



Usability of Interactive Systems

“Designing an object to be simple and clear takes at least twice as long as the usual way. It requires concentration at the outset on how a clear and simple system would work, followed by the steps required to make it come out that way—steps which are often much harder and more complex than the ordinary ones. It also requires relentless pursuit of that simplicity even when obstacles appear which would seem to stand in the way of that simplicity.”

T. H. Nelson

The Home Computer Revolution, 1977

CHAPTER OUTLINE

- 1.1 Introduction
- 1.2 Usability Goals and Measures
- 1.3 Usability Motivations
- 1.4 Universal Usability
- 1.5 Goals for Our Profession



1.1 Introduction

User-interface designers are becoming the heroes of a profound transformation. Their work has turned the personal computer into the social computer, enabling users to communicate and collaborate in remarkable ways. The desktop applications that once served the needs of professionals are now enabling broad communities of users to prepare user-generated content that can be shared with millions of World Wide Web users. And now the web-based social networking and social media applications that were once available only to desktop users are accessible through billions of cellphones and other mobile devices.

These dramatic shifts are possible because researchers and user-interface designers have harnessed the advancing technologies to serve human needs. Researchers created the interdisciplinary design science of *human-computer interaction* by applying the methods of experimental psychology to the powerful tools of computer science. Then they integrated lessons from educational and industrial psychologists, instructional and graphic designers, technical writers, experts in human factors or ergonomics, information architects, and adventure-some anthropologists and sociologists. The payoff is seen in the success of increasingly powerful social media, which might be called *social-computer interaction*. As the impact of these social tools and services spreads, researchers and designers are gathering fresh insights from policy analysts, intellectual property defenders, privacy protectors, consumer advocates, and ethicists.

User interfaces help produce business success stories and Wall Street sensations. They also produce intense competition, copyright-infringement suits, intellectual-property battles, mega-mergers, and international partnerships. Crusading Internet visionaries promote a world with free access to information and entertainment, while equally devoted protectors of creative artists argue for fair payments.

User interfaces are also controversial because of their central role in personal identification, national defense, crime fighting, electronic health records, and so on. In the aftermath of the September 11, 2001 terrorist attacks, some

members of the U.S. Congress blamed the inadequacies of user interfaces for the failure to detect the terrorists.

At an individual level, user interfaces change many people's lives: effective user interfaces for professionals mean that doctors can make more accurate diagnoses and pilots can fly airplanes more safely; at the same time, children can learn more effectively, users with disabilities can lead productive lives, and graphic artists can explore creative possibilities more fluidly. Some changes, however, are disruptive. Too often, users must cope with frustration, fear, and failure when they encounter excessively complex menus, incomprehensible terminology, or chaotic navigation paths. What user wouldn't be disturbed by receiving a message such as "Illegal Memory Exception: Severe Failure" with no guidance about what to do next?

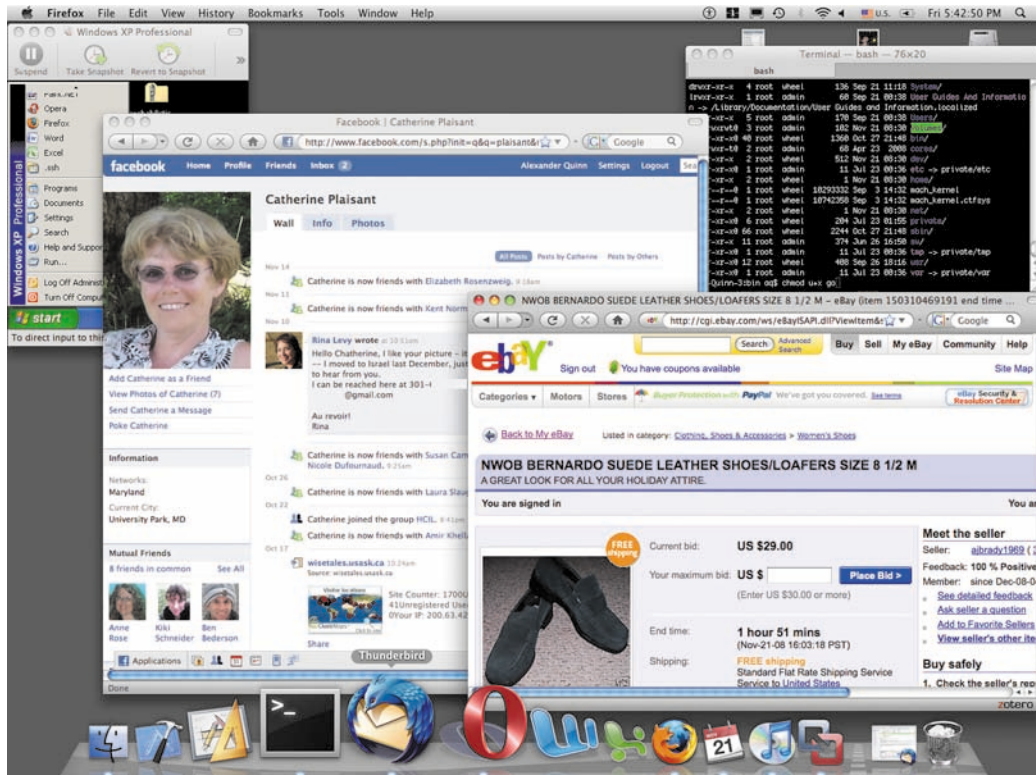


FIGURE 1.1

Apple® Mac OS X®. The top-left corner shows a Windows XP virtual machine and the Facebook social networking web site (<http://www.facebook.com/>). The top right is a Unix Terminal, and the bottom-right window shows eBay (<http://www.ebay.com/>), a popular online auction site. The bottom of the screen also shows the Dock, a menu of frequently accessed items whose icons grow larger on mouse-over.

The steadily growing interest in user-interface design stems from designers' desire to improve the users' computing experience (Figs. 1.1 and 1.2 show some popular operating systems). In business settings, better decision-support and document-sharing tools support entrepreneurs, while in home settings digital photo libraries and videoconferencing enhance family relationships. Millions of people take advantage of the World Wide Web's extraordinary educational and cultural heritage resources, which provide access to everything from outstanding art objects from China, music from Indonesia, sports from Brazil, and entertainment from Hollywood or Bollywood (Figs. 1.3 to 1.7 show some popular web sites). Mobile devices enrich daily life for many users, including those with disabilities, limited literacy, and low incomes (Fig. 1.8 shows some mobile

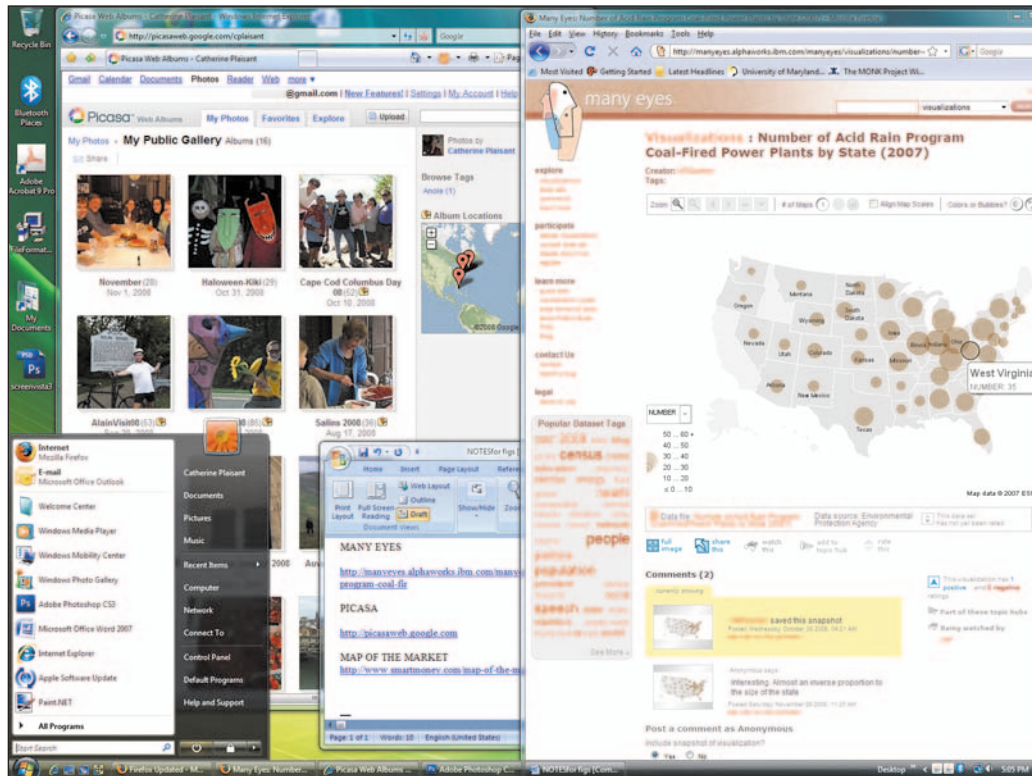


FIGURE 1.2

Microsoft® Windows Vista®, showing icons at the top left and the Start menu at the bottom left. Transparency reveals the window underneath the menu. The main window on the left is Google's picture sharing application Picasa™. On the right side IBM's many eyes application lets users post and visualize data (here showing the distribution of coal power plants on a US map). Other users can then post comments or add tags.

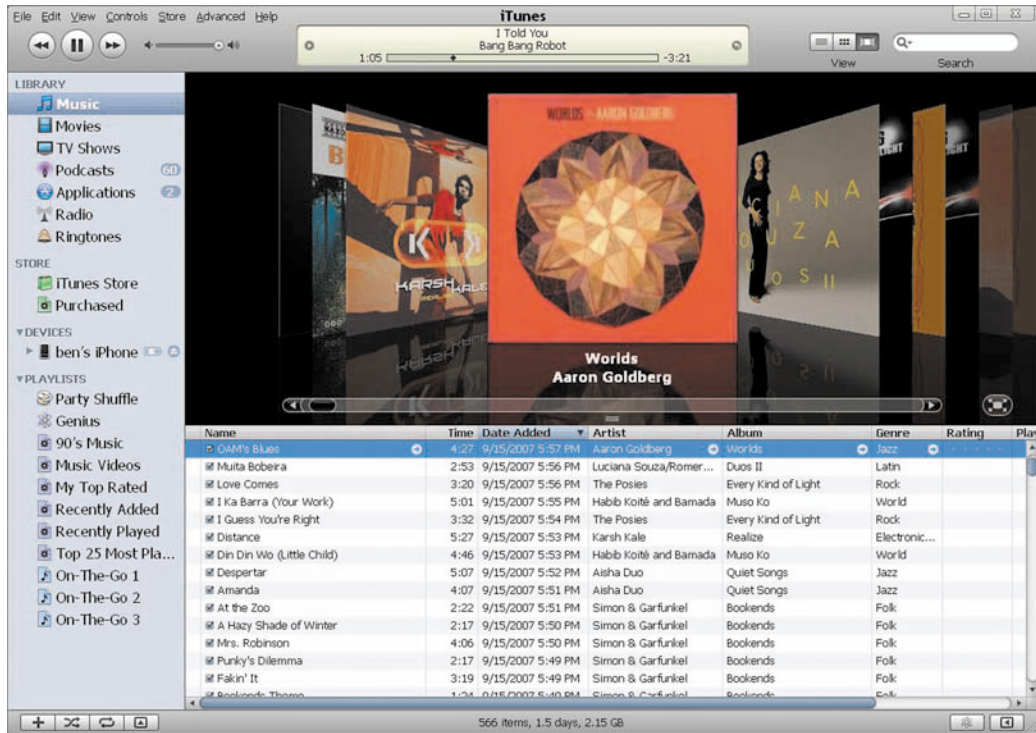


FIGURE 1.3

Apple's iTunes® interface (<http://www.apple.com/itunes/>) allows PC and Macintosh® users to shop for music, videos, and much more, then manage their media and synchronize their collections with music players like the iPod® and iPhone™.

devices). On a worldwide scale, promoters and opponents of globalization debate the role of technology in international development, while activists work to attain the United Nations Millennium Development Goals.

The transition away from desktop web-based applications is accelerating, encouraged by the explosive growth of mobile devices (especially cellphones) that support personal communication. The proliferation of such devices in developed as well as developing nations has been astonishing. Some analysts see a close linkage between economic growth and cellphone dissemination, since communications facilitate commerce and stimulate entrepreneurial ventures. Mobile devices also enrich family and friend relationships, enable timely medical care, and provide life-saving disaster response services to professionals and residents.

Explosive growth is also the appropriate description for what's happening in the realms of social networking and user-generated content. While older media,

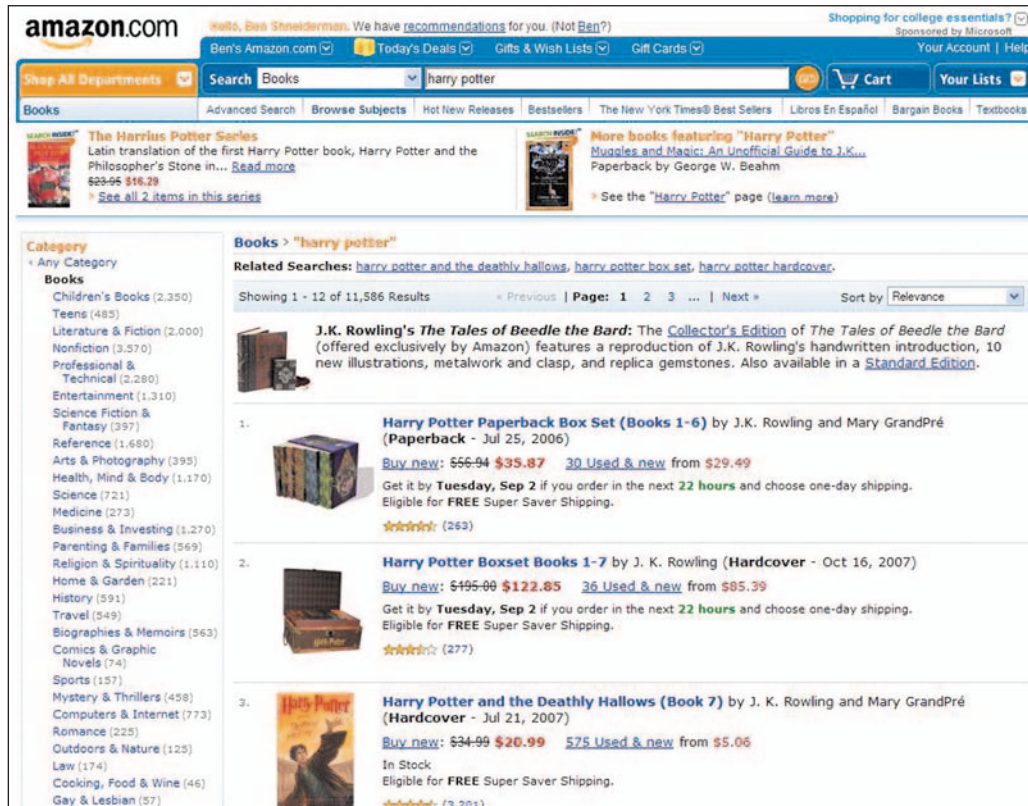


FIGURE 1.4

The Amazon.com web site (<http://www.amazon.com/>) will make book and product recommendations based on a user's personal history with the site.

such as newspapers and television, have sought to increase their audiences through new media, their audiences have dwindled in favor of social networking sites such as MySpace and Facebook and user-generated content presented by sites like YouTube and Wikipedia (all of which are among the top ten most visited web sites). These early leaders are just a taste of what is to come, as entrepreneurs generate ever more clever social media participation accessible through web-based applications and mobile devices.

Designers are enabling users to create, edit, and distribute three-dimensional representations, animations, music, voice, video recordings. The result is ever-richer multimedia experiences on web sites and a creative outpouring of user-generated content available on mobile devices.

Sociologists, anthropologists, policymakers, and managers are studying how social media participation is changing education, family life, personal relationships,

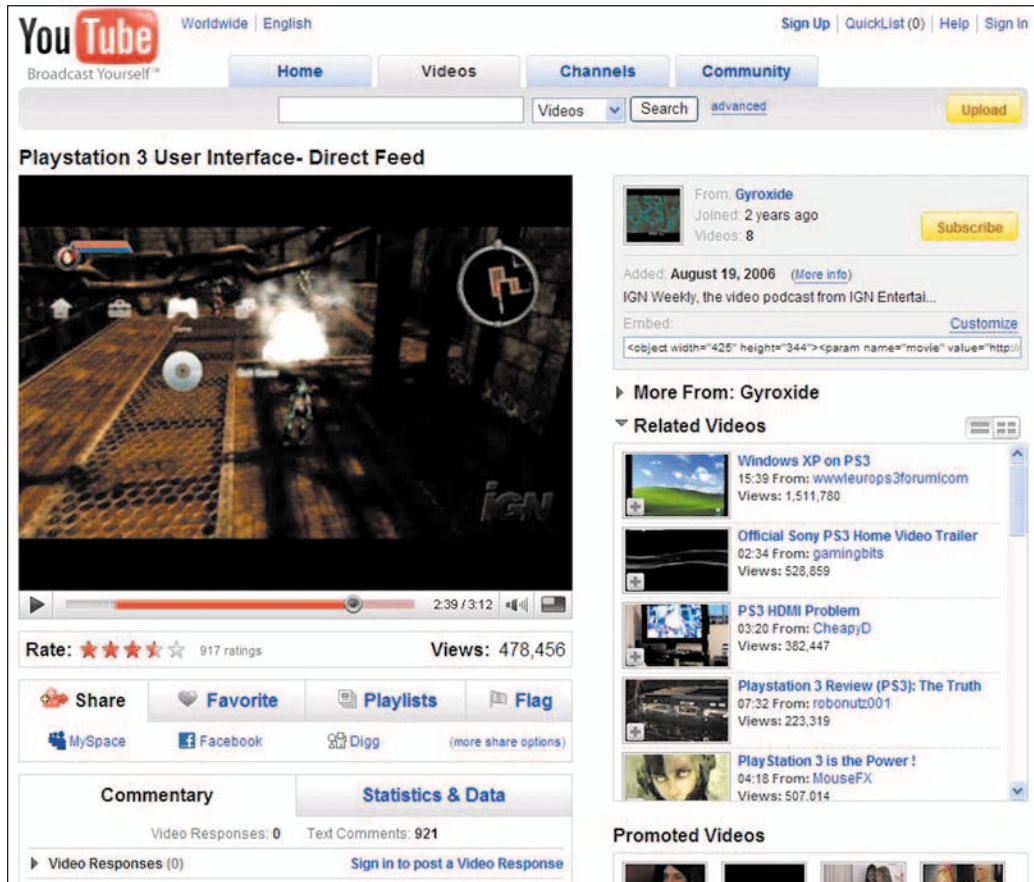
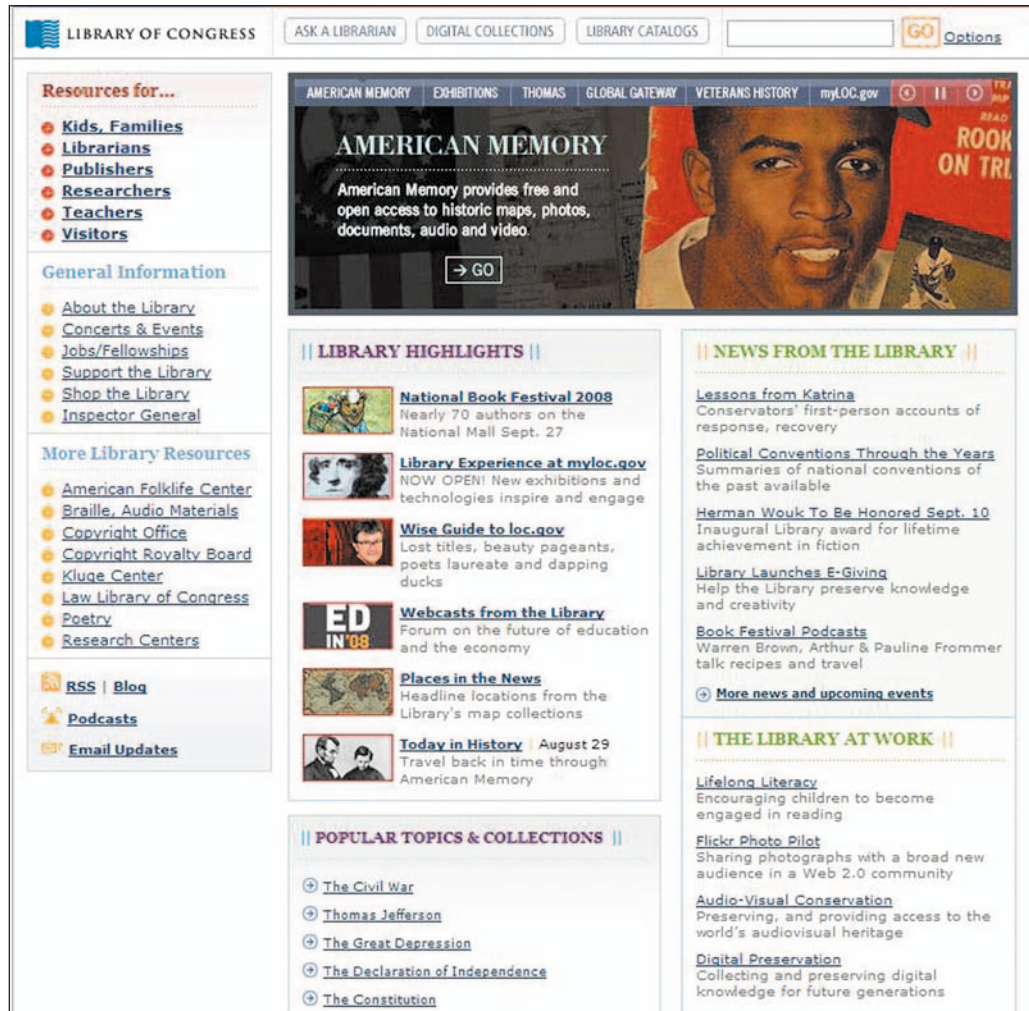


FIGURE 1.5

YouTube (<http://www.youtube.com/>) became a top-ten web site by offering free uploads and downloads of millions of videos, encouraging a creative outpouring of hilarious and serious short (2–10 minute) videos. This example shows a demonstration of the game *Untold Legends™* on a Sony™ PlayStation®3.

and services such as medical care, financial advice, and political organizations. They are also dealing with issues of organizational impact, job redesign, distributed teamwork, work-at-home scenarios, and long-term societal changes. As face-to-face interaction gives way to screen-to-screen, how can personal trust and organizational loyalty be preserved?

Designers face the challenge of providing services on small-, wall-, and mall-sized displays, ranging from mobile devices such as cellphones to large plasma panels and projected displays. The *plasticity* of their designs must ensure smooth conversion across different display sizes, delivery by

**FIGURE 1.6**

The Library of Congress web site (<http://www.loc.gov/>) provides access to primary sources from over 200 collections that cover diverse topics ranging from the American Civil War to Yiddish Theater in the 1920s.

way of desktop web browsers or pocket-sized cellphones, translation into multiple languages, and compatibility with accessibility-support devices for disabled users.

Some innovators promise that desktop computers and their user interfaces will disappear, while new interfaces will become ubiquitous, pervasive, invisible, and embedded in the surrounding environment. They believe that novel

The screenshot shows the Kayak.com search results page in Mozilla Firefox. The browser window title is "Kayak.com Search Results - Mozilla Firefox". The address bar shows the URL: <http://www.kayak.com/s/flights.jsp?searchid=7pEFIMrEnIMQRa0kUJcxfQ&c>. The search results are for flights from Washington, DC to Los Angeles, CA, for the dates Fri 3 Jul 2009 – Tue 7 Jul 2009.

The left sidebar contains filters for "Stops", "Airlines", and "Flight Times". The "Stops" filter shows "nonstop" selected with a price of \$499, and "1 stop" and "2+ stops" with prices of \$343 and \$343 respectively. The "Airlines" filter shows "Alaska Airlines only" selected with a price of \$564, and "Continental only", "Delta only", "Multiple Airlines only", "Northwest only", "United only", and "US Airways only" with prices of \$618, \$550, \$394, \$507, \$499, and \$343 respectively. The "Flight Times" filter shows "takeoff" and "landing" selected for both "Depart" and "Return" flights, with a range of "Fri 8:00a - 12:00p" for departure and "Tue 2:00p - 6:00p" for return.

The main content area shows a list of flight results. The "List View" tab is selected. The results are sorted by price, with the lowest price being \$499 for a nonstop flight on United. The results are displayed in a table with columns: Price, Airline, Takeoff, Landing, and Stops (Duration). The table shows 5 of 483 results shown – round-trip (show all).

Price	Airline	Takeoff	Landing	Stops (Duration)
\$499 per person	United	IAD 9:30a LAX 4:15p	LAX 11:58a IAD 12:19a	0 (5h 28m) 0 (5h 04m)
\$544 per person	United	IAD 8:35a LAX 4:15p	LAX 10:59a IAD 12:19a	0 (5h 24m) 0 (5h 04m)
\$564 per person	Alaska Airlines	IAD 8:05a LAX 3:55p	LAX 10:15a IAD 11:55p	0 (5h 10m) 0 (5h 00m)
\$599 per person	United / Alaska Airlines	IAD 8:35a LAX 3:55p	LAX 10:59a IAD 11:55p	0 (5h 24m) 0 (5h 00m)

FIGURE 1.7

Firefox® 3.0 showing the Kayak travel search web site (<http://www.kayak.com/>) with check boxes to select nonstop flights and specific airlines. This user has also specified a range of flight times using double-box range sliders.

devices will be context-aware, attentive, and perceptive, sensing users' needs and providing feedback through ambient displays that glow, hum, change shape, or blow air. Some visionaries foresee advanced mobile devices that are wearable, or even implanted under the skin. The individual sensors that track users entering buildings or FedEx packages arriving at destinations will give way to elaborate sensor nets that follow crowds, epidemics, and pollution.

**FIGURE 1.8**

Advanced cellphones, like the BlackBerry Curve™, Apple iPhone, and HTC Android™, have larger displays, provide Internet connections, and support a growing variety of applications.

Other designers promote persuasive technologies that change users' behavior, multi-modal or gestural interfaces that facilitate use, and affective interfaces that respond to the user's emotional state.

We are living in an exciting time for designers of user interfaces. The inspirational pronouncements from technology prophets can be thrilling, but rapid progress is more likely to come from those who do the hard work of tuning designs to genuine human needs. These designers will rigorously evaluate actual use with eager early adopters, as well as reluctant late adopters, and seriously study the resistant non-users. This book's authors believe that the next phase of human-computer interaction will be strongly influenced by those who are devoted to broadening the community of users by consciously promoting universal usability and highlighting social media participation.

This first chapter gives a broad overview of human-computer interaction from practitioners' and researchers' perspectives. It lays out usability goals, measures, and motivations in Sections 1.2 and 1.3, takes on the large topic of universal usability in Section 1.4, and closes with a statement of goals for our profession. Specific references cited in the chapter appear on page 42, and a set of general references begins on page 46: lists of relevant books, guideline documents, journals, video collections, and professional organizations give readers starting points for further study.

The second chapter reviews the guidelines, principles, and theories that will be drawn on and refined throughout the book. Chapters 3–4 introduce development processes and evaluation methods, while Chapters 5–9 cover interaction styles that range from graphical direct manipulation to textual commands and their implementation using common interaction devices. Collaboration is included in this part to emphasize the need for every designer to go beyond the personal computer and consider the many forms of social computing. Chapters 10–14 address the critical design decisions that often determine the success or failure of products and that may lead to breakthroughs that open the way to new possibilities. The Afterword reflects on the societal and individual impacts of technology.

1.2 Usability Goals and Measures

Every designer wants to build high-quality interfaces that are admired by colleagues, celebrated by users, and imitated by competitors. But getting such attention takes more than flamboyant promises and stylish advertising; it's earned by providing quality features such as usability, universality, and usefulness. These goals are achieved by thoughtful planning, sensitivity to user needs, devotion to requirements analysis, and diligent testing, all while keeping within budget and on schedule.

Managers who pursue user-interface excellence first select experienced designers and then prepare realistic schedules that include time for guidelines preparation and repeated testing. The designers begin by determining user needs, generating multiple design alternatives, and conducting extensive evaluations (see Chapters 3 and 4). Modern user-interface-building tools then enable implementers to quickly build working systems for further testing.

Successful designers go beyond vague notions of “user friendliness,” doing more than simply making checklists of subjective guidelines. They have a thorough understanding of the diverse community of users and the tasks that must be accomplished. They study evidence-based guidelines and pursue the research literature when necessary. Great designers are deeply committed to serving the users, which strengthens their resolve when they face difficult choices, time pressures, and tight budgets.

When managers and designers have done their jobs well, their effective interfaces generate positive feelings of success, competence, and mastery in the user community. The users have a clear mental model of the interface that enables them to confidently predict what will happen in response to their actions. In the best cases, the interface almost disappears, enabling users to concentrate on their work, exploration, or pleasure. This kind of calming environment gives users the feeling that they are “in the flow,” operating at their peak, while attaining their goals.

Close interaction with the user community leads to a well-chosen set of benchmark tasks that is the basis for usability goals and measures. For each user type and each task, precise measurable objectives guide the designer through the testing process. The ISO 9241 standard *Ergonomics of Human-System Interaction* (ISO, 2008) focuses on admirable goals—*effectiveness, efficiency, and satisfaction*—but the following usability measures, which focus on the latter two goals, lead more directly to practical evaluation:

1. *Time to learn.* How long does it take for typical members of the user community to learn how to use the actions relevant to a set of tasks?
2. *Speed of performance.* How long does it take to carry out the benchmark tasks?
3. *Rate of errors by users.* How many and what kinds of errors do people make in carrying out the benchmark tasks? Although time to make and correct errors might be incorporated into the speed of performance, error handling is such a critical component of interface usage that it deserves extensive study.
4. *Retention over time.* How well do users maintain their knowledge after an hour, a day, or a week? Retention may be linked closely to time to learn, and frequency of use plays an important role.
5. *Subjective satisfaction.* How much did users like using various aspects of the interface? The answer can be ascertained by interviews or by written surveys that include satisfaction scales and space for free-form comments.

Every designer would like to succeed in every measure, but there are often forced tradeoffs. If lengthy learning is permitted, task-performance times may be reduced by use of complex abbreviations, macros, and shortcuts. If the rate of errors is to be kept extremely low, speed of performance may have to be sacrificed. In some applications, subjective satisfaction may be the key determinant of success; in others, short learning times or rapid performance may be paramount. Project managers and designers who are aware of the tradeoffs can be more effective if they make their choices explicit and public. Requirements documents and marketing brochures that make clear which goals are primary are more likely to be valued.

After multiple design alternatives have been raised, the leading possibilities should be reviewed by designers and users. Low-fidelity paper mock-ups are useful, but high-fidelity online prototypes create a more realistic environment for expert reviews and usability testing. The user documentation and the online help can be written before the implementation, to provide another review and a new perspective on the design. Next, the implementation can be carried out with proper software tools; this task should be a modest one if the design is complete and precise. Finally, the acceptance test certifies that the delivered interface meets the goals of the designers and customers. These development processes and software tools are described more fully in Chapters 3 and 4.

BOX 1.1

Goals for requirements analysis.

1. Ascertain the users' needs.
2. Ensure proper reliability.
3. Promote appropriate standardization, integration, consistency, and portability.
4. Complete projects on schedule and within budget.

The business case for usability is strong and has been made repeatedly (Landauer, 1995; Norman, 2000; Bias and Mayhew, 2005). User-interface design success stories can also be managerial success stories, for projects that are on budget and on schedule. A thoroughly documented set of user needs clarifies the design process, and a carefully tested prototype generates fewer changes during implementation while avoiding costly updates after release. Thorough acceptance testing of the implementation produces robust interfaces that are aligned with user needs.

1.3 Usability Motivations

The enormous interest in interface usability arises from the growing recognition of the benefits well-designed interfaces bring to users. This increased motivation emanates from designers and managers of life-critical systems; industrial and commercial systems; home and entertainment applications; exploratory, creative, and collaborative interfaces; and sociotechnical systems.

1.3.1 Life-critical systems

Life-critical systems include those that control air traffic, nuclear reactors, power utilities, police or fire dispatch, military operations, and medical instruments. In these applications, high costs are expected, but they should yield high reliability and effectiveness. Lengthy training periods are acceptable to obtain rapid, error-free performance, even when the users are under stress. Subjective satisfaction is less of an issue because the users are well-motivated professionals. Retention is obtained by frequent use of common functions and practice sessions for emergency actions.

1.3.2 Industrial and commercial uses

Typical industrial and commercial uses include interfaces for banking, insurance, order entry, production management, airline and hotel reservations (Fig. 1.7), utility billing, and point-of-sales terminals. In these cases, costs shape many judgments. Operator training time is expensive, so ease of learning is important. Since many businesses are international, translation to multiple languages and adaptations to local cultures are necessary. The tradeoffs between speed of performance and error rates are governed by the total cost over the system's lifetime (see Chapter 10). Subjective satisfaction is of modest importance; retention is obtained by frequent use. Speed of performance is central for most of these applications because of the high volume of transactions, but operator fatigue, stress, and burnout are legitimate concerns. Trimming 10% off the mean transaction time could mean 10% fewer operators, 10% fewer workstations, and a 10% reduction in hardware costs.

1.3.3 Home and entertainment applications

The rapid expansion of home and entertainment applications is a further source of interest in usability. Personal-computing applications include e-mail clients, search engines, cellphones (Fig. 1.8), digital cameras, and music players. Entertainment applications have flourished, making computer games a larger industry than Hollywood, while novel game input devices like the Nintendo® Wii™ (Fig. 1.9) and *Guitar Hero*™'s simplified musical instrument (Fig. 1.10) open up entirely new possibilities in areas ranging from sports to education to rehabilitation. The social media applications include social networking (MySpace, Facebook), virtual environments (*Second Life*®, *EverQuest*®), and user-generated content (YouTube, Flickr). For these interfaces, ease of learning, low error rates, and subjective satisfaction are paramount because use is discretionary and competition is fierce. If the users cannot succeed quickly, they will give up or try a competing supplier.

Choosing the right functionality while keeping costs low is difficult. Novices are best served by a constrained, simple set of actions, but as users' experience increases, so does their desire for more extensive functionality and rapid performance. A layered or level-structured design is one approach to facilitating graceful evolution from novice to expert usage: Users can move up to higher layers when they need additional features or have time to learn them. A simple example is the design of search engines, which almost always have basic and advanced interfaces (see Chapter 13). Another approach to winning novice users is to carefully trim the features to make a simple device, such as the highly successful Blackberry or iPhone.

1.3.4 Exploratory, creative, and collaborative interfaces

An increasing fraction of computer use is dedicated to supporting human creativity. Exploratory applications include World Wide Web browsers and



FIGURE 1.9

The Nintendo Wii controller has been a huge success with sports games such as tennis or golf, character animation games such as *Mario*TM, and fitness software that helps with balance, stretching, muscle tone, etc.



FIGURE 1.10

Guitar Hero, a highly successful music playing game in which users learn to play popular songs and earn points for how well they keep up. The web site shows potential users how the provided special small guitar functions and how people use it; it also hosts a community for discussions and runs contests.

search engines (Figs. 1.11 to 1.13), scientific, and business team collaborations support. Creative applications include architectural design environments (Fig. 1.14), music-composition tools, and video-editing systems. Collaborative interfaces enable two or more people to work together (even if the users are separated by time and space) through use of text, voice, and video mail; through electronic meeting systems that facilitate face-to-face meetings; or through groupware that enables remote collaborators to work concurrently on a document, map, spreadsheet, or image.



FIGURE 1.11

The Yahoo! portal (<http://www.yahoo.com/>) gives users access to e-mail, weather, healthcare, banking, and personal photo services. It provides a search window (near top, center); 20 categories for browsing (left); plus news, shopping, and entertainment links.

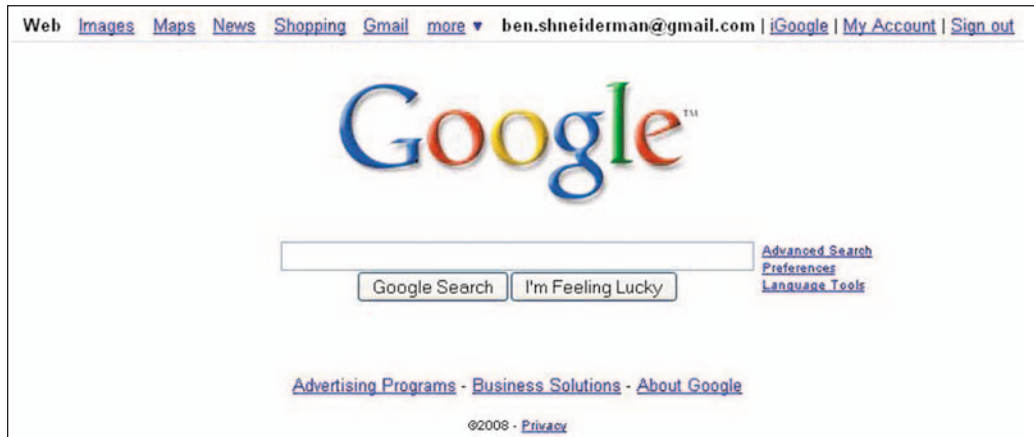


FIGURE 1.12A

The Google search engine (<http://www.google.com/>). This window shows the simple user interface for searching.

In these systems, the users may be knowledgeable in the task domains but novices in the underlying computer concepts. Their motivation is often high, but so are their expectations. Benchmark tasks are more difficult to describe because of the exploratory nature of these applications, and usage can range from occasional to frequent. In short, it is difficult to design and evaluate these systems. Designers can pursue the goal of having the computer “vanish” as users become completely absorbed in their task domains. This goal seems to be met most effectively when the computer provides a direct-manipulation representation of the world of action (see Chapter 5), supplemented by keyboard shortcuts. Then, tasks are carried out by rapid familiar selections or gestures, with immediate feedback and new sets of choices. Users can keep their focus on the task, with minimal distraction caused by operating the interface.

1.3.5 Sociotechnical systems

A growing domain for usability is in complex systems that involve many people over long time periods, such as systems for health support, identity verification, disaster response, and crime reporting. Interfaces for these systems, often created by governmental organizations, have to deal with trust, privacy, and responsibility, as well as limiting the harmful effects of malicious tampering, deception, and incorrect information. Users will want to know who to turn to when things go wrong, and maybe who to thank when things go right (Whitworth and de Moor, 2009).

Google **Advanced Search** [Advanced Search Tips](#) | [About Google](#)

search engine "human-computer interaction" visual OR graphic OR spatial filetype:ppt

Find web pages that have...

all these words:

this exact wording or phrase: [tip](#)

one or more of these words: OR OR [tip](#)

But don't show pages that have...

any of these unwanted words: [tip](#)

Need more tools?

Results per page:

Language:

File type:

Search within a site or domain:
(e.g. youtube.com, .edu)

[Date, usage rights, numeric range, and more](#)

Date: (how recent the page is)

[Usage rights:](#)

Where your keywords show up:

Region:

Numeric range: ..
(e.g. \$1500..\$3000)

[SafeSearch:](#) ☒ Off ☐ On

Advanced Search

Page-specific tools:

Find pages similar to the page: **Search**

Find pages that link to the page: **Search**

FIGURE 1.12B

This window shows the advanced user interface for searching, providing more ways to focus the search.

For example, in electronic voting systems (Herrnson et al., 2008) citizens need to have reassuring feedback that their votes were correctly recorded, possibly by having a printed receipt. In addition, government officials and professional observers from opposing parties need to have ways of verifying that the votes from each district and regional aggregations are correctly

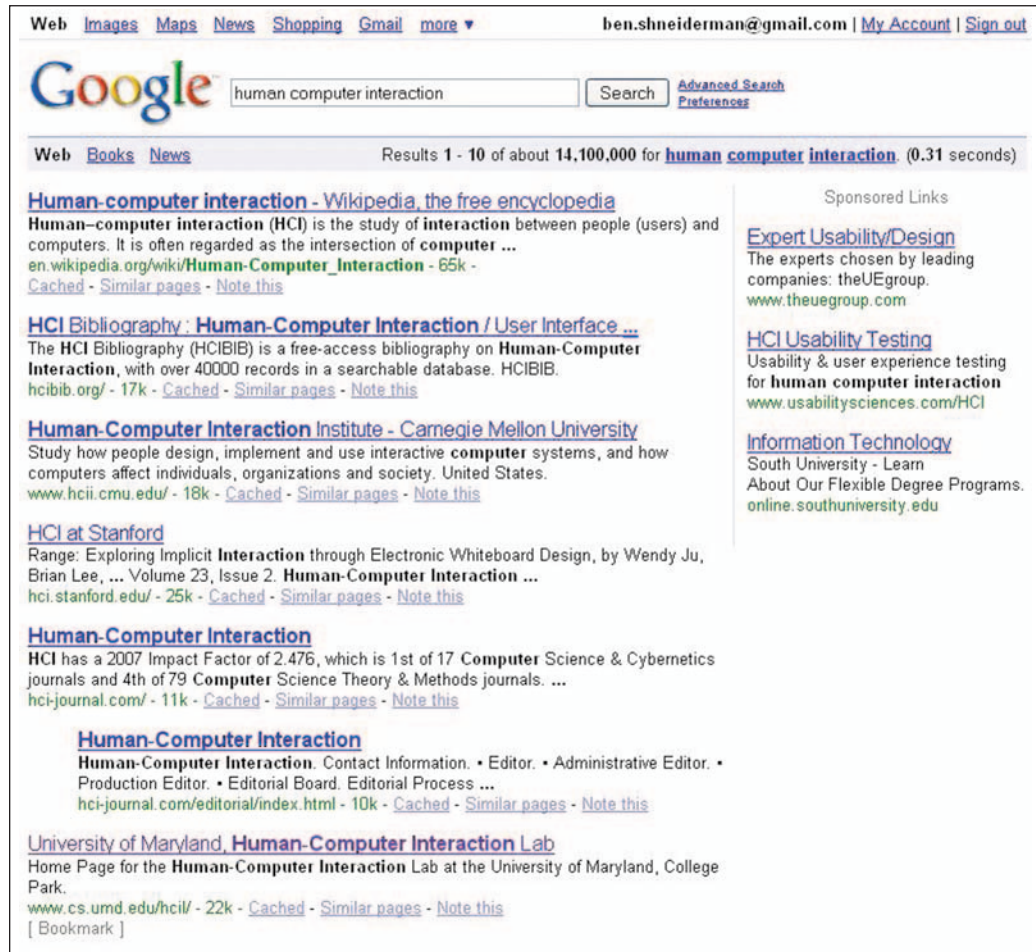
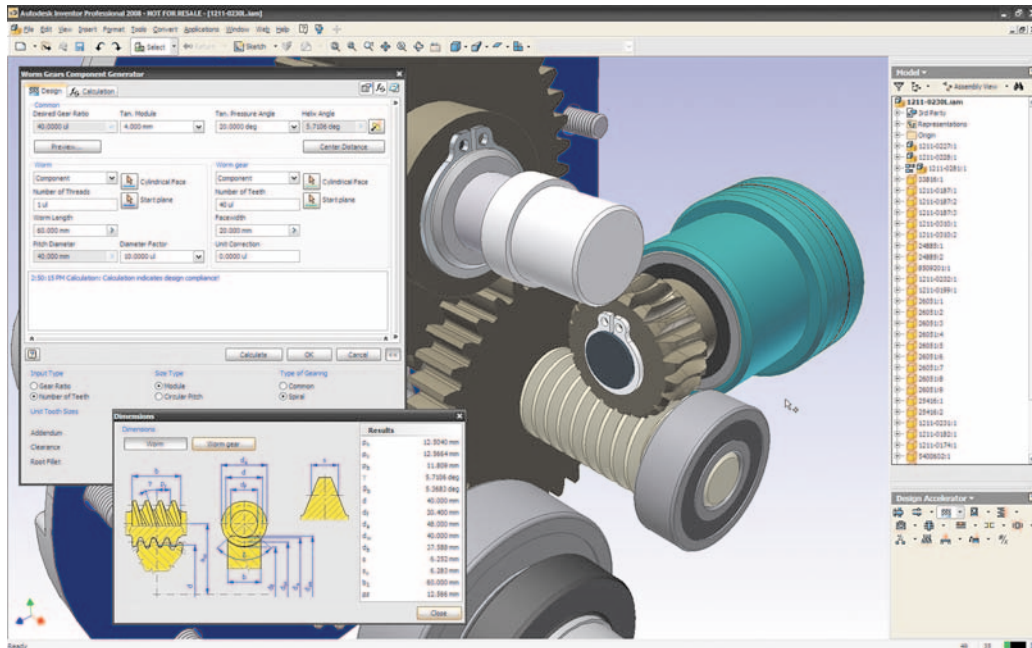


FIGURE 1.13

The Google search engine showing the results of a search on “human-computer interaction.”

reported. If complaints are registered, investigators need tools to review procedures at every stage.

Designers of sociotechnical systems have to take into consideration the diverse levels of expertise of users with different roles. Successful designs for the large number of novice and first-time users emphasize ease of learning and provide the feedback that builds trust. Designs for professional administrators and seasoned investigators enable rapid performance of complex procedures, perhaps with visualization tools to spot unusual patterns or detect fraud in usage logs.

**FIGURE 1.14**

Using Autodesk® Inventor®'s Design Accelerators for engineering tasks such as shaft design, gear design, and bearing selection, engineers at Stork Townsend, Inc. were able to create a custom gearbox with confidence that the unit would perform to expectations in a harsh environment. Shown here: The Worm Gear Component Generator is used to create matched sets of paired gears used in this gearbox design. All mating assembly constraints are automatically added, and an additional benefit to users is that this same interface is used for any edits to the gear pairs. (Courtesy of Autodesk and Stork Townsend, Inc.)

1.4 Universal Usability

The remarkable diversity of human abilities, backgrounds, motivations, personalities, cultures, and work styles challenges interface designers. A right-handed female designer in India with computer training and a desire for rapid interaction using densely packed screens may have a hard time designing a successful interface for left-handed male artists in France with a more leisurely and free-form work style. Understanding the physical, intellectual, and personality differences between users is vital for expanding market share, supporting required government services, and enabling creative participation by the broadest possible set of users. As a profession, we will be remembered for how well

we meet our users' needs. That's the ultimate goal: addressing the needs of all users (Shneiderman, 2000; Lazar, 2007).

The huge international consumer market in mobile devices, especially cellphones, is already raising the pressure for designs that are universally usable. While skeptics suggest that accommodating diversity requires dumbing-down or lowest-common-denominator strategies, our experience is that rethinking interface designs for differing situations often results in a better product for all users. Measures to accommodate the special needs of one group, such as curb cuts in sidewalks for wheelchair users, often have payoffs for many groups, such as parents with baby strollers, skateboard riders, travelers with wheeled luggage, and delivery people with handcarts. With this in mind, this section introduces the challenges posed by physical, cognitive, perceptual, personality, and cultural differences. It covers considerations for users with disabilities, older adults, and young users, ending with a discussion of hardware and software diversity. The important issues of different usage profiles (novice, intermittent, and expert), wide-ranging task profiles, and multiple interaction styles are covered in Section 2.3.3.

1.4.1 Variations in physical abilities and physical workplaces

Accommodating diverse human perceptual, cognitive, and motor abilities is a challenge to every designer. Fortunately, *ergonomics* researchers and practitioners have gained substantial experience from design projects with automobiles, aircraft, cellphones, and so on. This experience can be applied to the design of interactive computer systems and mobile devices.

Basic data about human dimensions comes from research in *anthropometry* (Dreyfuss, 1967; Pheasant, 1996). Thousands of measures of hundreds of features of people—male and female, young and adult, European and Asian, underweight and overweight, tall and short—provide data to construct 5- to 95-percentile design ranges. Head, mouth, nose, neck, shoulder, chest, arm, hand, finger, leg, and foot sizes have been carefully cataloged for a variety of populations. The great diversity in these static measures reminds us that there can be no image of an “average” user and that compromises must be made or multiple versions of a system must be constructed.

Cellphone keypad design parameters—distance between keys, size of keys, and required pressure (see Section 8.2)—evolved to accommodate differences in users' physical abilities. People with especially large or small hands may have difficulty using standard cellphones or keyboards, but a substantial fraction of the population is well served by one design. On the other hand, since screen-brightness preferences vary substantially, designers often enable users to control this parameter. Similarly, controls for chair seat and back heights and for display angles allow individual adjustment. When a single design

cannot accommodate a large fraction of the population, multiple versions or adjustment controls are helpful.

Physical measures of static human dimensions are not enough, though. Measures of dynamic actions—such as reach distance while seated, speed of finger presses, or strength of lifting—are also necessary (Bailey, 1996).

Since so much of work is related to perception, designers need to be aware of the ranges of human perceptual abilities, especially with regard to vision (Ware, 2004). For example, researchers consider human response time to varying visual stimuli or time to adapt to low or bright light. They examine human capacity to identify an object in context or to determine the velocity or direction of a moving point. The visual system responds differently to various colors, and some people are color-deficient, either permanently or temporarily (due to illness or medication). People's spectral range and sensitivity vary, and peripheral vision is quite different from the perception of images in the fovea (the central part of the retina). Designers need to study flicker, contrast, motion sensitivity, and depth perception, as well as the impact of glare and visual fatigue. Finally, designers must consider the needs of people who have eye disorders, damage, or disease, or who wear corrective lenses.

Other senses are also important: for example, touch for keyboard or touchscreen entry and hearing for audible cues, tones, and speech input or output (see Chapter 8). Pain, temperature sensitivity, taste, and smell are rarely used for input or output in interactive systems, but there is room for imaginative applications.

These physical abilities influence elements of the interactive-system design. They also play a prominent role in the design of the workplace or workstation (or playstation). The *Human Factors Engineering of Computer Workstations* standard (HFES, 2007) lists these concerns:

- Work-surface and display-support height
- Clearance under work surface for legs
- Work-surface width and depth
- Adjustability of heights and angles for chairs and work surfaces
- Posture—seating depth and angle, backrest height, and lumbar support
- Availability of armrests, footrests, and palmrests
- Use of chair casters

Workplace design is important in ensuring high job satisfaction, good performance, and low error rates. Incorrect table heights, uncomfortable chairs, or inadequate space to place documents can substantially impede work. The standards document also addresses such issues as illumination levels (200 to 500 lux); glare reduction (antiglare coatings, baffles, mesh, positioning); luminance

balance and flicker; equipment reflectivity; acoustic noise and vibration; air temperature, movement, and humidity; and equipment temperature.

The most elegant screen design can be compromised by a noisy environment, poor lighting, or a stuffy room, and that compromise will eventually lower performance, raise error rates, and discourage even motivated users. Thoughtful designs, such as workstations that provide wheelchair access and good lighting, will be even more appreciated by users with disabilities and older adults.

Another physical-environment consideration involves room layout and the sociology of human interaction. With multiple workstations in a classroom or office, different layouts can encourage or limit social interaction, cooperative work, and assistance with problems. Because users can often quickly help one another with minor problems, there may be an advantage to layouts that group several terminals close together or that enable supervisors or teachers to view all screens at once from behind. On the other hand, programmers, reservations clerks, or artists may appreciate the quiet and privacy of their own workspaces.

Mobile devices are increasingly being used while walking or driving and in public spaces, such as restaurants or trains where lighting, noise, movement, and vibration are part of the user experience. Designing for these more fluid environments presents opportunities for design researchers and entrepreneurs.

1.4.2 Diverse cognitive and perceptual abilities

A vital foundation for interactive-systems designers is an understanding of the cognitive and perceptual abilities of the users (Ashcraft, 2005). The journal *Ergonomics Abstracts* offers this classification of human cognitive processes:

- Short-term and working memory
- Long-term and semantic memory
- Problem solving and reasoning
- Decision making and risk assessment
- Language communication and comprehension
- Search, imagery, and sensory memory
- Learning, skill development, knowledge acquisition, and concept attainment

It also suggests this set of factors affecting perceptual and motor performance:

- Arousal and vigilance
- Fatigue and sleep deprivation

- Perceptual (mental) load
- Knowledge of results and feedback
- Monotony and boredom
- Sensory deprivation
- Nutrition and diet
- Fear, anxiety, mood, and emotion
- Drugs, smoking, and alcohol
- Physiological rhythms

These vital issues are not discussed in depth in this book, but they have a profound influence on the design of interactive systems. The term *intelligence* is not included in this list, because its nature is controversial and measuring pure intelligence is difficult.

In any application, background experience and knowledge in the task and interface domains play key roles in learning and performance. Task- or computer-skill inventories can be helpful in predicting performance.

1.4.3 Personality differences

Some people are eager to use computers, while others find them frustrating. Even people who enjoy using computers may have very different preferences for interaction styles, pace of interaction, graphics versus tabular presentations, dense versus sparse data presentation, and so on. A clear understanding of personality and cognitive styles can be helpful in designing interfaces for diverse communities of users.

One evident difference is between men and women, but no clear pattern of gender-related preferences in interfaces has been documented. While the majority of video-game players and designers are young males, some games (such as *The Sims*TM and *Guitar Hero*) draw ample numbers of female players. Designers can get into lively debates about why women prefer certain games, often speculating that women prefer less violent action and quieter soundtracks. Other conjectures are that women prefer social games, characters with appealing personalities, softer color patterns, and a sense of closure and completeness. Can these informal conjectures be converted to measurable criteria and then validated?

Turning from games to productivity tools, the largely male designers may not realize the effects on women users when command names require the users to KILL a process or ABORT a program. These and other potentially unfortunate mismatches between the user interface and the users might be avoided by more thoughtful attention to individual differences among users (Beckwith et al., 2006).

Unfortunately, there is no simple taxonomy of user personality types. A popular, but controversial, technique is to use the Myers-Briggs Type Indicator, or MBTI (Keirsey, 1998), which is based on Carl Jung's theories of personality types. Jung conjectured that there were four dichotomies:

- *Extroversion versus introversion.* Extroverts focus on external stimuli and like variety and action, whereas introverts prefer familiar patterns, rely on their inner ideas, and work alone contentedly.
- *Sensing versus intuition.* Sensing types are attracted to established routines, are good at precise work, and enjoy applying known skills, whereas intuitive types like solving new problems and discovering new relations but dislike taking time for precision.
- *Perceptive versus judging.* Perceptive types like to learn about new situations but may have trouble making decisions, whereas judging types like to make a careful plan and will seek to carry through the plan even if new facts change the goal.
- *Feeling versus thinking.* Feeling types are aware of other people's feelings, seek to please others, and relate well to most people, whereas thinking types are unemotional, may treat people impersonally, and like to put things in logical order.

The theory behind the MBTI provides portraits of the relationships between professions and personality types and between people of different personality types. It has been applied to testing user communities and has provided guidance for designers, but the linkage between personality types and interface features is weak.

Successors to the MBTI include the Big Five Test, based on the OCEAN model: Openness to Experience/Intellect (closed/open), Conscientiousness (disorganized/organized), Extraversion (introverted/extraverted), Agreeableness (disagreeable/agreeable), and Neuroticism (calm/nervous). There are hundreds of other psychological scales, including risk taking versus risk avoidance; internal versus external locus of control; reflective versus impulsive behavior; convergent versus divergent thinking; high versus low anxiety; tolerance for stress; tolerance for ambiguity, motivation, or compulsiveness; field dependence versus independence; assertive versus passive personality; and left- versus right-brain orientation. As designers explore computer applications for the home, education, art, music, and entertainment, they may benefit from paying greater attention to personality types.

Another approach to personality assessment is by studying user behavior. For example, some users file thousands of e-mails in a well-organized hierarchy of folders, while others keep them all in the inbox, using search strategies to find what they want later. These distinct approaches may well relate to personality variables, and for the designer, the message of dual requirements is clear.

1.4.4 Cultural and international diversity

Another perspective on individual differences has to do with cultural, ethnic, racial, or linguistic background (Fernandes, 1995; Marcus and Gould, 2000). Users who were raised learning to read Japanese or Chinese will scan a screen differently from users who were raised learning to read English or French. Users from reflective or traditional cultures may prefer interfaces with stable displays from which they select a single item, while users from action-oriented or novelty-based cultures may prefer animated screens and multiple clicks. Preferred content of web pages also varies; for example, university home pages in some cultures emphasize their impressive buildings and respected professors lecturing to students, while others highlight student team projects and a lively social life. Mobile device preferences also vary across cultures and have rapidly changing styles—for example, the thin and sharp-edged RAZR™ phone from Motorola® was a great success, but it then gave way to the rounded corners of iPhones and other competitors.

More and more is being learned about computer users from different cultures, but designers are still struggling to establish guidelines for designing for multiple languages and cultures. The growth of a worldwide computer market (many U.S. companies have more than half of their sales in overseas markets) means that designers must prepare for internationalization. Software architectures that facilitate customization of local versions of user interfaces offer a competitive advantage. For example, if all text (instructions, help, error messages, labels, and so on) is stored in files, versions in other languages can be generated with little or no additional programming. Hardware issues include character sets, keyboards, and special input devices. User-interface design concerns for internationalization include the following:

- Characters, numerals, special characters, and diacriticals
- Left-to-right versus right-to-left versus vertical input and reading
- Date and time formats
- Numeric and currency formats
- Weights and measures
- Telephone numbers and addresses
- Names and titles (Mr., Ms., Mme., M., Dr.)
- Social security, national identification, and passport numbers
- Capitalization and punctuation
- Sorting sequences
- Icons, buttons, and colors
- Pluralization, grammar, and spelling
- Etiquette, policies, tone, formality, and metaphors

The list is long and yet incomplete. Whereas early designers were often excused from cultural and linguistic slips, the current highly competitive atmosphere means that more effective localization may produce a strong advantage. To develop effective designs, companies run usability studies with users from different countries, cultures, and language communities.

The role of information technology in international development is steadily growing, but much needs to be done to accommodate the diverse needs of users with vastly different language skills and technology access. To promote international efforts to foster successful implementation of information technologies, representatives from around the world met for the 2003 and 2005 United Nations World Summit on the Information Society. They declared their

desire and commitment to build a people-centered, inclusive and development-oriented Information Society, where everyone can create, access, utilize and share information and knowledge, enabling individuals, communities and peoples to achieve their full potential in promoting their sustainable development and improving their quality of life, premised on the purposes and principles of the Charter of the United Nations and respecting fully and upholding the Universal Declaration of Human Rights.

The plan called for applications to be “accessible to all, affordable, adapted to local needs in languages and culture, and [to] support sustainable development.” The UN Millennium Development Goals, which are hoped to be achieved by 2015, include: eradicate extreme poverty and hunger; reduce child mortality; combat HIV/AIDS, malaria and other diseases; and ensure environmental sustainability. Information and communications technologies can play important roles in developing the infrastructure that is needed to achieve these goals.

1.4.5 Users with disabilities

The flexibility of desktop, web, and mobile devices makes it possible for designers to provide special services to users who have disabilities (Vanderheiden, 2000; Stephanidis, 2001; Horton, 2005; Thatcher et al., 2006). In the United States, the Amendment to Section 508 of the Rehabilitation Act requires federal agencies to ensure access to information technology, including computers and web sites, by employees and the public (<http://www.access-board.gov/508.htm>). The Access Board spells out the guidelines for vision-impaired, hearing-impaired, and mobility-impaired users; these include keyboard or mouse alternatives, color-coding, font-size settings, contrast settings, textual alternatives to images, and web features such as frames, links, and plug-ins. Similar legislation has stimulated activity in many countries, and tool developers have responded by making web-page authoring tools that guarantee compliance in most circumstances and web-page code checkers that provide feedback about needed changes.

Screen magnification to enlarge portions of a display and text-to-speech conversion can be done with hardware and software supplied by many vendors (Blenkhorn et al., 2003). Text-to-speech conversion can help blind users to receive e-mail or to read text files, and speech-recognition devices permit voice-controlled operation of some user interfaces. Graphical user interfaces were a setback for vision-impaired users, but technology innovations such as Freedom Scientific's JAWS®, GW Micro's Window-Eyes™, or Dolphin's Hal™ screen reader facilitate conversion of spatial information into spoken text (Thatcher et al., 2006). Similarly, IBM®'s Home Page Reader™ and Conversa®'s voice-enabled web browser enable access to web-based information and services. Speech generation and auditory interfaces are also appreciated by sighted users under difficult conditions, such as when driving an automobile, riding a bicycle, or working in bright sunshine.

Users with hearing impairments generally can use computers with only simple changes (conversion of tones to visual signals is often easy to accomplish) and can benefit from office environments that make heavy use of e-mail and facsimile (fax) transmissions. Telecommunications devices for the deaf (TDD or TTY) enable telephone access to information, such as train or airplane schedules, and services (federal agencies and many companies offer TDD or TTY access). Numerous special input devices for users with physical disabilities are available, depending on the specific impairment; speech recognition and eye-gaze control devices, head-mounted optical mice, and many other innovative devices (even the telephone) were pioneered for the needs of disabled users (see Chapter 8).

Designers can benefit by planning early to accommodate users who have disabilities, since at this point substantial improvements can be made at low or no cost. For example, moving the on/off switch to the front of a computer adds a minimal charge, if any, to the cost of manufacturing, but it improves ease of use for all users, and especially for the mobility-impaired. Other examples are the addition of closed captions to television programs for deaf viewers, which can be useful for hearing viewers as well, and the use of ALT tags to describe web graphics for blind users, which improves search capabilities for all users.

The motivation to accommodate users who have visual, auditory, and motor disabilities has increased since the enactment of U.S. Public Laws 99-506 and 100-542, which require U.S. government agencies to establish accessible information environments for employees and citizens. Any company wishing to sell products to the U.S. government should adhere to these requirements. Further information about accommodation in workplaces, schools, and the home is available from many sources:

- Private foundations (e.g., the American Foundation for the Blind and the National Federation of the Blind)
- Associations (e.g., the Alexander Graham Bell Association for the Deaf, the National Association for the Deaf, and the Blind Veterans Association)

- Government agencies (e.g., the National Library Service for the Blind and Physically Handicapped of the Library of Congress and the Center for Technology in Human Disabilities at the Maryland Rehabilitation Center)
- University groups (e.g., the TRACE Research and Development Center at the University of Wisconsin, Web Accessibility in Mind at Utah State University, and the Web Accessibility Initiative at MIT)
- Manufacturers (e.g., Apple, IBM, Microsoft, and Sun Microsystems™)

The potential for benefit to people with disabilities is one of the gifts of computing; it brings dividends in the increased capacity for learning, gainful employment, social participation, and community contribution. In addition, many users are temporarily disabled: they may forget their glasses, be unable to read while driving, or struggle to hear in a noisy environment. The University of Wisconsin's TRACE Center and Utah State University's Web Accessibility in Mind (WebAIM) organization have web sites that provide guidelines and resources for designers who are addressing universal usability. WebAIM covers cognitive disabilities, such as memory loss, dementia, aphasia, and attention disorders, as well as reading, linguistic, and visual comprehension difficulties. It offers specific guidance to designers, such as ways to clearly structure sequences of operations, highlight key information, and make the structure explicit. The Web Accessibility Initiative at MIT's World Wide Web Consortium produces consensus guidelines and tools to help developers promote web accessibility.

Improving designs for users with disabilities is an international concern. The United Nations Enable web site (<http://www.un.org/disabilities/>) promotes awareness, while country-specific web sites, such as AccessiWeb in France (<http://www.accessiweb.org/>), describe legal requirements and language-specific software tools.

1.4.6 Older adult users

Seniority offers many pleasures and all the benefits of experience, but aging can also have negative physical, cognitive, and social consequences. Understanding the human factors of aging can help designers to create user interfaces that facilitate access by older adult users. The benefits to senior citizens include improved chances for productive employment and opportunities to use writing, e-mail, and other computer tools, plus the satisfactions of education, entertainment, social interaction, and challenge (Furlong and Kearsley, 1990; Hart et al., 2008). Older adults are particularly active participants in health support groups (Xie, 2008). The benefits to society include increased access to seniors, which is valuable for their experience and the emotional support they can provide to others.

The National Research Council's report *Human Factors Research Needs for an Aging Population* describes aging as

a nonuniform set of progressive changes in physiological and psychological functioning. . . . Average visual and auditory acuity decline considerably with age, as do average strength and speed of response. . . . [People experience] loss of at least some kinds of memory function, declines in perceptual flexibility, slowing of "stimulus encoding," and increased difficulty in the acquisition of complex mental skills, . . . visual functions such as static visual acuity, dark adaptation, accommodation, contrast sensitivity, and peripheral vision decline, on average, with age. (Czaja, 1990)

This list has its discouraging side, but many people experience only moderate effects and continue participating in many activities, even throughout their nineties.

The further good news is that interface designers can do much to accommodate older adult users and, thus, to give older adults access to the beneficial aspects of computing and network communication. How many young people's lives might be enriched by e-mail access to grandparents or great-grandparents? How many businesses might benefit from electronic consultations with experienced senior citizens? How many government agencies, universities, medical centers, or law firms could advance their goals from easily available contact with knowledgeable, older adult citizens? As a society, how might we all benefit from the continued creative work of senior citizens in literature, art, music, science, or philosophy?

As the world's population ages, designers in many fields are adapting their work to serve older adults. Baby boomers have already begun to push for larger street signs, brighter traffic lights, and better nighttime lighting to make driving safer for drivers and pedestrians. Similarly, desktop, web, and mobile devices can be improved for all users by providing users with control over font sizes, display contrast, and audio levels. Interfaces can also be designed with easier-to-use pointing devices, clearer navigation paths, consistent layouts, and simpler command languages to improve access for older adults and every user (Czaja and Lee, 2002; Hart et al., 2008). Researchers and designers are beginning to work on improving interfaces to golden-age software (Czaja et al., 2006). Let's do it *before* Bill Gates turns 65! In the United States, the AARP's Older Wiser Wired initiatives provide education for older adults and guidance for designers. The European Union also has multiple initiatives and research support for computing for older adults.

Networking projects, such as the San Francisco-based SeniorNet, are providing adults over the age of 50 with access to and education about computing and the Internet "to enhance their lives and enable them to share their knowledge and wisdom" (<http://www.seniornet.org/>). Computer games are attractive for older adults, as shown by the surprising success of Nintendo's Wii, because they

stimulate social interaction, provide practice in sensorimotor skills such as eye-to-hand coordination, enhance dexterity, and improve reaction time. In addition, meeting a challenge and gaining a sense of accomplishment and mastery are helpful in improving self-image for anyone.

In our experiences in bringing computing to two residences for older adults, we also encountered residents' fear of computers and belief that they were incapable of using computers. These fears gave way quickly after a few positive experiences. The older adults, who explored e-mail, photo sharing, and educational games, felt quite satisfied with themselves and were eager to learn more. Their newfound enthusiasm encouraged them to try automated bank machines and supermarket touchscreen kiosks. Suggestions for redesigns to meet the needs of older adults (and possibly other users) also emerged—for example, the appeal of high-precision touchscreens compared with the mouse was highlighted (see Chapter 8).

In summary, making computing more attractive and accessible to older adults enables them to take advantage of technology and enables others to benefit from their participation. For more information on this topic, check out the Human Factors & Ergonomics Society, which has an Aging Technical Group that publishes a newsletter and organizes sessions at conferences.

1.4.7 Children

Another lively community of users is children, whose uses emphasize entertainment and education. Even pre-readers can use computer-controlled toys, music generators, and art tools (Fig. 1.15). As they mature, begin reading, and gain limited keyboard skills, they can use a wider array of desktop applications, web services, and mobile devices. When they become teenagers, they may become highly proficient users who often help their parents or other adults. This idealized growth path is followed by many children who have easy access to technology and supportive parents and peers. However, many children without financial resources or supportive learning environments struggle to gain access to technology. They are often frustrated with its use and are endangered by threats surrounding privacy, alienation, pornography, unhelpful peers, and malevolent strangers.

The noble aspirations of designers of children's software include educational acceleration, facilitating socialization with peers, and fostering the self-confidence that comes from skill mastery. Advocates of educational games promote intrinsic motivation and constructive activities as goals, but opponents often complain about the harmful effects of antisocial and violent games.

For teenagers, the opportunities for empowerment are substantial. They often take the lead in employing new modes of communication, such as instant messaging and text messaging on cellphones, and in creating cultural or fashion trends that surprise even the designers (for example, playing with simulations and fantasy games and participating in web-based virtual worlds).

**FIGURE 1.15**

Two children using an educational package (LeapFrog®'s Tag™ Reading Basics) that has books and a pen that children can use for learning to read, learning letter sounds, and playing games (<http://www.leapfrog.com>).

Appropriate design principles for children's software recognize young people's intense desire for the kind of interactive engagement that gives them control with appropriate feedback and supports their social engagement with peers (Druin and Inkpen, 2001; Bruckman et al., 2007). Designers also have to find the balance between children's desire for challenge and parents' requirements for safety. Children can deal with some frustrations and with threatening stories, but they also want to know that they can clear the screen, start over, and try again without severe penalties. They don't easily tolerate patronizing comments or inappropriate humor, but they like familiar characters, exploratory environments, and the capacity for repetition. Younger children will sometimes replay a game, reread a story, or replay a music sequence dozens of times, even after adults have tired of it. Some designers work by observing children and testing software with children, while the innovative approach of "children as our technology-design partners" engages them in a long-term process of cooperative inquiry during which children and adults jointly design novel products and services. A notable successful product of working with children as design partners is the International Children's Digital Library (Fig. 1.16), which offers 2500+ of the world's best children's books in 40+ languages using an interface in 15 languages while supporting low- and high-speed networks (Druin et al., 2007).

Designing for younger children requires attention to their limitations. Their evolving dexterity means that mouse dragging, double-clicking, and small targets cannot always be used; their emerging literacy means that written instructions and error messages are not effective; and their low capacity for abstraction



FIGURE 1.16

Children using the International Children’s Digital Library on the XO device from the One Laptop Per Child project. Courtesy of International Children’s Digital Library Foundation (<http://www.childrenslibrary.org/>).

means that complex sequences must be avoided unless an adult is involved. Other concerns are short attention spans and limited capacity to work with multiple concepts simultaneously. Designers of children’s software also have a responsibility to attend to dangers, especially in web-based environments, where parental control over access to violent, racist, or pornographic materials is unfortunately necessary. Appropriate information for the education of children about privacy issues and threats from strangers is also a requirement.

The capacity for playful creativity in art, music, and writing and the value of educational activities in science and math remain potent reasons to pursue children’s software. Enabling them to make high-quality images, photos, songs, or poems and then share them with friends and family can accelerate children’s personal and social development. Offering access to educational materials from libraries, museums, government agencies, schools, and commercial sources enriches their learning experiences and serves as a basis for children to construct their own web resources, participate in collaborative efforts, and contribute to

community-service projects. Providing programming and simulation-building tools enables older children to take on complex cognitive challenges and construct ambitious artifacts for others to use. These and other opportunities have motivated efforts (such as One Laptop Per Child) to bring low-cost computers to children around the world—hopefully coupled with rich content, parental guidance materials, and effective teacher training.

1.4.8 Accommodating hardware and software diversity

In addition to accommodating different classes of users and skill levels, designers need to support a wide range of hardware and software platforms. The rapid progress of technology means that newer systems may have a hundred or a thousand times greater storage capacity, faster processors, and higher-bandwidth networks. However, designers need to accommodate older devices and deal with newer mobile devices that may have low-bandwidth connections and small screens.

The challenge of accommodating diverse hardware is coupled with the need to ensure access through many generations of software. New operating systems, web browsers, e-mail clients, and application programs should provide backward compatibility in terms of their user-interface design and file structures. Skeptics will say that this requirement can slow innovation, but designers who plan ahead carefully to support flexible interfaces and self-defining files will be rewarded with larger market shares (Shneiderman, 2000).

For at least the next decade, three of the main technical challenges will be:

- *Producing satisfying and effective Internet interaction on high-speed (broadband) and slower (dial-up and some wireless) connections.* Some technological breakthroughs have already been made in compression algorithms to reduce file sizes for images, music, animations, and even video, but more are needed. New technologies are needed to enable pre-fetching or scheduled downloads. User control of the amount of material downloaded for each request could also prove beneficial (for example, allowing users to specify that a large image should be reduced to a smaller size, sent with fewer colors, converted to a simplified line drawing, replaced with just a text description, or downloaded at night when Internet charges are lower).
- *Enabling access to web services from large displays (1200 × 1600 pixels or larger) and smaller mobile devices (640 × 480 and smaller).* Rewriting each web page for different display sizes may produce the best quality, but this approach is probably too costly and time-consuming for most web providers. New software-tool breakthroughs are needed to allow web-site designers to specify their content in a way that enables automatic conversions for an increasing range of display sizes.
- *Supporting easy maintenance of or automatic conversion to multiple languages.* Commercial operators recognize that they can expand their markets if they can

provide access in multiple languages and across multiple countries. This means isolating text to allow easy substitution, choosing appropriate metaphors and colors, and addressing the needs of diverse cultures (see Section 1.4.4).

The good news is that rethinking designs to accommodate these diverse needs can improve the quality for all users. As for costs, with appropriate software tools, e-commerce providers are finding that a small additional effort can expand markets by 20% or more.

1.5 Goals for Our Profession

Clear goals are useful not only for interface development but also for educational and professional enterprises. Three broad goals seem attainable: (1) influencing academic and industrial researchers; (2) providing tools, techniques, and knowledge for commercial designers; and (3) raising the computer consciousness of the general public.

1.5.1 Influencing academic and industrial researchers

Early research in human-computer interaction was done largely by introspection and intuition, but this approach suffered from a lack of validity, generality, and precision. The techniques of psychologically oriented, controlled experimentation can lead to a deeper understanding of the fundamental principles of human interaction with computers. The scientific method for interface research, which is based on controlled experimentation, has this basic outline:

- Understanding of a practical problem and related theory
- Lucid statement of a testable hypothesis
- Manipulation of a small number of independent variables
- Measurement of specific dependent variables
- Careful selection and assignment of subjects
- Control for bias in subjects, procedures, and materials
- Application of statistical tests
- Interpretation of results, refinement of theory, and guidance for experimenters

Materials and methods must be tested by pilot experiments, and results must be validated by replication in various situations.

Of course, the scientific method based on controlled experimentation has its weaknesses. It may be difficult or expensive to find adequate subjects, and laboratory conditions may distort the situation so much that the conclusions

have no application. Controlled experiments typically deal with short-term usage, so understanding long-term consumer behavior or experienced user strategies is difficult. Since controlled experiments emphasize statistical aggregation, extremely good or poor performance by individuals may be overlooked. Furthermore, anecdotal evidence or individual insights may be given too little emphasis because of the authoritative influence of statistics.

Because of these concerns, controlled experimentation is balanced by ethnographic observation methods. Anecdotal experiences and subjective reactions are recorded, thinking aloud or protocol approaches are employed, and field or case studies can be carried out. Other research methods include automated logging of user behavior, surveys, focus groups, and interviews.

Within computer science, there is a growing awareness of the need for greater attention to usability issues. Courses on human-computer interaction are required for some undergraduate degrees, and interface-design issues are being added to many courses. Researchers who propose new programming languages, privacy-protection schemes, or network services are more aware of the need to match human cognitive skills. Designers of advanced graphics systems, agile manufacturing equipment, or consumer products increasingly recognize that the success of their proposals depends on the construction of a suitable human interface.

There is a grand opportunity to apply the knowledge and techniques of traditional psychology (and of subfields such as cognitive psychology) to the study of human-computer interaction. Psychologists are investigating human problem solving and creativity with computers to gain an understanding of cognitive processes. The benefit to psychology is great, but psychologists also have a golden opportunity to dramatically influence an important and widely used technology.

Researchers in information science, business and management, education, sociology, anthropology, and other disciplines are benefiting from and contributing to the study of human-computer interaction. There are so many fruitful directions for research that any list can be a provocative starting point. Here are a few:

- *Reduced anxiety and fear of computer usage.* Although computers are widely used, some otherwise competent people resist using e-mail and engaging in e-commerce because they are anxious about—or even fearful of—breaking the computer, making an embarrassing mistake, or having their privacy violated. Fear of scams and frustration with e-mail spam could also be reduced by improved designs that promote security and privacy while increasing the users' control over their experiences.
- *Graceful evolution.* Although novices may begin their interactions with a computer by using just a few features, they may later wish to move up to more powerful facilities. Refined multi-layer interface designs and training materials are needed to smooth the transition from novice to knowledgeable user to expert. The differing requirements of novices and experts in terms of prompting, error messages, online assistance, display complexity, locus of control,

pacing, and informative feedback all need investigation. Users may be allowed to customize their interfaces far beyond changing backgrounds and ring tones, but methods for guiding users through such a process are an open topic.

- *Social media participation.* The recent remarkable spread of social media and social networking is just an early indicator of larger changes to come. Enabling web-based sharing of user-generated content, especially from mobile devices, is just beginning; much work remains to be done in raising the quality of what is produced, enabling effective annotations, making these materials accessible, and facilitating reuse in ways that protect users' desires for privacy or profit.
- *Input devices.* The plethora of input devices presents opportunities and challenges to interface designers (see Chapter 5). There are heated discussions about the relative merits of multi-touch screens; voice, eye-gaze, and gestural input; and haptic devices. Such conflicts could be resolved through experimentation with multiple tasks and users. Underlying issues include speed, accuracy, fatigue, error correction, and subjective satisfaction.
- *Online help.* Although many interfaces offer help text and video tutorials online, we have only limited understanding of what constitutes effective instruction for novices, knowledgeable users, and experts (see Chapter 12). The role of these aids and of online user communities could be studied to assess user success and satisfaction, even on the small screens found on mobile devices.
- *Information exploration.* As navigation, browsing, and searching in multimedia digital libraries and the World Wide Web become more common, the pressure for more effective strategies and tools will increase (see Chapter 13). Users will want to filter, select, and restructure their information rapidly with minimum effort and without fear of getting lost or finding misleading information. Large databases of text, images, graphics, sound, and scientific data will become easier to explore with emerging information-visualization and visual analytic tools.

1.5.2 Providing tools, techniques, and knowledge for commercial designers

User-interface design and development are hot topics, and international competition is lively. Employers who used to see usability as a secondary topic are increasingly hiring user-interface designers, information architects, user-interface implementers, and usability testers. These employers recognize the competitive advantage from high-quality consumer interfaces and from improving the performance of their employees. There is a great thirst for knowledge about software tools, design guidelines, and testing techniques. User-interface-building tools provide support for rapid prototyping and interface development while aiding design consistency, supporting universal usability, and simplifying evolutionary refinement.

Guidelines documents have been written for general and specific audiences (see the list at end of this chapter). Many projects are taking the productive route of writing their own guidelines, which are tied to the problems of their application environments. These guidelines are constructed from experimental results, experience with existing interfaces, and knowledgeable guesswork.

Iterative usability studies and acceptance testing are appropriate during interface development. Once the initial interface is available, refinements can be made on the basis of online or printed surveys, individual or group interviews, or more controlled empirical tests of novel strategies (see Chapter 4).

Feedback from users during the development process and for evolutionary refinement can provide useful insights and guidance. E-mail facilities allow users to send comments directly to the designers. Online user consultants and fellow users can provide prompt assistance and supportive encouragement.

1.5.3 Raising the computer consciousness of the general public

The media are so filled with stories about computers that raising public consciousness of these tools may seem unnecessary. However, many people are still uncomfortable with computers. When they do finally use a bank machine, a cell phone, or e-mail, they may feel fearful of making mistakes, anxious about damaging the equipment, worried about feeling incompetent, or threatened by the computer “being smarter than I am.” These fears are generated, in part, by poor designs that have complex commands, hostile and vague error messages, tortuous and unfamiliar sequences of actions, or a deceptive anthropomorphic style.

One of our goals is to encourage users to translate their internal fears into outraged action (Shneiderman, 2002). Instead of feeling guilty when they get a message such as SYNTAX ERROR, users should express their anger at the interface designer who was so inconsiderate and thoughtless. Instead of feeling inadequate or foolish because they cannot remember a complex sequence of actions, they should complain to the designer who did not provide a more convenient mechanism or should seek another product that does.

Usability ultimately becomes a question of national priorities. Advocates of electronic voting and other services, promoters of e-healthcare, and visionaries of e-learning increasingly recognize the need to influence allocation of government resources and commercial research agendas. Policymakers and industry leaders become heroes when they facilitate access and promote quality, but they become villains when failures threaten children, disrupt travel, or menace consumers.

As examples of successful and satisfying interfaces become more visible, the crude designs will begin to appear archaic and will become commercial failures. As designers improve interactive systems, some users' fears will recede, and the positive experiences of their competence, mastery, and satisfaction will flow in. Then, the images of computer scientists and interface designers will change in

the public's view: The machine-oriented and technical image will give way to one of personal warmth, sensitivity, and concern for the users.

Practitioner's Summary

If you are designing an interactive system, thorough user and task analyses can provide the information for a proper functional design. A positive outcome is more likely if you pay attention to reliability, availability, security, integrity, standardization, portability, integration, and the administrative issues of schedules and budgets. As design alternatives are proposed, they can be evaluated for their role in providing short learning times, rapid task performance, low error rates, ease of retention, and high user satisfaction. Designs that accommodate the needs of children, older adults, and users with disabilities can improve the quality for all users. As your design is refined and implemented, evaluation by pilot studies, expert reviews, usability tests, user observations, and acceptance tests can accelerate improvement. Success in product development is increasingly being measured in terms of hard evidence that universal usability is being attained, (rather than testimonials from a few enthusiastic users). The rapidly proliferating literature and sets of evidence-based guidelines may be of assistance in designing your project while accommodating the increasingly diverse and growing community of users.

Researcher's Agenda

The criteria for success in research favor innovations that work for broad communities of users performing useful tasks over longer time periods. At the same time, researchers are struggling to understand what kinds of imaginative consumer products will attract, engage, and satisfy diverse populations. The opportunities for researchers are unlimited. There are so many interesting, important, and doable projects that it may be hard to choose a direction. The goal of universal usability through plasticity of interface designs will keep researchers busy for years. Getting past vague promises and measuring user performance with alternate interfaces will be central to rapid progress. Each experiment has two parents: the practical problems facing designers, and the fundamental theories based on principles of human behavior and interface design. Begin by proposing a lucid, testable hypothesis. Then consider the appropriate research methodology, conduct the experiment, collect the data, and analyze the results. Each experiment also has three children: specific recommendations for the practical problem, refinements of theories, and guidance for future experimenters. Each chapter of this book ends with specific research proposals.

WORLD WIDE WEB RESOURCES

<http://www.aw.com/DTUI/>

This book is accompanied by a web site (<http://www.aw.com/DTUI/>) that includes pointers to additional resources tied to the contents of each chapter. In addition, this web site contains information for instructors, students, practitioners, and researchers. The links for Chapter 1 include pointers to general resources on human-computer interaction, such as professional societies, government agencies, companies, bibliographies, and guideline documents.

Readers seeking references to scientific journals and conferences can consult the online searchable bibliography for human-computer interaction (<http://www.hcibib.org/>). Built under the heroic leadership of Gary Perlman, it makes available more than 40,000 journal, conference, and book abstracts, plus link collections on many topics, including consulting companies, history, and international development.

Some wonderful World Wide Web resources are:

1. The HCI Index (<http://degraaff.org/hci/>)
2. Diamond Bullet Design (<http://www.usabilityfirst.com/>)
3. Usability.gov, a great resource on usability methods and guidelines for the U.S. government (<http://www.usability.gov/>)
4. IBM's extensive guide to user-centered design methods (<https://www-306.ibm.com/software/ucd/>)

E-mail lists for announcements and discussion lists are maintained by ACM SIGCHI (<http://www.acm.org/sigchi/>) and by the British HCI Group (<http://www.bcs-hci.org.uk/>), which also sponsors the frequently updated Usability News (<http://www.usabilitynews.com/>).

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Specialized references for this chapter appear here; general information resources are listed in the following section.

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General information resources

Primary journals include the following:

ACM interactions: A Magazine for User Interface Designers, ACM Press, New York
ACM Transactions on Accessible Computing, ACM Press, New York
ACM Transactions on Computer-Human Interaction, ACM Press, New York
AIS Transactions on Human-Computer Interaction, AIS, Atlanta, GA
Behaviour & Information Technology (BIT), Taylor & Francis Ltd., London, U.K.
Computer Supported Cooperative Work, Springer, Berlin, Germany
Human-Computer Interaction, Taylor & Francis Ltd., London, U.K.
Information Visualization, Palgrave Macmillan, Houndmills, Basingstoke, U.K.
Interacting with Computers, Butterworth Heinemann Ltd., Oxford, U.K.
International Journal of Human-Computer Interaction, Taylor & Francis Ltd., London, U.K.
International Journal of Human-Computer Studies, Academic Press, London, U.K.
Journal of Organizational Computing and Electronic Commerce, Taylor & Francis Ltd., London, U.K.
Journal of Usability Studies, Usability Professionals Assn., Bloomington, IL
New Review of Hypermedia and Multimedia, Taylor & Francis Ltd., London, U.K.
Universal Access in the Information Society, Springer, Berlin, Germany

Other journals that regularly carry articles of interest include:

ACM: Communications of the ACM (CACM)
ACM Computers in Entertainment
ACM Computing Surveys
ACM Transactions on Graphics
ACM Transactions on Information Systems
AIS: Communications of the Association for Information Systems
Cognitive Science
Computers in Human Behavior
Ergonomics
Human Factors (HF)
IEEE Computer
IEEE Computer Graphics and Applications
IEEE Multimedia
IEEE Software
IEEE Transactions on Systems, Man, and Cybernetics (IEEE SMC)
Journal of Computer-Mediated Communication, Wiley Interscience Publishers, Malden, MA.
Journal of Visual Languages and Computing
Personal and Ubiquitous Computing
Presence
Technical Communication

UMUIAI: User Modeling and User-Adapted Interaction
World Wide Web: Internet and Web Information Systems

The Association for Computing Machinery (ACM) has a Special Interest Group on Computer & Human Interaction (SIGCHI), which publishes a newsletter and holds regularly scheduled conferences. ACM also publishes the highly regarded *Transactions on Human-Computer Interaction* and the lively magazine *interactions*. Other ACM Special Interest Groups, such as Graphics and Interactive Techniques (SIGGRAPH), Accessible Computing (SIGACCESS), Multimedia (SIGMM), and Hypertext, Hypermedia, and Web (SIGWEB), also produce conferences and newsletters. Other relevant ACM groups are Computers and Society (SIGCAS), Design of Communication (SIGDOC), Groupware (SIGGROUP), Information Retrieval (SIGIR), and Mobility of Systems, Users, Data, and Computing (SIGMOBILE).

The IEEE Computer Society, through its many conferences, transactions, and magazines, covers user-interface issues. The American Society for Information Science & Technology (ASIST) has a Special Interest Group on Human-Computer Interaction (SIGHCI) that publishes a newsletter and organizes sessions at the annual ASIST convention. Similarly, the business-oriented Association for Information Systems (AIS) has a SIGHCI that publishes a newsletter and a journal and runs sessions at several conferences. The long-established Human Factors & Ergonomics Society also runs annual conferences and has a Computer Systems Technical Group with a newsletter. Additionally, the Society for Technical Communications (STC), the American Institute of Graphic Arts (AIGA), the International Ergonomics Association, and the Ergonomics Society increasingly focus on user interfaces. The influential business-oriented Usability Professionals Association (UPA) publishes the *UX - User Experience* magazine and the online *Journal of Usability Studies*. The UPA also spawned the annual World Usability Day with hundreds of events around the world each November.

The International Federation for Information Processing has a Technical Committee (TC.13) and Working Groups on Human-Computer Interaction. The British Computer Society Human-Computer Interaction Group and the French Association Francophone pour l'Interaction Homme-Machine (AFIHM) promote development within their countries. Other national and regional groups conduct events in South Africa, Australia/New Zealand, Scandinavia, Asia, and Latin America.

Conferences—such as the ones held by the ACM (especially SIGCHI and SIGGRAPH), IEEE, ASIST, Human Factors & Ergonomics Society, and IFIP—often have relevant papers presented and published in the proceedings. INTERACT, Human-Computer Interaction International, and Work with Computing Systems are conference series that cover user-interface issues broadly. Many specialized conferences may also be of interest: for example, User Interfaces Software and Technology, Hypertext, Computer-Supported Cooperative Work, Intelligent User Interfaces, Computers and Accessibility, Ubiquitous Computing, Wearable, Computers and Cognition, Designing Interactive Systems, and more.

Brad Myers's brief history of HCI (ACM *interactions*, March 1998) is one starting point for those who want to study the emergence and evolution of this field. James Martin provided a thoughtful and useful survey of interactive systems in his 1973 book, *Design of Man-Computer Dialogues*. Ben Shneiderman's 1980 book, *Software Psychology: Human Factors in Computer and Information Systems*, promoted the use of controlled experimental techniques and scientific research methods. Rubinstein and Hershey's *The Human Factor: Designing Computer Systems for People* (1984) offered an appealing introduction to

computer-system design and many useful guidelines. The first edition of this book, published in 1987, reviewed critical issues, offered guidelines for designers, and suggested research directions.

A steady flow of influential books have stimulated widespread media and public attention about usability issues, including Nielsen's *Usability Engineering* (1993), Landauer's *The Trouble with Computers* (1995), and Nielsen's *Designing Web Usability* (1999). Don Norman's 1988 book *The Psychology of Everyday Things* (reprinted as *The Design of Everyday Things*) is a refreshing look at the psychological issues involved in the design of the everyday technology that surrounds us.

As the field matures, subgroups and publications centered around specialized topics emerge; this is happening with mobile computing, web design, online communities, information visualization, virtual environments, and so on. The following list of guidelines documents and books is a starting point to an exploration of the large and growing literature.

Guidelines documents

Apple Computer, Inc., *Apple Human Interface Guidelines*, Apple, Cupertino, CA (June 2008). Available at <http://developer.apple.com/>.

—Explains how to design consistent visual and behavioral properties for Mac OS X with the Aqua user interface.

Apple Computer, Inc., *iPhone Human Interface Guidelines for Web Applications* (2008). Available at <http://developer.apple.com>.

—Explains how to design applications for the iPhone mobile web platform.

Dept. of Defense, *Human Engineering Design Criteria for Military Systems, Equipment and Facilities*, Military Standard MIL-STD-1472F, U.S. Government Printing Office, Washington, DC (1999).

—Covers traditional ergonomic and anthropometric issues. Later editions pay increasing attention to user-computer interfaces. Interesting and thought-provoking reminder of many human-factors issues.

Federal Aviation Administration, *The Human Factors Design Standard*, Atlantic City, NJ (updated July 2007). Available at <http://hf.tc.faa.gov/hfds/>.

—Extensive compilation of human-factors standards for contractors to follow, especially relevant to aircraft and air-traffic control.

Human Factors & Ergonomics Society, *ANSI/HFES 100-2007 Human Factors Engineering of Computer Workstations*, Santa Monica, CA (2007).

—Carefully considered revised standards for the design, installation, and use of computer workstations. Emphasizes ergonomics and anthropometrics.

International Organization for Standardization, *ISO 9241 Ergonomics of Human-System Interaction*, Geneva, Switzerland (updated 2008). Available at <http://www.iso.org/>.

—Thorough general introduction, covering dialog principles, guidance on usability, presentation of information, user guidance, menu dialogs, command dialogs, direct-manipulation dialogs, form-filling dialogs, and much more. This is an important source for many countries and companies.

Microsoft, Inc., *The Microsoft Windows User Experience*, Microsoft Press, Redmond, WA (1999).

- Provides thoughtful analyses of usability principles (user in control, directness, consistency, forgiveness, aesthetics, and simplicity) and gives detailed guidance for Windows software developers.
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- Describes the information architecture and user-interface design for the NASA portal.
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- Authoritative and packed with numerous full-color examples of information-oriented web sites.
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- Describes human factors integration processes, requirements, and acceptance testing.
- World Wide Web Consortium's Web Accessibility Initiative, *Web Content Accessibility Guidelines 2.0*, Geneva, Switzerland (2008). Available at <http://www.w3.org/WAI/>.
- Practical, implementable three-level prioritization of web design guidelines for users with disabilities. The Web Accessibility Initiative (WAI) develops strategies, guidelines, and resources to help make the Web accessible to people with disabilities. Four principles are offered: Perceivable, Operable, Understandable, and Robust.
- World Wide Web Consortium, *Web Accessibility Evaluation Tools*, Geneva, Switzerland (2008). Available at <http://www.w3.org/WAI/ER/existingtools.html>.
- An occasionally updated list of software tools related to accessibility; demonstrates lively activity.

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Video Recordings

Video is an effective medium for presenting the dynamic, graphical, and interactive nature of modern user interfaces. The Technical Video Program of the ACM SIGCHI conferences presents excellent demonstrations of often-cited but seldom-seen systems. Many CHI videos are available from the Open Video project, at <http://www.open-video.org/>. The brief videos from the Human-Computer Interaction Lab at the University of Maryland, dating back to 1991, are online at <http://www.cs.umd.edu/hcil/pubs/video-reports.shtml>, and a selection are also on the Open Video project. A wonderful set of lectures from Stanford University's CS547 Human-Computer Interaction Seminar can be found at <http://scpd.stanford.edu/scpd/students/cs547archive.htm>. A Georgia Tech team produces a Human-Centered Computing Education Digital Library with videos, lectures, slides, and other materials, available at <http://hcc.cc.gatech.edu/>.

Inspirational videos from the annual Technology, Entertainment & Design Conference, which covers a wide range of topics including visionary user-interface themes, are found at <http://www.ted.com/index.php/talks/>. Another exceptional resource is YouTube (<http://www.youtube.com/>), where a search on "user interfaces" produces a list of hundreds of recent product demonstrations, research reports, and some clever and funny technology demonstrations.