"Kenneth Olsen, the engineer who founded and still runs Digital Equipment Corp., confessed at the annual meeting that he can't figure out how to heat a cup of coffee in the company's microwave oven."1

You Would Need an Engineering Degree to Figure This Out

"You would need an engineering degree from MIT to work this," someone once told me, shaking his head in puzzlement over his brand new digital watch. Well, I have an engineering degree from MIT. (Kenneth Olsen has two of them, and he can't figure out a microwave oven.) Give me a few hours and I can figure out the watch. But why should it take hours? I have talked with many people who can't use all the features of their washing machines or cameras, who can't figure out how to work a sewing machine or a video cassette recorder, who habitually turn on the wrong stove burner.

Why do we put up with the frustrations of everyday objects, with objects that we can't figure out how to use, with those neat plastic-wrapped packages that seem impossible to open, with doors that trap people, with washing machines and dryers that have become too con-

fusing to use, with audio-stereo-television-video-cassette-recorders that claim in their advertisements to do everything, but that make it almost impossible to do anything?

The human mind is exquisitely tailored to make sense of the world. Give it the slightest clue and off it goes, providing explanation, rationalization, understanding. Consider the objects—books, radios, kitchen appliances, office machines, and light switches—that make up our everyday lives. Well-designed objects are easy to interpret and understand. They contain visible clues to their operation. Poorly designed objects can be difficult and frustrating to use. They provide no clues—or sometimes false clues. They trap the user and thwart the normal process of interpretation and understanding. Alas, poor design predominates. The result is a world filled with frustration, with objects that cannot be understood, with devices that lead to error. This book is an attempt to change things.

The Frustrations of Everyday Life

If I were placed in the cockpit of a modern jet airliner, my inability to perform gracefully and smoothly would neither surprise nor bother me. But I shouldn’t have trouble with doors and switches, water faucets and stoves. “Doors?” I can hear the reader saying, “you have trouble opening doors?” Yes. I push doors that are meant to be pulled, pull doors that should be pushed, and walk into doors that should be slid. Moreover, I see others having the same troubles—unnecessary troubles. There are psychological principles that can be followed to make these things understandable and usable.

Consider the door. There is not much you can do to a door: you can open it or shut it. Suppose you are in an office building, walking down a corridor. You come to a door. In which direction does it open? Should you pull or push, on the left or the right? Maybe the door slides. If so, in which direction? I have seen doors that slide up into the ceiling. A door poses only two essential questions: In which direction does it move? On which side should one work it? The answers should be given by the design, without any need for words or symbols, certainly without any need for trial and error.

A friend told me of the time he got trapped in the doorway of a post office in a European city. The entrance was an imposing row of perhaps six glass swinging doors, followed immediately by a second, identical row. That’s a standard design: it helps reduce the airflow and thus maintain the indoor temperature of the building.

My friend pushed on the side of one of the leftmost pair of outer doors. It swung inward, and he entered the building. Then, before he could get to the next row of doors, he was distracted and turned around for an instant. He didn’t realize it at the time, but he had moved slightly to the right. So when he came to the next door and pushed it, nothing happened. “Hmm,” he thought, “must be locked.” So he pushed the side of the adjacent door. Nothing. Puzzled, my friend decided to go outside again. He turned around and pushed against the side of a door. Nothing. He pushed the adjacent door. Nothing. The door he had just entered no longer worked. He turned around once more and tried the inside doors again. Nothing. Concern, then mild panic. He was trapped! Just then, a group of people on the other side of the entranceway (to my friend’s right) passed easily through both sets of doors. My friend hurried over to follow their path.

How could such a thing happen? A swinging door has two sides. One contains the supporting pillar and the hinge, the other is unsupported. To open the door, you must push on the unsupported edge. If you push on the hinge side, nothing happens. In this case, the designer aimed for beauty, not utility. No distracting lines, no visible pillars, no visible hinges. So how can the ordinary user know which side to push
Visibility problems come in many forms. My friend, trapped between the glass doors, suffered from a lack of clues that would indicate what part of a door should be operated. Other problems concern the mappings between what you want to do and what appears to be possible, another topic that will be expanded upon throughout the book. Consider one type of slide projector. This projector has a single button to control whether the slide tray moves forward or backward. One button to do two things? What is the mapping? How can you figure out how to control the slides? You can’t. Nothing is visible to give the slightest hint. Here is what happened to me in one of the many unfamiliar places I’ve lectured in during my travels as a professor:

The Leitz slide projector illustrated in figure 1.3 has shown up several times in my travels. The first time, it led to a rather dramatic incident. A conscientious student was in charge of showing my slides. I started my talk and showed the first slide. When I finished with the first slide and asked for the next, the student carefully pushed the control button and watched in dismay as the tray backed up, slid out of the projector and plopped off the table onto the floor, spilling its entire contents. We had to delay the lecture fifteen minutes while I struggled to reorganize the slides. It wasn’t the student’s fault. It was the fault of the elegant projector. With only one button to control the slide advance, how could one switch from forward to reverse? Neither of us could figure out how to make the control work.

All during the lecture the slides would sometimes go forward, sometimes backward. Afterward, we found the local technician, who explained it to us. A brief push of the button and the slide would go on? While distracted, my friend had moved toward the (invisible) supporting pillar, so he was pushing the doors on the hinged side. No wonder nothing happened. Pretty doors. Elegant. Probably won a design prize.

The door story illustrates one of the most important principles of design: visibility. The correct parts must be visible, and they must convey the correct message. With doors that push, the designer must provide signals that naturally indicate where to push. These need not destroy the aesthetics. Put a vertical plate on the side to be pushed, nothing on the other. Or make the supporting pillars visible. The vertical plate and supporting pillars are natural signals, naturally interpreted, without any need to be conscious of them. I call the use of natural signals natural design and elaborate on the approach throughout this book.

Taste (7) für Diawechsel am Gerät
Diawechsel vorwärts = kurz drücken,
Diawechsel rückwärts = länger drücken.

Button (7) for changing the slides
Slide change forward = short press,
Slide change backward = longer press.

1.3 Leitz Pravodit Slide Projector. I finally tracked down the instruction manual for that projector. A photograph of the projector has its parts numbered. The button for changing slides is number 7. The button itself has no labels. Who could discover this operation without the aid of the manual? Here is the entire text related to the button, in the original German and in my English translation:
forward, a long push and it would reverse. (Pity the conscientious student who kept pushing it hard—and long—to make sure that the switch was making contact.) What an elegant design. Why, it managed to do two functions with only one button! But how was a first-time user of the projector to know this?

As another example, consider the beautiful Amphithéâtre Louis-Laird in the Paris Sorbonne, which is filled with magnificent paintings of great figures in French intellectual history. (The mural on the ceiling shows lots of naked women floating about a man who is valiantly trying to read a book. The painting is right side up only for the lecturer—it is upside down for all the people in the audience.) The room is a delight to lecture in, at least until you ask for the projection screen to be lowered. "Ah," says the professor in charge, who gestures to the technician, who runs out of the room, up a short flight of stairs, and out of sight behind a solid wall. The screen comes down and stops. "No, no," shouts the professor, "a little bit more." The screen comes down again, this time too much. "No, no, no!" the professor jumps up and down and gestures wildly. It's a lovely room, with lovely paintings. But why can't the person who is trying to lower or raise the screen see what he is doing?

New telephone systems have proven to be another excellent example of incomprehensible design. No matter where I travel, I can count upon finding a particularly bad example.

When I visited Basic Books, the publishers of this book, I noticed a new telephone system. I asked people how they liked it. The question unleashed a torrent of abuse. "It doesn't have a hold function," one woman complained bitterly—the same complaint people at my university made about their rather different system. In older days, business phones always had a button labeled "hold." You could push the button and hang up the phone without losing the call on your line. Then you could talk to a colleague, or pick up another telephone call, or even pick up the call at another phone with the same telephone number. A light on the hold button indicated when the function was in use. It was an invaluable tool for business. Why didn't the new phones at Basic Books or in my university have a hold function, if it is so essential? Well, they did, even the very instrument the woman was complaining about. But there was no easy way to discover the fact, nor to learn how to use it.

I was visiting the University of Michigan and I asked about the new

system there. "Yech!" was the response, "and it doesn't even have a hold function!" Here we go again. What is going on? The answer is simple: first, look at the instructions for hold. At the University of Michigan the phone company provided a little plate that fits over the keypad and reminds users of the functions and how to use them. I carefully unhooked one of the plates from the telephone and made a photocopy (figure 1.4). Can you understand how to use it? I can't. There is a "call hold" operation, but it doesn't make sense to me, not for the application that I just described.

The telephone hold situation illustrates a number of different problems. One of them is simply poor instructions, especially a failure to relate the new functions to the similarly named functions that people already know about. Second, and more serious, is the lack of visibility of the operation of the system. The new telephones, for all their added sophistication, lack both the hold button and the flashing light of the old ones. The hold is signified by an arbitrary action: dialing an arbitrary sequence of digits (*8, or *99, or what have you: it varies from one phone system to another). Third, there is no visible outcome of the operation.

Devices in the home have developed some related problems: functions and more functions, controls and more controls. I do not think that simple home appliances—stoves, washing machines, audio and television sets—should look like Hollywood's idea of a spaceship control room. They already do, much to the consternation of the consumer who, often as not, has lost (or cannot understand) the instruction
of visibility, appropriate clues, and feedback of one’s actions. These principles constitute a form of psychology—the psychology of how people interact with things. A British designer once noted that the kinds of materials used in the construction of passenger shelters affected the way vandals responded. He suggested that there might be a psychology of materials.

AFFORDANCES

“In one case, the reinforced glass used to panel shelters (for railroad passengers) erected by British Rail was smashed by vandals as fast as it was renewed. When the reinforced glass was replaced by plywood boarding, however, little further damage occurred, although no extra force would have been required to produce it. Thus British Rail managed to elevate the desire for defacement to those who could write, albeit in somewhat limited terms. Nobody has, as yet, considered whether there is a kind of psychology of materials. But on the evidence, there could well be.”

There already exists the start of a psychology of materials and of things, the study of affordances of objects. When used in this sense, the term affordance refers to the perceived and actual properties of the thing, primarily those fundamental properties that determine just how the thing could possibly be used (see figures 1.5 and 1.6). A chair affords (“is for”) support and, therefore, affords sitting. A chair can also be carried. Glass is for seeing through, and for breaking. Wood is normally used for solidity, opacity, support, or carving. Flat, porous, smooth surfaces are for writing on. So wood is also for writing on. Hence the problem for British Rail: when the shelters had glass, vandals smashed it; when they had plywood, vandals wrote on and carved it. The planners were trapped by the affordances of their materials.

Affordances provide strong clues to the operations of things. Plates are for pushing. Knobs are for turning. Slots are for inserting things into. Balls are for throwing or bouncing. When affordances are taken advantage of, the user knows what to do just by looking: no picture, label, or instruction is required. Complex things may require explanation, but simple things should not. When simple things need pictures, labels, or instructions, the design has failed.

A psychology of causality is also at work as we use everyday things.
Something that happens right after an action appears to be caused by that action. Touch a computer terminal just when it fails, and you are apt to believe that you caused the failure, even though the failure and your action were related only by coincidence. Such false causality is the basis for much superstition. Many of the peculiar behaviors of people using computer systems or complex household appliances result from such false coincidences. When an action has no apparent result, you may conclude that the action was ineffective. So you repeat it. In earlier days, when computer word processors did not always show the results of their operations, people would sometimes attempt to change their manuscript, but the lack of visible effect from each action would make them think that their commands had not been executed, so they would repeat the commands, sometimes over and over, to their later astonishment and regret. It is a poor design that allows either kind of false causality to occur.

TWENTY THOUSAND EVERYDAY THINGS

There are an amazing number of everyday things, perhaps twenty thousand of them. Are there really that many? Start by looking about you. There are light fixtures, bulbs, and sockets; wall plates and screws; clocks, watches, and watchbands. There are writing devices (I count twelve in front of me, each different in function, color, or style). There are clothes, with different functions, openings, and flaps. Notice the variety of materials and pieces. Notice the variety of fasteners—buttons, zippers, snaps, laces. Look at all the furniture and food utensils: all those details, each serving some function for manufacturability, usage, or appearance. Consider the work area: paper clips, scissors, pads of paper, magazines, books, bookmarks. In the room I'm working in, I counted more than a hundred specialized objects before I tired. Each is simple, but each requires its own method of operation, each has to be learned, each does its own specialized task, and each has to be designed separately. Furthermore, many of the objects are made of many parts. A desk stapler has sixteen parts, a household iron fifteen, the simple bathtub-shower combination twenty-three. You can’t believe these simple objects have so many parts? Here are the eleven basic parts to a sink: drain, flange (around the drain), pop-up stopper, basin, soap dish, overflow vent, spout, lift rod, fittings, hot-water handle, and cold-water handle. We can count even more if we start taking the faucets, fittings, and lift rods apart.
The book *What's What: A Visual Glossary of the Physical World* has more than fifteen hundred drawings and pictures and illustrates twenty-three thousand items or parts of items. Irving Biederman, a psychologist who studies visual perception, estimates that there are probably “30,000 readily discriminable objects for the adult.” Whatever the exact number, it is clear that the difficulties of everyday life are amplified by the sheer profusion of items. Suppose that each everyday thing takes only one minute to learn; learning 20,000 of them occupies 20,000 minutes—333 hours or about 8 forty-hour work weeks. Furthermore, we often encounter new objects unexpectedly, when we are really concerned with something else. We are confused and distracted, and what ought to be a simple, effortless, everyday thing interferes with the important task of the moment.

How do people cope? Part of the answer lies in the way the mind works—in the psychology of human thought and cognition. Part lies in the information available from the appearance of the objects—the psychology of everyday things. And part comes from the ability of the designer to make the operation clear, to project a good image of the operation, and to take advantage of other things people might be expected to know. Here is where the designer’s knowledge of the psychology of people coupled with knowledge of how things work becomes crucial.

CONCEPTUAL MODELS

Consider the rather strange bicycle illustrated in figure 1.7. You know it won’t work because you form a conceptual model of the device and mentally simulate its operation. You can do the simulation because the parts are visible and the implications clear.

Other clues to how things work come from their visible structure—in particular from affordances, constraints, and mappings. Consider a pair of scissors: even if you have never seen or used them before, you can see that the number of possible actions is limited. The holes are clearly there to put something into, and the only logical things that will fit are fingers. The holes are affordances: they allow the fingers to be inserted. The sizes of the holes provide constraints to limit the possible fingers: the big hole suggests several fingers, the small hole only one. The mapping between holes and fingers—the set of possible operations—is suggested and constrained by the holes. Moreover, the operation is not sensitive to finger placement: if you use the wrong fingers,

Principles of Design for Understandability and Usability

We have now encountered the fundamental principles of designing for people: (1) provide a good conceptual model and (2) make things visible.

PROVIDE A GOOD CONCEPTUAL MODEL

A good conceptual model allows us to predict the effects of our actions. Without a good model we operate by rote, blindly; we do operations as we were told to do them; we can’t fully appreciate why, what effects to expect, or what to do if things go wrong. As long as things work properly, we can manage. When things go wrong, however, or when
we come upon a novel situation, then we need a deeper understanding, a good model.

For everyday things, conceptual models need not be very complex. After all, scissors, pens, and light switches are pretty simple devices. There is no need to understand the underlying physics or chemistry of each device we own, simply the relationship between the controls and the outcomes. When the model presented to us is inadequate or wrong (or, worse, nonexistent), we can have difficulties. Let me tell you about my refrigerator.

My house has an ordinary, two-compartment refrigerator—nothing very fancy about it. The problem is that I can't set the temperature properly. There are only two things to do: adjust the temperature of the freezer compartment and adjust the temperature of the fresh food compartment. And there are two controls, one labeled "freezer," the other "fresh food." What's the problem?

You try it. Figure 1.8 shows the instruction plate from inside the refrigerator. Now, suppose the freezer is too cold, the fresh food section just right. You want to make the freezer warmer, keeping the fresh food constant. Go on, read the instructions, figure them out.

1.8 My Refrigerator. Two compartments—fresh food and freezer—and two controls (in the fresh food unit). The illustration shows the controls and instructions. Your task: Suppose the freezer is too cold, the fresh food section just right. How would you adjust the controls so as to make the freezer warmer and keep the fresh food the same? (From Norman, 1986.)
Oh, perhaps I'd better warn you. The two controls are not independent. The freezer control affects the fresh food temperature, and the fresh food control affects the freezer. And don't forget to wait twenty-four hours to check on whether you made the right adjustment, if you can remember what you did.

Control of the refrigerator is made difficult because the manufacturer provides a false conceptual model. There are two compartments and two controls. The setup clearly and unambiguously provides a simple model for the user: each control is responsible for the temperature of the compartment that carries its name. Wrong. In fact, there is only one thermostat and only one cooling mechanism. One control adjusts the thermostat setting, the other the relative proportion of cold air sent to each of the two compartments of the refrigerator. This is why the two controls interact. With the conceptual model provided by the manufacturer, adjusting the temperatures is almost impossible and always frustrating. Given the correct model, life would be much easier (figure 1.9).

Why did the manufacturer present the wrong conceptual model?

1.10 Conceptual Models. The design model is the designer's conceptual model. The user's model is the mental model developed through interaction with the system. The system image results from the physical structure that has been built (including documentation, instructions, and labels). The designer expects the user's model to be identical to the design model. But the designer doesn't talk directly with the user—all communication takes place through the system image. If the system image does not make the design model clear and consistent, then the user will end up with the wrong mental model. (From Norman, 1986.)

Perhaps the designers thought the correct model was too complex, that the model they were giving was easier to understand. But with the wrong conceptual model, it is impossible to set the controls. And even though I am convinced I now know the correct model, I still cannot accurately adjust the temperatures because the refrigerator design makes it impossible for me to discover which control is for the thermostat, which control is for the relative proportion of cold air, and in which compartment the thermostat is located. The lack of immediate feedback for the actions does not help: with a delay of twenty-four hours, who can remember what was tried?

The topic of conceptual models will reappear in the book. They are part of an important concept in design: mental models. The models people have of themselves, others, the environment, and the things with which they interact. People form mental models through experience, training, and instruction. The mental model of a device is formed largely by interpreting its perceived actions and its visible structure. I call the visible part of the device the system image (figure 1.10). When the system image is incoherent or inappropriate, as in the case of the refrigerator, then the user cannot easily use the device. If it is incomplete or contradictory, there will be trouble.

MAKE THINGS VISIBLE

The problems caused by inadequate attention to visibility are all neatly demonstrated with one simple appliance: the modern telephone.

I stand at the blackboard in my office, talking with a student, when my telephone rings. Once, twice it rings. I pause, trying to complete my sentence before answering. The ringing stops. "I'm sorry," says the student. "Not your fault," I say. "But it's no problem, the call now transfers to my secretary's phone. She'll answer it." As we listen we hear her phone start to ring. Once, twice. I look at my watch. Six o'clock: it's late, the office staff has left for the day. I rush out of my office to my secretary's phone, but as I get there, it stops ringing. "Ah," I think, "it's being transferred to another phone." Sure enough, the phone in the adjacent office now starts ringing. I rush to that office, but it is locked. Back to my office to get the key, out to the locked door, fumble with the lock, into the office, and to the now quiet phone. I hear a telephone down the hall start to ring. Could that still be my call,
making its way mysteriously, with a predetermined lurching path, through the phones of the building? Or is it just another telephone call coincidentally arriving at this time?

In fact, I could have retrieved the call from my office, had I acted quickly enough. The manual states: “Within your pre-programmed pick-up group, dial 14 to connect to incoming call. Otherwise, to answer any ringing extension, dial ringing extension number, listen for busy tone. Dial 8 to connect to incoming call.” Huh? What do those instructions mean? What is a “pre-programmed pick-up group,” and why do I even want to know? What is the extension number of the ringing phone? Can I remember all those instructions when I need them? No.

Telephone chase is the new game in the modern office, as the automatic features of telephones go awry—features designed without proper thought, and certainly without testing them with their intended users. There are several other games, too. One game is announced by the plea, “How do I answer this call?” The question is properly whined in front of a ringing, flashing telephone, receiver in hand. Then there is the paradoxical game entitled “This telephone doesn’t have a hold function.” The accusation is directed at a telephone that actually does have a hold function. And, finally, there is “What do you mean I called you, you called me!”

Many of the modern telephone systems have a new feature that automatically keeps trying to dial a number for you. This feature resides under names such as automatic redialing or automatic callback. I am supposed to use this feature whenever I call someone who doesn’t answer or whose line is busy. When the person next hangs up the phone, my phone will dial it again. Several automatic callbacks can be active at a time. Here’s how it works. I place a phone call. There’s no answer, so I activate the automatic callback feature. Several hours later my telephone rings. I pick it up and say “Hello,” only to hear a ringing sound and then someone else saying “Hello.”

“How do I answer this call?”

“No,” I say, “you called me, my phone just rang.”

Slowly I realize that perhaps this is my delayed call. Now, let me see, who was I trying to call several hours ago? Did I have several callbacks in place? Why was I making the call?

The modern telephone did not happen by accident: it was carefully designed. Someone—more likely a team of people—invited a list of features thought desirable, invented what seemed to them to be plausible ways of controlling the features, and then put it all together. My university, focusing on cost and perhaps dazzled by the features, bought the system, spending millions of dollars on a telephone installation that has proved vastly unpopular and even unworkable. Why did the university buy the system? The purchase took several years of committee work and studies and presentations by competing telephone companies, and piles of documentation and specification. I myself took part, looking at the interaction between the telephone system and the computer networks, ensuring that the two would be compatible and reasonable in price. To my knowledge, nobody ever thought of trying out the telephones in advance. Nobody suggested installing them in a sample office to see whether users’ needs would be met or whether users could understand how to operate the phone. The result: disaster. The main culprit—lack of visibility—was coupled with a secondary culprit—a poor conceptual model. Any money saved on the installation and purchase is quickly disappearing in training costs, missed calls, and frustration. Yet from what I have seen, the competing phone systems would not have been any better.

I recently spent six months at the Applied Psychology Unit in Cambridge, England. Just before I arrived the British Telecom Company had installed a new telephone system. It had lots and lots of features. The telephone instrument itself was unremarkable (figure 1.11). It was the standard twelve-button, push-button phone, except that it had an extra key labeled “R” off on the side. (I never did find out what that key did.)

The telephone system was a standing joke. Nobody could use all the features. One person even started a small research project to record people’s confusions. Another person wrote a small “expert systems” computer program, one of the new toys of the field of artificial intelligence; the program can reason through complex situations. If you wanted to use the phone system, perhaps to make a conference call among three people, you asked the expert system and it would explain how to do it. So, you’re on the line with someone and you need to add a third person to the call. First turn on your computer. Then load the expert system. After three or four minutes (needed for loading the program), type in what you want to accomplish. Eventually the computer will tell you what to do—if you can remember why you want to
do it, and if the person on the other end of the line is still around. But, as it happens, using the expert system is a lot easier than reading and understanding the manual provided with the telephone (figure 1.12).

Why is that telephone system so hard to understand? Nothing in it is conceptually difficult. Each of the operations is actually quite simple. A few digits to dial, that’s all. The telephone doesn’t even look complicated. There are only fifteen controls: the usual twelve buttons—ten labeled 0 through 9, #, and *—plus the handset itself, the handset button, and the mysterious “R” button. All except the “R” are the everyday parts of a normal modern telephone. Why was the system so difficult?

A designer who works for a telephone company told me the following story:

“I was involved in designing the faceplate of some of those new multifunction phones, some of which have buttons labeled “R.” The “R” button is kind of a vestigial feature. It is very hard to remove features of a newly designed product that had existed in an earlier version. It’s kind of like physical evolution. If a feature is in the genome, and if that feature is not associated with any negativity (i.e., no customers gripe about it), then the feature hangs on for generations.

“It is interesting that things like the “R” button are largely determined through examples. Somebody asks, ‘What is the “R” button used for?’ and the answer is to give an example: ‘You can push “R” to access loudspeaker paging.’ If nobody can think of an example, the feature is dropped. Designers are pretty bright people, however. They can come up with a plausible-sounding example for almost anything. Hence, you get features, many many features, and these features hang on for a long time. The end result is complex interfaces for essentially simple things.”

As I pondered this problem, I decided it would make sense to compare the phone system with something that was of equal or greater complexity but easier to use. So let us temporarily leave the difficult telephone system and take a look at my automobile. I bought a car in Europe. When I picked up the new car at the factory, a man from the company sat in the car with me and went over each control, explaining its function. When he had gone through the controls once, I said fine, thanked him, and drove away. That was all the instruction it took. There are 112 controls inside the car. This isn’t quite as bad as it
sounds. Twenty-five of them are on the radio. Another 7 are the temperature control system, and 11 work the windows and sunroof. The trip computer has 14 buttons, each matched with a specific function. So four devices—the radio, temperature controls, windows, and trip computer—have together 57 controls, or just over 50 percent of the ones available.

Why is the automobile, with all its varied functions and numerous controls, so much easier to learn and to use than the telephone system, with its much smaller set of functions and controls? What is good about the design of the car? Things are visible. There are good mappings, natural relationships, between the controls and the things controlled. Single controls often have single functions. There is good feedback. The system is understandable. In general, the relationships among the user's intentions, the required actions, and the results are sensible, nonarbitrary, and meaningful.

What is bad about the design of the telephone? There is no visible structure. Mappings are arbitrary: there is no rhyme or reason to the relationship between the actions the user must perform and the results to be accomplished. The controls have multiple functions. There isn't good feedback, so the user is never sure whether the desired result has been obtained. The system, in general, is not understandable; its capabilities aren't apparent. In general, the relationships among the user's intentions, the required actions, and the results are completely arbitrary.

Whenever the number of possible actions exceeds the number of controls, there is apt to be difficulty. The telephone system has twenty-four functions, yet only fifteen controls—none of them labeled for specific action. In contrast, the trip computer for the car performs seventeen functions with fourteen controls. With minor exceptions, there is one control for each function. In fact, the controls with more than one function are indeed harder to remember and use. When the number of controls equals the number of functions, each control can be specialized, each can be labeled. The possible functions are visible, for each corresponds with a control. If the user forgets the functions, the controls serve as reminders. When, as on the telephone, there are more functions than controls, labeling becomes difficult or impossible. There is nothing to remind the user. Functions are invisible, hidden from sight. No wonder the operation becomes mysterious and difficult. The controls for the car are visible and, through their location and mode of operation, bear an intelligent relationship to their action. Visi-

bility acts as a good reminder of what can be done and allows the control to specify how the action is to be performed. The good relationship between the placement of the control and what it does makes it easy to find the appropriate control for a task. As a result, there is little to remember.

THE PRINCIPLE OF MAPPING

Mapping is a technical term meaning the relationship between two things, in this case between the controls and their movements and the results in the world. Consider the mapping relationships involved in steering a car. To turn the car to the right, one turns the steering wheel clockwise (so that its top moves to the right). The user must identify two mappings here: one of the 112 controls affects the steering, and the steering wheel must be turned in one of two directions. Both are somewhat arbitrary. But the wheel and the clockwise direction are natural choices: visible, closely related to the desired outcome, and providing immediate feedback. The mapping is easily learned and always remembered.

Natural mapping, by which I mean taking advantage of physical analogies and cultural standards, leads to immediate understanding. For example, a designer can use spatial analogy: to move an object up, move the control up. To control an array of lights, arrange the controls in the same pattern as the lights. Some natural mappings are cultural or biological, as in the universal standard that a rising level represents more, a diminishing level, less. Similarly, a louder sound can mean a greater amount. Amount and loudness (and weight, line length, and brightness) are additive dimensions: add more to show incremental increases. Note that the logically plausible relationship between musical pitch and amount does not work: Would a higher pitch mean less or more of something? Pitch (and taste, color, and location) are substitutive dimensions: substitute one value for another to make a change. There is no natural concept of more or less in the comparison of different pitches, or hues, or taste qualities. Other natural mappings follow from the principles of perception and allow for the natural grouping or patterning of controls and feedback (see figure 1.13).

Mapping problems are abundant, one of the fundamental causes of difficulties. Consider the telephone. Suppose you wish to activate the callback on "no reply" function. To initiate this feature on one tele-
A device is easy to use when there is visibility to the set of possible actions, where the controls and displays exploit natural mappings. The principles are simple but rarely incorporated into design. Good design takes care, planning, thought. It takes conscious attention to the needs of the user. And sometimes the designer gets it right:

Once, when I was at a conference at Gmunden, Austria, a group of us went off to see the sights. I sat directly behind the driver of the brand new, sleek, high-technology German tour bus. I gazed in wonder at the hundreds of controls scattered all over the front of the bus.

"How can you ever learn all those controls?" I asked the driver (with the aid of a German-speaking colleague). The driver was clearly puzzled by the question.

"What do you mean?" he replied. "Each control is just where it ought to be. There is no difficulty."

A good principle, that. Controls are where they ought to be. One function, one control. Harder to do, of course, than to say, but essentially this is the principle of natural mappings: the relationship between controls and actions should be apparent to the user. I return to this topic later in the book, for the problem of determining the "naturalness" of mappings is difficult, but crucial.

I've already described how my car's controls are generally easy to use. Actually, the car has lots of problems. The approach to usability used in the car seems to be to make sure that you can reach everything and see everything. That's good, but not nearly good enough.

Here is a simple example: the controls for the loudspeakers—a simple control that determines whether the sound comes out of the front speakers, the rear, or a combination (figure 1.14). Rotate the wheel from left to right or right to left. Simple, except how do you know which way to rotate the control? Which direction moves the sound to the rear, which to the front? If you want sound to come out of the front speaker, you should be able to move the control to the front. To get it out of the back, move the control to the back. Then the form of the motion would mimic the function and make a natural mapping. But the way the control is actually mounted in the car, forward and backward get translated into left and right. Which direction is which? There is no natural relationship. What's worse, the control isn't even labeled. Even the instruction manual does not say how to use it.
than when they are not. In addition, there must be a close, natural relationship between the control and its function: a natural mapping.

THE PRINCIPLE OF FEEDBACK

Feedback—sending back to the user information about what action has actually been done, what result has been accomplished—is a well-known concept in the science of control and information theory. Imagine trying to talk to someone when you cannot even hear your own voice, or trying to draw a picture with a pencil that leaves no mark: there would be no feedback.

In the good old days of the telephone, before the American telephone system was divided among competing companies, before telephones were fancy and had so many features, telephones were designed with much more care and concern for the user. Designers at the Bell Telephone Laboratories worried a lot about feedback. The push buttons were designed to give an appropriate feel—tactile feedback. When a button was pushed, a tone was fed back into the earpiece so the user could tell that the button had been properly pushed. When the phone call was being connected, clicks, tones, and other noises gave the user feedback about the progress of the call. And the speaker’s voice was always fed back to the earpiece in a carefully controlled amount, because the auditory feedback (called “sidedone”) helped the person regulate how loudly to talk. All this has changed. We now have telephones that are much more powerful and often cheaper than those that existed just a few years ago—more function for less money. To be fair, these new designs are pushing hard on the paradox of technology: added functionality generally comes along at the price of added complexity. But that does not justify backward progress.

Why are the modern telephone systems so difficult to learn and to use? Basically, the problem is that the systems have more features and less feedback. Suppose all telephones had a small display screen, not unlike the ones on small, inexpensive calculators. The display could be used to present, upon the push of a button, a brief menu of all the features of the telephone, one by one. When the desired one was encountered, the user would push another button to indicate that it should be invoked. If further action was required, the display could tell the person what to do. The display could even be auditory, with speech instead of a visual display. Only two buttons need be added to the
The world is permeated with small examples of good design, with the amazing details that make important differences in our lives. Each detail was added by some person, a designer, carefully thinking through the uses of the device, the ways that people abuse things, the kinds of errors that can get made, and the functions that people wish to have performed.

Then why is it that so many good design ideas don't find their way into products in the marketplace? Or something good shows up for a short time, only to fall into oblivion? I once spoke with a designer about the frustrations of trying to get the best product out:

It usually takes five or six attempts to get a product right. This may be acceptable in an established product, but consider what it means in a new one. Suppose a company wants to make a product that will perhaps make a real difference. The problem is that if the product is truly revolutionary, it is unlikely that anyone will quite know how to design it right the first time; it will take several tries. But if a product is introduced into the marketplace and fails, well that is it. Perhaps it could be introduced a second time, or maybe even a third time, but after that it is dead: everyone believes it to be a failure.

I asked him to explain. "You mean," I said, "that it takes five or six tries to get an idea right?"

"Yes," he said, "at least that."

"But," I replied, "you also said that if a newly introduced product doesn't catch on in the first two or three times, then it is dead?"

"Yup," he said.

"Then new products are almost guaranteed to fail, no matter how good the idea."

"Now you understand," said the designer. "Consider the use of voice messages on complex devices such as cameras, soft-drink machines, and copiers. A failure. No longer even tried. Too bad. It really is a good idea, for it can be very useful when the hands or eyes are busy elsewhere. But those first few attempts were very badly done and the public scoffed—properly. Now, nobody dares try it again, even in those places where it is needed."

The Paradox of Technology

Technology offers the potential to make life easier and more enjoyable; each new technology provides increased benefits. At the same time,
added complexities arise to increase our difficulty and frustration. The
development of a technology tends to follow a U-shaped curve of
complexity: starting high; dropping to a low, comfortable level; then
climbing again. New kinds of devices are complex and difficult to use.
As technicians become more competent and an industry matures, de-
"vices become simpler, more reliable, and more powerful. But then, after
the industry has stabilized, newcomers figure out how to add increased
power and capability, but always at the expense of added complexity
and sometimes decreased reliability. We can see the curve of complex-
ity in the history of the watch, radio, telephone, and television set.
Take the radio. In the early days, radios were quite complex. To tune
in a station required several adjustments, including one for the anten-
a, one for the radio frequency, one for intermediate frequencies,
and controls for both sensitivity and loudness. Later radios were sim-
pler and had controls only to turn it on, tune the station, and adjust
the loudness. But the latest radios are again very complex, perhaps even
more so than early ones. Now the radio is called a tuner, and it is
littered with numerous controls, switches, slide bars, lights, displays,
and meters. The modern sets are technologically superior, offering
higher quality sound, better reception, and enhanced capability. But
what good is the technology if it is too complex to use?

The design problem posed by technological advances is enormous.
Consider the watch. A few decades ago, watches were simple. All you
had to do was set the time and keep them wound. The standard con-
"rol was the stem: a knob at the side of the watch. Turning the knob
wound the spring that worked the watch. Pulling the knob out and
turning it made the hands move. The operations were easy to learn
and easy to do. There was a reasonable relation between the turning
of the knob and the resulting turning of the hands. The design even
took into account human error: the normal position of the stem was
for winding the spring, so that an accidental turn would not reset the
time.

In the modern digital watch the spring is gone, replaced by a motor
run by long-lasting batteries. All that remains is the task of setting
the watch. The stem is still a sensible solution, for you can go fast or slow,
forward or backward, until the exact desired time is reached. But the
stem is more complex (and therefore more expensive) than simple
push-button switches. If the only change in the transition from the
spring-wound analog watch to the battery-run digital watch were in
how the time was set, there would be little difficulty. The problem is
that new technology has allowed us to add more functions to the

watch: the watch can give the day of the week, the month, and the year;
it can act as a stop watch (which itself has several functions), a count-
down timer, and an alarm clock (or two); it has the ability to show the
time for different time zones; it can act as a counter and even as a
calculator. But the added functions cause problems: How do you design
a watch that has so many functions while trying to limit the size, cost,
and complexity of the device? How many buttons does it take to make
the watch workable and learnable, yet not too expensive? There are no
easy answers. Whenever the number of functions and required oper-
ations exceeds the number of controls, the design becomes arbitrary,
unnatural, and complicated. The same technology that simplifies life by
providing more functions in each device also complicates life by mak-
ing the device harder to learn, harder to use. This is the paradox of
technology.

The paradox of technology should never be used as an excuse for
poor design. It is true that as the number of options and capabilities of
any device increases, so too must the number and complexity of the
controls. But the principles of good design can make complexity man-
geable.

In one of my courses I gave as homework the assignment to design
a multiple-function clock radio:

You have been employed by a manufacturing company to design
their new product. The company is considering combining the follow-
ing into one item:

- AM-FM radio
- Cassette player
- CD player
- Telephone
- Telephone answering machine
- Clock
- Alarm clock (the alarm can turn on a tone, radio, cassette, or CD)
- Desk or bed lamp

The company is trying to decide whether to include a small (two-
inch screen) TV set and a switched electric outlet that can turn on a
coffeemaker or toaster.

Your job is (A) to recommend what to build, then (B) to design the
control panel, and finally (C) to certify that it is actually both what
customers want and easy to use.
State what you would do for the three parts of your job: A, B, and C. Explain how you would go about validating and justifying your recommendations.

Draw a rough sketch of a control panel for the items in the indented list, with a brief justification and analysis of the factors that went into the choice of design.

There are several things I looked for in the answer. (Figure 1.15 is an unacceptable solution.) First, how well did the answer address the

1.15 Possible Solution to My Homework Assignment. Completely unacceptable. (Thanks to Bill Gaver for devising and drawing this sample.)

real needs of the user? I expected my students to visit the homes of potential users to see how their current devices were being used and to determine how the combined multipurpose device would be used. Next, I evaluated whether all the controls were usable and understandable, allowing all the desired functions to be operated with minimum confusion or error. Clock radios are often used in the dark, with the user in bed and reaching overhead to grope for the desired control. Therefore the unit had to be usable in the dark by feel only. It was not supposed to be possible to make a serious mistake by accidentally hitting the wrong control. (Alas, many existing clock radios do not tolerate serious errors—for example, the user may reset the time by hitting the wrong button accidentally.) Finally, the design was expected to take into account real issues in cost, manufacturability, and aesthetics. The finished design had to pass muster with users. The point of the exercise was for the student to realize the paradox of technology: added complexity and difficulty cannot be avoided when functions are added, but with clever design, they can be minimized.
more people come over to help, and then another. The voices grow louder, in three languages: Italian, German, and English. One person investigates the controls, manipulating each and announcing the result. Confusion mounts. I can no longer observe all that is happening. The conference organizer comes over. After a few moments he turns and faces the audience, which has been waiting patiently in the auditorium. "Ahem," he says, "is anybody expert in projectors?" Finally, fourteen minutes after the speaker had started to thread the film (and eight minutes after the scheduled start of the session) a blue-coated technician appears. He scowls, then promptly takes the entire film off the projector, rethreads it, and gets it working.

What makes something—like threading the projector—difficult to do? To answer this question, the central one of this book, we need to know what happens when someone does something. We need to examine the structure of an action.

The basic idea is simple. To get something done, you have to start with some notion of what is wanted—the goal that is to be achieved. Then, you have to do something to the world, that is, take action to move yourself or manipulate someone or something. Finally, you check to see that your goal was made. So there are four different things to consider: the goal, what is done to the world, the world itself, and the check of the world. The action itself has two major aspects: doing something and checking. Call these execution and evaluation (figure 2.2).

Real tasks are not quite so simple. The original goal may be imprecisely specified—perhaps "get something to eat," "get to work," "get dressed," "watch television." Goals do not state precisely what to do—where and how to move, what to pick up. To lead to actions goals must be transformed into specific statements of what is to be done, statements that I call intentions. A goal is something to be achieved, often vaguely stated. An intention is a specific action taken to get to the goal. Yet even intentions are not specific enough to control actions.

Suppose I am sitting in my armchair, reading a book. It is dusk, and the light has gotten dimmer and dimmer. I decide I need more light (that is the goal: get more light). My goal has to be translated into the intention that states the appropriate action in the world: push the switch button on the lamp. There's more: I need to specify how to move my body, how to stretch to reach the light switch, how to extend my finger to push the button (without knocking over the lamp). The goal
ordinary people in ordinary situations: it is only the amount of reliance upon the external world that differs. There is a tradeoff between the amount of mental knowledge and the amount of external knowledge required in performing tasks. People are free to operate variously in allowing for this tradeoff.

Precise Behavior from Imprecise Knowledge

INFORMATION IS IN THE WORLD

Whenever information needed to do a task is readily available in the world, the need for us to learn it diminishes. For example, we lack knowledge about common coins, even though we recognize them just fine (figure 3.1). Or consider typing. Many typists have not memorized the keyboard. Usually each letter is labeled, so nontypists can hunt and peck letter by letter, relying on knowledge in the world and minimizing the time required for learning. The problem is that such typing is slow and difficult. With experience, of course, hunt-and-peck typists learn the positions of many of the letters on the keyboard, even without instruction, and typing speed increases notably, quickly surpassing handwriting speeds and, for some, reaching quite respectable rates. Peripheral vision and the feel of the keyboard provide some information about key locations. Frequently used keys become completely learned, infrequently used keys are not learned well, and the other keys are partially learned. But as long as the typist needs to watch the keyboard, the speed is limited. The knowledge is still mostly in the world, not in the head.

If a person needs to type large amounts of material regularly, further investment is worthwhile: a course, a book, or an interactive computer program. The important thing is to learn the proper placement of fingers on the keyboard, to learn to type without looking, to get knowledge about the keyboard from the world into the head. It takes several hours to learn the system and several months to become expert. But the payoff of all this effort is increased typing speed, increased accuracy, and decreased mental load and effort at the time of typing.

There is a tradeoff between speed and quality of performance and mental effort. Thus, in finding your way through a city, locating items in a store or house, or working complex machinery, the tradeoff can determine what needs to be learned. Because you know that the infor-

3.1 Which Is the U. S. One Cent Coin—The Penny? Fewer than half of the American college students who were given this set of drawings and asked to select the correct one could do so. Pretty bad performance, except that the students, of course, have no difficulty using the money: in normal life, we have to distinguish between the penny and other U.S. coins, not between several versions of one denomination. (From Nickerson & Adams, Cognitive Psychology, 11, ⑫ 1979. Reprinted by permission of Academic Press.)

mation is available in the environment, the information you internally code in memory need be precise enough only to sustain the quality of behavior you desire. This is one reason people can function well in their environment and still be unable to describe what they do. For example, a person can travel accurately through a city without being able to describe the route precisely.

People function through their use of two kinds of knowledge: knowledge of and knowledge how. Knowledge of—what psychologists call declarative knowledge—includes the knowledge of facts and rules. “Stop at red lights.” “New York City lies on a parallel a bit south of Madrid, San Diego’s longitude is east of Reno.” “To get the key out of the ignition, the car must be in reverse.” Declarative knowledge is easy to write down and to teach. Knowledge how—what psychologists call procedural knowledge—is the knowledge that enables a person to perform music, to stop a car smoothly with a flat tire on an icy road, to return a serve in tennis, or to move the tongue properly when saying the phrase “frightening witches.” Procedural knowledge is difficult or
impossible to write down and difficult to teach. It is best taught by
demonstration and best learned through practice. Even the best teach-
ers cannot usually describe what they are doing. Procedural knowledge
is largely subconscious.

Knowledge from the world is usually easy to come by. Designers
provide a large number of memory aids. The letters on the typewriter
keyboard are one example. The lights and labels on controls act as
external memory aids, reminding the user of the purpose and state of
the control. Industrial equipment is replete with signal lights, indica-
tors, and other reminders. We make extensive use of written notes. We
place items in specific locations as reminders. In general, people struc-
ture the environment to provide a considerable amount of the informa-
tion required for something to be remembered.

Many people organize their lives in the world, creating a pile here,
a pile there, each indicating some activity to be done, some event in
progress. Probably everybody uses such a strategy to some extent. Look
around you at the variety of ways people structure their rooms and
desks. Many styles of organization are possible, but the physical ar-
rangement and visibility of the items frequently convey information
about relative importance. Want to do your friends a nasty turn? Do
them a favor—clean up their desks or rooms. Do this to some people
and you can completely destroy their ability to function.²

GREAT PRECISION IS NOT REQUIRED

Normally, people do not need precise memory information. People
can remember enough to distinguish one familiar coin from another
although they may be unable to remember the faces, pictures, and
words on the coins.³ But make more precise memory necessary and
you get havoc. Three countries have rediscovered this fact in recent
years: the United States, when it introduced the Susan B. Anthony
one-dollar coin; Great Britain, when it introduced the one-pound
coin; and France, when it introduced a new ten-franc coin. The new
U.S. dollar coin was confused with the existing twenty-five-cent
piece (the quarter), and the British pound coin was confused with the
existing five-pence piece. (The one-pound coin has the same diameter
as the five-pence piece, but is considerably thicker and heavier.) Here
is what happened in France:

“PARIS . . .” With a good deal of fanfare, the French government
released the new 10-franc coin (worth a little more than $1.50) on Oct.
22 [1986]. The public looked at it, weighed it, and began confusing it
so quickly with the half-franc coin (worth only 8 cents) that a cre-
scendo of fury and ridicule fell on both the government and the coin.

“Five weeks later, Minister of Finance Edouard Balladur suspended
circulation of the coin. Within another four weeks, he canceled it
altogether.

“In retrospect, the French decision seems so foolish that it is hard to
fathom how it could have been made . . . After much study, designers
came up with a silver-colored coin made of nickel and featuring a
modernistic drawing by artist Joaquin Jimenez of a Gallic rooster on
one side and of Marianne, the female symbol of the French republic,
on the other. The coin was light, sported special ridges on its rim for
easy reading by electronic vending machines and seemed tough to
counterfeit.

“But the designers and bureaucrats were obviously so excited by
their creation that they ignored or refused to accept the new coin’s
similarity to the hundreds of millions of silver-colored, nickel-based
half-franc coins in circulation . . . [whose] size and weight were peri-
lously similar.”⁴

The confusions probably occurred because the users of coins formed
representations in their memory systems that were sufficiently precise
only to distinguish among the coins that they actually had to use. It is
a general property of memory that we store only partial descriptions
of the things to be remembered, descriptions that are sufficiently pre-
cise to work at the time something is learned, but that may not work
later on, when new experiences have also been encountered and en-
tered into memory. The descriptions formed to distinguish among the
old coins were not precise enough to distinguish between the new one
and at least one of the old ones.⁵

Suppose I keep all my notes in a small red notebook. If this is my
only notebook, I can describe it simply as my notebook. If I buy several
more notebooks, the earlier description will no longer work. Now I
must call the first one small or red, or maybe both small and red,
whichever allows me to distinguish it from the others. But what if I
acquire several small, red notebooks? Now I must find some other
means of describing the first book, adding to the richness of the de-
The need for timely reminders has created loads of products that make it easier to put the knowledge in the world—alarm clocks, diaries, calendars. A variety of sophisticated watches and small, calculator-sized reminding devices are starting to appear. So far they are limited in power and difficult to use. But I believe there is a need for them. They just need more work, better technology, and better design.

Would you like a pocket-size device that reminded you of each appointment and daily event? I would. I am waiting for the day when portable computers become small enough that I can keep one with me at all times. I will definitely put all my reminding burdens upon it. It has to be small. It has to be convenient to use. And it has to be relatively powerful, at least by today's standards. It has to have a full, standard typewriter keyboard and a reasonably large display. It needs good graphics, because that makes a tremendous difference in usability, and a lot of memory—a huge amount, actually. It should be easy to hook up to the telephone; I need to connect it to my home and laboratory computers. Of course, it should be relatively inexpensive.

What I ask for is not unreasonable. The technology I need is available today. It's just that the full package has never been put together, partly because the cost in today's world would be prohibitive. But it will exist in imperfect form in five years, possibly in perfect form in ten.

3.2 Carelman's Preknotted Handkerchief. What an aid to the forgetful—except that the act of tying the knot is probably just as useful a memory cue as the knot itself. (Jacques Carelman: "Preknotted Handkerchief" Copyright @ 1969-76-80 Jacques Carelman and A. D. A. G. P. Paris. From Jacques Carelman, Catalog of Unfindable Objects. Balland, éditeur, Paris-France. Used by permission of the artist.)

The arrangement of burners and controls on the kitchen stove provides a good example of the power of natural mappings to reduce the need for information in memory. Without a good mapping, the user cannot readily determine which burner goes with which control. Consider the standard stove with four burners, arranged in the traditional rectangle. If the four controls were truly arbitrary, as in figure 3.3, the user would have to learn each control separately: twenty-four possible arrangements. Why twenty-four? Start with the leftmost control; it could work any of the four burners. That leaves three possibilities for the next leftmost. So there are $12 \times (4 \times 3)$ possible arrangements of the first two controls: four for the first, three for the second. The third control could work either of the two remaining burners, and then there is only one burner left for the last control. This makes twenty-four possible mappings between the controls and burners: $4 \times 3 \times 2 \times 1 = 24$. With the completely arbitrary arrangement, the stove is unworkable unless each control is fully labeled to indicate which burner it controls.

Most stoves have controls arranged in a line, even though the burners are arranged rectangularly. Controls are not mapped naturally to burners. As a result, you have to learn which control goes with which burner. Consider how the use of spatial analogies can relieve the memory burden. Start with a partial mapping that is in common use today: the controls are segregated into left and right halves, as in figure 3.4. Now we need know only which left burner each of the two left controls affects and which right burner each right control affects—two alternatives for each of the four burners. The number of possible arrangements is now only four—two possibilities for each side: quite a reduction from the twenty-four. But the controls must still be labeled, which indicates that the mapping is still imperfect. Since some of the information is now in the spatial arrangement, each control need only be labeled back or front; the left and right labels are no longer needed.

What about a proper, full, natural mapping, with the controls spatially arranged in the same pattern as the burners, as in figure 3.5? The organization of the controls now carries all the information required. We know immediately which control goes with which burner. Such is the power of natural mapping. We can see that the number of possible sequences has been reduced from twenty-four to one. If all possible
3.3 Arbitrary Arrangement of Stove Controls (top of opposite page). Couple the usual rectangular arrangement of burners with this arbitrary row of controls, and there is trouble: which control goes with which burner? You don't know unless the controls are labeled. The memory load for this arrangement is high: there are twenty-four possible arrangements, and you have to remember which of the twenty-four this one is. Fortunately, the controls are seldom arranged quite this arbitrarily.

3.4 Paired Stove Controls (bottom of opposite page). This is the type of partial mapping of controls to burners in common use today. The two controls on the left work the left burners, and the two controls on the right work the right burners. Now there are only four possible arrangements (two for each side). Even so, confusion is possible (and, I can assure you, it occurs often).

3.5 Full Natural Mapping of Controls and Burners (below). Two of the Possible Ways. There is no ambiguity, no need for learning or remembering, no need for labels. Why can't all stoves be like these?
natural mappings were applied in our lives, the cumulative effect would be enormous.

The problem of the stove top may seem trivial, but in fact it is a cause of great frustration for many homeowners. Why do stove designers insist on arranging the burners in a rectangular pattern and the controls in a row? We have known for forty years just how bad such an arrangement is. Sometimes the stove comes with clever little diagrams to indicate which control works which burner. Sometimes there is a short label. But the proper natural mapping requires no diagrams, no labels, and no instructions. There is a simple design principle lurking here:

If a design depends upon labels, it may be faulty. Labels are important and often necessary, but the appropriate use of natural mappings can minimize the need for them. Wherever labels seem necessary, consider another design.

The shame about stove design is that it isn’t hard to do right. Textbooks of ergonomics, human factors, psychology, and industrial engineering all show various sensible solutions. And some stove manufacturers do use good designs. Oddly, some of the very best and the very worst are manufactured by the same companies and are illustrated side by side in the same catalogs.

Why do designers insist on frustrating users? Why do users still purchase stoves that cause so much trouble? Why not revolt and refuse to buy them unless the controls have an intelligent relationship to the burners? I bought a bad one myself.

*Usability is not often thought of as a criterion during the purchasing process. Moreover, unless you actually test a number of units in a realistic environment doing typical tasks, you are not likely to notice the ease or difficulty of use. If you just look at something, it appears straightforward enough, and the array of wonderful features seems to be a virtue. You may not realize that you won’t be able to figure out how to use those features. I urge you to test products before you buy them. Pretending to cook a meal, or setting the channels on a video set, or attempting to program a VCR will do. Do it right there in the store. Do not be afraid to make mistakes or ask stupid questions. Remember, any problems you have are probably the design’s fault, not yours.*

A major problem is that often the purchaser is not the user. Appliances may be in a home when people move in. In the office, the purchasing department orders equipment based upon such factors as price, personal relationships with the supplier, and perhaps reliability: usability is seldom considered. Finally, even when the purchaser is the end user, it is sometimes necessary to trade one desirable feature for an undesirable one. In the case of my family’s stove, we did not like the arrangement of controls, but we bought the stove anyway: we traded off layout of the burner controls for another feature that was more important to us and available only from one manufacturer. (I return to these issues in chapter 6.)

**The Tradeoff between Knowledge in the World and in the Head**

Knowledge (or information) in the world and in the head are both essential in our daily functioning. But to some extent we can choose to lean more heavily on one or the other. That choice requires a trade-

<table>
<thead>
<tr>
<th>PROPERTY</th>
<th>KNOWLEDGE IN THE WORLD</th>
<th>KNOWLEDGE IN THE HEAD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retrievability</td>
<td>Retrievable whenever visible or audible.</td>
<td>Not readily retrievable. Requires memory search or reminding.</td>
</tr>
<tr>
<td>Learning</td>
<td>Learning not required. Interpretation substitutes for learning. How easy it is to interpret information in the world depends upon how well it exploits natural mappings and constraints.</td>
<td>Requires learning, which can be considerable. Learning is made easier if there is meaning of structure to the material (or if there is a good mental model).</td>
</tr>
<tr>
<td>Efficiency of use</td>
<td>Tends to be slowed up by the need to find and interpret the external information.</td>
<td>Can be very efficient.</td>
</tr>
<tr>
<td>Ease of use at first encounter</td>
<td>High.</td>
<td>Low.</td>
</tr>
<tr>
<td>Aesthetics</td>
<td>Can be unaesthetic and inelegant, especially if there is a need to maintain a lot of information. This can lead to clutter. In the end, aesthetic appeal depends upon the skill of the designer.</td>
<td>Nothing need be visible, which gives more freedom to the designer, which in turn can lead to better aesthetics.</td>
</tr>
</tbody>
</table>
off—gaining the advantages of knowledge in the world means losing the advantages of knowledge in the head (figure 3.6).

Knowledge in the world acts as its own reminder. It can help us recover structures that we otherwise would forget. Knowledge in the head is efficient: no search and interpretation of the environment is required. In order to use knowledge in the head we have to get it there, which might require considerable amounts of learning. Knowledge in the world is easier to learn, but often more difficult to use. And it relies heavily upon the continued physical presence of the information; change the environment and the information is changed. Performance relies upon the physical presence of the task environment.

Reminders provide a good example of the relative tradeoffs between the roles of internal versus external knowledge. Knowledge in the world is accessible. It is self-reminding. It is always there, waiting to be seen, waiting to be used. That is why we structure our offices and our places of work so carefully. We put piles of papers where they can be seen, or if we like a clean desk, we put them in standardized locations and teach ourselves (knowledge in the head) to look in these standard places routinely. We use clocks and calendars and notes. Knowledge in the mind is ephemeral: here now, gone later. We can’t count on something being present in mind at any particular time, unless it is triggered by some external event or unless we deliberately keep it in mind through constant repetition (which then prevents us from having other conscious thoughts). Out of sight, out of mind.17

Q. I read a news item about a new videotape-only player and rejoiced when the writer took a healthy swipe at the incomprehensible instructions that accompany VCRs. I can’t even set the time of day on mine!

“There are many consumers out here like me—thwarted by an unfathomable machine and baffled by senseless instructions.

“Is there anyone, anywhere who will translate OR give a short course in VCR at play school level?”

Video cassette recorders—VCRs—can be frightening to people who are unfamiliar with them. Indeed, the number of options, buttons, controls, displays, and possible courses of action is formidable. But at least when we have trouble operating a VCR we have something to blame: the machine’s bewildering appearance and the lack of clues to suggest what can be done and how to do it. Even more frustrating, however, is that we often have trouble working devices that we expect to be simple.

The difficulty of dealing with novel situations is directly related to the number of possibilities. The user looks at the situation and tries to discover which parts can be operated and what operations can be done.