

GENERAL READINGS AND NOTES

In the notes below, I first provide general readings. Then, chapter by chapter, I give the specific sources used or cited in the book.

In this world of rapid access to information, you can find information about the topics discussed here by yourself. Here is an example: In [Chapter 5](#), I discuss root cause analysis as well as the Japanese method called the Five Whys. Although my descriptions of these concepts in [Chapter 5](#) are self-sufficient for most purposes, readers who wish to learn more can use their favorite search engine with the critical phrases in quotes.

Most of the relevant information can be found online. The problem is that the addresses (URLs) are ephemeral. Today's locations of valuable information may no longer be at the same place tomorrow. The creaky, untrustworthy Internet, which is all we have today, may finally, thank goodness, be replaced by a superior scheme. Whatever the reason, the Internet addresses I provide may no longer work. The good news is that over the years that will pass after the publication of this book, new and improved search methods will certainly arise. It should be even easier to find more information about any of the concepts discussed in this book.

These notes provide excellent starting points. I provide critical references for the concepts discussed in the book, organized by the chapters where they were discussed. The citations serve two purposes. First, they provide credit to the originators of the ideas. Second, they serve as starting points to get a deeper understanding of the concepts. For more advanced information (as well as newer, further developments), go out and search. Enhanced search skills are important tools for success in the twenty-first century.

GENERAL READINGS

When the first edition of this book was published, the discipline of interaction design did not exist, the field of human-computer interaction was in its infancy, and most studies were done under the guise of “usability” or “user interface.” Several very

different disciplines were struggling to bring clarity to this enterprise, but often with little or no interaction among the disciplines. The academic disciplines of computer science, psychology, human factors, and ergonomics all knew of one another's existence and often worked together, but design was not included. Why not design? Note that all the disciplines just listed are in the areas of science and engineering—in other words, technology. Design was then mostly taught in schools of art or architecture as a profession rather than as a research-based academic discipline. Designers had remarkably little contact with science and engineering. This meant that although many excellent practitioners were trained, there was essentially no theory: design was learned through apprenticeship, mentorship, and experience.

Few people in the academic disciplines were aware of the existence of design as a serious enterprise, and as a result, design, and in particular, graphical, communication, and industrial design worked completely independently of the newly emerging discipline of human-computer interaction and the existing disciplines of human factors and ergonomics. Some product design was taught in departments of mechanical engineering, but again, with little interaction with design. Design was simply not an academic discipline, so there was little or no mutual awareness or collaboration. Traces of this distinction remain today, although design is more and more becoming a research-based discipline, where professors have experience in practice as well as PhDs. The boundaries are disappearing.

This peculiar history of many independent, disparate groups all working on similar issues makes it difficult to provide references that cover both the academic side of interaction and experience design, and the applied side of design. The proliferation of books, texts, and journals in human-computer interaction, experience design, and usability is huge: too large to cite. In the materials that follow, I provide a very restricted number of examples. When I originally put together a list of works I considered important, it was far too long. It fell prey to the problem described by Barry Schwartz in his book *The Paradox of Choice: Why More Is Less* (2005). So I decided to simplify by providing less. It is easy to find other works, including important ones that will be published after this book. Meanwhile, my apologies to my many friends whose important and useful works had to be trimmed from my list.

Industrial designer Bill Moggridge was extremely influential in establishing interaction within the design community. He played a major role in the design of the first portable computer. He was one of the three founders of IDEO, one of the world's most influential design firms. He wrote two books of interviews with key people in the early development of the discipline: *Designing Interactions* (2007) and *Designing Media* (2010). As is typical of discussions from the discipline of design, his works focus almost entirely upon the practice of design, with little attention to the science. Barry Katz, a design professor at San Francisco's California College of the Arts, Stanford's d.school, and an IDEO Fellow, provides an excellent history of design practice within

the community of companies in Silicon Valley, California: *Ecosystem of Innovation: The History of Silicon Valley Design* (2014). An excellent, extremely comprehensive history of the field of product design is provided by Bernhard Bürdek's *Design: History, Theory, and Practice of Product Design* (2005). Bürdek's book, originally published in German but with an excellent English translation, is the most comprehensive history of product design I have been able to find. I highly recommend it to those who want to understand the historical foundations.

Modern designers like to characterize their work as providing deep insight into the fundamentals of problems, going far beyond the popular conception of design as making things pretty. Designers emphasize this aspect of their profession by discussing the special way in which they approach problems, a method they have characterized as “design thinking.” A good introduction to this comes from the book *Change by Design* (2009), by Tim Brown and Barry Katz. Brown is CEO of IDEO and Katz an IDEO Fellow (see the previous paragraph).

An excellent introduction to design research is provided in Jan Chipchase and Simon Steinhardt's *Hidden in Plain Sight* (2013). The book chronicles the life of a design researcher who studies people by observing them in their homes, barber shops, and living quarters around the world. Chipchase is executive creative director of global insights at Frog Design, working out of the Shanghai office. The work of Hugh Beyer and Karen Holtzblatt in *Contextual Design: Defining Customer-Centered Systems* (1998) presents a powerful method of analyzing behavior; they have also produced a useful workbook (Holtzblatt, Wendell, & Wood, 2004).

There are many excellent books. Here are a few more:

- Buxton, W. (2007). *Sketching user experience: Getting the design right and the right design*. San Francisco, CA: Morgan Kaufmann. (And see the companion workbook [Greenberg, Carpendale, Marquardt, & Buxton, 2012].)
- Coates, D. (2003). *Watches tell more than time: Product design, information, and the quest for elegance*. New York: McGraw-Hill.
- Cooper, A., Reimann, R., & Cronin, D. (2007). *About face 3: The essentials of interaction design*. Indianapolis, IN: Wiley Pub.
- Hassenzahl, M. (2010). *Experience design: Technology for all the right reasons*. San Rafael, California: Morgan & Claypool.
- Moggridge, B. (2007). *Designing interactions*. Cambridge, MA: MIT Press. <http://www.designinginteractions.com>. Chapter 10 describes the methods of interaction design: <http://www.designinginteractions.com/chapters/10>

Two handbooks provide comprehensive, detailed treatments of the topics in this book:

- Jacko, J. A. (2012). *The human-computer interaction handbook: Fundamentals, evolving technologies, and emerging applications* (3rd edition). Boca Raton, FL: CRC Press.
- Lee, J. D., & Kirlik, A. (2013). *The Oxford handbook of cognitive engineering*. New York: Oxford University Press.

Which book should you look at? Both are excellent, and although expensive, well worth the price for anyone who intends to work in these fields. The *Human-Computer Interaction Handbook*, as the title suggests, focuses primarily on computer-enhanced interactions with technology, whereas the *Handbook of Cognitive Engineering* has a much broader coverage. Which book is better? That depends upon what problem you are working on. For my work, both are essential.

Finally, let me recommend two websites:

Interaction Design Foundation: Take special note of its Encyclopedia articles. www.interaction-design.org

SIGCHI: The Computer-Human Interaction Special Interest Group for ACM. www.sigchi.org

CHAPTER ONE: THE PSYCHOPATHOLOGY OF EVERYDAY THINGS

- 2 *Coffeepot for Masochists*: This was created by the French artist Jacques Carelman (1984). The photograph shows a coffeepot inspired by Carelman, but owned by me. Photograph by Aymin Shamma for the author.
- 10 *Affordances*: The perceptual psychologist J. J. Gibson invented the word *affordance* to explain how people navigated the world (Gibson, 1979). I introduced the term into the world of interaction design in the first edition of this book (Norman, 1988). Since then, the number of writings on affordance has been enormous. Confusion over the appropriate way to use the term prompted me to introduce the concept of “signifier” in my book *Living with Complexity* (Norman, 2010), discussed throughout this book, but especially in [Chapters 1 and 4](#).

CHAPTER TWO: THE PSYCHOLOGY OF EVERYDAY ACTIONS

- 38 *Gulfs of execution and evaluation*: The story of the gulfs and bridges of execution and evaluation came from research performed with Ed Hutchins and Jim Hollan, then part of a joint research team between the Naval Personnel Research and Development Center and the University of California, San Diego (Hollan and Hutchins are now professors of cognitive science at the University of California, San Diego). The work examined the development of computer systems that were easier to learn and easier to use, and in particular, of what has been called direct manipulation computer systems. The initial work is described in the chapter “Direct Manipulation Interfaces” in the book from our laboratories, *User Centered System Design: New Perspectives on Human-Computer Interaction* (Hutchins, Hollan, & Norman, 1986). Also see the paper by Hollan, Hutchins, and David Kirsh, “Distributed Cognition: A New Foundation for Human-Computer Interaction Research” (Hollan, Hutchins, & Kirsh, 2000).
- 43 *Levitt*: “People don’t want to buy a quarter-inch drill. They want a quarter-inch hole!” See Christensen, Cook, & Hal, 2006. The fact that Harvard Business School marketing professor Theodore Levitt is credited with the quote about the drill and the hole is a good example of Stigler’s law: “No scientific discovery is named after its original discoverer.” Thus, Levitt himself attributed the statement about drills and holes to Leo McGinneva (Levitt, 1983). Stigler’s law is, itself, an example of the law: Stigler, a professor of statistics, wrote that he learned the law from the sociologist Robert Merton. See more at Wikipedia, “Stigler’s Law of Eponymy” (Wikipedia contributors, 2013c).
- 46 *Doorknob*: The question “In the house you lived in three houses ago, as you entered the front door, was the doorknob on the left or right?” comes from my paper “Memory, Knowledge, and the Answering of Questions” (Norman, 1973).
- 53 *Visceral, behavioral, and reflective*: Daniel Kahneman’s book, *Thinking Fast and Slow* (Kahneman, 2011), gives an excellent introduction to modern conceptions of the role of conscious and subconscious processing. The distinctions between visceral, behavioral, and reflective processing form the basis of my book *Emotional Design* (Norman, 2002, 2004). This model of the human cognitive and emotional system is described in more technical detail in the scientific paper I wrote with Andrew Ortony and William Revelle: “The Role of Affect and Proto-affect in Effective Functioning” (Ortony, Norman, & Revelle, 2005). Also see “Designers and Users: Two Perspectives on Emotion and Design” (Norman & Ortony, 2006). *Emotional Design* contains numerous examples of the role of design at all three levels.

- 58 *Thermostat*: The valve theory of the thermostat is taken from Kempton, a study published in the journal *Cognitive Science* (1986). Intelligent thermostats try to predict when they will be required, turning on or off earlier than the simple control illustrated in [Chapter 2](#) can specify, to ensure that the desired temperature is reached at the desired time, without over- or undershooting the target.
- 63 *Positive psychology*: Mihaly Csikszentmihalyi's work on flow can be found in his several books on the topic (1990, 1997). Martin (Marty) Seligman developed the concept of learned helplessness, and then applied it to depression (Seligman, 1992). However, he decided that it was wrong for psychology to continually focus upon difficulties and abnormalities, so he teamed up with Csikszentmihalyi to create a movement for positive psychology. An excellent introduction is provided in the article by the two of them in the journal *American Psychologist* (Seligman & Csikszentmihalyi, 2000). Since then, positive psychology has expanded to include books, journals, and conferences.
- 66 *Human error*: People blame themselves: Unfortunately, blaming the user is imbedded in the legal system. When major accidents occur, official courts of inquiry are set up to assess the blame. More and more often, the blame is attributed to "human error." But in my experience, human error usually is a result of poor design: why was the system ever designed so that a single act by a single person could cause calamity? An important book on this topic is Charles Perrow's *Normal Accidents* (1999). [Chapter 5](#) of this book provides a detailed examination of human error.
- 72 *Feedforward*: Feedforward is an old concept from control theory, but I first encountered it applied to the seven stages of action in the paper by Jo Vermeulen, Kris Luyten, Elise van den Hoven, and Karin Coninx (2013).

CHAPTER THREE: KNOWLEDGE IN THE HEAD AND IN THE WORLD

- 74 *American coins*: Ray Nickerson and Marilyn Adams, as well as David Rubin and Theda Kontis, showed that people could neither recall nor recognize accurately the pictures and words on American coins (Nickerson & Adams, 1979; Rubin & Kontis, 1983).
- 80 *French coins*: The quotation about the French government release of the 10-franc coin comes from an article by Stanley Meisler (1986), reprinted with permission of the *Los Angeles Times*.
- 80 *Descriptions in memory*: The suggestion that memory storage and retrieval is mediated through partial descriptions was put forth in a paper with Danny Bobrow (Norman & Bobrow, 1979). We argued that, in general, the required specificity of a description depends on the set of items among which a person is trying to distinguish. Memory retrieval can therefore involve a prolonged series of attempts during which the initial retrieval descriptions yield incomplete or erroneous results, so that the person must keep trying, each retrieval attempt coming closer to the answer and helping to make the description more precise.
- 83 *Constraints of rhyming*: Given just the cues for meaning (the first task), the people David C. Rubin and Wanda T. Wallace tested could guess the three target words used in these examples only 0 percent, 4 percent, and 0 percent of the time, respectively. Similarly, when the same target words were cued only by rhymes, they still did quite poorly, guessing the targets correctly only 0 percent, 0 percent, and 4 percent of the time, respectively. Thus, each cue alone offered little assistance. Combining the meaning cue with the rhyming cue led to perfect performance: the people got the target words 100 percent of the time (Rubin & Wallace, 1989).
- 86 *'Ali Baba*: Alfred Bates Lord's work is summarized in his book *The Singer of Tales* (1960). The quotation from "'Ali Baba and the Forty Thieves" comes from *The Arabian Nights: Tales of Wonder and Magnificence*, selected and edited by Padraic Colum, translated by Edward William Lane (Colum & Ward, 1953). The names here are in an unfamiliar form: most of us know the magic phrase as "Open Sesame," but according to Colum, "Simsim" is the authentic transliteration.
- 87 *Passwords*: How do people cope with passwords? There are lots of studies: (Anderson, 2008; Florêncio, Herley, & Coskun, 2007; National Research Council Steering Committee on the Usability, Security, and Privacy of Computer Systems, 2010; Norman, 2009; Schneier, 2000).
- To find the most common passwords, just search using some phrase such as "most common passwords." My article on security, which led to numerous newspaper column references to it, is available on my website and was also published in the magazine for human-computer interaction, *Interactions* (Norman, 2009).
- 89 *Hiding places*: The quotation about professional thieves' knowledge of how people hide things comes from Winograd and Soloway's study "On Forgetting the Locations of Things Stored in Special Places" (1986).

- 93 *Mnemonics*: Mnemonic methods were covered in my book *Memory and Attention*, and although that book is old, the mnemonic techniques are even older, and are still unchanged (Norman, 1969, 1976). I discuss the effort of retrieval in *Learning and Memory* (Norman, 1982). Mnemonic techniques are easy to find: just search the web for “mnemonics.” Similarly, the properties of short- and long-term memory are readily found by an Internet search or in any text on experimental psychology, cognitive psychology, or neuropsychology (as opposed to clinical psychology) or a text on cognitive science. Alternatively, search online for “human memory,” “working memory,” “short-term memory” or “long-term memory.” Also see the book by Harvard psychologist Daniel Schacter, *The Seven Sins of Memory* (2001). What are Schacter’s seven sins? Transience, absent-mindedness, blocking, misattribution, suggestibility, persistence, and bias.
- 101 *Whitehead*: Alfred North Whitehead’s quotation about the power of automated behavior is from [Chapter 5](#) of his book *An Introduction to Mathematics* (1911).
- 107 *Prospective memory*: Considerable research on prospective memory and memory for the future is summarized in the articles by Dismukes on prospective memory and the review by Cristina Atance and Daniela O’Neill on memory for the future, or what they call “episodic future thinking” (Atance & O’Neill, 2001; Dismukes, 2012).
- 112 *Transactive memory*: The term *transactive memory* was coined by Harvard professor of psychology Daniel Wegner (Lewis & Herndon, 2011; Wegner, D. M., 1987; Wegner, T. G., & Wegner, D. M., 1995).
- 113 *Stove controls*: The difficulty in mapping stove controls to burners has been understood by human factors experts for over fifty years: Why are stoves still designed so badly? This issue was addressed in 1959, the very first year of the *Human Factors Journal* (Chapanis & Lindenbaum, 1959).
- 118 *Culture and design*: My discussion of the impact of culture on mappings was heavily informed by my discussions with Lera Boroditsky, then at Stanford University, but now in the cognitive science department at the University of California, San Diego. See her book chapter “How Languages Construct Time” (2011). Studies of the Australian Aborigine were reported by Núñez & Sweetser (2006).

CHAPTER FOUR: KNOWING WHAT TO DO: CONSTRAINTS, DISCOVERABILITY, AND FEEDBACK

- 126 *InstaLoad*: A description of Microsoft’s InstaLoad technology for battery contacts is available on its website: www.microsoft.com/hardware/en-us/support/licensing-instaload-overview.
- 129 *Cultural frames*: See Roger Schank and Robert B. Abelson’s *Scripts, Plans, Goals, and Understanding* (1977) or Erving Goffman’s classic and extremely influential books *The Presentation of Self in Everyday Life* (1959) and *Frame Analysis* (1974). I recommend *Presentation* as the most relevant (and easiest to read) of his works.
- 129 *Violating social conventions*: “Try violating cultural norms and see how uncomfortable that makes you and the other people.” Jan Chipchase and Simon Steinhardt’s *Hidden in Plain Sight* provides many examples of how design researchers can deliberately violate social conventions so as to understand how a culture works. Chipchase reports an experiment in which able-bodied young people request that seated subway passengers give up their seat to them. The experimenters were surprised by two things. First, a large proportion of people obeyed. Second, the people most affected were the experimenters themselves: they had to force themselves to make the requests and then felt bad about it for a long time afterward. A deliberate violation of social constraints can be uncomfortable for both the violator and the violated (Chipchase & Steinhardt, 2013).
- 137 *Light switch panel*: For the construction of my home light switch panel, I relied heavily on the electrical and mechanical ingenuity of Dave Wargo, who actually did the design, construction, and installation of the switches.
- 156 *Natural sounds*: Bill Gaver, now a prominent design researcher at Goldsmiths College, University of London (UK), first alerted me to the importance of natural sounds in his PhD dissertation and later publications (Gaver, W., 1997; Gaver, W. W., 1989). There has been considerable research on sound since the early days: see, for example, Gygi & Shafiro (2010).
- 160 *Electric vehicles*: The quotation from the US government rule on sounds for electric vehicles can be found on the Department of Transportation’s website (2013).

CHAPTER FIVE: HUMAN ERROR? NO, BAD DESIGN

There has been a lot of work on the study of error, human reliability, and resilience. A good source, besides the items cited below, is the Wiki of Science article on human error (Wiki of Science, 2013). Also see the book *Behind Human Error* (Woods, Decker, Cook, Johannesen, & Sarter, 2010).

Two of the most important workers in human error are British psychologist James Reason and Danish engineer Jens Rasmussen. Also see the books by the Swedish investigator Sidney Dekker, and MIT professor Nancy Leveson (Dekker, 2011, 2012, 2013; Leveson, N., 2012; Leveson, N. G., 1995; Rasmussen, Duncan, & Leplat, 1987; Rasmussen, Pejtersen, & Goodstein, 1994; Reason, J. T., 1990, 2008).

Unless otherwise noted, all the examples of slips in this chapter were collected by me, primarily from the errors of myself, my research associates, my colleagues, and my students. Everyone diligently recorded his or her slips, with the requirement that only the ones that had been immediately recorded would be added to the collection. Many were first published in Norman (1981).

- 165 *F-22 crash*: The analysis of the Air Force F-22 crash comes from a government report (Inspector General United States Department of Defense, 2013). (This report also contains the original Air Force report as Appendix C.)
- 170 *Slips and mistakes*: The descriptions of skill-based, rule-based, and knowledge-based behavior is taken from Jens Rasmussen's paper on the topic (1983), which still stands as one of the best introductions. The classification of errors into slips and mistakes was done jointly by me and Reason. The classification of mistakes into rule-based and knowledge-based follows the work of Rasmussen (Rasmussen, Goodstein, Andersen, & Olsen, 1988; Rasmussen, Pejtersen, & Goodstein, 1994; Reason, J. T., 1990, 1997, 2008). Memory lapse errors (both slips and mistakes) were not originally distinguished from other errors: they were put into separate categories later, but not quite the same way I have done here.
- 172 *"Gimli Glider"*: The so-called Gimli Glider accident was an Air Canada Boeing 767 that ran out of fuel and had to glide to a landing at Gimli, a decommissioned Canadian Air Force base. There were numerous mistakes: search for "Gimli Glider accident." (I recommend the Wikipedia treatment.)
- 174 *Capture error*: The category "capture error" was invented by James Reason (1979).
- 178 *Airbus*: The difficulties with the Airbus and its modes are described in (Aviation Safety Network, 1992; Wikipedia contributors, 2013a). For a disturbing description of another design problem with the Airbus—that the two pilots (the captain and the first officer) can both control the joysticks, but there is no feedback, so one pilot does not know what the other pilot is doing—see the article in the British newspaper *The Telegraph* (Ross & Tweedie, 2012).
- 181 *The Kiss nightclub fire in Santa Maria, Brazil*: It is described in numerous Brazilian and American newspapers (search the web for "Kiss nightclub fire"). I first learned about it from the *New York Times* (Romero, 2013).
- 186 *Tenerife crash*: My source for information about the Tenerife crash is from a report by Roitsch, Babcock, and Edmunds issued by the American Airline Pilots Association (Roitsch, Babcock, & Edmunds, undated). It is perhaps not too surprising that it differs in interpretation from the Spanish government's report (Spanish Ministry of Transport and Communications, 1978), which in turn differs from the report by the Dutch Aircraft Accident Inquiry Board. A nice review of the 1977 Tenerife accident—written in 2007—that shows its long-lasting importance has been written by Patrick Smith for the website Salon.com (Smith, 2007, Friday, April 6, 04:00 AM PDT).
- 188 *Air Florida crash*: The information and quotations about the Air Florida crash are from the report of the National Transportation Safety Board (1982). See also the two books entitled *Pilot Error* (Hurst, 1976; Hurst,

- R. & Hurst, L. R., 1982). The two books are quite different. The second is better than the first, in part because at the time the first book was written, not much scientific evidence was available.
- 190 *Checklists in medicine*: Duke University's examples of knowledge-based mistakes can be found at Duke University Medical Center (2013). An excellent summary of the use of checklists in medicine—and the many social pressures that have slowed up its adoption—is provided by Atul Gawande (2009).
- 192 *Jidoka*: The quotation from Toyota about *Jidoka*, and the Toyota Production System comes from the auto maker's website (Toyota Motor Europe Corporate Site, 2013). Poka-yoke is described in many books and websites. I found the two books written by or with the assistance of the originator, Shigeo Shingo, to provide a valuable perspective (Nikkan Kogyo Shimbun, 1988; Shingo, 1986).
- 193 *Aviation safety*: The website for NASA's Aviation Safety Reporting System provides details of the system, along with a history of its reports (NASA, 2013).
- 197 *Hindsight*: Baruch Fischhoff's study is called "Hindsight ≠ Foresight: The Effect of Outcome Knowledge on Judgment Under Uncertainty" (1975). And while you are at it, see his more recent work (Fischhoff, 2012; Fischhoff & Kadvany, 2011).
- 198 *Designing for error*: I discuss the idea of designing for error in a paper in *Communications of the ACM*, in which I analyze a number of the slips people make in using computer systems and suggest system design principles that might minimize those errors (Norman, 1983). This philosophy also pervades the book that our research team put together: *User Centered System Design* (Norman & Draper, 1986); two chapters are especially relevant to the discussions here: my "Cognitive Engineering" and the one I wrote with Clayton Lewis, "Designing for Error."
- 200 *Multitasking*: There are many studies of the dangers and inefficiencies of multitasking. A partial review is given by Spink, Cole, & Waller (2008). David L. Strayer and his colleagues at the University of Utah have done numerous studies demonstrating rather severe impairment in driving behavior while using cell phones (Strayer & Drews, 2007; Strayer, Drews, & Crouch, 2006). Even pedestrians are distracted by cell phone usage, as demonstrated by a team of researchers from West Washington University (Hyman, Boss, Wise, McKenzie, & Caggiano, 2010).
- 200 *Unicycling clown*: The clever study of the invisible clown, riding a unicycle, "Did you see the unicycling clown? Inattention blindness while walking and talking on a cell phone" was done by Hyman, Boss, Wise, McKenzie, & Caggiano (2010).
- 208 *Swiss cheese model*: James Reason introduced his extremely influential Swiss cheese model in 1990 (Reason, J., 1990; Reason, J. T., 1997).
- 210 *Hersman*: Deborah Hersman's description of the design philosophy for aircraft comes from her talk on February 7, 2013, discussing the NTSB's attempts to understand the cause of the fires in the battery compartments of Boeing 787 aircraft. Although the fires caused airplanes to make emergency landings, no passengers or crew were injured: the multiple layers of redundant protection maintained safety. Nonetheless, the fires and resulting damage were unexpected and serious enough that all Boeing 787 airlines were grounded until all parties involved had completed a thorough investigation of the causes of the incident and then gone through a new certification process with the Federal Aviation Agency (for the United States, and through the corresponding agencies in other countries). Although this was expensive and greatly inconvenient, it is an example of good proactive practice: take measures before accidents lead to injury and death (National Transportation Safety Board, 2013).
- 212 *Resilience engineering*: The excerpt from "Prologue: Resilience Engineering Concepts," in the book *Resilience Engineering*, is reprinted by permission of the publishers (Hollnagel, Woods, & Leveson, 2006).
- 213 *Automation*: Much of my research and writings have addressed issues of automation. An early paper, "Coffee Cups in the Cockpit," addresses this problem as well as the fact that when talking about incidents in a large country—or that occur worldwide—a "one-in-a-million chance" is not good enough odds (Norman, 1992). My book *The Design of Future Things* deals extensively with this issue (Norman, 2007).
- 214 *Royal Majesty accident*: An excellent analysis of the mode error accident with the cruise ship *Royal Majesty* is contained in Asaf Degani's book on automation, *Taming HAL: Designing Interfaces Beyond 2001* (Degani, 2004), as well as in the analyses by Lützhöft and Dekker and the official NTSB report (Lützhöft & Dekker, 2002; National Transportation Safety Board, 1997).

CHAPTER SIX: DESIGN THINKING

As pointed out in the “General Readings” section, a good introduction to design thinking is *Change by Design* by Tim Brown and Barry Katz (2009). Brown is CEO of IDEO and Katz a professor at the California College of the Arts, visiting professor at Stanford’s d.school, and an IDEO Fellow. There are multiple Internet sources; I like designthinkingforeducators.com.

- 220 *Double diverge-converge pattern*: The double diverge-converge pattern was first introduced by the British Design Council in 2005, which called it the “Double-Diamond Design Process Model” (Design Council, 2005).
- 221 *HCD process*: The human-centered design process has many variants, each similar in spirit but different in the details. A nice summary of the method I describe is provided by the HCD book and toolkit from the design firm IDEO (IDEO, 2013).
- 227 *Prototyping*: For prototyping, see Buxton’s book and handbook on sketching (Buxton, 2007; Greenberg, Carpendale, Marquardt, & Buxton, 2012). There are multiple methods used by designers to understand the nature of the problem and come to a potential solution. Vijay Kumar’s *101 Design Methods* (2013) doesn’t even cover them all. Kumar’s book is an excellent treatment of design research methods, but its focus is on innovation, not the production of products, so it does not cover the actual development cycle. Physical prototyping, their tests, and iterations are outside the domain, as are the practical concerns of the marketplace, the topic of the last part of this chapter and all of chapter 7.
- 227 *Wizard of Oz technique*: The Wizard of Oz technique is named after L. Frank Baum’s book *The Wonderful Wizard of Oz* (Baum & Denslow, 1900). My use of the technique is described in the resulting paper from the group headed by artificial intelligence researcher Danny Bobrow at what was then called the Xerox Palo Alto Research Center (Bobrow et al., 1977). The “graduate student” sitting in the other room was Allen Munro, who then went on to a distinguished research career.
- 229 *Nielsen*: Jakob Nielsen’s argument that five users is the ideal number for most tests can be found on the Nielsen Norman group’s website (Nielsen, 2013).
- 233 *Three goals*: Marc Hassenzahl’s use of the three levels of goals (be-goals, do-goals, and motor-goals) is described in many places, but I strongly recommend his book *Experience Design* (Hassenzahl, 2010). The three goals come from the work of Charles Carver and Michael Scheier in their landmark book on the use of feedback models, chaos, and dynamical theory to explain much of human behavior (Carver & Scheier, 1998).
- 246 *Age and performance*: A good review of the impact of age on human factors is provided by Frank Schieber (2003). The report by Igo Grossman and colleagues is a typical example of research showing that careful studies reveal superior performance with age (Grossmann et al., 2010).
- 254 *Swatch International Time*: Swatch’s development of .beat time and the French decimal time are discussed in the Wikipedia article on decimal time (Wikipedia contributors, 2013b).

CHAPTER SEVEN: DESIGN IN THE WORLD OF BUSINESS

- 261 *Creeping featurism*: A note for the technology historians. I’ve managed to trace the origin of this term to a talk by John Mashey in 1976 (Mashey, 1976). At that time Mashey was a computer scientist at Bell Laboratories, where he was one of the early developers of UNIX, a well-known computer operating system (which is still active as Unix, Linux, and the kernel underlying Apple’s Mac OS).
- 262 *Youngme Moon*: Youngme Moon’s book *Different: Escaping the Competitive Herd* (Moon, 2010) argues that “If there is one strain of conventional wisdom pervading every company in every industry, it is the importance of competing hard to differentiate yourself from the competition. And yet going head-to-head with the competition—with respect to features, product augmentations, and so on—has the perverse effect of making you just like everyone else.” (From the jacket of her book: see <http://youngmemoon.com/Jacket.html>.)
- 266 *Word-gesture system*: The word-gesture system that works by tracing the letters on the screen keyboard to type rapidly and efficiently (although not as fast as with a traditional ten-finger keyboard) is described in

considerable detail by Shumin Zhai and Per Ola Kristensson, two of the developers of this method of typing (Zhai & Kristensson, 2012).

- 269 *Multitouch screens*: In the more than thirty years multitouch screens have been in the laboratories, numerous companies have launched products and failed. Nimish Mehta is credited with the invention of multitouch, discussed in his master's thesis (1982) from the University of Toronto. Bill Buxton (2012), one of the pioneers in this field, provides a valuable review (he was working with multitouch displays in the early 1980s at the University of Toronto). Another excellent review of multitouch and gestural systems in general (as well as design principles) is provided by Dan Saffer in his book *Designing Gestural Interfaces* (2009). The story of Fingerworks and Apple is readily found by searching the web for "Fingerworks."
- 270 *Stigler's law*: See the comment about this in the notes for [Chapter 2](#).
- 271 *Telephonoscope*: The illustration of the "Telephonoscope" was originally published in the December 9, 1878, issue of the British magazine *Punch* (for its 1879 Almanack). The picture comes from Wikipedia (Wikipedia contributors, 2013d), where it is in the public domain because of its age.
- 276 *QWERTY keyboard*: The history of the QWERTY keyboard is discussed in numerous articles. I thank Professor Neil Kay of University of Strathclyde for our e-mail correspondence and his article "Rerun the Tape of History and QWERTY Always Wins" (2013). This article led me to the "QWERTY People Archive" website by the Japanese researchers Koichi and Motoko Yasuoka, an incredibly detailed, valuable resource for those interested in the history of the keyboard, and in particular, of the QWERTY configuration (Yasuoka & Yasuoka, 2013). The article on the typewriter in the 1872 *Scientific American* is fun to read: the style of *Scientific American* has changed drastically since then (Anonymous, 1872).
- 278 *Dvorak keyboard*: Is Dvorak faster than QWERTY? Yes, but not by much: Diane Fisher and I studied a variety of keyboard layouts. We thought that alphabetically organized keys would be superior for beginners. No, they weren't: we discovered that knowledge of the alphabet was not useful in finding the keys. Our studies of alphabetical and Dvorak keyboards were published in the journal *Human Factors* (Norman & Fisher, 1984). Admirers of the Dvorak keyboard claim much more than a 10 percent improvement, as well as faster learning rates and less fatigue. But I will stick by my studies and my statements. If you want to read more, including a worthwhile treatment of the history of the typewriter, see the book *Cognitive Aspects of Skilled Typewriting*, edited by William E. Cooper, which includes several chapters of research from my laboratory (Cooper, W. E., 1963; Norman & Fisher, 1984; Norman & Rumelhart, 1963; Rumelhart & Norman, 1982).
- 278 *Keyboard ergonomics*: Health aspects of keyboards are reported in National Institute of Health (2013).
- 279 *Incremental and radical innovation*: The Italian business professor Roberto Verganti and I discuss the principles of incremental and radical innovation (Norman & Verganti, 2014; Verganti, 2009, 2010).
- 281 *Hill climbing*: There are very good descriptions of the hill-climbing process for design in Christopher Alexander's book *Notes on the Synthesis of Form* (1964) and Chris Jones's book *Design Methods* (1992; also see Jones, 1984).
- 286 *Humans versus machines*: The remarks by MIT professor Erik Brynjolfsson were made in his talk at the June 2012 National Academy of Engineering symposium on manufacturing, design, and innovation (Brynjolfsson, 2012). His book, coauthored with Andrew McAfee—*Race Against the Machine: How the Digital Revolution Is Accelerating Innovation, Driving Productivity, and Irreversibly Transforming Employment and the Economy*—contains an excellent treatment of design and innovation (Brynjolfsson & McAfee, 2011).
- 290 *Interactive media*: Al Gore's interactive media book is *Our Choice* (2011). Some of the videos from my early interactive book are still available: see Norman (1994 and 2011b).
- 295 *Rise of the small*: The section "The Rise of the Small" is taken from my essay written for the hundredth anniversary of the Steelcase company, reprinted here with Steelcase's permission (Norman, 2011a).