of a type that does not allow for user adjustment or extension (as in some security-related situations) would create the highest priority for providing not only an accessible, but a highly usable interface for the group or situation.

3.4.4 A Pseudo-Priority Dimension: Ease of Implementation

In setting priorities for implementation of usability features in products, a factor that is often used to select features is the ease with which they can be implemented in the product. In this context, *ease* may have many different characteristics, including low or no increase in product cost, low or no increase in development time line, ease in getting clearance from supervisors, minimized impact on other features, minimized impact on testing, minimal impact on documentation, and so on. Often referred to as "low hanging fruit," such features are often very tempting when compared to features that are much more difficult to implement. Although it is always good to look at this dimension, it can result in a belief that five low hanging fruit features are better than one that is more difficult to achieve. This can lead to the implementation of multiple usability features instead of essential accessibility features. Often this occurs with features intended to benefit the same disability group, so that a product may have usability features for a disability group that cannot, in fact, use the product.

Within the essential accessibility features, however, one will also often find either a low hanging fruit or features that would have such mass-market appeal that their "costs" are offset by their market benefit.

3.4.5 Cognitive Constraints: A Unique Dimension

In looking at the dimensions, it is important to note that the cognitive dimension is unique with respect to the other dimensions (see also Chapter 7, "Cognitive Disabilities"). It is possible to make most products usable to individuals with no vision or no hearing and even with severely limited physical ability. However, there are very few products, if any, that are usable by individuals with low cognitive abilities. This is due to the fact that it is possible to translate most types of information between sensory modalities and most types of activities between physical interface techniques, but there is no mechanism for transferring cognitive processing into another domain. While it is true that there are some activities and some types of information for which good strategies do not exist for providing access to by individuals with severe or total visual limitation, severe or total hearing limitations, or severe or total physical limitations, the number of devices and activities that are excluded are much smaller than for severe cognitive limitations. For this reason, strategies for enabling access for people with cognitive disabilities basically look like techniques to facilitate, with each technique that facilitates pushing a few more people over the threshold into the category of individuals who can use a product.

It is also important to note that there are a number of dimensions that are often lumped in with cognitive disabilities, where products can be made accessible. For example, there are strategies that can allow individuals who think clearly but are completely unable to read for some reason to be able to effectively use a very wide variety of products. In this case, the difficulty is not in general cognitive processing or memory, but rather in a specific skill, which is decoding printed information on a page.

The point is just now being reached where there is the computing power and language processing knowledge needed to begin to effectively tackle some of these areas. While some of this specialized cognitive processing may not be appropriate for mainstream devices, approaches like pluggable user interfaces may allow users to carry cognitive orthoses with them.

In the meantime, there is much that can be done to mainstream products to make them easier for people with cognitive, language, and learning disabilities to use, and to make them easier to use by everyone else as well.

3.4.6 Setting Priorities

The suggestion overall is to focus on what is important to people with the full range of disabilities rather than cost or difficulty. Do what can be done and then look for opportunities where difficult or expensive solutions become possible due to other events or discoveries.

Ordering options by difficulty often results in unimportant or even useless (by themselves) features being added (e.g., only half of the provisions needed for access for each disability are included, resulting in a product no one can use). It is also important to remember that what is a usability enhancement for one, may be required for another to be able to use a product, process, or service.

3.5 Impact of Technology Trends on Accessibility in the Future

Going forward it is clear that electronics are being incorporated into practically everything, making it more and more important to be able to access electronic interfaces if one is to be able to live, learn, work, or even move about in one's community.

Recently, a report looking at emerging trends was prepared for the U.S. National Council on Disability. A version was also prepared and submitted to the European eInclusion initiative. Below is an overview and summary of the issues highlighted in the report. The complete U.S. report can be found at http://www.ncd.gov/publications.

3.5.1 Rapid and Accelerating Pace of Technology Advancement

Information and communication technologies are changing at an ever-increasing rate. What used to be multiyear product life cycles have now decreased in many instances to life cycles of less than 1 year. Previous accessibility strategies involving the development of adaptive technologies, or accessible versions of new technologies, are failing due to this rapid turnover (National Task Force on Technology and Disability, 2004). This is exacerbated by the fact that it is not just products that turn over, but the underlying technologies as well. For example, analog cell phones were made accessible just as they were being replaced with digital cell phones. Now some digital phone formats are being phased out in favor of newer technologies (Subcommittee on Telecommunications and the Internet, 2003). This same technology churn, however, is also opening up new opportunities for better assistive technologies and more accessible mainstream technologies.

Many of the changes in technology are evolutionary, but some revolutionary changes are also ahead. Several of these changes may even cause a rethinking of concepts and the definitions of such terms as *disability, assistive technology,* and *universal design*, or how these terms are used.

3.5.2 Technological Advances That Are Changing the Rules

To understand how technological advances can lead to the need to rethink technology and disability funding and policy, it is important to understand just how fundamentally things are changing. Four key technology trends are highlighted here. Opportunities and barriers created by these advances follow.

Some technologies mentioned in the following discussion challenge imagination. Yet, except where indicated otherwise, everything discussed is already commercially available or has been demonstrated by researchers.

3.5.2.1 Trend 1: Ever-Increasing Computational Power plus Decreasing Size and Cost

Computational power is growing at an exponential rate. At the same time, the size of electronic components is shrinking, decreasing product size, power consumption, and cost. Raymond Kurzweil helped to make this growth real to those not used to dealing in exponentials with the following: in 2000, $1,000 could buy a computer that had the computational power of an insect. By 2010, $1,000 will purchase the computational power of a mouse. By 2020, $1,000 will purchase the computational power of the human brain. By 2040, $1,000 will purchase the computational power of all the brains in the human race (Kurzweil, 2001). Kurzweil has also “projected 2029 as the year for having both the hardware and software to have computers that operate at human levels” (Kurzweil, 2006).

Personal digital assistants have shrunk from the size of paperback books to credit card size, and now to a function that runs in the back of a cell phone.[2] Cell phones have shrunk from something just under the size and weight of a brick to cigarette-lighter size, most of which is occupied by the battery. Multiple web servers can fit on a fingernail (sans power supply), and RJ45 (Internet) cable jacks are available that have web servers built directly inside the jack.[3]

Researchers have created gears the diameter of a human hair (Sandia National Laboratories, 1997), motors that are a hundred times smaller than a human hair (Carey and Britt, 2005), and are now exploring tiny cellular-scale mechanisms that would use flagella to move about in the bloodstream (Avron et al., 2004; Svidinenko, 2004). The entire field of nanotechnology is taking off, supported by major federal funding.

Although very expensive technologies are needed to create these devices, the cost per device is dropping precipitously. Sensors that were once hand-assembled are now created en masse, and sometimes even created in a “printing-like” process (Kahn, 2005). The cost of computing drops by a factor of 10 approximately every 4 to 5 years. It is not uncommon to find children’s video games that have more computing power than supercomputers of just 10 to 15 years prior. Scientists are now turning to light instead of wires in microchips to keep up with the speed (Paniccia et al., 2004).

This trend toward more computational power, coupled with decreased size and cost, can make possible improved and entirely new types of assistive technology. This trend is also providing capabilities in mainstream technologies that can enable them to more easily and effectively meet the needs of people with disabilities.

3.5.2.2 Trend 2: Technology Advances Enabling New Types of Interfaces

The human interface is one of the most important determinants of whether a technology product can be used by people with disabilities. Advances in interface technology are creating new opportunities for better assistive technologies, more accessible mainstream technologies, and entirely new concepts for controlling both.

3.5.2.2.1 Projected Interfaces

Using a projector and camera, companies have created products that can project anything from a keyboard to a full display and control panel onto a tabletop, a wall, or any other flat surface. People can then touch the “buttons” in this image. The camera tracks movements, and the buttons or keys operate as if they really existed (Borkowski et al., 2004). One device is pocket-sized, projects a keyboard onto the tabletop, and allows users to enter data into their PDA by typing on the image of the keyboard on the tabletop (Alpern, 2003).[4] Other projected interfaces use sound waves (Good, 2004).

3.5.2.2.2 Virtual Interfaces

Going one step further, researchers have demonstrated the ability to project an image that floats in space in front of a person. With this glasses- or goggle-based system, only the user can see the image floating there (Billinghurst and Kato, 1999, Figure 6). Some systems project the image directly onto the retina (Kollin, 1993). A pocket controller or gesture recognition can be used to operate the controls that float along the display. Motion sensors can cause the displays to move with the user’s head, or stay stationary.

3.5.2.2.3 Augmented Reality

Researchers are also using this ability to project images to overlay them with what a person is seeing in reality, to create an “augmented reality.” One project envisions travelers who can move about in a city in a foreign country by wearing a pair of glasses that automatically recognizes all of the signs and translates them. Whenever foreign travelers look at a sign, they would see a translation of that sign (in their native language) projected over the top of the sign (Spohrer, 1999; Vallino, 2006).

3.5.2.2.4 Virtual Reality

Research on ultra-high-resolution displays has a target of being able to display images that appear with the same fidelity as reality. Researchers look forward to the day when the resolution and costs drop to the point that entire walls can be “painted” with display technology, to allow them to serve as “windows,” work spaces, artwork, or entertainment, as the user desires. Introducing three-dimensional viewing and displays that work in 360 degrees, researchers have a goal of eventually creating walls or environments that are indistinguishable from reality.

Realistic imaging technologies are already being used in classrooms, primarily (but not exclusively) to teach science. The ability to virtually “shrink oneself” can be used to explore things that would otherwise not be visible or manipulable by humans. The ability to zoom out can provide more global perspectives. The ability to carry out virtual chemistry experiments can allow

[2] Xun-chi-138-worlds-smallest-cellphone(2006):http://www.mobilewhack.com/reviews/xun-chi-138-worlds-smallest-cellphone.html.

[3] XPort—embedded ethernet device server (2006): http://www.lantronix.com/device-networking/embedded-device-servers/xport.html.

[4] The I-tech virtual laser keyboard: http://www.virtual-laser-keyboard.com.

students to conduct the experiments that are most interesting or educational, rather than those that are the safest (from poisoning or explosion) or cheapest (not involving expensive chemicals or elements). Time can also be expanded or compressed as needed to facilitate perception, manipulations, or learning (Taubes, 1994). Virtual and augmented reality are addressed in detail in Chapter 12 of this handbook.

3.5.2.2.5 Hands-Free Operation and Voice Control

There are already hands-free telephones. New phase-array microphones have been developed that can pick up a single person's voice and cancel out surrounding sounds, allowing communication and voice control in noisy environments.[5] There are cameras that can self-adjust to track a user's face, allowing face-to-face communication for those who cannot reach out to adjust cameras.[6] Rudimentary speech recognition is available on a $3 chip,[7] and speech recognition within a limited topic domain is commonly used. IBM has a "superhuman speech recognition project," the goal of which is to create technology that can recognize speech better than humans can (Howard-Spink, 2002).

3.5.2.2.6 Speech Output

The cost to build speech output into products has plummeted to the point where speech can be provided on almost anything. All of the common operating systems today have free speech synthesizers built into them or available for them. Hallmark has a series of greeting cards with speech output that, at $3.99, are just 50 cents more expensive than paper, nonelectronic cards. Recently, a standard cell phone that had been on the market for a year received a software-only upgrade and became a talking cell phone, with not only digitized speech talking menus, but also text-to-speech capability for short message service (SMS) messages. The phone, with all speech functionality, is sold for $29, with a service contract.[8]

3.5.2.2.7 Natural Language Processing

The ability of technology to understand people as they normally talk continues to evolve. Although full, open topic natural language processing is a way off, natural language processing for constrained topics is being used on the telephone and soon may allow people to talk successfully to products (see also Chapter 31 of this handbook).

3.5.2.2.8 Artificial Intelligence Agents

Web sites are available that allow users to text chat with a virtual person, who will help them find information on the site.[9] Research on task modeling, artificial intelligence, and natural language are targeted toward creating agents users can interact with, helping them find information, operate controls, etc. (see also Chapter 14 of this handbook). Often the subject of science fiction, simple forms of intelligent agents are reaching the point in technology development where they can become a reality in the home.

3.5.2.2.9 Microprocessor-Controlled User Interfaces

When products are controlled by microprocessor running programs as they are today, they can be programmed to operate in different ways at different times. The use of more powerful processors, with more memory, is resulting in the emergence of new devices that can be controlled in many different ways and can be changed to meet user preferences or needs.

3.5.2.2.10 Multimodal Communication

There is a rapid diversification taking place in the ways people can communicate. Video conferencing allows simultaneous text, visual, and voice communications. Chat and other text technologies are adding voice and video capabilities. In addition, the technology to cross-translate between modalities is maturing (see also Chapter 40 of this handbook). The ability to have individuals talking on one end and reading on the other is already available using human agents in the network.[10] In the future, this ability to translate between sensory modalities may become common for all users.

3.5.2.2.11 Direct Control from the Brain

External electrodes in the form of a band or cap are available today as commercial products for elementary control directly from the brain (Wickelgren, 2003). Research involving electrode arrays that are both external and embedded in the brain have demonstrated the ability to interface directly with the brain to allow rudimentary control of computers, communicators, manipulators, and environmental controls (see also Chapter 37, of the handbook).

3.5.2.3 Trend 3: Ability to Be Connected Anywhere, Anytime—with Services on Demand

New advances will soon enable people to be connected to communication and information networks no matter where they are. People can leave caretakers and still be a button-press away. Everything in the environment will be connected, most often wirelessly, allowing people to think about communication, control, and "presence" in entirely new ways. Individuals who have trouble with wires and connectors will not need them. Network-based services can provide assistance, on demand, to people

[5] Andrea electronics headsets (2005): http://www.andreaelectronics.com.

[6] Logitech—leading web camera, wireless keyboard and mouse maker (2006): http://www.logitech.com.

[7] Sensory, Inc. embedded speech technologies, including recognition, synthesis, verification, and music (unspecified date): http://www.sensoryinc.com.

[8] LG VX4500 from Verizon Wireless offers latest in voice command and text-to-speech features (2004): http://news.vzw.com/news/2004/11/pr2004-11-29.html.

[9] KurzweilAI.net (click on Ramona!) (2006): http://www.kurzweilai.net/index.html?flash=1.

[10] Ultratec—CapTel (2006): http://www.ultratec.com/captel.

wherever they are. These advances will create opportunities for whole new categories of assistive technology.

3.5.2.3.1 Wireless Electronics—Connected World

There are already wireless headsets, computer networks, music players, and sensors. New technologies, such as ZigBee, will allow devices that are very small, wirelessly connected, and draw very little power.[11] Light switches, for example, could run off a small 10-year battery and have no wires coming to or from them. People would simply place a light switch on the wall where it was convenient, at a convenient height. Flipping the switch would control the lights as it does now. If someone else needed the light switch in a different place, they would simply move it by pulling it off the wall and replacing it where desired, or placing an additional switch wherever they liked, including on their wheelchair or lap tray.

High-speed wireless networks are also evolving, and costs are dropping. No wires will be needed between televisions, video recorders, or anything else (except sometimes the wall, for power). A person in a power wheelchair could have an on-chair controller connected to everything in the house, and yet still be completely mobile.

3.5.2.3.2 Virtual Computers

Computers may disappear, and computing power will be available in the network. Wherever a person is, he or she will be able to use whatever display is convenient (e.g., on the wall or in a pocket) to access any information, carry out computing activities, view movies, listen to music, and so on. Instead of making each product accessible, things would exist as services and capabilities, which could be accessed through a person's preferred interface (see also Chapter 60 of this handbook).

3.5.2.3.3 Control of Everything from Controller of Choice

New URC standards have been developed that would allow products to be controlled from other devices.[12] Products implementing these standards could be controlled from interfaces other than the ones on the product. A thermostat with a touch screen interface, or a stove with flat buttons, for example, could be controlled from a cell phone via speech, or from a small portable Braille device.

3.5.2.3.4 Location Awareness

Global positioning system (GPS) devices enable people to determine their position when outside and are already small enough to fit into cell phones and large wristwatches. Other technologies, such as radio frequency identification (RFID) and devices that send signals embedded in the light emitted from overhead light fixtures, are being explored to provide precise location information where GPS does not work (see also Chapter 59 of this handbook).

[11] ZigBee Alliance (2006): http://www.zigbee.org.

[12] Myurc.org (unspecified date): http://www.myurc.org.

3.5.2.3.5 Object Identification

Tiny chips can be embedded into almost anything to give it a digital signature. RFID chips are now small enough that they are being embedded inside money in Japan.

3.5.2.3.6 Assistance on Demand—Anywhere, Anytime

With the ability to be connected everywhere comes the ability to seek assistance at any time. A person who does not understand how to operate something can instantly involve a friend, colleague, or professional assistant who can see what she is looking at and help work through the problem. Someone who needs assistance if he gets into trouble (and who would currently not be allowed out on his own) could travel independently, yet have someone available at the touch of a button. These assistants could help think something through, see how to get past an obstacle, listen for something, translate something, or provide any other type of assistance and then disappear immediately.

3.5.2.3.7 Wearable Technology

Today there are jackets with built-in music players, with speakers and microphones in the collar (Benfield, 2005).[13] There are keyboards that fold up, and circuitry that is woven into shirts and other clothing. There are now glasses and shoes with a built-in computer that can detect objects within close proximity through echo location and then send a vibrating warning signal to the wearer. The shoes also will use a GPS system to tell the wearer where they are and in which direction she is going.

3.5.2.3.8 Implantable Technology

There are cochlear implants to provide hearing. Heart and brain pacemakers are common. Increasing miniaturization will allow all types of circuits to be embedded in humans. In addition, research is continuing not only on biocompatible materials, but also on biological "electronics."

3.5.2.4 Trend 4: Creation of Virtual Places, Service Providers, and Products

Possibly one of the most revolutionary advances in information and communication technologies has been the development of the World Wide Web. Although the Internet had been around for a relatively long time by the 1990s, web technologies allowed it to be approachable and usable by people in a way not previously possible. It has not only given people new ways of doing things, but has fostered the development of entirely new social, commercial, and educational concepts. It also has allowed for virtual "places" that exist only in cyberspace. This includes virtual environments, virtual stores, virtual community centers, and complete virtual communities. E-travel is allowing people to go places and see things that once were

[13] The raw feed: New jacket sports built-in GPS, MP3, phone (2006): http://72.14.203.104/search?q=cache:TB1l942nXQEJ:www.therawfeed.com/2006/03/new-jacket-sports-built-in-gps-mp3.html.

possible only through books or documentaries. Electronic re-creation can allow people to explore real places, as if they were there, and at their own speed. They could wander in a famous museum, for example. The web also provides an array of products and services that is unmatched in physical stores in most localities.

3.5.3 New Opportunities

Advances in information and communication technology will provide a number of new opportunities for improvement in the daily lives of individuals with disabilities, including work, education, travel, entertainment, health care, and independent living. There is great potential for more accessible mainstream technology with less effort from industry. There is also great potential for better, cheaper, and more effective versions of existing AT, and entirely new types or classes of AT.

3.5.3.1 Opportunity 1: More Accessible Mainstream Products

Some of the changes that will result from mainstream product design are evolutionary continuations of current trends. Other changes will be revolutionary, changing the nature of mainstream technologies and their usability by people with different types of disabilities. Some examples:

3.5.3.1.1 Potential for More Built-In Accessibility

Almost everything today, including cell phones, alarm clocks, microwaves, ovens, washers, and thermostats, is being controlled by one or more microcomputers. The increasing flexibility and adaptability that technology advances bring to mainstream products will make it more practical and cost effective to build accessibility directly into these products, often in ways that increase their mass market appeal.

3.5.3.1.2 Products That Are Simpler to Use

Although products have been getting progressively more complex for some time now, advances in key technologies such as task modeling, language processing, and constrained voice recognition will soon make it possible to reverse that trend and make products simpler.

3.5.3.1.3 Interoperability: To Reduce the Need for Built-In Direct Access

Improvements in connectivity and interoperability will enable individuals with severe or multiple disabilities, who could not operate the standard interface even on universally designed products, to use products via a personal interface device that matches their abilities.

3.5.3.1.4 Flexible "Any-Modality" Communication

The trend toward ubiquitous multimodal communication (voice, video, chat) all using the same device, can be a boon for individuals with sensory disabilities, especially individuals who are deaf, hard-of-hearing, deaf-blind, or have speech impairments.

3.5.3.2 Opportunity 2: Better (Cheaper, More Effective) AT and New Types of AT

Technology advances will result in the improvement of current assistive technologies and the introduction of entirely new types of AT. Some of these technologies are realizable today. Some will emerge in the future.

3.5.3.2.1 Advances in Cost, Size, and Power

Advances allow for less costly and more effective assistive technologies (AT). More importantly, however, emerging technologies will enable the development of new types of AT, including technologies that can better address the needs of individuals with language, learning, and some types of cognitive disabilities.

3.5.3.2.2 A Potential for New Intelligent AT

Previously not possible, opening the door to self-adaptive and environmentally and user-responsive technologies.

3.5.3.2.3 Translating and Transforming AT

Takes information that is not perceivable or understandable to many with sensory or cognitive impairments, and render it into a form that they can use.

3.5.3.2.4 Human Augmentation

Technologies will enhance some individuals' basic abilities, enabling them to better deal with the world as they encounter it.

3.5.3.2.5 Losable and Wearable Technologies

Advances in technology will also reduce the size and cost of products, making them easier to carry, wear, and, in some instances, replace. This can allow the provision of assistive devices (including alternate interface devices) to those who would not have been able to get them in the past out of a concern that they might lose them.

3.5.4 Barriers, Concerns, and Issues

Many of the same technological advances that show great promise of improved accessibility also have the potential to create new barriers for people with disabilities. The following are some emerging technology trends that are causing accessibility problems.

3.5.4.1 Increasing Complexity of Devices and User Interfaces

Devices will continue to become more complex to operate before they get simpler. This is already a problem for mainstream users, but even more of a problem for individuals with cognitive disabilities and people who have cognitive decline due to aging.

3.5.4.2 The Trend toward Digital Controls

Increased use of digital controls (e.g., push buttons used in combination with displays, touch screens, etc.) is creating problems for individuals with blindness, cognitive, and other disabilities.

3.5.4.3 Devices Too Small and Closed to Physically Adapt

The shrinking size of products is creating problems for people with physical and visual disabilities.

3.5.4.4 Closed/Locked Systems

The trend toward closed systems, for digital rights management or security reasons, is preventing individuals from adapting devices to make them accessible, or from attaching assistive technology so they can access the devices.

3.5.4.5 The Trend toward Automated and Self-Service Devices in Public Places

Increasing use of automated self-service devices, especially in unattended locations, is posing problems for some and absolute barriers for others.

3.5.4.6 The Trend away from Face-to-Face Interaction

The decrease in face-to-face interaction and increase in e-business, e-government, e-learning, e-shopping, and so on is resulting in a growing portion of our everyday world and its products and services becoming inaccessible to those who are unable to access these Internet-based places and services.

3.5.4.7 Technology Advancing into Forms Not Compatible with Assistive Technology

In addition, the incorporation of new technologies into products is causing products to advance beyond current accessibility techniques and strategies. The rapid churn of mainstream technologies, that is, the rapid replacement of one product by another, is so fast that assistive technology developers cannot keep pace. Even versions of mainstream technologies that happen to be accessible to a particular group can quickly churn back out of the marketplace.

3.5.4.8 Decreasing Ability of Adaptive AT to Keep Up

To complicate the situation further, the convergence of functions is accompanied by a divergence of implementation. That is, products increasingly perform multiple functions that were previously performed by separate devices, but these "converged" products are using different (and often incompatible) standards or methods to perform the functions. This can have a negative effect on interoperability between AT and mainstream technology where standards and requirements are often weak or nonexistent. Thus, without action, the gap will increase between the mainstream technology products being introduced and the assistive technologies necessary to make them accessible, as will the number of technologies for which no accessibility adaptations are available.

3.5.4.9 Accessibility Rules Being Too Specific to Cover New Technologies as They Emerge

Another concern is that technology advances are causing functions and product types to develop in ways that move them out of the scope of existing policy. For example, in the United States when telephony moved from the public switched telephone network (PSTN) to the Internet (VoIP), the accessibility regulations did not keep pace. The U.S. Federal Communications Commission (FCC) determined that the Internet was information technology, and for some years the telephony access regulations did not apply to VoIP, even though people were using the same phones and the same household wiring to make phone calls to the same people, many of whom were on the PSTN. Although the FCC has recently applied some telecommunications policies to VoIP, VoIP is still not classified as telecommunication.

Internet Protocol Television (IPTV) manufacturers are now talking about including conversation capabilities in their base technologies, again raising the question as to whether telecommunication accessibility will apply to these "phone calls." When accessibility is tied to technologies that become obsolete, often to be replaced by multiple new technologies, the accessibility requirements are often late or deemed not applicable. The shift of education, retail sales, and so on, to the Internet after the Americans with Disabilities Act (ADA) was drafted resulted in the Internet versions of these activities not being specifically mentioned in the law. This is leading some judges to determine that web sites are not places of business as mentioned in the ADA and therefore not covered. This is another example of policy not keeping pace with technology (see also Chapter 53, of this handbook).

3.5.4.10 Open versus Content-Constrained Internet Connections

There is currently debate about whether those who provide Internet connections to a house, or other location, should be able to control the types of information sent to the house, by whom, and at what level of quality connection. If those who provide the connection are allowed to decide what equipment will connect to their systems, or to degrade performance if equipment or software is not from preferred vendors, people who can more easily use other vendors' products, or who must use special equipment, may find their equipment does not work or find its performance is degraded, causing accessibility problems. This problem is exacerbated by the fact that individuals may have to use their technologies from multiple locations and not just from their homes. Unless the Internet operates more like the public road system, where individuals are allowed to take any vehicle that meets safety standards onto the road, rather than having to drive only certain companies' vehicles on certain roads or to certain locations, individuals who must rely on accessible versions of technologies will run into problems.

3.5.4.11 Digital Rights Management

A very interesting subarea in this discussion is digital rights management (DRM). While the need to protect the rights of those who publish authors is critical, the ability to allow access for people with disabilities must be addressed as well. If content is to be locked so that it cannot be copied electronically, then some mechanism for rendering it in different forms should be built into the secure digital media players. For example, if a digital book can be presented visually but the text cannot be read by the operating system (so that assistive technology such as screen readers could read it aloud), then a mechanism within the book player for enlarging it and reading it aloud should be provided. Technologically, this is not a problem, and voice synthesizers with speed control can be, and have been, built into the eBook products directly. A marketing policy, however, whereby publishing companies sell the print (visual access) rights for a book to one distributor but the audio (spoken) rights for the book to another, has created an obstacle. Book player companies have been required to support a bit in their players that, when set by a book publisher, will prevent the voice output option in the book player from functioning. Thus, even though the book reader is capable of reading the book to the blind person, it will not perform that function if the book publisher sets the bit that tells the book reader to not read this book aloud. The same book is also protected, so that it cannot be read by any other technology.

3.6 Conclusion

The needs of people with disabilities are knowable, as are the strategies for providing access to yesterday's technologies. Yet implementation of this knowledge is fairly minimal. This is due in large part to the fact that making products more accessible is not profitable or is not perceived as profitable. Since profit is the underlying motivating force in all product development and deployment, better ways to address this problem need to be found. First, those areas where it is profitable need to be documented. The increasing age of the population coupled with the increasing complexity of products may provide some added impetus to this area. For example, a recent industry survey showed that the rate at which consumers are returning new products has been increasing, with the "no defect found" return rate running 50% to as high as 90%+ (depending on product category) (Sullivan and Sorenson, 2004). These data are for mainstream customers, but the impact of increasing complexity of products on individuals with cognitive disabilities is even greater. And the percentage of elders is increasing, providing a larger market with increasing problems. For those companies for whom a natural market pressure is not sufficient, legislation or regulation may be needed to inject the social concerns into the profit equation. But regulation should not be a replacement for careful research and documentation of the benefits of accessible design for mainstream users.

Even with motivation and action by who design new products to address needs that can be met through universal design/design for all, however, the pace of technology advance will still be a major concern for those who need special access systems. Better methods must be found for creating generic access rather than catch-up patches and adaptations, and these same technological advances are providing some of the keys to doing so. The next decade promises to bring about interesting and revolutionary steps forward in accessibility and information and communication technologies.

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II

Diversity in the User Population

4

Dimensions of User Diversity

Mahima Ashok and
Julie A. Jacko

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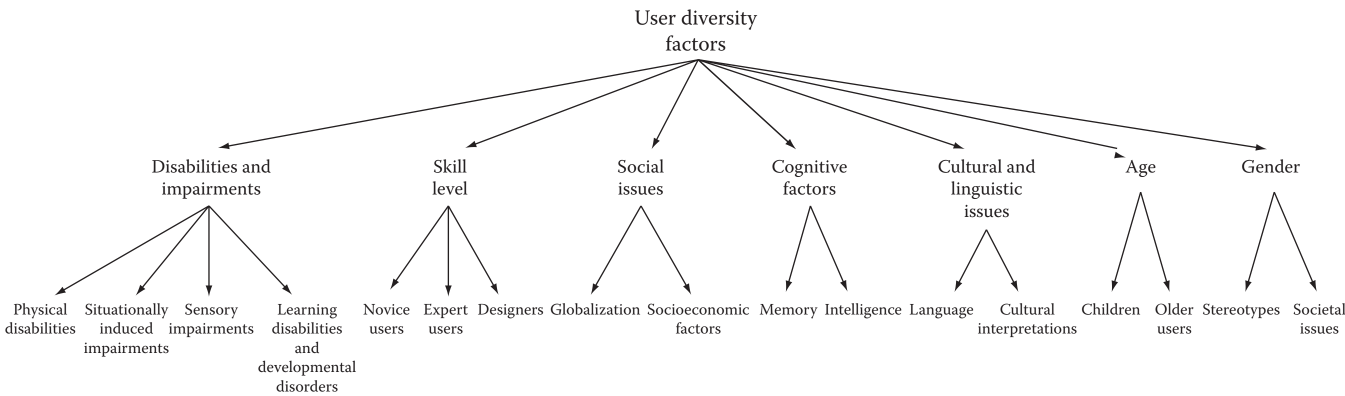
4.1 Introduction

User diversity is vital for effective conceptualization and practice of universal access. Failure to consider user diversity during design, development, and testing of applications leads to "technological exclusion" (Gabriel and Benoit, 2003) of some sections in society, preventing them from participating in the dynamic of scientific progress. Technological exclusion refers to a phenomenon whereby a technological environment ignores the presence and needs of the demographic heterogeneity of its users and excludes certain segments of society from benefiting from technological applications. In our globalized world interconnected by technology, failure to consider user diversity in the design and application of technology can lead to a lack of cohesion in society itself. The phenomenon of technological privilege arises when certain users are provided with opportunities to benefit from applications while others are denied the same because of a failure to include their needs during the design process. Hence, technological privilege can add another divisive layer to existing barriers such as class, race, and gender. With an understanding of user differences, designers will be able to incorporate techniques to enable all users to obtain equal advantage when using the system. With this objective in mind, the Web Accessibility Initiative (http://www.w3.org/WAI) was created by the World Wide Web Consortium (W3C). This initiative provides guidelines to ensure and improve accessibility by taking into consideration various diversity factors. Through the development of guidelines for design, educational and outreach programs, and research operations, the Web Accessibility Initiative aims to make the World Wide Web more usable for all users. Initiatives such as this are required in all areas of technological development, and the widely used World Wide Web provides a good example of such an inclusive application cognizant of diversity.

When studying universal access, it is important to consider not only the nuances of diversity, but also the nuances of every component of the application. For instance, considering again the example of a web site, it is composed of various segments such as text, images, video, audio, scripts, and so on (Freitas and Ferreira, 2003). The designer must take into account these different components, as well as the needs of the users, while composing every facet of a web site design that is universally accessible.

The objective behind the study and understanding of user diversity is to create applications and systems that allow users to access these systems and to prevent their differences from becoming impairments during the use of technology, thereby affecting the quality of interaction. This concept of equal opportunity is vital to the design of usable computing tools, which will benefit all users. This chapter will consider different diversity factors, and how these can affect technological interactions, design, and development. The user diversity schematic is meant



to serve as a guiding tool for this chapter. This schematic represents the various diversity issues and serves as a framework for the content. It shows that diversity is not monolithic, and that there are many different kinds of diversity. Designers, developers, and all members of the human-computer interaction (HCI) community need to understand the heterogeneous nature of diversity, because such an understanding leads to the design of more efficient and usable systems. Factors in user diversity include disabilities and impairments, skill level, cognitive factors, social issues, cultural and linguistic issues, age, and gender. Diversity, a defining feature of the contemporary world, must not become a barrier to access and effective use of technological applications.

4.2 Disabilities and Impairments

Technological tools have become all-pervasive and have found their way into almost every facet of life. For most individuals, these applications increase efficiency, facilitate easier communication, and reduce the time taken for otherwise time-consuming tasks. However, for those users who have certain disabilities, technology may actually reduce efficiency and alter the quality of what can be a positive experience. In this case, technology becomes a barrier by exclusionary design. If the impairments of the users had been considered during the design process, the application could have facilitated or improved communication, and even led to a greater sense of independence among users (Young et al., 2000). Furthermore, designs that lack disabilities-awareness cause, as noted already, a societal divide between the technologically enabled and the technologically excluded. Many established methods of development and evaluation in HCI need to be modified to derive optimal results for technology designs when diverse user populations are considered. For instance, evaluation methods such as iterative user feedback must be suitably modified to ensure valid representation of user groups when dealing with users with learning disabilities (Neale et al., 2003). Designers who consider disabilities during the development process will contribute to a well-integrated society. To be able to design with these concepts in mind, designers must be familiar with the kinds of disabilities and impairments that may affect the use of technology. It is also important to note the ways in which these disabilities and impairments affect interactions with technology.

Disabilities and impairments take on many forms, such as physical disabilities, situationally induced impairments, and sensory disabilities. Physical disabilities are those that directly affect a user's physical interaction with technology, such as arthritis, multiple sclerosis, and cerebral palsy. Situationally induced impairments are those that arise due to the environment where the user is located, or specific activities that the user is involved in, or is surrounded by, which have special characteristics that affect human-computer interaction. Sensory impairments refer to impairments of the senses such as visual and auditory impairments.

There is an intricate nexus of connections between these terms often used as synonyms: disabilities, handicaps, and impairments (Sears and Young, 2002). The World Health Organization made these distinctions clear in their study published in 1980 (World Health Organization, 2000). These definitions were further clarified in the publication of the World Health Organization in 2000 and are briefly summarized in the following (World Health Organization, 2000; Sears and Young, 2002):

- Health conditions are those that arise because of a disease or injury, such as with multiple sclerosis, joint-related pain due to arthritis, and so on.
- Impairments are those conditions caused when a particular part of the human body begins to function in an abnormal manner or loses its ability to function altogether. For example, people without an arm or with a paralyzed arm suffer from an impairment.
- Disabilities are conditions that prevent a person from completing a task as would have normally been expected. For instance, learning disabilities can hamper communication and can cause difficulties for an individual when interacting with a computing tool.
- Handicaps are defined as those conditions that cause "participation restrictions" in various situations, which could cause problems in transferring information and in communication.

It is clear from these definitions that health conditions can cause impairments, disabilities can result in a handicap, and so on. Therefore, instead of considering the impairments, handicaps, or disabilities in isolation, designers need to understand the user, the environment, and the task holistically in the design process.

4.2.1 Physical Disabilities

Physical impairments interfere with the bodily functions that are necessary for interacting with technology. They may be a genetic condition, or may be caused by trauma, injury, accidents, or illness. This section will consider some specific instances of physical disabilities to illustrate how design transformation to make technology user-centric can assist in improving the quality of experience of diverse users.

Quadriplegia is a disease in which affected individuals are paralyzed in their limbs as a result of spinal damage. Since typical technological interaction requires the use of hands and eyes, quadriplegic users are likely to encounter various problems while engaged in activities such as web browsing (Larson and Gips, 2003). Using a mouse can be extremely challenging and material on the web is often too small to decipher. Due to various vision-related problems, complex visual designs can often make simple tasks very difficult. To overcome many of these difficulties that quadriplegics face, a new browser called WebForward was developed (Larson and Gips, 2003). This browser is equipped with larger buttons that are easier to see and understand, a simple uncomplicated design that reduces the cognitive burden placed on users, and a text reader that reads the text of the page to the user. While designing tools such as these, it should be noted that while these tools help users with impairments and disabilities gain more from the technology, they need not detract from the experience of a user without these disabilities.

Another example of a physical disability that commonly affects many users is arthritis. The Centers for Disease Control has stated that arthritis is the leading cause of disability in the United States. More than 20 million people in the United States have arthritis and by the year 2030, 70 million citizens will be at risk for developing it. Arthritis results in pain, stiffness, and difficulty in moving and performing regular tasks using joints. There are two major kinds of arthritis: osteoarthritis and rheumatoid arthritis. The former, caused by deterioration of cartilage, is the most common form of arthritis in the United States. Rheumatoid arthritis is an inflammatory disease in which severe pains in the joint areas are caused by the weakening of the immune system. All variations of arthritis cause difficulty in movement and debilitating pain in the joints. The inability to freely and painlessly move joints in hands and fingers causes immense difficulty in using a keyboard, mouse, speaker controls, and other commonly used devices. Voice input of spoken commands, in the place of motor-dependent tools such as keyboards, can greatly ease the difficulty faced by users with joint problems. Another possibility for users who have limited or no motor ability (such as those with paralyzed limbs or amputees) is to simulate the functionality of a keyboard and mouse with head movement applications. These applications recognize head movements as commands and are able to translate them appropriately. Head movement applications can be combined with speech recognition software. Results of a study combining head movements with speech recognition to simulate keyboard and mouse controls were positive (Malkewitz, 1998). A study conducted substituting a head-operated joystick for a regular mouse proved appealing to users and also enhanced usability (Evans et al., 2000).

Cerebral palsy is a neurological affliction that affects individuals from birth. It can result in impairment in muscle coordination, speech, and learning. Up to 4 individuals out of 1000 births are affected by this disease. Individuals with cerebral palsy often find coordinated use of keyboard and other similar input devices extremely challenging, due to lack of muscle coordination. Applications to recognize gestures made by individuals, including facial expressions and movements, can ease the difficulty faced by technology users with cerebral palsy and other diseases that affect muscle coordination, such as Parkinson's disease, multiple sclerosis and muscular dystrophy. Researchers who studied a gesture recognition interface found it to be worth exploring as a method to improve the technology experience of users with cerebral palsy (Roy et al., 1994).

Some of the applications discussed previously, such as speech and gesture recognition software, can provide increased usability and access to users without long-term disabilities or impairments. For example, many users undergo periods in which certain muscles are strained or sprained, or when an arm is broken during an accident or injury. While these users may not otherwise require speech or gesture applications, these tools would be of great benefit during particular times of use.

A more detailed discussion of motor impairments and their impact on access to interactive technologies is provided in Chapter 5 of this handbook.

4.2.2 Situationally Induced Impairments

Temporary states of impairment may be created by the particular contexts in which users interact with technology. For instance, a working environment in which noise level and visual distractions of the environment are extremely high can interfere with the efficient use and navigation through computer-based applications. These impairments, caused by contextual factors influencing the quality of interaction in a negative way, are known as situationally induced impairments (Sears et al., 2003). It is important to understand that context refers to a larger group of factors and not just the physical environment surrounding the user (Sears et al., 2003). Environmental factors can increase feelings of stress, which could impair technology use. Consider the example of an individual working at home when the heating unit is malfunctioning in winter. Due to uncomfortable cold temperatures in the home, the user may suffer from temporary disabling conditions such as mild numbness in the fingers. Cold temperatures also cause a general feeling of physical discomfort leading to a less than optimal computing experience. The same would be true of extreme heat, which could occur in summer when the user works outside. It is also possible for the nature or the number of tasks that the user is working on to become a source of impairment. When a user is performing several tasks at the same time, not necessarily all on the computer, it is possible for attention to be diverted and quality to be affected. A commonly seen example is when a student trying to complete a computerized homework assignment is also on the phone with music playing at the same time. It is likely that, under such circumstances, the capacity to work efficiently on the computer may be so diminished as to justify the term *impairment*.

In a world where computing has become a pervasive phenomenon, there is a steep increase in the variability of environments that users find themselves in. This has also led to increased attention on situationally induced impairments (Sears et al., 2003). Using a personal computer to complete an assignment in a quiet office might produce startlingly different results if the same individual was to use the same computer in an active, noisy kitchen. Another cause of situationally induced impairments is the technology itself. When screens are too small, the user may become vision-impaired in this particular situation (Grammenos et al., 2005). If the volume controls on a music-playing technology do not allow the volume to be loud enough, the user would be unable to use the application as intended. While it would be impossible to come up with all the various situationally induced impairments that a user might be prone to, it is important for designers to be aware of common contextual factors that might affect technology use. An inventory tracking system for use in a noisy warehouse environment should be designed with minimal auditory function, or with attachable headphones that would permit users to block out external sounds. A handheld computing tool should permit for a large-enough screen to allow people to view information comfortably, but not so large that it leads to increased weight, thus making it less portable. Designing with possible contexts in mind helps in the creation of technology that may be widely used and, more importantly, widely well used. Hence, designers must imagine typical and not so typical scenarios of usage for their interactive systems.

4.2.3 Sensory Impairments

Sensory impairments that significantly affect human-computer interaction are those that affect visual and auditory capabilities. Difficulty in seeing and hearing can cause cognitive confusion in the users, as well as prevent them from completing tasks effectively. Statistical estimates show that 1 out of 10 people have a "significant hearing impairment" (Newell and Gregor, 1997). One in 100 people have visual impairments and 1 in 475 people is legally blind (Newell and Gregor, 1997). The 1990 United States Census found that out of the 95.2 million people who are older than 40 years of age, more than 900,000 people are legally blind and 2.3 million suffer from visual impairments. Thus, the extent of sensory impairments and their effect on technology use might be greater than one would expect. It is therefore very important to understand the extent and nature of visual and auditory impairments.

Many forms of visual impairment affect human beings. Age-related macular degeneration (AMD) is one of the leading causes of vision loss in the United States, and understanding the disease and its effects on lifestyle (which includes the use of technology) can help raise the quality of life for millions of individuals. AMD is a disease in which central vision is distorted and lost. The central portion of the retina, known as the macula, undergoes degeneration and destruction, resulting in this severe condition. The "dry" form of the disease is the most common, but the "wet" form is the cause of the most severe kind of macular degeneration. As is clear from the name of the disease, aging is an important risk factor for this disease; most people affected by macular degeneration are over the age of 60 (Prevent Blindness America, 2002). Extensive testing using advanced eye movement tracking applications has shown that those with AMD and those with full sight show different performance levels when using visual search strategies on a computerized tool (Jacko et al., 2002a). The nature of particular features on the display, such as color and icon size, played a strong role in determining performance. Thus, when the nature of impairments and their effect on technology use is studied, it is possible to design systems that enable more and more people to effectively use technology. For example, the use of multimodal feedback to provide cues to users can improve the performance of users with visual impairments by providing a "different sensory feedback" (Jacko et al., 2002b). Multimodal feedback technology would include auditory, visual, and haptic feedback to reinforce the message to be conveyed. For users without visual impairments, a message on the screen would likely be sufficient. However, for users with AMD, when central vision is lost or seriously distorted, audio or haptic feedback can provide useful information. Another example of improving access to technology for those with severe visual impairments is to implement interventions and design strategies into handheld computing that are shown to significantly improve user performance, particularly concerning users with AMD (Leonard et al., 2006). Many of these strategies to make the concept of universal access a reality are low-cost and easy to implement.

Besides AMD, several other visual impairments affect the interaction between a human and technology. Cataract is a disease in which the lens of the eye becomes cloudy and opaque and consequently, vision deteriorates. More than 20.5 million people in the United States suffer from cataract and this disease affects even young people, sometimes from birth. In many situations, loss of vision caused by cataract can be countered by lens replacement surgery (Prevent Blindness America, 2002). For those awaiting surgery, or for those who cannot, for some reason, undergo surgery, technology augmented with systems such as multimodal feedback can be of immense assistance. Glaucoma is another serious eye-related disorder that progresses in stages and finally causes blindness. It is actually a set of diseases that results from increased pressure within the eye, leading to damage in the optic nerve. It is estimated that between 90,000 and 120,000 people have lost their vision due to glaucoma. In diabetic retinopathy, the blood vessels in the retina are affected, which leads to blindness in some diabetic patients. About 5.3 million people in the United States, over the age of 18, have diabetic retinopathy (Prevent Blindness America, 2002). Because the length of time for which a person has diabetes is strongly related to the risk for diabetic retinopathy, most people who develop juvenile diabetes will suffer from some form of diabetic retinopathy during their lives.

Technologists interested in universal access have studied the use of special tools to assist and improve the experience that people with impaired vision have with technology. The use of touch-based interfaces that rely on haptic tools rather than on vision-based feedback has been studied (Ramstein, 1996; Sjöström, 2001). By using Braille displays that can be felt by the hand, blind or visually impaired users are able to read and understand digital information. Adhering to certain guidelines of good design, such as providing reference points on the screen that are easy to identify and not changing reference points very often, can enhance the quality of haptic-based design for the visually impaired (Sjöström, 2001). Some users do not suffer from vision loss but rather from a loss in the ability to distinguish colors. Incorporating additional color palettes in technologies can improve universal access by making the system easier to use by those with color vision deficiencies (Knepshield, 2001).

Loss of hearing is another serious type of sensory impairment that can significantly affect interaction with technology. Hearing loss may be either temporary or permanent, depending on the nature of damage to the ear. In conductive deafness, problems with the ear drum or the bones in the middle ear can cause failure of hearing. It is very possible that hearing will return once proper care has been given to the ear. In nerve deafness, the cochlear nerve is damaged by serious trauma or by other forces. The damage could even be in the brain, resulting in a condition of irreparable hearing loss. There are many reasons for loss of hearing, including genetic predisposition, exposure to noisy environments, accidents, illnesses, and aging. The inclusion of caption-text, text-based descriptions of audio, and the use of simultaneous sign language video transmission can immensely benefit hearing-impaired users of technology (Drigas et al., 2004). Caption-text is now available for most television programs. The topic of situational-induced impairments comes up here, as television viewers (without any permanent hearing impairments) may find it useful to turn on caption-text when children play noisily in the house, or when the telephone rings often, because their hearing is temporarily impaired due to the situation they are in. Therefore, considering sensory impairments, both temporary and permanent, prior to design can provide beneficial results to a large population.

Perceptual design is a design paradigm that humanizes the interaction between the perceptually impaired human operator and technology. Perceptual design defines the human-computer communication in terms of the perceptual capabilities of the individual using the application. Combining knowledge about the abilities of human operators with the performance needs of the system enables designers to create applications that consider human needs. Perceptual interfaces prescribe humanlike perceptual capabilities to the computer. Both multimedia and multimodal interfaces offer increased accessibility to technologies for individuals with perceptual impairments (Jackoet et al., 2002c). The flow of information when dealing with perceptual, multimodal, and multimedia interfaces is clearly shown in Figure 4.1.

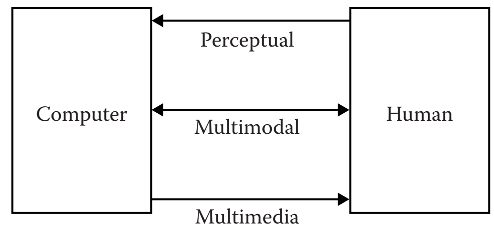


FIGURE 4.1 Flow of information in perceptual, multimodal, and multimedia interfaces. (From Jacko, J.A., Vitense, H.S., and Scott, I.U., Perceptual impairments and computing technologies, in *The Universal Access Handbook*, Lawrence Erlbaum Associates, Mahwah, NJ, 2003.)

Sensory impairments are discussed in more detail in Chapter 6, "Sensory Impairments," of this handbook.

4.2.4 Learning Disabilities and Developmental Disorders

In addition to the disabilities and impairments discussed thus far, there are certain conditions that inhibit individuals from processing complex information that is a part of technology use. These conditions include learning disabilities, such as dyslexia, and other disorders, such as autism. Autism is a disorder of the central nervous system, which results in problems with communication, imagination, and social activities. Special care is taken in educating autistic children, and great care is needed in the development of technology for those with autism. Already, technology is being used as an integral part of the educational process for autistic children (Mirenda et al., 2000). Understanding the unique needs of children with autism helps in developing technology that enhances the quality of education (Barry and Pitt, 2006). In fact, it has been observed that using software enhanced with unique sounds and movements increased attention span when used as an educational tool with autistic children (Moore and Calvert, 2000). Incorporating special features into widely used tools, such as the personal computer, can help those with autism. Similarly, taking special care to design tools for those with learning disabilities, such as dyslexia, can enhance education and the quality of daily life. The fundamental concept here from a design perspective is that a clear knowledge of the mental models used by users with these disabilities is required. Such knowledge allows incorporating features into technology that are suitable for these models. Involving end-users throughout the development process is essential to receive useful feedback during design. When involving users with autism, for example, there may be significant challenges in communication during the process, which need to be planned for. Evaluation methods must be specially modified depending on the nature of the group of evaluators and users. For instance, using numerous pictures and designs in questionnaires for those with learning disabilities could improve feedback when compared to using regular heavy-text questionnaires (Neale et al., 2001). The interdisciplinary nature of design is obvious here: universal access technology is not a venture of just software engineers, but a joint effort of members of the educational community, medical community, and technologists. See Chapter 7 of this handbook for more details on this issue.

4.3 Skill Level

4.3.1 Novice Users, Expert Users, and Designers

With the pervasiveness of technology today, many routine activities are now performed electronically. Shopping, banking, information searching, reading, writing, entertainment, are all activities that are now performed easily with personal computers, handheld devices, and even mobile phones. The wide use of technology by a large group of the population has resulted in increased comfort with basic technological tools. However, the level of comfort and the ease of use of technology vary significantly depending on the skill levels of users, and is a valid source of diversity among users. Some groups of users are unfamiliar with technology, particularly older users and those with minimal or no education, and are now required to use computing tools to keep up with the information society we live in. The result is a mix of users with great diversity in technology skill level.

The challenge of designing systems for users who fall within a wide and uneven spectrum of skills can be daunting. This is especially so because designers are typically experts in their respective domains and find it difficult to understand and incorporate the needs of novices. The tendency to homogenize can detract designers from designing with the objective of universal access. As a corrective, it is essential to include the user participation in the design process. A design cycle that does not include feedback from a diverse group of users will result in a design that is not equally accessible by all. Judging the skill levels of users can be more difficult than assessing impairments or difficulties because users who are experts on a particular tool may find a new replacement tool hard to use and understand—this results in a situation where a person who you may think is an expert actually behaves like a novice. Feedback from users with differential skill levels can provide fresh perspectives and new insights.

Including useful help options and explanations that can be expanded and viewed in more detail, consistent naming conventions, and uncluttered user interfaces are just a few ways in which technology can be made accessible by users with less knowledge of the domain and system while at the same time not reducing efficiency for expert users. In fact, these suggestions are guidelines of good design, which will benefit all users, irrespective of skill level.

Users with different levels of skill respond differently to various features in the system, such as feedback methods. A study of older users with varying levels of skill shows that experienced users responded well to all combinations of multimodal feedback while those with less experience showed preference for certain specific combinations (Jacko et al., 2004). In addition, skill level also plays a role in the attitude users have toward using and accepting new technologies. Those who are unfamiliar with using the Internet might resist a web-based service to replace their daily banking chores. To assist in the transition, the service must be built in a way that is easy to understand and maps well to typical mental models of users who perform simple banking tasks.

Skill level differences are often related to differences in age, education, and other factors to make for a complex variable. The example of multimodal feedback described previously is one instance of how age and computer experience play a role in the user's interaction with technology. Another example of the digital divide is the case of people with varying income levels. Inequality in economic status causes inequality in computer access, which in turn causes inequality in computer skill level. This chain of events could lead to a situation where two children of the same age have different levels of comfort using the same word processing tool, because of differences in their home environments. As with all diversity markers, understanding the needs and nature of users is the single most important factor in developing technologies that are easy to use for those with varying levels of skill. Questionnaires handed out during user evaluation must consider technology experience and background as an important parameter. Simple questions regarding how often the user accesses a tool, and so on, can help designers gain valuable insight into the level of experience a user has. Without this understanding, the resulting technology will increase the digital divide and will play a role in furthering the technological exclusion prevalent in today's society.

4.4 Cognitive Factors

Cognition is an intangible quality, which manifests itself tangibly in interactions with other people and with technology. Cognition is the ability of the human mind to process information, think, remember, reason, and make decisions. While all human beings possess some level of cognitive ability, the extent of this ability varies from person to person. This spectrum of variability makes it difficult to define the exact point of cognitive impairment, although it is possible to generally state that there is an accepted level of "normal" cognitive ability (Newell et al., 2002). Levels of cognition that fall below this "normal" level are considered impaired states. Some of the conditions discussed previously, such as dyslexia and autism, create a situation where the cognitive ability of the individual may be different from one who does not have the condition. Some research has shown the potential of technology use with autistic individuals, based on preliminary evidence, that these individuals have more productive interactions with computers than with people (Newell et al., 2002). This section will focus on understanding cognition, how it is measured, how cognitive factors play a role as markers of diversity, and how technology use and design is affected by this.

4.4.1 Memory

The cognitive ability of a human being includes many facets, and one of these is the ability to recall and remember past actions and experiences. This ability is a very important part of cognition. Being able to recall actions from the past enables us to perform them at quicker speeds in the present. Memory is used on a daily basis when performing routine computing tasks. For example, when typing on a keyboard, the location of the various keys in QWERTY format is recalled to type faster. Very often, memory recall in everyday actions may happen unconsciously. Although this happens at a rapid speed, recall helps in finding the keys faster without having to look for their location every time.

It is postulated that there are three distinct kinds of memory: sensory memory, short-term memory (or working memory), and long-term memory (Dix et al., 1998). The first of these, sensory memory, can be compared to a buffer that holds the various bits of information received by the senses. Information is filtered and passed into the short-term memory. As the name indicates, short-term memory serves the purpose of storing information for short intervals of time while the information is processed. Information that is stored for longer periods is moved into long-term memory, which is essentially a collection of memories. Aging is a natural process in which memory is eroded. It also is possible that, as people grow older, the capacity to move information from short-term to long-term memory is also decreased. This could explain why some (not all) older people may require repeated relearning of concepts in technology use before they can independently use a system. Serious conditions such as Alzheimer's disease, as well as various forms of dementia and amnesia, can result in varying degrees of memory loss.

4.4.2 Intelligence

Once information is stored in memory, human beings use their reasoning skills to process and understand information. Great differences are seen in this particular segment of cognitive ability. A 20-year-old man will have better reasoning skills than a 10-year-old boy by virtue of his age, experience, and education. The capacity to process information is vital in technology use where users are constantly bombarded with all forms of data: textual, audio, and video. Sometimes these three forms of data are provided simultaneously, placing a large cognitive workload on the user. The way in which an individual is trained to process information affects her experience with information. For instance, a person whose education has been entirely computer-based will find it easier to use computer tools in the workplace than someone who has used a computer only occasionally. Understanding the educational background of users is vital during the design of systems, as it can provide insight on cognitive capabilities.

Though "cognition" and "intelligence" are sometimes used interchangeably or in association with each other, the ambiguous nature of the concept of intelligence has made this term a controversial measurement of cognitive ability (Newell et al., 2002). Howard Gardner, a renowned theorist of human intelligence, points out that intelligence is not a single identity but is multipronged. Mathematical and linguistic intelligence are valued and prioritized highly in our educational system, but there are other kinds of intelligence that need to be tapped (Gardner, 1993b). Also, the evolution and progress of human societies will depend on our ability to deploy the multiple levels of intelligence in individuals (Gardner, 1993a). This theory of cognition can be usefully applied to technology design. Some people are especially skilled at processing visual information, while others require detailed text-based explanations. It is not possible to say whether one shows more intelligence than the other. Intelligence, hence, is not a univocal term, but a multifaceted concept, the ramifications of which have immense practical relevance for the technological world. Theories of intelligence need to be translated into the theory and practice of technology design.

The need to standardize this concept of intelligence leads to the idea of the intelligence quotient. The intelligence quotient, popularly known as IQ, is a commonly used scheme for measurement purposes. IQ is a score given to an individual based on performance on a test. Although there has been much debate on the value of IQ scores as a determinant of intellectual prowess, it is one of the most widely recognized and used assessment tools.

Technology plays a major role in improving cognitive abilities and honing various skills. The use of technology with autistic children was discussed earlier. Using computer-based learning tools for children with dyslexia and other learning disabilities can be of immense assistance to both the student and the teacher. These creatively designed tools are structured with complex teaching algorithms and other aids, which help instructors teach dyslexic students. A study of dyslexic undergraduate and graduate students using simple writing software showed that these students uniquely use technology to maximize their cognitive abilities (Price, 2006). The fact that the "simple" application was the one that provided the most benefit shows that the design of technology plays a major role in how useful it will be to end-users.

Ideally, technology is a functional aid to help enhance quality of work and life. However, cognitive impairments can sometimes make technology an impediment rather than a tool of efficiency and quality. For instance, cognitive impairment can decelerate a person's response time and in this situation, technology needs to be adapted to the user's cognitive capacity to help rather than hinder. W. A. Gordon rightly notes that for a cognitively impaired user, the processing time of all "information-laden stimuli" will be considerably increased (Gordon, 2001). Added to this will be the incremental layering of unprocessed information forming a backlog of uncovered territory. Cognitive impairment can result in decreased attention span, and hence any stimulus that is stretched out can be lost on the impaired user.

4.5. Social Issues

4.5.1 Globalization and Socioeconomic Factors

Advances in technology have brought distant and diverse societies closer together. People living thousands of miles apart communicate with each other instantaneously, news is transmitted simultaneously with the occurrence of actual events, and state-of-the-art techniques have helped diasporic lives to connect with each other as an electronic family or community. Globalization has created an environment of rich information and easy communication. However, social issues such as economic and social status pose a serious challenge to universal access. In many parts of the world, only the wealthier segments of society have the opportunity to use technology and benefit from it. Poverty, social status, and meager or nonexistent educational opportunities create barriers to technology access. An overview of globalization and its impact on access to technology enlightens us with an understanding of social challenges for universal access.

The economic structure of the world today is an open channel where barriers in trade are diminishing and organizations from various parts of the planet come together for economic and financial benefit. The "global village" we live in is dependent on information technology not only for simple communications, but also for the dissemination of complex information. Critics of globalization believe that small-scale rural businesses are left behind in the race to establish high-tech corporations around the world. Countries such as the United States tend to develop technologies that are well suited for its own consumers without realizing the varying needs of users in different parts of the world (Marcus, 2002). While proponents of globalization present a strong argument citing the benefits of free flow of trade, finance, and people, others perceive globalization as widening the existing socioeconomic gap in many societies. Designing applications that are equally accessible and equally easy to use for every single socioeconomic group in the world is virtually impossible, but there are lessons to be learned from considering the needs of various social groups. For instance, financial software applications to be deployed in the United States and in Japan need to include translational software to translate commands into Japanese and back to English. Therefore, identifying user demographics within the target populations is important, because it allows designers to refine access parameters.

The use of the Internet has changed fundamental concepts of communication and information access. While the benefits of technology are undoubtedly tremendous, technology in the globalized world has, in some situations, contributed to the rift between the rich and the poor, and the educated and the uneducated. Econometric studies have revealed that a certain level of education, technical education to be precise, is required to receive optimal productivity from the use of technology (Castells, 1999). The two-pronged nature of technology is seen here. On one hand, technology helps greatly in improving the economic status of societies, allowing nations to work with one another, learn from each other, and participate in economic, educational, and political transactions with each other. On the other hand, the fast-paced advances made by a technology-powered globalized world leave behind the poorest of the poor and those who are unable to keep up with these changes. One is comforted by the fact that as technologies gain popularity, they are easier to implement due to sharp decreases in costs. This implies that technological advances will one day become universally affordable.

The realization that technological benefits are available more readily to the educated conveys a simple message regarding the responsibility of designers, developers, engineers, and all those involved in the creation of technology. This team of people creates and distributes technology, and it is critically important for them to be educated in matters of universal access and issues in the diversity of users, including the need to consider designing for the undereducated. Designing for technological literacy must become a top priority.

While globalization deals with the delivery of goods, services, and financial transactions on a global scale, the term *localization* refers to customizing products for specific markets to enable effective use (Marcus, 2002). The process of localizing technology is an important balance to globalization. Included in localization is language translation, changes to graphics, icons, content, and so on (Marcus, 2002). To achieve effective localization of a product, it is necessary to identify groups with similar needs within larger groups of the population. Even though localization is discussed here with respect to social diversity, this concept is applicable to other types of user differences. For example, providing certain audio cues and feedback for users with visual impairments can be compared to a localization process for a particular subgroup of users. An example of localization of technology for a specific social group would be customizing a product for a group of villagers in southern India. India is unique because there are numerous languages and dialects that vary from state to state. Thus, to properly customize a tool for a group in southern India, the developers must be aware of exactly which state the users reside in and which language they speak. In addition, literacy issues would be a major concern when dealing with members of certain rural communities. User interviews and surveys to determine the extent of literacy must be completed, so that the user interface can use the appropriate amount of icons and text-based cues. Furthermore, because of the fact that the users reside in a village, it is likely that their exposure to technology is extremely low. Complex features would be lost on a group that would struggle with basic keyboard functionality. Perhaps in such a situation, speech-recognition software would benefit the users more than regular keyboard entry. The mental models used by people in different parts of the world vary significantly—what appears obvious and simple to one user in California may seem complex and even impossible to decipher to someone residing in a small village in southern India. Understanding users is, as always, vital to the design and development of technological applications for a global audience. This example presents a complex challenge for designing technology for users who have minimal exposure to technology, low literacy levels, and no knowledge of the English language. Nevertheless, even when dealing with English-language users, there are various items that may require localization to be optimally effective and understood. These include changes to address formats, nomenclature, environmental standards, keyboard formats, punctuation symbols, telephone number formats, name formats, icons, symbols, colors, calendar formats, licensing standards, and so on (Marcus, 2002). Fundamental rules such as which side of the road to drive on are different in different countries. A car-manufacturing web site offering online test drives would benefit from localization. An online test drive where the cars ride on the right side of the road would seem quite unusual to a user in the United Kingdom. Certain words, phrases, and even colors have different meanings in different societies. Spellings of words are different as well: examples include behaviour vs. behavior, color vs. colour, etc. Being sensitive to cultural differences is crucial during the design process. The following section will look into cultural and linguistic issues in greater detail.

Class differences in societies, common in earlier centuries, still exist in different parts of the world. Differences in socioeconomic status result in classes of unspoken privileges and denial. Regions in which the more advanced segments of the population are the focus of technological implementations create a situation in which people from all parts migrate to these regions to share in the benefit, while many groups of society from the region itself are neglected (Castells, 1999). This can lead to many consequences, both socioeconomic and political. The same principle applies on the individual level, where differences in education and socioeconomic status can create or contribute to rifts. The cost of technological systems is sometimes prohibitive. For example, the purchase of a basic personal computer may be financially challenging for one family, while posing no financial stress for another. Dealing with, and developing solutions for, socioeconomic conditions is beyond the scope of this chapter. The intention here is to shed light on the fact that, while technologies may be created equal, the ability to purchase, access, and use them is not always equal between all persons and populations. A Harvard study involving telecommunications in Algeria and educational television in El Salvador concluded that new technologies create situations of power concentration as well as a group of "technocratic elite" (Garson, 1995). The concept of an elite group of society who has access to the latest in technological inventions takes us back to the concept of technological exclusion. It is clear that for technology to be accessible to larger groups of the population it is critical not only to be aware of potential individual differences, such as impairments, disabilities, cognitive abilities, and the like, but also of societal differences between segments of people.

4.6 Cultural and Linguistic Issues

Closely related to social issues is the reality of cultural differences. Culture, defined in general, refers to specific habits of everyday living that make us who we are. It is a central factor of human self-definitions, and is crucial to our identities, with which we negotiate our everyday life in the societies we live in. During ancient times, when modes of communication and travel were not technologically advanced, culture was only a matter of geography. However, with the globalized technology shrinking the world and redefining our understanding of the near and the far, home and the world, cultures are not as remote from one another as they used to be. Still, when people visit countries far from their own, their initial surprise at the change in the cultural environment can evoke what is referred to in common parlance as "culture shock." Many residents of the Western world are surprised when they visit countries in Asia, such as India, where many attributes of society, from eating habits to transportation modes, are radically different. Seeing cow-drawn carriages moving routinely through busy streets is an unfamiliar sight for many. In the same way, visitors to the Western world are sometimes amazed by differences in clothing habits—for example, the wearing of shorts by women, even in the most scorching of summers, is taboo in some countries in Asia. Differences in religious practices and beliefs constitute another aspect of culture. Recognizing the importance of cultural diversity and of the need to acknowledge and appreciate it, UNESCO held a convention on the protection and promotion of diverse cultural expressions in 2005. In today's world, we have entered a significant shifting point in the perception, understanding, and experience of cultural epistemology. The inclusion of this knowledge in technology will lead to more inclusiveness and tolerance. Cultural issues relevant to universal access are addressed in Chapter 9, "International and Intercultural User Interfaces," of this handbook.

4.6.1 Language

Language is an integral part of culture and much, as we know, can be lost in translation due to language barriers. For example, many technological applications use English, and this in itself could be a restricting factor for people who do not speak or write the language. Even within the same linguistic group, the usage of language can vary, and certain words or phrases can have many different connotations. In the United States, the word *subway* refers to a popular sandwich brand as well as the underground train system. In England, *tube* is used to refer to these trains. *Elevator* and *lift* both mean the same, but used in the wrong environment can lead to misunderstanding. Abbreviations, spelling, punctuations are all linguistic variables. The connection between language and the layout of text on technical applications is a factor to be considered, since certain languages like English and French lend themselves to shorter representations, while other languages may require longer formats (Marcus, 2001).

4.6.2 Cultural Interpretations

In technology, the design of an application that is not aware of cultural nuances can inhibit access. Differences in culture include interpretations of symbols, colors, movements, phrases, and so on. Aaron Marcus points out the following interesting differences: green is a sacred color in Islam, and saffron yellow is sacred in Buddhism. Reading direction is left to right in North America and Europe, while it is right to left in the Middle Eastern region (Marcus, 2001). In certain Hindu wedding ceremonies, red is considered the festive and appropriate choice for bridal attire, while in Christian ceremonies, the bride wears white. Even within the Hindu culture, red is not uniformly a sacred color. The design of a bridal web site for a primarily Hindu audience with extensive usage of the color white would be inappropriate for this cultural context. Culture-specific notions of the sacred need to be respected during design of technology. Symbols and icons can also mean different things to people from different cultures. In fact, sometimes symbols can be interpreted to have diametrically opposite meanings. Ideas on clothing, food, and aesthetic appeal also vary from culture to culture. These numerous differences make it imperative that designers avoid treating all cultures as the same, but to be sensitive to these differences during the creation of technology. Rather than neutralize cultural and linguistic differences, universal access acknowledges, recognizes, appreciates, and integrates these differences. In theory, this may appear to be a formidable challenge, but investing energy into assessing diversity of users is a valuable effort.

To gain an understanding of the heterogeneity of the human community that is expected to comprise the user group for the technology under consideration, the following guidelines for designers are emphasized:

- Understand the target user population in terms of geographical location, cultural identities, and language usage. Recognize that not all user groups from the same general geographic area speak the same language or hold the same cultural beliefs.
- Ensure that evaluation sessions with users include user groups that are truly representative of the target user population.
- Invest time, effort, and monetary allowances on sessions with users supported by translators and any other assistance that may be required for evaluators to obtain as much useful information as possible from these sessions. This will save considerable time, effort, and money during iterative design, testing, quality assurance, and implementation.

4.7 Age

Age plays a significant role in how a person perceives and processes information. Knowing the age of the target population of a technology product can provide vital clues about how to present information, feedback, video, audio, and so on. The design process becomes more challenging when a wide range of ages is included in the list of potential user groups. While there are some variations in adult users between the ages of 18 and 65, the focus of this chapter is on the two user groups whose age is one of the significant defining factors about them: children (defined as users below the age of 18, but particular focus on younger children less than the age of 12) and the elderly (defined as users over the age of 65). Design for children is a unique realm of study as is design for older users. Older users present a set of challenges that include the fact that they are typically accustomed to performing tasks in a certain way that usually does not include technology. Bringing technology into the picture and requiring that older users adapt to these new systems can be a challenging endeavor.

4.7.1 Children

Children's physical and cognitive abilities develop over a period of years from infancy to adulthood. Children, particularly those who are very young, do not have a wide repertoire of experiences that guide their responses to cues. In addition to this lack of experience, children perceive the world differently from adults (Piaget, 1970). Today, many software applications are developed with the sole purpose of providing entertainment and knowledge to children. Various applications are used to teach children everything from the alphabet to algebra, from shape recognition to grammar. Unlike many applications, which are designed by adults for adults, the design of tools for children poses a special challenge, in that designers must learn how to perceive systems through the eyes of a child. Testing applications with children requires special planning and care. Younger children may experience feelings of anxiety when being asked to perform tasks on an application, or may fear the instructor. If the child is separated from the parent, this may increase feelings of anxiety. Guidelines have been developed to conduct usability testing with children. These guidelines provide a useful framework to obtain maximum feedback from children, while at the same time ensuring their comfort, safety, and sense of well-being. Some of these guidelines are as follows (Hanna et al., 1997):

- The area where the testing takes place should appear colorful and friendly without being overly distracting.
- Preschool-age children have difficulty when asked to use an input device they are unfamiliar with. This situation can be avoided by finding out what device they are comfortable with and having that installed on the system.
- For preschool-age children, it is advisable to set cursor speeds at the slowest possible level.
- Keep fatigue levels in mind and do not schedule long sessions, as even older children will tend to become tired as time goes by.
- Include a representative group of children for the study instead of using one's own children or the children of associates.

- Establish a friendly relationship with children when they arrive.
- To reduce feelings of anxiety, allow parents to be present with young children when needed.

This subset of guidelines makes it clear that usability testing for children is a special process. While the effort to set up these testing procedures may be exhausting at times, the value derived from effective usability testing is immense and is crucial to designing technology for children. The need to involve children in every stage of design, using methods such as cooperative inquiry, is particularly important in the case of children's technology, because for adult designers it is difficult (and often incorrect) to make assumptions about how a child may view or interpret data. Children also tend to view certain specific things differently from adults. Audio feedback may alarm very young children and extremely bright colors and video could easily distract them from the task. When developing systems for very young children, it is important to remember that they may not understand words used regularly to convey information. For example, a picture-based application for toddlers with a Help button on the navigation bar would be futile, since the child may not be able to read the word "help." Complex functionality embedded in applications for children would increase their cognitive workload and result in a frustrating computing experience for the child. As with many of the discussed diversity issues, often more than one factor comes into play. For instance, when developing applications for autistic children, it is important to keep in mind the special needs of children as well as the special needs of those with autism. Designing applications for worldwide consumption requires that social and cultural diversity issues be considered along with specific issues for design for children. The point here is that while in theory the details of specific issues are discussed in isolation, in reality, many of these issues occur together and must be considered as a network of issues that may influence each other and come into play concurrently.

4.7.2 Older Users

The realities of old age present a set of challenges to technology design and delivery that have significant impact on the outcome of access and utilization by the elderly. With children, the experience level they have is minimal and so their interactions with technology are oftentimes the formative and impressionable experiences with the tasks being dealt with and with technology itself. On the other hand, with elderly users, the amount of experience is on the other end of the spectrum: a vast set of memories from experiences in the past compose a large repertoire. This naturally influences their feelings toward technology. Older users may feel a sense of resistance to certain technologies, especially when dealing with applications for tasks that people are used to completing without technology, such as online banking systems. The feeling of being "forced" to adapt to technology during the later years of life can add to these feelings of resistance. Many applications such as writing, shopping, and so on, have now become computer based. The Internet is now a preferred mode of communication, where messages are delivered instantly. These advances in technology have created a "keep up or be left out" paradigm, and many older users are unable to manage the emerging multitude of technological innovations. In addition to an emotional situation that may create resistance to technology, problems for older users are further compounded by various disabilities and impairments that are a common effect of the aging process (see Chapter 8 of this handbook). Memory loss, associated with aging, is often seen with the elderly. Learning and remembering instructions for technology use is further complicated by limited memory. Cataract is a common cause of vision impairment in older adults. Complications from illnesses, such as diabetic retinopathy caused by diabetes, can also contribute to vision impairments. Hearing loss and arthritis are also ailments that are commonly seen in older individuals. As one's age increases, so does the risk for developing impairments such as these. The level of computer experience and skill also varies greatly among users over the age of 65 today. Some of these individuals work in fields where the integration of technology is continual and seamless over the years. This gradual influx of technology has made it easier for these users to adapt to the growing computerization of society. In other cases, particularly in nontechnical fields and in areas of the world where technological integration has been slower to follow than the Western world, the intrusion of technology has been quick and sudden. Many manual procedures have hurriedly been replaced with computers to keep up with the rest of the world. This difference in the ways in which technology has been implemented, combined with various cultural and socioeconomic issues, has resulted in older users with varying levels of computer experience. Researchers, realizing the importance of computer experience as a variable factor in performance, have conducted studies on the utility of various combinations of multimodal feedback for older computer users (Jacko et al., 2004).

Individuals over the age of 65 will comprise 20% of the population of the United States by the year 2030 (U.S. Department of Health and Human Services Administration on Aging, 2003). The diverse landscape of America includes people from a variety of different cultures who speak different languages. The U.S. Department of Health and Human Services Administration of Aging estimates that over 16.1% of elders (those who are over the age of 65) in the United States are minority elders and that this percentage will increase by 217% by the year 2030. In comparison, the population of white elders will increase by 81%. Considering the language needs as well as understanding the cultural background of the population is important when designing technology for older users. This point is driven home when we see the statistics for the Hispanic older population in the United States. In 2004, the Hispanic older population comprised 6% of the total older adult population. By the year 2050, 17.5% of the older population will be comprised of Hispanic adults (see Figure 4.2). In addition to the growing population of elders in the United States, these numbers are increasing on the global scale as well (see Figure 4.3). It is estimated that, for the first time

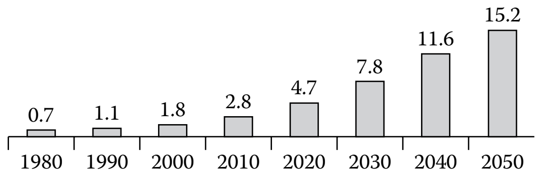


FIGURE 4.2 Population and projection of Hispanic adults over age 65. From U.S. Census Bureau. (http://www.census.gov).

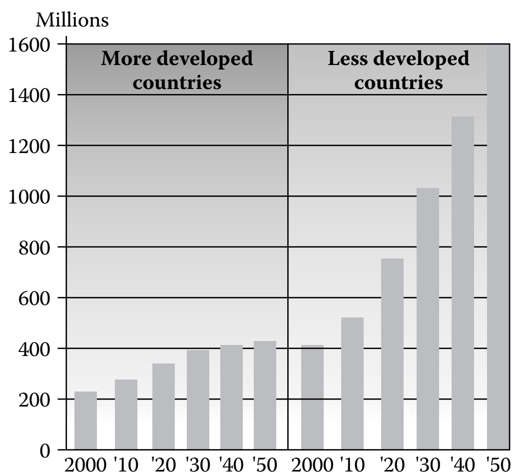


FIGURE 4.3 Aging: a global phenomenon. From U.S. Census Bureau, International Database; and the U.S. Department of Health and Human Services Administration on Aging. (http://www.aoa.gov).

in history, the population of older adults will exceed the population of children (ages 0 to 14) in the year 2050. Almost 2 billion people will be considered older adults by 2050 (U.S. Department of Health and Human Services Administration on Aging, 2003). The pervasive availability and use of technology requires that the access needs of older users be considered during design. This is particularly true when considering the enormous numbers of older individuals, because this indicates that a large percentage of technology consumers will be in this age group. In addition, it is important to be aware of the social and cultural issues pertaining to these users, since aging is a global phenomenon and not just restricted to English-speakers or those who reside in the United States. Again, interconnectedness between various diversity issues plays an important role.

Technology can be of use to older adults in a variety of ways. The first and most obvious use of technology is as a tool for communicating with friends, relatives, and colleagues. E-mail and instant messaging have provided ways for older adults and their caregivers to communicate with family even if they are physically distant. Communication can also help to create and maintain networks of friends. Maintaining communities in this way can improve feelings of well-being and help to reduce feelings of isolation. The Internet is a source of vast information and can be specifically beneficial to older adults looking for information on nursing homes, prescriptions, illnesses, alternative therapies, and so on. Many tasks, which once involved leaving one's home and making a trip to a specific location, can now be performed online. Computers are now common in the workplace and are replacing many older manual methods of performing tasks. With more and more people aging in today's world, the importance of improving computer access for older adults is critical. The computerization of the workplace generally implied less physical activity but increased cognitive activity. This must be taken into consideration especially for older users, since there are cognitive changes as people age (Czaja and Lee, 2002).

To design technology for older users, the first step is to understand these users, their special needs and conditions. As mentioned, many physical conditions affect older users. Impairments to the sensory systems affect how users perceive and process information.

Motor skills are also affected in older adults and there are significant changes associated with response time, coordination abilities, and flexibility (Czaja and Lee, 2002). A word processing task involves typing on a keyboard, viewing this information on a computer screen, and using the mouse to save data and make changes. All these stages can be seriously affected by various impairments of old age. Decreased coordination ability can make the task of saving and editing extremely complex because of the requirement to balance mouse and keyboard activities. In addition, changes in cognitive abilities are also associated with aging. The gradual decline of cognitive capabilities with increasing age has consequences for technology use. The training process for older users is typically longer than for younger adults. Increased complexity in design can lead to decreased quality of performance from older adults due to heightened cognitive strain. While older users can use and benefit from a variety of technologies, due to the natural effects of aging, the training time, help required, and response times are all higher than for a younger population of users (Czaja and Lee, 2002). Various recommendations have been put forth in the design of technology for older adults. A summary of some of these suggestions is provided in the following (Czaja and Lee, 2002; Jacko et al., 2004):

- Special attention should be given to design and layout of information, with improved contrast to reduce screen glare, enlargement of information presented on the screen, etc.
- Careful organization of information to facilitate easy search and find tasks.
- Analysis of input devices to determine which device will be the easiest to use—the use of a mouse appears to be a source of complexity, and research into alternative input methodologies such as speech-recognition will be valuable.
- Design of software should consider potential limitations in memory and other cognitive abilities on older users, and should not rely extensively on remembering information.
- Cues and feedback are important forms of communication in which the user learns if the task has been completed as expected, the level of progress, and if errors have occurred. Offering effective feedback combinations for

older users can help to minimize cognitive burden and can assist in task completion.
- Feedback itself must not be complicated and should not require extensive cognitive deciphering.

4.8 Gender

4.8.1 Stereotypes and Societal Issues

Differences in the way we perceive things, process information, and feel toward objects and persons can be conceived of as gender-based issues. Men and women, and their child-counterparts, boys and girls, have numerous obvious differences, and the question arising is whether there is also a difference in how the two genders relate to technology. Designers keep beliefs about boys' and girls' attitudes to computers in mind while developing applications: technology for girls is created with a learning-tool model, while similar technology for boys is designed in a game-type format (Cassell, 2002). Considering gender as a marker for differences leads to the societal constructs differentiating women and men. A stereotypical conception of the masculine is to associate masculinity with tools, technology, machinery, cars, and the like. It is encouraging to note that recent studies have shown that in technology-based science classes girls show equal proficiency as boys (Mayer-Smith et al., 2000). Nowadays, many conventional ideas are being changed and challenged, with men and women working in nontraditional roles and crossing boundaries set decades, sometimes even centuries, ago. The pervasiveness of technology has contributed to this equal access, with men and women requiring, demanding, and utilizing technology in every facet of life.

The gender differences that are operative in society are sometimes reflected in the language used in technology. A language of exclusion that relies primarily on masculine pronouns such as "he," "his," and "him" can be an inhibiting factor for women accessing technology. It has been argued that this exclusionary language in technology mirrors the power imbalance in society as a whole (Wilson, 1992). Some technology applications do not reflect women's interest and roles adequately, and instead promote stereotypes. For instance, in many video games in the past, women rarely played a major role and were often relegated to playing passive roles of women who needed rescue (Cassell, 2002). This is a unique kind of access problem, where even though there is no physical or cognitive impairment that may affect usability or performance, a psychological alienation and lack of motivation can result in decreased access by women. In 2006, a BBC report concluded that women enjoy video games, and that video game makers need to recognize this (BBC News, 2004). Several games such as the *Legend of Zelda, The Sims,* and *The Prince of Persia: The Sands of Time* are appealing to women—the report makes a special note of *The Prince of Persia* and its very interesting storyline involving its players (BBC News, 2004). The study points out that women prefer games that take less time to learn, as opposed to games that require extensive time commitment and complex controls. A game like *Lara Croft, Tomb Raider* that projects the role of a women as an active, strong, and aggressive leader presents an interesting case study in the area of intersection between gender and technology. On the one hand, the concept of a woman being the hero in the world of action and adventure, traditionally assigned to men, could be viewed as subverting norms of gender. Still, such a concept, despite this transgressive femininity, can distance women users by fostering the stereotype of women as thin, sensual, and physically attractive individuals. In addition to video games, e-mail provides another interesting example of gender as a diversity factor. A study of e-mail use and perception among men and women showed that while women perceived e-mail differently from men, their use of e-mail was not different (Gefern and Straub, 1997).

The issues surrounding the topic of technology and gender raise the question of how to develop technologies that are universally accessible by men and women. Cassell tackles this issue by pointing out available options (Cassell, 2002). One line of thought is that because much of technology is designed for men by men, there should be separate applications designed for women catering to their needs and interests. This includes a wide range of applications from video games for entertainment purposes, to advanced financial software for use in professional contexts. This suggestion is challenged by critics who foresee that such a trend in divisive technology would exacerbate the current dichotomy between men and women. Cassell is an advocate of a position he calls the "philosophy of undetermined design." Although Cassell speaks specifically with regard to video games, this principle can be applied to many technical applications, and encourages the design of technology, which is comprehensive in nature and allows the users to engender themselves as they choose to. With respect to video games, this engenderment would happen based on what activities the user chooses to participate in. This kind of design permits users to customize their experience and does not box them within preconceived ideas of gender.

Gender differences are an important and unique issue in user diversity. Differences caused by gender association can be subtle and difficult to quantify. Providing customizable experiences for users provides an effective way to ensure that users, irrespective of gender, can personalize their interaction with technology. While providing this level of personalization may present enormous design challenges, the resulting product would be one that enables all users, men and women, to experience the product in its maximal effectiveness.

4.9 Conclusion

In this chapter, the importance of user diversity for universal access in technology has been discussed. There are different forms of diversity, and each of these affects the user's interaction with technology in different ways. For example, certain physical disabilities can make it very difficult for a user to utilize the widely available technological tools. Diversity issues also arise out of disparities in skill level and cognitive abilities. In addition, societal factors, cultural and linguistic differences, age, and gender can all play a role in shaping a user's unique interaction with technology. In many such situations, user interaction can be improved if some changes are made during the design process, after careful consideration of the nature of diversity and the particular needs of the heterogeneous group of users.

The ideal and practice of universal access in technological design are pivotal. A comprehensive recognition and understanding of various diversity issues ranging from physical and cognitive differences to sociocultural and gender issues will lead to more participatory and inclusive technological communities. The importance of diversity issues in technology design also brings to the forefront the interdisciplinary nature of this field—technologists, doctors, psychologists, economists, and various other experts are required to provide a complete picture of the needs and requirements of users. Of course, the most important group of people is the users themselves, whose specific requirements and capabilities have the potential to give new direction to technology's march toward universal access.

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5

Motor Impairments and Universal Access

Simeon Keates

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5.1 Introduction

For people with functional impairments, access to, and independent control of, a computer can be an important part of everyday life. For example, people whose impairments prevent communication through writing or speaking can, with appropriate technology, perform these activities with computer assistance. Improved computer access has also been shown to give significant gains in educational success and employment opportunities for people with impairments. However, to be of benefit, computer systems must be accessible. That is, after all, the underlying message of this handbook.

Computer use often involves interaction with a graphical user interface (GUI), typically using a keyboard, mouse, and monitor. However, people with motor impairments often have difficulty with accurate control of standard pointing devices. Conditions such as cerebral palsy, muscular dystrophy, Parkinson's disease, and spinal injuries can give rise to symptoms that affect a user's motor capabilities. Symptoms relevant to computer operation include joint stiffness, paralysis in one or more limbs, numbness, weakness, bradykinesia (slowness of movement), rigidity, impaired balance and coordination, tremor, pain, and fatigue. These symptoms can be stable or highly variable, both within and between individuals, and can restrict the extent to which a keyboard and mouse are useful.

In a study commissioned by Microsoft (Forrester Research, Inc., 2003) it was found that one in four working-age adults have some dexterity difficulty or impairment. The most prevalent conditions that give rise to motor impairments include rheumatic diseases, stroke, Parkinson's disease, multiple sclerosis, cerebral palsy, traumatic brain injury, and spinal injuries or disorders. Cumulative trauma disorders represent a further significant category of injury that may be specifically related to computer use. While many of these conditions may seem remote for many computer users, repetitive strain injury and carpal tunnel syndrome are not. Thus, consideration of the prevalence and effects of motor impairments in the user population is an important facet of designing for universal access.

5.2 Prevalence of Motor Impairments

It is worth beginning by considering the prevalence of motor impairments in the context of universal access. There are several reasons for this.

First, much research in universal access has focused on vision impairments, blindness in particular. This focus is not the result of considering other functional or sensory impairments to be somehow less important. Instead, it is the result of a highly discernible impairment (white canes, guide dogs, etc.), an impairment that is easy to simulate (close your eyes or remove your monitor), and one that clearly affects a user's ability to interact with a GUI. However, as will be shown later in this chapter, blindness is a comparatively rare, though serious, impairment. Motor impairments and, indeed, cognitive impairments, are much more common.

Second, investigation of the prevalence of motor impairments also helps provide a framework for understanding the nature of the impairments. Such a framework is important for communicating to the designers of new computer systems and interfaces how motor impairments affect users.

Estimates of the prevalence of disability derived from any study depend on the purpose of the study and the methods used (Martin et al., 1988). Since disability has no scientific or commonly agreed upon definition (Pfeiffer, 2002), a major problem lies in the confusion over terminology. However, the ICIDH-2: International Classification of Functioning (ICF), Disability and Health (WHO, 2007) represents a rationalization of the terminology frequently used. The ICF defines disability as "any restriction or lack (resulting from an impairment) of ability to perform an activity in the manner or within the range considered normal for a human being" (WHO, 2001).

This definition has been used widely for both disability research (Martin et al., 1988; Grundy et al., 1999) and design research (Pirkl, 1994). However, such language is now generally considered too negative, and it is preferable to describe users in terms of their capabilities rather than disabilities. Thus, "capability" describes a continuum from high (i.e., "able-bodied") to low representing those that are severely "disabled." Data that describe such continua provide the means to define the populations that can use given products, thus leading to the possibility of evaluating metrics for a product's accessibility.

5.2.1 American Community Survey

The U.S. Census Bureau's 1999–2004 American Community Survey (USCB, 2004) adopted a straightforward approach to defining what constitutes a disability. Respondents were asked if they had any kind of disability, defined here as "a long-lasting sensory, physical, mental or emotional condition" (ACSO, 2007). Table 5.1 shows the prevalence of disabilities in the U.S. adult (16+) population recorded by the survey.

In Great Britain, the Office of National Statistics commissioned two surveys in the late 1980s and 1990s that attempted to describe the prevalence and severity of impairments across the entire British population (i.e., the combined populations of England, Scotland, and Wales, but not Northern Ireland) in a more rigorous manner. The surveys involved over 7500 respondents, sampled to provide representative coverage of the population.

5.2.2 The Survey of Disability in Great Britain

The Survey of Disability in Great Britain (Martin et al., 1988) was carried out between 1985 and 1988. It aimed to provide up-to-date information about the number of disabled people in Britain with different levels of severity of functional impairment and their domestic circumstances. The survey used 13 different types of disabilities ranging from locomotion to stomach issues, and gave estimates of the prevalence of each type. It showed that musculoskeletal complaints, most notably arthritis, were the most commonly cited causes of disability among adults.

An innovative feature of the survey was the construction of an overall measure of severity of disability, based on a consensus of assessments of specialists acting as judges. In essence, the severity of all 13 types of disability is established, and the 3 highest scores combined to give an overall score, from which people are allocated to 1 of 10 overall severity categories. A scale that runs from a minimum possible 0.5 to a maximum possible 13.0 represents each impairment. Note though, that not all of the scales extend across this complete range, with some having maximum values of only 9.5, for example.

TABLE 5.1 The Prevalence of Disabilities in the U.S. Adult (16+) Population

Respondents	Percentage of Total	Margin of Error
Population 16 years +	***220,073,798***	***+/– 129,242***
With any disability	16.0	+/– 0.1
With a sensory disability (i.e., with *blindness, deafness, severe vision or hearing impairment*)	4.7	+/– 0.1
With a physical disability (i.e., with a condition that substantially limits *walking, climbing stairs, reaching, lifting or carrying*)	10.6	+/– 0.1
With a mental disability (i.e., with a condition that makes it difficult to *learn, remember or concentrate*)	5.2	+/– 0.1
With a self-care disability (i.e., with a condition that makes it difficult to *dress, bathe or get around inside the home*)	3.1	+/– 0.1
With a go-outside-home disability (i.e., with a condition that makes it difficult to *go outside the home alone to a shop or doctor's office*)	4.9	+/– 0.1
With an employment disability[a] (i.e., with a condition that makes it difficult to *work at a job or business*)	5.6	+/– 0.1

Source: USCB, *American Community Survey*, http://factfinder.census.gov/jsp/saff/SAFFInfo.jsp? _pageId=sp1_acs&_submenuId=, 2004.

[a] Data for employment disability collected for ages 16–64 years only.

A person's sum physical impairment is derived using a weighted sum as shown in Equation 5.1. The weighted sum is then mapped from the resulting 0 to 18.5 (the maximum possible upper limit) scale to a 0 to 10 scale.

$$\text{Weighted sum} = \text{worst score} + 0.4 \times \text{2nd worst} + 0.3 \times \text{3rd worst} \tag{5.1}$$

5.2.3 The Disability Follow-Up Survey

The Disability Follow-Up Survey (DFS) (Grundy et al., 1999) to the 1996/97 Family Resources Survey (Semmence et al., 1998) was designed to update information collected by the earlier Survey of Disability in Great Britain (Martin et al., 1988). For the purposes of this chapter, 7 of the 13 separate capabilities proposed in the Family Resources Survey and used in the DFS are of particular relevance, specifically:

- Locomotion
- Reaching and stretching
- Dexterity
- Seeing
- Hearing
- Communication
- Intellectual functioning

These individual impairments may be grouped into three overall capabilities:

- *Motor*—locomotion, reaching and stretching, dexterity
- *Sensory*—seeing, hearing
- *Cognitive*—communication, intellectual functioning

The survey results showed that an estimated 8,582,200 adults in Great Britain (GB)—that is, 20% of the adult population—had a disability according to the definitions used. Of these 34% had mild levels of impairment (categories 1 and 2—i.e., high capability), 45% had moderate impairment (categories 3 to 6—i.e., medium capability), and 21% had severe impairment (categories 7 to 10—i.e., low capability). It was also found that 48% of the disabled population was aged 65 or older and 29% was aged 75 years or more.

5.2.4 Multiple Capability Losses

Traditionally, universal access research has tended to focus on accommodating single, primarily major, capability losses. Unfortunately, many people do not have solely single functional impairments, but several. This is especially true when considering older adults. Consequently, it is important to be aware of the prevalence of not only single, but also multiple capability losses. Therein lies a problem, as most user data focus on single impairments.

Fortunately, both the American Community Survey and the DFS provide valuable information for analyzing multiple capability losses. Tables 5.2 and 5.3 summarize the data extracted from those surveys. It is evident that in both surveys at least half of those respondents with some loss of capability have more than one loss of capability.

The comparative magnitudes of prevalence of motor and sensory impairments from the DFS (6.71 million and 3.98 million, respectively) are self-evident.

As discussed earlier, many designers and researchers automatically assume that universal access is really just enabling access for people who are blind. In practice, designing an interface that is easier to manipulate is likely to enable more people to use it than, say, supporting a Braille display. Only a comparatively small proportion of people who are blind have the skills to read Braille.

As discussed earlier, blindness is an important impairment that should not be overlooked when designing for universal access, but has comparatively low prevalence. Even within the sensory impairment category, 1.93 million people in Great Britain have vision impairments compared with 2.9 million with hearing impairments. Note that 1.93 million + 2.9 million does not equal the 3.98 million in Table 5.3 because approximately 1 million people have both some hearing and some vision impairment, especially among older adults, and so the 3.98 million figure has been corrected to remove such double-counting. Of those 1.93 million people with vision impairments, the vast majority have low vision (i.e., they can see to some extent, but have difficulty reading regular size print, even with spectacles). Only a small percentage (less than 20%) of people with a vision impairment are classified as blind. Thus people who are blind constitute approximately only 5% of the total disabled population within Great Britain.

5.2.5 Aging and Motor Impairments

In virtually every country in the developed world, the population is aging and aging rapidly. Countries such as Japan have even reached the stage of no longer being considered "aging," but "aged" with 28% of its population projected to be over 65

TABLE 5.2 Multiple Capability Losses as Reported in the 2004 American Community Survey

Respondents	Percentage of Total	Margin of Error
Population 5 years and over	***264,965,834***	***+/– 65,181***
Without any disability	85.7	+/– 0.1
With one type of disability	6.7	+/– 0.1
With two or more types of disabilities	7.6	+/– 0.1

TABLE 5.3 Multiple Capability Losses for Great Britain: Total Population ~46.9 Million Adults

Loss of Capability	Number of GB 16+ Population	Percentage of GB 16+ Population
Motor	6,710,000	14.3
Sensory	3,979,000	8.5
Cognitive	2,622,000	5.6
Motor only	2,915,000	6.2
Sensory only	771,000	1.6
Cognitive only	431,000	0.9
Motor and sensory only	1,819,000	3.9
Sensory and cognitive only	213,000	0.5
Cognitive and motor only	801,000	1.7
Motor, sensory, and cognitive	1,175,000	2.5
Motor, sensory, or cognitive	8,126,000	17.3

by 2025. A more delicate choice of phrasing would be to regard the populations as "maturing" (rather like a good wine). In a report published in 2002, the Population Division of the United Nations' Department of Economic and Social Affairs reported that:

> In 1950, there were 205 million persons aged 60 or over throughout the world … At that time, only 3 countries had more than 10 million people 60 or older: China (42 million), India (20 million), and the United States of America (20 million). Fifty years later, the number of persons aged 60 or over increased about three times to 606 million. In 2000, the number of countries with more than 10 million people aged 60 or over increased to 12, including 5 with more than 20 million older people: China (129 million), India (77 million), the United States of America (46 million), Japan (30 million) and the Russian Federation (27 million). Over the first half of the current century, the global population 60 or over is projected to expand by more than three times to reach nearly 2 billion in 2050.… By then, 33 countries are expected to have more than 10 million people 60 or over, including 5 countries with more than 50 million older people: China (437 million), India (324 million), the United States of America (107 million), Indonesia (70 million) and Brazil (58 million). (UN, 2002)

Keeping an aging workforce productively employed is a key challenge. The costs of premature medical retirement are difficult to evaluate, but the Royal Mail in the United Kingdom conducted what is believed to be the first survey of its kind to estimate the cost to its business. It found that preventable premature medical retirement was costing the company over $200 million per year, without taking into consideration the costs of recruiting replacement staff or the loss of organizational memory (the knowledge and skills accumulated over the years by experienced employees). At the time, the company was losing $800 million per year and so the costs of preventable premature medical retirement became a major target for cost reductions. Their definition of "preventable" premature medical retirement was where an employee was deemed capable of doing a job, just not one of the jobs available within the Royal Mail's working environment (Coy, 2002).

Implicit in the argument that the aging of the population is relevant to universal access is the fact that the aging process is associated with certain decreases in user capabilities—see the DFS data discussed earlier (see also Chapter 8, "Age-Related Difference in the Interface Design Process," for further details). In many cases, these are fairly minor losses of an individual's capabilities, but the minor losses can often have a cumulative effect. Thus, someone whose eyesight is not quite as sharp as it was, whose keeps needing to turn the volume up a little bit louder on the television, and whose fingers are not quite as nimble as they once were, may find some products as difficult to use as someone with a single, but more severe, impairment. In particular, conditions such as arthritis and Parkinson's disease have strong links to decreased motor capabilities in older adults. The effects on computer access will be examined later in this chapter.

5.3. Effects of Functional Impairments on Universal Access

Having looked at the prevalence of impairments, it is helpful to think about how each of those impairment types affects someone's ability to use a computer. To illustrate how different users' capabilities can influence the difficulties that those users can expect to encounter, Table 5.4 shows the kinds of difficulties that users with specific impairments may encounter when trying to use a computer and the kinds of assistive technology that they may use.

Table 5.4 represents broad difficulties and solutions. It is also instructive to think more deeply about how users with different impairments may be affected by common graphical user interface activities, for example clicking an onscreen button.

Consider a small button or icon on a software interface. Someone who is blind would not be able to see the button, or locate it. Someone with low vision may be able to see that there