in the keyboard. Millions of people would have to learn a new style of typing. Millions of typewriters would have to be changed. The severe constraints of existing practice prevent change, even where the change would be an improvement.[7]

Couldn't we at least do better with two hands at once? Yes, we could. Court stenographers can outtype anyone else. They use chord keyboards, typing syllables directly onto the page—syllables, not letters. Chord keyboards have very few keys—as few as five or six, but usually ten to fifteen. Many chord keyboards allow you to type single letters or whole words with one depression of the hand on several keys. If you use all ten fingers at the same time, then there are 1,023 possible combinations. That is enough for all the letters and numbers, lower case and upper case, plus a lot of words—if only you can learn the patterns. Chord keyboards have a horrible disadvantage: they are very hard to learn and very hard to retain; all the knowledge has to be in the head. Walk up to any regular keyboard and you can use it right away. Just search for the letter you want and push the key. With a chord keyboard, you have to press several keys simultaneously. There is no way to label the keys properly and no way to know what to do just by looking. Some chord keyboards are incredibly clever and remarkably easy to learn, considering. I tried to learn one of the easier ones. Thirty minutes' practice, and I knew the alphabet. But if I didn't use the keyboard for a week, I forgot the chords. The gain did not seem worth the effort. What about one-handed chord keyboards? Wouldn't it be worth a lot of time and effort to be able to type with one hand? Perhaps, if you are flying a jet aircraft with one hand and need to enter data into your computer with the other. But not for the rest of us.[8]

All this brings up an important lesson in design. Once a satisfactory product has been achieved, further change may be counterproductive, especially if the product is successful. You have to know when to stop.

You can observe the design iterations and experiments with the computer keyboard. The layout of the basic keyboard is now standardized through international agreement. But computer keyboards need extra keys, and these are not standardized. Some keyboards have an extra key between the shift key and the "z" key. The return key takes on different shapes and locations. The special keys of the computer keyboard—for example, control, escape, break, delete (not to be confused with backspace), and the "arrow" or cursor control keys—vary in location with the phases of the year, varying even among the products of a single manufacturer. Much confusion and strong emotions result.

Note, too, that the computer allows for flexible letter arrangements. It is a simple matter on some computers to switch the interpretation of the keys from qwerty to Dvorak: one command and the change is done. But unless the Dvorak fan also pries off and rearranges the keycaps, the Dvorak fan has to ignore the labels on the keys and rely on memory. Someday key labeling will be done by electronic displays on each key, so changing the labels will also become trivial. So computer technology may liberate users from forced standardization. Everyone could select the keyboard of personal choice.

Why Designers Go Astray

"[Frank Lloyd] Wright evidently wasn't very sympathetic about complaints. When Herbert F. Johnson, the late president of S. C. Johnson, Inc., in Racine, Wis., called Wright to say that his roof was leaking all over a dinner guest, the architect is said to have responded, 'Tell him to move his chair.' "[9]

If everyday design were ruled by aesthetics, life might be more pleasing to the eye but less comfortable; if ruled by usability, it might be more comfortable but uglier. If cost or ease of manufacture dominated, products might not be attractive, functional, or durable. Clearly, each consideration has its place. Trouble occurs when one dominates all the others.

Designers go astray for several reasons. First, the reward structure of the design community tends to put aesthetics first. Design collections feature prize-winning clocks that are unreadable, alarms that cannot easily be set, can openers that mystify. Second, designers are not typical users. They become so expert in using the object they have designed that they cannot believe that anyone else might have problems; only interaction and testing with actual users throughout the design process can forestall that. Third, designers must please their clients, and the clients may not be the users.

PUTTING AESTHETICS FIRST

"It probably won a prize" is a disparaging phrase in this book. Why? Because prizes tend to be given for some aspects of a design, to the neglect of all others—usually including usability. Consider the following example, in which a usable, livable design was penalized by the design profession. The assignment was to design the Seattle offices of the Federal Aviation Administration (FAA). The most noteworthy feature of the design process was that those who would work in the building had a major say in the planning. One of the members of the design team, Robert Sommer, describes the process as follows:

"Architect Sam Sloan coordinated a project in which employees . . . were able to select their own office furniture and plan office layout. This represented a major departure from prevailing practices in the federal services where such matters were decided by those in authority. Since both the Seattle and Los Angeles branches of the FAA were scheduled to move into new buildings at about the same time, the client for the project, the General Services Administration, agreed with architect Sloan's proposal to involve employees in the design process in Seattle, while leaving the Los Angeles office as a control condition where traditional methods of space planning would be followed."[10]

So there really were two designs: one in Seattle, with heavy participation by the users, and one in Los Angeles, designed in the conventional manner by architects. Which design do the users prefer? Why the Seattle one, of course. Which one got the award? Why the Los Angeles one, of course. Here is Sommer's description of the outcome:

"Several months following the move into the new buildings, surveys by the research team were made in Los Angeles and Seattle. The Seattle workers were more satisfied with their building and work areas than were the Los Angeles employees. . . . It is noteworthy that the Los Angeles building has been given repeated awards by the American Institute of Architects while the Seattle building received no recognition. One member of the AIA jury justified his denial of an award to the Seattle building on the basis of its 'residential quality' and 'lack of discipline and control of the interiors,' which was what the employees liked the most about it. This reflects the well-documented differences in preferences between architects and occupants. . . . The director of the Seattle office admitted that many visitors were surprised that this is a federal facility. Employees in both locations rated their satisfaction with their job performance before and after the move into the new building. There was no change in the Los Angeles office and a 7 percent improvement in rated job performance in the Seattle office."[11]

Aesthetics, not surprisingly, comes first at museums and design centers. I have spent much time in the science museum of my own city, San Diego, watching visitors try out the displays. The visitors try hard, and although they seem to enjoy themselves, it is quite clear that they usually miss the point of the display. The signs are highly decorative; but they are often poorly lit, difficult to read, and have lots of gushing language with little explanation. Certainly the visitors are not enlightened about science (which is supposed to be the point of the exhibit). Occasionally I help out when I see bewildered faces by explaining the scientific principles being demonstrated by the exhibit (after all, many of the exhibits in this sort of museum are really psychology demonstrations, many of which I explain in my own introductory classes). I am often rewarded with smiles and nods of understanding. I took one of my graduate classes there to observe and comment; we all agreed about the inadequacy of the signs, and, moreover, we had useful suggestions. We met with a museum official and tried to explain what was happening. He didn't understand. His problems were the cost and durability of the exhibits. "Are the visitors learning anything?" we asked. He still didn't understand. Attendance at the museum was high. It looked attractive. It had probably won a prize. Why were we wasting his time?

Many museums and design centers make prime examples of pretty displays and signs coupled with illegible and uninformative labels. Mostly, I suspect, it's because these buildings are judged as places of art, where the exhibits are meant to be admired, not to be learned from. I made several trips to the Design Centre in London to collect material for this book. I hoped it would have a good library and bookshop (it did) and good exhibits, demonstrating the proper principles for combining aesthetics, economics, usability, and manufacturability. I found the London Design Centre itself to be an exercise in poor design. Take the cafeteria: just about impossible to use. Behind the counter, the four workers continually get in each other's way. The layout of the back-counter facilities seems without structure or function. Food is carefully heated for the customer, but it gets cold by the time the customer gets through the line. The cafeteria has tiny round tables, which are also too high. There are elegant round stools to sit on. The set up is impossible to use if you are elderly or young or have your hands full of packages. Of course, the design may have been a deliberate attempt to discourage use of the cafeteria. Consider this scenario.

The cafeteria is well designed, with spacious tables and comfortable chairs. But it then becomes too popular, interfering with the true pur-

pose of the Design Centre, which is to encourage good design among British manufacturers. The popularity of the Centre and its cafeteria to tourists is unexpected. The Design Centre decides to discourage people from using the cafeteria. They take out the original tables and chairs and replace them with dysfunctional, uncomfortable ones, all in the name of good design—the goal in this case being to discourage people from using the cafeteria and lingering. Actually, restaurants often install uncomfortable chairs for just this reason. Fast-food places often have no chairs or tables. So my complaints provide evidence that the design criteria were met, that the design was successful.[12]

In London I visited the Boilerworks, a part of the Victoria and Albert Museum, to look at a special exhibit called "natural design." The exhibit itself was one of the best examples of unnatural design I have ever witnessed. Pretty, tasteful signs near each display. Dramatically striking layout of the objects. But you couldn't tell which sign went with which exhibit, or what the text meant. Alas, this seems typical of museums.

A major part of the design process ought to be the study of just how the objects being designed are to be used. In the case of the cafeteria at the London Design Centre, the designers should imagine a crowd of people in line, imagine where the line will start and end, and study what effect the line will have on the rest of the museum. Study the work patterns of the cafeteria employees: consider them responding to customer requests. Where will they have to move? What objects will they have to reach? If there are several employees, will they get in each other's way? And then consider the customers. Grandparents with heavy coats, umbrellas, packages, and perhaps three small children—how will they pay for their purchases? Is there a place for them to put down their packages so they can open their wallets or purses and get out their money? Can this be done in a way that minimizes the disruption for the next people in line and improves the speed and efficiency of the cashier? And finally, consider the customers at the tables. Struggling to get up on a high stool to eat off a tiny table. And don't just imagine: go out and look at the current design, or at other cafeterias. Interview potential customers, interview the cafeteria employees.

In the case of science museums, studies have to be made on people who are the same as the intended audience. The designers and employees already know too much: they can no longer put themselves into the role of the viewer.

Let me be positive for a change: there are science museums and exhibits that work well. The science museums in Boston and in Toronto, the Monterey Aquarium, the Exploratorium in San Francisco. There are probably many others that I do not know about. Consider the Exploratorium. It is dark and grungy on the outside, located in a remodeled, left-over building. Very little is devoted to sleekness or aesthetics. The emphasis is on using and understanding the exhibits. The staff is interested in explaining things.

It is possible to do things right. Just don't let the focus on cost, or durability, or aesthetics destroy the major point of the museum: to be used, to be understood. The problem of focus, I call this.

DESIGNERS ARE NOT TYPICAL USERS

Designers often think of themselves as typical users. After all, they are people too, and they are often users of their own designs. Why don't they notice, why don't they have the same problems as the rest of us? The designers I have spoken with are thoughtful, concerned people. They do want to do things properly. Why, then, are so many failing?

All of us develop an everyday psychology—professionals call it "folk psychology" or, sometimes, "naive psychology"—and it can be as erroneous and misleading as the naive physics that we examined in chapter 2. Worse, actually. As human beings, we have access to our conscious thoughts and beliefs but not to our subconscious ones. Conscious thoughts are often rationalizations of behavior, explanations after the fact. We tend to project our own rationalizations and beliefs onto the actions and beliefs of others. But the professional should be able to realize that human belief and behavior are complex and that the individual is in no position to discover all the relevant factors. There is no substitute for interaction with and study of actual users of a proposed design.

"Steve Wozniak, the whiz-kid co-founder of Apple Computer offered the first public glimpse of CORE, his latest brainchild. . . .

"CORE, which stands for controller of remote electronics, is a single device that allows consumers to fully operate their home equipment by remote control as long as the equipment is all in one room. . . .

"CORE comes with a 40-page user manual. But Wozniak says users of his gizmo . . . won't be daunted because, initially, most will be 'techies.' "[13]

There is a big difference between the expertise required to be a designer and that required to be a user. In their work, designers often become expert with the *device* they are designing. Users are often expert at the *task* they are trying to perform with the device.[14]

Steve Wozniak designs a device to help people like himself, people who complain that their house is cluttered with too many remote control devices for their electronic components. So he produces a single controller that replaces the many. But the task is complex, the instruction manual thick. Not a problem, we are told, the initial users will be "techies." Just like Wozniak, presumably. But how accurate is that characterization? Do we even know that the technically ambitious, the "techies," will really be able to understand and use the device? The only way to find out is to test the designs on users—people as similar to the eventual purchaser of the product as possible. Furthermore, the designer's interaction with potential users must take place from the very beginning of the design process, for it soon becomes too late to make fundamental changes.

Professional designers are usually aware of the pitfalls. But most design is not done by professional designers, it is done by engineers, programmers, and managers. One designer described the issues to me this way:

"People, generally engineers or managers, tend to feel that they are humans, therefore they can design something for other humans just as well as the trained interface expert. It's really interesting to watch engineers and computer scientists go about designing a product. They argue and argue about how to do things, generally with a sincere desire to do the right thing for the user. But when it comes to assessing the tradeoffs between the user interface and internal resources in a product, they almost always tend to simplify their own lives. They will have to do the work, they try to make the internal machine architecture as simple as possible. Internal design elegance sometimes maps to user interface elegance, but not always. Design teams really need vocal advocates for the people who will ultimately use the interface."[15]

Designers have become so proficient with the product that they can no longer perceive or understand the areas that are apt to cause difficulties. Even when designers become users, their deep understanding and close contact with the device they are designing means that they operate it almost entirely from knowledge in the head. The user, especially the first-time or infrequent user, must rely almost entirely on knowledge in the world. That is a big difference, fundamental to the design.

Innocence lost is not easily regained. The designer simply cannot predict the problems people will have, the misinterpretations that will arise, and the errors that will get made. And if the designer cannot anticipate errors, then the design cannot minimize their occurrence or their ramifications.

THE DESIGNER'S CLIENTS MAY NOT BE USERS

Designers must please their clients, who are often not the end users. Consider major household appliances such as stoves, refrigerators, dishwashers, and clothes washers and dryers; and faucets and thermostats for heating and air conditioning systems. They are often purchased by housing developers or landlords. In business, purchasing departments make decisions for large companies and owners or managers make decisions in small companies. In all these cases, the purchaser is probably interested primarily in price, perhaps in size or appearance, almost certainly not in usability. And once devices are purchased and installed, the purchaser has no further interest in them. The manufacturer is primarily concerned about these decision makers, its immediate customers, not the eventual users.

In some situations cost must be put first, especially in government or industry. In my university, copying machines are purchased by the Printing and Duplicating Center, then dispersed to the various departments. The copiers are purchased after a formal "request for proposals" has gone out to manufacturers and dealers of machines. The selection is almost always based solely on price, plus a consideration of the cost of maintenance. Usability? Not considered. The state of California requires by law that universities purchase things on a price basis; there are no legal requirements regarding understandability or usability of the product. That is one reason we get unusable copying machines and telephone systems. If users complained strongly enough, usability could become a requirement in the purchasing specifications, and that demand could trickle back to the designers. But without this feedback, designers must often design the cheapest possible products because those are what sell.

Designers face a tough task. They answer to their clients, and it may be hard to find out who the actual users are. Sometimes they are even prohibited from contacting the users for fear they will incidentally reveal company plans for new products or mislead users into believing that new products are about to be developed. The design process is a captive of corporate bureaucracy, with each stage in the process adding its own assessment and dictating the changes it believes essential for its concerns. The design is almost certainly altered as it leaves the designers and proceeds through manufacturing and marketing. All participants are well intentioned, and their particular concerns are legitimate. The factors should all be considered simultaneously, however, and not subject to the accidents of time sequence or the realities of corporate rank and clout. One designer wrote me this about his problems:

"Most designers live in a world where the gulf of evaluation is infinite. True, we often know the product too well to envision how people will use it, yet we are separated from the end users by multiple layers of corporate bureaucracy, marketing, customer services, etc. These people believe they know what customers want and feedback from the real world is limited by filters they impose. If you accept the problem definition (product requirements) from these outside sources without personal investigation you will design an inferior product regardless of your best intentions. If this initial hurdle is overcome you are only halfway home. The best design ideas are often ruined by the development-manufacturing process that takes place when they leave the design studio. What this really points out is that the process by which we design is flawed, probably more so than our conception of how to create quality designs."[16]

The Complexity of the Design Process

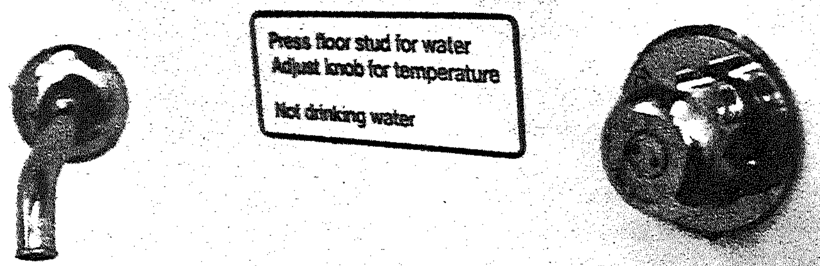
"Design is the successive application of constraints until only a unique product is left."[17]

You might think that a water faucet would be pretty easy to design. After all, you merely want to start or stop the flow of water. But consider some of the problems. Suppose the faucets are for use in public places, where users may fail to turn them off. You can make a spring-operated faucet, which operates only as long as the handle is held. This automatically turns the faucet off; but it is difficult for users to hold the handle while wetting their hands. Ok, so you add a timer; then one push on the faucet handle yields five or ten seconds of water flow. But the extra complexity of the faucet design adds to the cost and lowers the reliability of the faucet. Furthermore, it is difficult to decide how long the water should stay on. Somehow it never seems like long enough for the user.

How about a foot-operated faucet, which overcomes the problems of springs and timers because the water stops as soon as the foot leaves the pedal (figure 6.4 *A*)? This solution requires slightly more elaborate plumbing, again raising the cost. It also makes the control invisible, violating a major design principle and making it difficult for a new user to find the control. How about a high-technology solution, with automatic sensors that turn on the water as soon as a hand is placed in the sink, turning it off as soon as it leaves (figure 6.4 *B*)? This solution has several problems. First, it is expensive. Second, it makes the controls invisible, causing difficulty for new users. And third, it is not easy to see how the user could control either the volume of water or the temperature. More on this faucet later.

Not all faucets are designed under the constraints of public faucets. At home, aesthetic considerations tend to dominate. Styles often reflect the social and economic class of the user. And different kinds of users have different requirements.

The same considerations hold true for most everyday things. The variety of possible solutions to the usual problems is enormous. The range of expression permitted the designer is vast. Moreover, the number of tiny details that must be accounted for is astounding. Pick up almost any manufactured item and examine its details with care. The little wiggly bends on a hairpin are essential in keeping it from slipping out of the hair: someone had to think of that, then design special equipment to create the bends. The felt-tip pen I am examining as I write has six different sizes on the pen body, two different sizes on the cap. The pen changes its taper at numerous spots, each change serving some function. Four different substances comprise the pen body (and I am not counting the ink, the container that holds the ink, or the felt



6.4 Nonstandard Faucets. There are often good reasons for using nonstandard means for operating faucets, but the result is that the user is apt to need help to operate them. *A* (above) shows the faucet and operating instructions from the sink in a British train. *B* (right) shows an advertisement for an automatic faucet: simply put the hand under it and the water comes out at a preset temperature and rate of flow. Convenient, but only for those who know the secret.

tip). The cap is made of two kinds of plastic and one kind of metal. The inside of the cap has a number of subtle indentations and internal structures that clearly match up with corresponding parts of the pen body, both to hold the cap on firmly and to prevent the felt tip from drying out. There are more parts and variables than I would ever have imagined.

The pen's designer must be aware of hundreds of requirements. Make the pen too thin, and it will not be strong enough to stand up to the hard use of schoolchildren. Make the middle section too thick, and it can neither be grasped properly by the fingers nor controlled with enough precision. Yet people with arthritic hands may need a thick body because they can't close their fingers entirely. Leave out the tiny hole near the tip, and pressure changes in the atmosphere will cause the ink to leak out. And what of those who use the pen as a measuring device or as a mechanical implement to pry, poke, stab, and twist? For example, the instructions for the clock in my automobile say to set it by depressing the recessed button with the tip of a ball-point pen. How could the pen designer have known about this? What obligation does the designer have to consider varied and obscure uses?

DESIGNING FOR SPECIAL PEOPLE

There is no such thing as the average person. This poses a particular problem for the designer, who usually must come up with a single design for everyone; the task is difficult when all sorts of people are expected to use the item. The designer can consult handbooks with tables that show average arm reach and seated height, how far the average person can stretch backward while seated, and how much room is needed for average hips, knees, and elbows. Physical anthropometry the field is called. With the data the designer can try to meet the size requirements for almost everyone, say for the 90th, 95th, or even the 99th percentile. Suppose you design a product for the 95th percentile, that is, for everyone except the 5 percent of people who are smaller or larger. You're leaving out a lot of people. If the United States has 250 million people, 5 percent is 12.5 million. Even if you design for the 99th percentile you'll leave out 1 percent of the population—2.5 million.

Consider typists. Typists need to have their hands comfortably poised above the keyboard. Because of the thickness of typewriters, typing tables are designed to be lower than work tables. Of course, what matters is not the table height or the keyboard thickness, but the distance from the normal position of the typist's hands to the keyboard, which is determined by several factors:

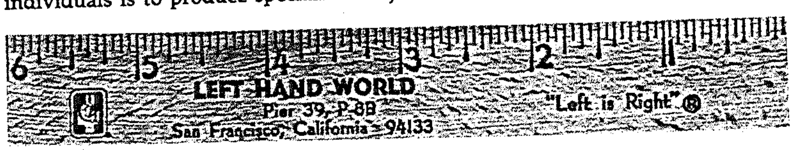
- How big the typist is: legs, chest, hands
- How high the table is
- How thick the keyboard is
- How high the chair is

What can the designer do? One solution is to make everything adjustable: chair height, height and angle of the typing table. In fact, good typing tables have several parts: a part for the keyboard, a part for the computer screen, a part that holds working papers. Let each part be separately adjustable in height and angle. Then everyone can be accommodated.

Some problems are not solved by adjustments. Left-handed people, for example, present special problems. Simple adjustments won't work, nor will averages: average a left-hander with a right-hander and what do you get? Here is where special products help—left-handed scissors and knives, left-handed rulers (figure 6.5). These special-purpose devices don't always work, of course, not when one device is to be used by many, or where the items are too large or expensive for each person to own or to carry around. In such cases the only solution is to make the device itself ambidextrous, even if that makes it a bit less efficient for each person.

Consider the special problems of the aged and infirm, the handicapped, the blind or near-blind, the deaf or hard of hearing, the very short or very tall, or the foreign. Wheelchairs, for example, cannot easily manipulate curbs, stairs, or narrow aisles. As we age, our physical agility decreases, our reaction time slows, our visual skills deteriorate,

6.5 Left-handed Ruler. Writing from left to right with the left hand means that you cover what you write, making rulers hard to use, smearing the ink. A left-handed pen is a pen with fast-drying ink. This ruler for left-handers has the numbers going from right to left. One solution to the problem of diversity among individuals is to produce specialized objects.



and our ability to attend to several things at once or to switch rapidly among competing events decreases.

High-speed highways pose special problems for the aged. An automobile traveling at high speed on a crowded highway at dusk is already pushing the limit of the driver's capabilities. The elderly are pushed beyond their limit. The solution adopted by many elderly drivers is to travel very slowly, to adjust their speed to what their processing can handle comfortably. Unfortunately, the slow driver poses a hazard to other drivers: on high-speed highways, things are considerably safer if everyone travels at approximately the same speed. I see no simple solution to this problem. In many cities, especially in the United States, there is no easy way to get from one place to another except by private automobile. Yet the elderly can't be expected to stay home. The solution has got to be either increased public transportation, or supplied drivers, or perhaps special streets or highway lanes with slower speed limits. Automated cars, the dream of science fiction writers and city planners, may still one day come about; they would take care of this problem.

Those of you who are young, do not smirk. Our abilities begin to deteriorate relatively early, starting in our mid-twenties. By our mid-forties our eyes can no longer adjust sufficiently to focus over the entire range of distances, so most of us need reading glasses or bifocals. Bifocals make it harder to do fine work, harder to use computer terminals (whose screens seem to be designed for twenty-year-olds).

I type these words seated in front of my computer terminal, head tilted upward at an uncomfortable angle so that I can see the screen out of the bottom half of my eyeglasses. I can't figure out how to get comfortable. Lower the screen and it gets in the way of my typing. Use special "computer" glasses adjusted for screen size and distance, and I can't read all the notes and outlines scattered about me at various distances. Fortunately, I can change the size of the type that appears on the screen. I use a twelve-point font, one whose letters are comfortably large. Alas, this is a tradeoff, for the larger the letters on the screen, the less material can fit. Change to nine-point font and I can see 78 percent more material (33 percent more lines, each with 33 percent more words): a non-trivial difference when I'm trying to write long sections. But the letters are 33 percent smaller, making it harder both to read and to correct them. At least my computer allows flexibility in type size; most do not.

By the time we're sixty, enough stray material has scattered about in our eyes that visual contrast is diminished, enough to be one of the major reasons that airline pilots are forced to retire at this age. At the age of sixty a person is still in good mental and physical shape, and the accumulated wisdom of the years leads to superior performance in many tasks. But physical strength is lessened, the agility of the body decreased, and the speed of some operations lessened. In a world where the average age is increasing, sixty is still relatively young: most sixty-year-olds have another twenty years to live, many have forty. We need to design with these people in mind—think of it as designing with our future selves in mind.

There is no simple solution, no one size fits all. But designing for flexibility helps. Flexibility in the size of the images on computer screens, in the sizes, heights, and angles of tables and chairs. Flexibility on our highways, perhaps making sure there are alternative routes with different speed limits. Fixed solutions will invariably fail with some people; flexible solutions at least offer a chance for those with special needs.

SELECTIVE ATTENTION: THE PROBLEM OF FOCUS

The ability of conscious attention is limited: focus on one thing and you reduce your attention to others. Psychologists call the phenomenon "selective attention." Excessive focus leads to a kind of tunnel vision, where peripheral items are ignored.

I watched a consumer show on British television on toasters that caught fire when the bread was too dry. The consumer representatives pointed out that people often inserted their fingers, a fork, or a knife into the toaster to extract the toast. This was very dangerous (even more dangerous in Britain than in the United States because the voltage is 240 volts, not the 120 of the United States). Yet some toasters had exposed wires very close to the top, quite reachable by the finger or the metal utensil. The consumer representatives argued that manufacturers should not have placed the wires so close to the opening.

The manufacturers denied that their toasters were dangerous. "Why," they asked, "would someone stick their fingers or a knife into a toaster?" Certainly the instructions warned them not to. Certainly they must know it is dangerous. To the designer, such an action is so unthinkable that prevention did not enter into the design considerations.

Consider the matter from the user's point of view. The person sees a problem—stuck or burning toast—and focuses on the solution—to extract it. The danger does not come to mind. To my own surprise, I did the same thing the very next day. I inserted two crumpets into the toaster; a few minutes later, smoke was pouring out. Quick, I ran over to the toaster, popped up the crumpets as far as they would go, and then quickly (but carefully?) inserted a knife blade into the toaster, down the side, to lift them out. What was I doing?

Selective attention: attend to the immediate problem, forget the rest. Sure I was being careful, but that is probably what the people who electrocuted themselves also believed. It just didn't seem dangerous, that's all.

The same story is repeated over and over again. Underwater divers focus so much on struggling to the surface that they fail to release the lead weights (on a special easy-to-release belt) that are keeping them underwater. People who are fleeing a fire push hard against a door, harder and harder, failing to recognize that the door opens by pulling. Someone is trapped behind a door, pushing against the left side when it opens from the right. Motorcyclists have their helmets strapped to their bike, not their head. People don't use seatbelts, or they drive too fast, because it is inconvenient to do otherwise and because they don't see the danger.

When there is a problem, people are apt to focus on it to the exclusion of other factors. The designer must design for the problem case, making other factors more salient, or easier to get to, or perhaps less necessary. That's what the forcing functions of chapter 5 were all about. Make the power cutoff switch of the toaster a forcing function, so that a person can't stick something into the toaster without flipping a power cutoff switch (which should be easy to get to and use). Or change the design of the wiring and heating elements so that lethal elements cannot be reached from outside, no matter what flesh or metal gets put into the toaster.

A corollary principle is that designers must guard against the problems of focus in their own design. Did their attention to one set of variables cause them to neglect another? Did safety suffer for usability? Usability for aesthetics? Aesthetics for manufacturability?

The Faucet: A Case History of Design Difficulties

It may be hard to believe that an everyday water faucet could need an instruction manual. I saw one, this time at the meeting of the British Psychological Society in Sheffield, England. The participants stayed in dormitories. Upon checking into one of these, the Ranmoor House, a guest was given a pamphlet that gave useful information: where the churches were, the times of meals, the location of the post office, and how to work the taps (faucets). "The taps on the washhand basin are operated by pushing down gently."

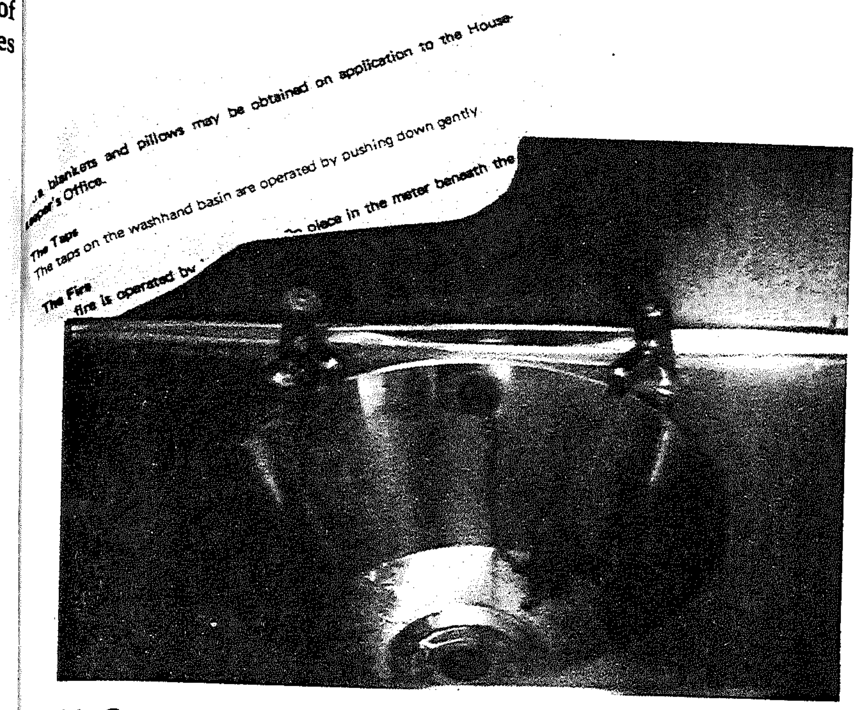
When it was my turn to speak at the conference, I asked the audience about those taps. How many had trouble using it? Polite, restrained titterings from the audience. How many tried to turn the handle? A large show of hands. How many had to seek help? A few honest folks raised their hands. Afterward, one woman came up to me and said that she had given up and had to walk up and down the halls until she found someone who could explain the taps to her.

A simple sink, a simple-looking faucet. But it looks like it should be turned, not pushed (figure 6.6 A*). If you want the faucet to be pushed, make it look like it should be pushed. It can be done: the airlines do it right (figure 6.6* B*).*

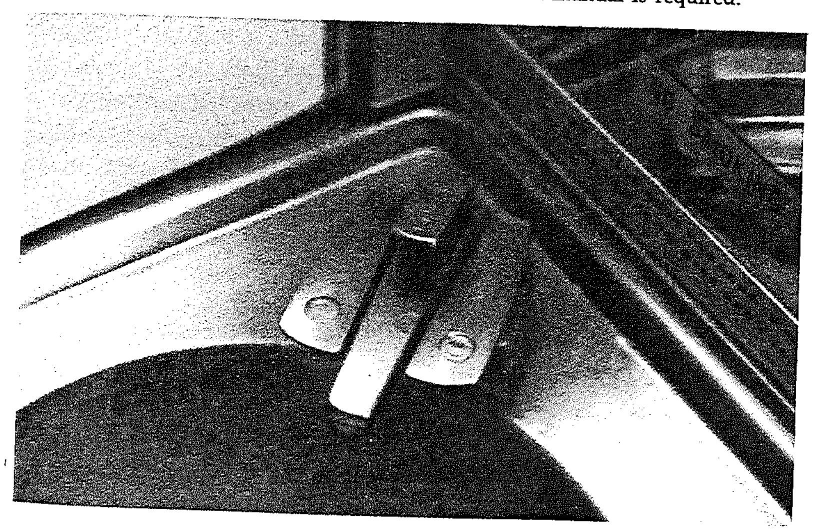
Pity the poor house porters, always getting calls for help about the faucets. So instructions were put in the orientation sheet. Who would ever think of having to read instructions before using a faucet? At least put them on the faucets, where they can't be missed. But when simple things need instructions, it is a certain sign of poor design.

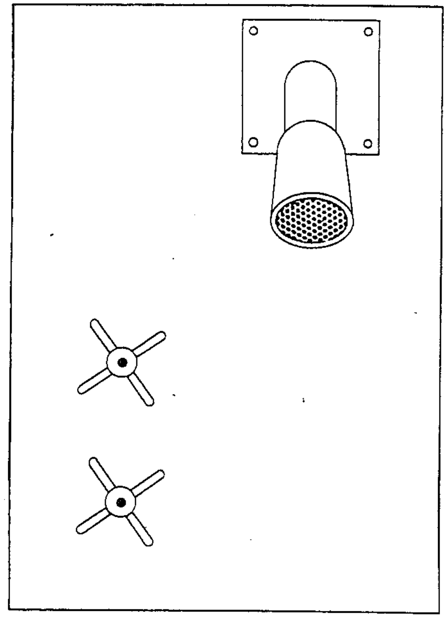
Why are faucets so hard to get right? Let us take a closer look at the two major variables (they will give us quite enough to do). The person who uses the faucets cares about two things: the water temperature and volume. Two things to control. We should be able to do that with two controls, one for each. Except that water comes in two pipes, hot and cold, and so the two things that are easiest to control—volume of hot water and volume of cold water—are not the two things we want to have controlled. Hence the designer's dilemma.

There are three problems; two relate to the mapping of intentions to actions, and the third is the problem of evaluation:



6.6 Contrasting Designs for "Push" Faucets. The faucets *A* (above) in the Ranmoor dormitory at the University of Sheffield give little clue to their mode of operation. As a result, occupants must be supplied with the instruction sheet for "the taps". The faucets *B* (below) on the sink of a commercial airline are designed properly. Pushing is clearly indicated. No instruction manual is required.





6.7 Vertical Faucets. The world standard is that hot is on the left, cold on the right. What do you do here? Why would anyone dream up this scheme?

- Which faucet controls the hot, which the cold?
- What do you do to the faucet to make it increase or decrease the water flow?
- How do you determine if the volume or temperature is correct?

The two mapping problems are solved through cultural conventions, or constraints. It is a worldwide convention that the left faucet should be hot, the right cold. It is also a universal convention that screw threads are made to tighten with clockwise turning, loosen with counterclockwise. You turn off a faucet by tightening a screw thread (tightening a washer against its seat), thereby shutting off the flow of water. So clockwise turning shuts off the water, counterclockwise turns it on.

Unfortunately, the constraints do not always hold. Most of the English people I asked were not aware that left/hot, right/cold was a convention; it is violated too often to be considered a convention in England. But the convention isn't universal in the United States. Look at the picture of a shower control from my own university (figure 6.7). Here we have vertical faucets. Vertical? If left is the standard for hot, how does that translate to vertical arrangements? Is hot the top or the bottom? Weird.

Sometimes a designer messes with the convention on purpose. The human body has a mirror-image symmetry, says this pseudopsychologist. So if the left hand moves clockwise, why, the right hand should move counterclockwise. Watch out, your plumber or architect may install a bathroom fixture where clockwise rotation turns the hot water off and the cold water on. Or is it the other way around? No matter, as you try to control the water temperature, soap running down over your eyes, groping to change the water control with one hand, soap or shampoo clutched in the other, you are guaranteed to get it wrong. The water is freezing, so you try to increase the amount of hot. You will probably turn on the shower, or the bath, or open the drain (or shut it), or turn off the hot water completely, or scald yourself.

Whoever invented that mirror-image nonsense should be forced to take a shower. Yes, there is some logic to it. To be a bit fair to the inventor of the scheme, it does work reasonably well as long as you always use the faucets by placing both hands on them at the same time, adjusting both controls simultaneously. It fails miserably, however, when one hand is used to alternate between the two controls. Then you cannot remember which direction does what.

What about the evaluation problem? Feedback in the use of most faucets is rapid and direct, so turning them the wrong way is easy to discover and correct—the evaluate-action cycle is easy to traverse. As a result, the discrepancy from normal rules is often not noticed. Unless you are in the shower and the feedback occurs when you scald yourself.

Older sinks have two separate spouts. Here evaluation is difficult. You can wave your hand rapidly back and forth between the spouts, hoping thereby to get a good mix of temperatures, or you can fill up the basin, adjusting the amount of hot and cold water so that the accumulating mixture reaches the desired temperature. Usually you settle for anything in the neighborhood. Each problem alone isn't a big deal. But the total sum of all the trivial mal-design unnecessarily adds to the trauma of everyday life.

Now consider the modern single-spout, single-control faucet. Technology to the rescue. Move the control one way, it adjusts temperature. Move it another, it adjusts volume. Hurrah! We control exactly the variables of interest, and the mixing spout solves the evaluation problem.

Yes, these new faucets are beautiful. Sleek, elegant, prize winning.

Unusable. They solved one set of problems only to create yet another. The mapping problems now predominate.

- Which control is associated with which action?
- What operations do you apply to the controls?

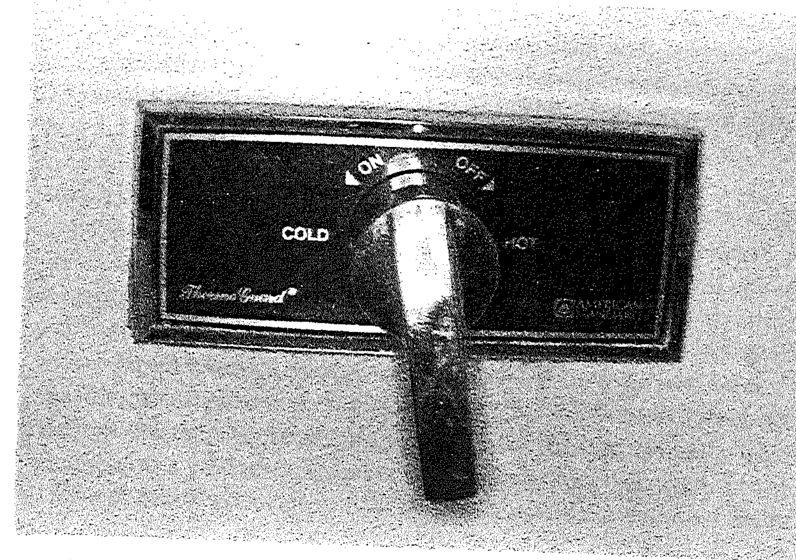
The problem is that it is very difficult to figure out which part of the sleek faucet is the control. And even if you figure that out, it is hard to figure out in which direction it moves. And once you figure that out, it is hard to figure out which direction controls which action. And when these fancy, multipurpose, sleek designs also control the basin plug and the diversion of water to shower or bath, disaster awaits.

There are two problems here. First, in the name of elegance, the moving parts sometimes meld invisibly into the faucet structure, making it nearly impossible even to find the controls, let alone figure out which way they move or what they control. Second, in the name of novelty, the new designs have forfeited the power of cultural constancy. Users don't want each new design to use a different method for controlling the water. Users need standardization. If all makers of faucets could agree on a standard set of motions to control amount and temperature (how about up and down to control amount—up meaning increase—and left and right to control temperature—left meaning hot?), then we could all learn the standards once, and forever afterward use the knowledge for every new faucet we encountered.

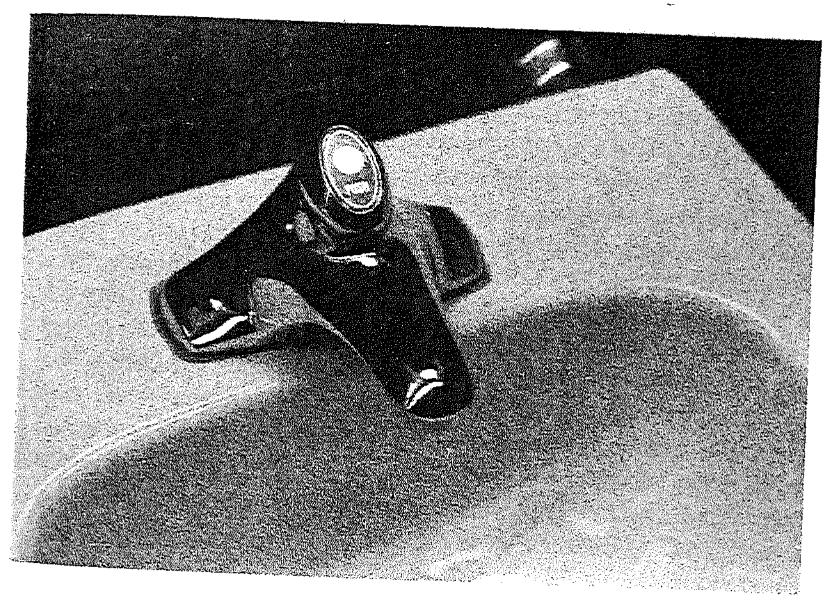
> If you can't put the knowledge on the device, then develop a cultural constraint: standardize what has to be kept in the head.

There could be small variations in the standard. Suppose a designer wanted temperature to be controlled by a knob that turned rather than a lever that moved left and right. Fortunately, there is a natural mapping that relates turning to direction: a clockwise turning is the same as moving to the right—getting colder—and a counterclockwise turning is the same as moving to the left—hotter.

Technological development never ceases. There is yet another solution to the control problem, one that has a slight virtue over the others: it is cheaper. One control turns the water on or off and lets you adjust either temperature or volume, but not both (figure 6.8). All you have to do is to locate the control and operate it. Think of all the mental energy and confusion you have been saved. We finally have a control that is truly easy to use. Success.



6.8 Simpler Faucets. In *A* (above) the mapping problem is solved—the faucet is presumed to be easy to use. The problem is that you cannot control the amount of water. On top of that, once the knob has been turned 180°, it is no longer clear which way to turn it in order to make the water hotter or colder. Faucet *B* (below) couldn't be simpler. It certainly is easy to use. Of course, you can only turn it on; you get a fixed temperature and a fixed volume of water.



Wait, we really do want to control both amount and temperature independently. This solution gives us only one control. So we can adjust temperature, but we get out whatever amount of water the designer thought was good for us. Or we can adjust the amount while getting an arbitrary temperature. The story of progress.

Some variants on this faucet control only on or off: you have control over neither volume nor temperature. Sometimes there is no visible means to turn on the water. How does the novice user realize that one is supposed to wave the hands under the faucet? There is no sign of the required operation, no relevant information in the world.

Perhaps you have a big sign: "Do not adjust controls, simply place hand under spout." The sign ruins the elegance, doesn't it? Interesting choice—understandability or elegance. Of course, if such faucets became common, then people would know how to use them and the signs could come down. Someday.

Two Deadly Temptations for the Designer

Let's return to the designer's problems. I've mentioned the time and economic pressures on them. Now let me tell you of two deadly temptations that await the unwary, temptations that lead toward products that are overly complex, products that drive users to distraction—I call these creeping featurism and the worshipping of false images.

CREEPING FEATURISM

I recently attended a demonstration of a new word processing program, held in a large, crowded auditorium. A representative from the company sat in front of the computer, a video projector putting a large image of the computer screen onto the movie screen. The audience was skeptical: they were experts and knew the limitations of such programs. The demonstrator was smooth and convincing, composing an outline, expanding it into text, indenting the paragraphs, numbering them, changing their styles, flipping into a drawing program, drawing a figure, inserting the drawing into the text with the text flowing neatly around the drawing. "You want two columns?" asked the demonstrator. "Here it is. Three columns? Four? Just name it." The screen flowed: three columns of text neatly lined up, illustrations just where they ought to be, page headers, footers, paragraph numbers, boldface italics. Large type, small type, footnotes neatly displayed at the end of columns. You could even highlight just the things that had been changed in the last revision. You could leave notes for yourself or a co-author, notes that would appear on the screen but need not be printed in the final text.

The audience applauded. They called out for their favorite features. Usually the demonstrator would say, "Yes, I am glad you asked, here it is," and whiz, bang, wave of hands, click of keys, swish of the mouse, and the screen would display the latest called-for feature. Sometimes the demonstrator would say, "Not yet, it will be in the second release—in a few months."

Creeping featurism is the tendency to add to the number of features that a device can do, often extending the number beyond all reason. There is no way that a program can remain usable and understandable by the time it has all of those special-purpose features. The word processor I use on my home computer comes with a 340-page reference manual, plus a 150-page introductory manual intended for first-time users (who probably can't understand the reference manual until they have first read the learning manual). EMACS, the text editor I use on my university computer, comes with a 250-page manual, which would be longer if you weren't assumed to be expert at many things.

How can users cope? How can users protect themselves from themselves? After all, as the story of the demonstration illustrates, it is the users who request the features; the designers are simply obliging them. But each new set of features adds immeasurably to the size and complexity of the system. More and more things have to be made invisible, in violation of all the principles of design. No constraints, no affordances; invisible, arbitrary mappings. And all because the users have demanded features.

Creeping featurism is a disease, fatal if not treated promptly. There are some cures, but, as usual, the best approach is to practice preventive medicine. The problem is that the disease comes so naturally, so innocently. Analyze a task, and you see how it can be made easier. Why, adding features seems so virtuous, following the very preachings of this book, simply trying to make life easier for everyone. But with extra features comes extra complexity. Each new feature adds yet another control, or display, or button, or instruction. Complexity probably increases as the square of the features: double the number of features, quadruple the complexity. Provide ten times as many features, multiply the complexity by one hundred.

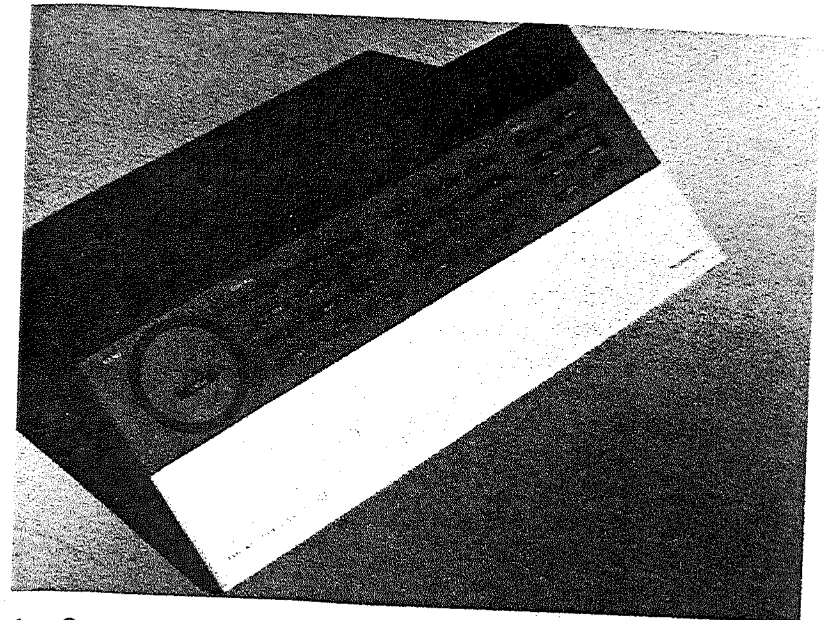
There are two paths to treating featurism. One is avoidance, or at the least, great restraint. Yes, allow features that seem absolutely necessary, but steel yourself to the rigors of doing without the rest. Once a device has multiple functions, there is no way to avoid having multiple controls and operations, multiple pages of instructions, multiple difficulties and confusions.

The second path is organization. Organize, modularize, use the strategy of divide and conquer. Suppose we take each set of features and hide them away in separate locations, perhaps with dividing barriers between sets. The technical word is *modularization.* Create separate functional modules, each with a limited set of controls, each specialized for some different aspect of the task. The virtue is that each separate module has limited properties, limited features. Yet the sum total of features in the device is unchanged. The proper division of a complex set of controls into modules allows you to conquer complexity (as can be seen in figure 6.9).

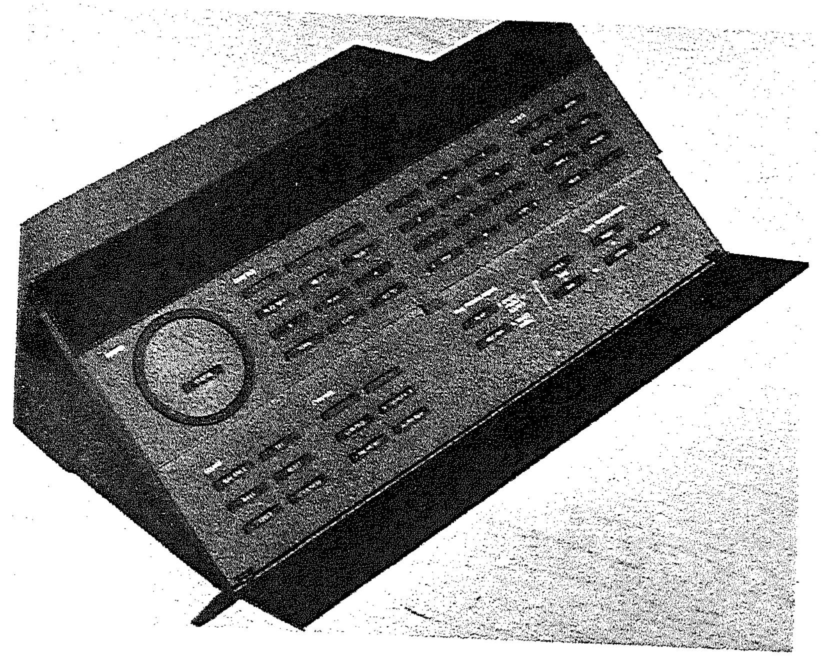
THE WORSHIPPING OF FALSE IMAGES

The designer—and user—may further be tempted to worship complexity. Some of my students did a study of office copying machines. They discovered that the most expensive, most feature-laden machines were best sellers among law firms. Did the firms need the extra features of the machines? No. It turns out that they liked to put them in the front offices where clients were waiting—impressive machines, with flashing lights and pretty displays. The firm gained an aura of being modern and up to date, capable of dealing with the rigors of modern high technology. The fact that the machines were too complex to be mastered by most of the people in the firms was irrelevant: the copiers did not even have to be used—appearance alone did the job. Ah, yes, the worshipping of false images, in this case, by the customers.

A colleague told me of her difficulties with her home audio/television set. It was comprised of separate components, each alone not too complex. But the combination was so overwhelming that she could not



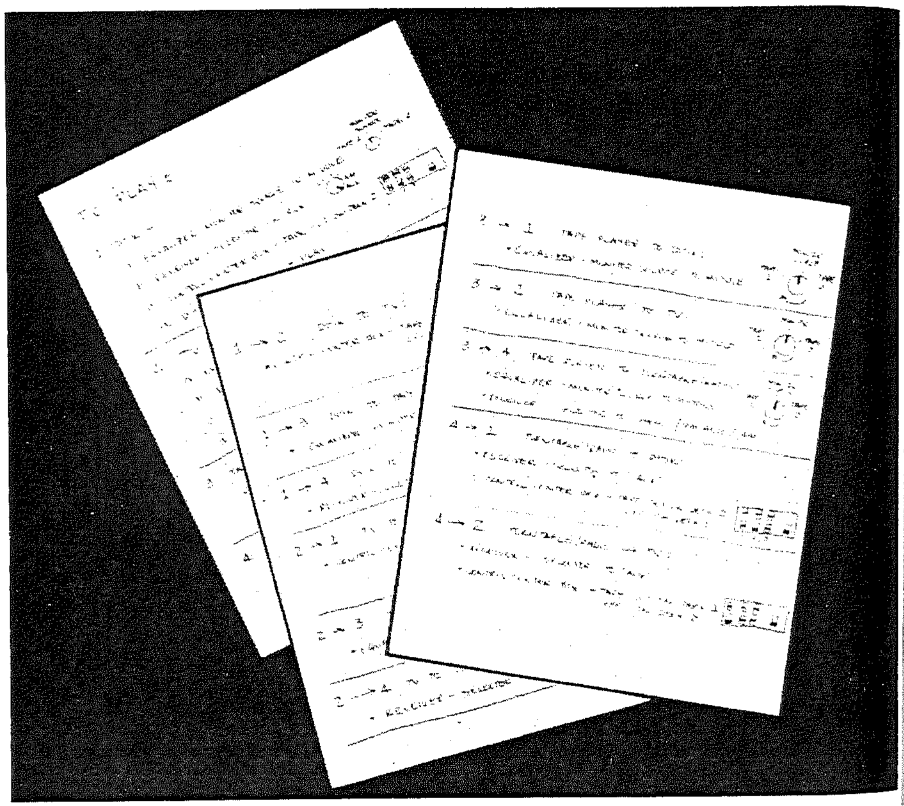
6.9 Overcoming Complexity through Organization. The remote control device *A* (above) for the Bang & Olufsen audio set (there are no controls on the set itself) serves numerous features and options. The controls are made simple through several principles. First, the buttons are grouped into logical, functional modules. Second, the display on the remote gives good feedback about the operation. Third, infrequently used controls are hidden beneath a panel *B* (below), which reduces the visual complexity in normal use but is available when needed.



use it. Her solution was to work through each of the operations she wished to perform and write explicit instructions for herself (figure 6.10). And even with these instructions, operation was not easy. Here the culprit clearly is the interactions among components. Imagine having to write several pages of instructions in order to use your own audio set!

In the case of the overly complex audio/television set, the components were from different manufacturers. Nonetheless, they were intended to be purchased and used individually. I have seen equal complexity in components from a single manufacturer. Some salespeople try to create the impression that this is how it has to be, that anyone with any technical competence can manage to work the devices. No,

6.10 A Personal Instruction Manual. My colleague had to write out three pages of instructions to help herself set up any desired configuration of her audio/video components. Too many interacting parts, too much complexity.



that attitude won't work. The equipment is simply too complex, the interaction between components too overwhelming. There was nothing particularly elaborate about my colleague's equipment. This person was reasonably sophisticated in technical things—she has a Ph.D. in computer science—but was baffled by an everyday audio set.

One of the problems with audio/video equipment is that even if each component has been designed with care, the interaction between components causes problems. The tuner, cassette deck, television, VCR, CD player, and so on, all seem to be designed in relative isolation. Put them all together and there is chaos: an amazing proliferation of controls, lights, meters, and interconnections that can defeat even the most talented.

In this case, the false image is appearance of technical sophistication. This is the sin responsible for the extra complexity of many of our devices, from telephones and televisions to dishwashers and washing machines, from automobile dashboards to audiovisual sets. There is no remedy except through education. You might argue that this is a victimless sin, hurting only those who practice it, but this is not true. Manufacturers and designers produce products for what they perceive as their market demands; therefore, if enough people sin in this way—and the evidence is that they do—then all the rest of us must pay for the pleasures of a few. We pay in fancy, colorful-looking equipment that is nearly impossible to use.

The Foibles of Computer Systems

Now turn to the computer, an area where all the major difficulties of design can be found in profusion. In this realm the user is seldom considered. There is nothing particularly special about the computer; it is a machine, a human artifact, just like the other sorts of things we have looked at, and it poses few problems that we haven't encountered already. But designers of computer systems seem particularly oblivious to the needs of users, particularly susceptible to all the pitfalls of design. The professional design community is seldom called in to help with computer products. Instead, design is left in the hands of engineers and programmers, people who usually have no experience, and no expertise in designing for people.

The abstract nature of the computer poses a particular challenge for the designer. The computer works electronically, invisibly, with no sign of the actions it is performing. And it is instructed through an