From
The Design of
Everyday Things.
By Donald A. Norman.
Currency and Doubleday,
New York, 1988.

CHAPTER ONE

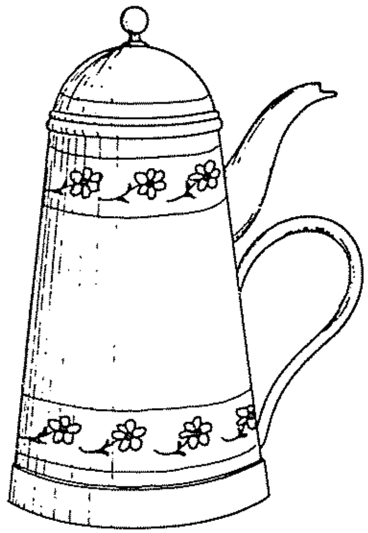
THE PSYCHOPATHOLOGY OF EVERYDAY THINGS

"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-



1.1 Carelman's Coffeepot for Masochists. The French artist Jacques Carelman in his series of books *Catalogue d'objets introuvables (Catalog of unfindable objects)* provides delightful examples of everyday things that are deliberately unworkable, outrageous, or otherwise ill-formed. Jacques Carelman: "Coffeepot for Masochists." Copyright © 1969–76–80 by 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.

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

1.2 A Row of Swinging Glass Doors in a Boston Hotel. A similar problem to the doors from that European post office. On which side of the door should you push? When I asked people who had just used the doors, most couldn't say. Yet only a few of the people I watched had trouble with the doors. The designers had incorporated a subtle clue into the design. Note that the horizontal bars are not centered: they are a bit closer together on the sides you should push on. The design almost works—but not entirely, for not everyone used the doors right on the first try.

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.

visibility
natural signals / design.

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

Taste (7) für Diawechsel am Gerät

Diawechsel vorwärts = kurz drücken,

Diawechsel rückwärtz = 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:

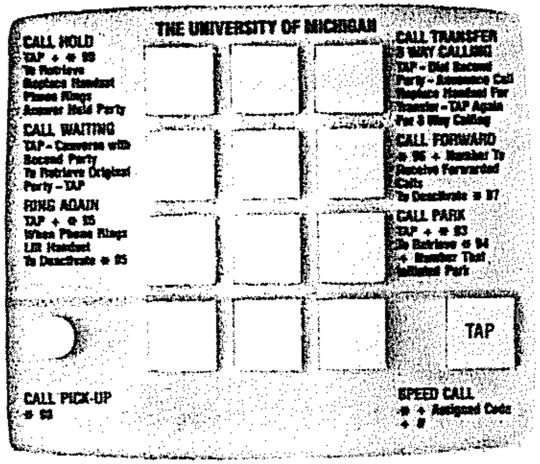
forward, a long push and it would reverse. (Pity the conscientious student who kept pushing it hard—and long—to make sure that the switch was making contact.) What an elegant design. Why, it managed to do two functions with only one button! But how was a first-time user of the projector to know this?*

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



1.4 Plate Mounted Over the Dial of the Telephones at the University of Michigan. These inadequate instructions are all that most users see. (The button labeled "TAP" at the lower right is used to transfer or pick up calls—it is pressed whenever the instruction plate says "TAP." The light on the lower left comes on whenever the telephone rings.)

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 mapping · action → operation · → everyday things

manual, so—faced with the bewildering array of controls and displays—simply memorizes one or two fixed settings to approximate what is desired. The whole purpose of the design is lost.

In England I visited a home with a fancy new Italian washer-drier combination, with super-duper multi-symbol controls, all to do everything you ever wanted to do with the washing and drying of clothes. The husband (an engineering psychologist) said he refused to go near it. The wife (a physician) said she had simply memorized one setting and tried to ignore the rest.

Someone went to a lot of trouble to create that design. I read the instruction manual. That machine took into account everything about today's wide variety of synthetic and natural fabrics. The designers worked hard; they really cared. But obviously they had never thought of trying it out, or of watching anyone use it.

If the design was so bad, if the controls were so unusable, why did the couple purchase it? If people keep buying poorly designed products, manufacturers and designers will think they are doing the right thing and continue as usual.

The user needs help. Just the right things have to be visible: to indicate what parts operate and how, to indicate how the user is to interact with the device. Visibility indicates the mapping between intended actions and actual operations. Visibility indicates crucial distinctions—so that you can tell salt and pepper shakers apart, for example. And visibility of the effects of the operations tells you if the lights have turned on properly, if the projection screen has lowered to the correct height, or if the refrigerator temperature is adjusted correctly. It is lack of visibility that makes so many computer-controlled devices so difficult to operate. And it is an excess of visibility that makes the gadget-ridden, feature-laden modern audio set or video cassette recorder (VCR) so intimidating.

The Psychology of Everyday Things

This book is about the psychology of everyday things. POET emphasizes the understanding of everyday things, things with knobs and dials, controls and switches, lights and meters. The instances we have just examined demonstrate several principles, including the importance 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.

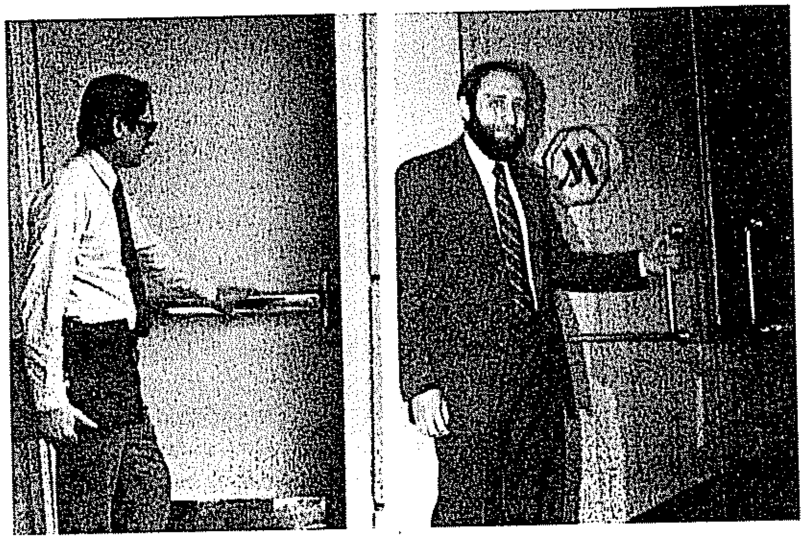
AFFORDANCES

"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!"[2]

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.[3]

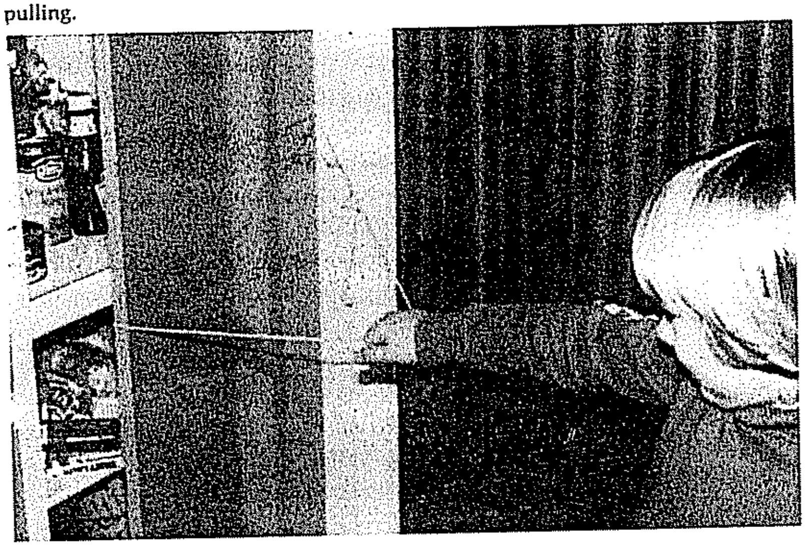
Affordances provide strong clues to the operations of things. Plates are for pushing. Knobs are for turning. Slots are for inserting things into. Balls are for throwing or bouncing. When affordances are taken advantage of, the user knows what to do just by looking: no picture, label, or instruction is 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.



1.5 Affordances of Doors. Door hardware can signal whether to push or pull without signs. The flat horizontal bar of *A* (above left) affords no operations except pushing: it is excellent hardware for a door that must be pushed to be opened. The door in *B* (above right) has a different kind of bar on each side, one relatively small and vertical to signify a pull, the other relatively large and horizontal to signify a push. Both bars support the affordance of grasping: size and position specify whether the grasp is used to push or pull—though ambiguously.

1.6 When Affordances Fail. I had to tie a string around my cabinet door to afford pulling.



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.[4] Irving Biederman, a psychologist who studies visual perception, estimates that there are probably "30,000 readily discriminable objects for the adult."[5] 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.

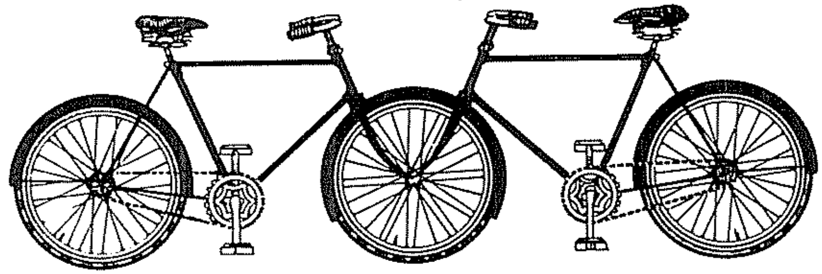
The way the mind works
Designers make operations clear

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 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,

visible structure: affordances, constraints, mapping — conceptual model



1.7 Carelman's Tandem "Convergent Bicycle (Model for Fiancés)." Jacques Carelman: "Convergent Bicycle" Copyright © 1969–76–80 by 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 scissors still work. You can figure out the scissors because their operating parts are visible and the implications clear. The conceptual model is made obvious, and there is effective use of affordances and constraints.

As a counterexample, consider the digital watch, one with two to four push buttons on the front or side. What are those push buttons for? How would you set the time? There is no way to tell—no evident relationship between the operating controls and the functions, no constraints, no apparent mappings. With the scissors, moving the handle makes the blades move. The watch and the Leitz slide projector provide no visible relationship between the buttons and the possible actions, no discernible relationship between the actions and the end result.

vs digital watch

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

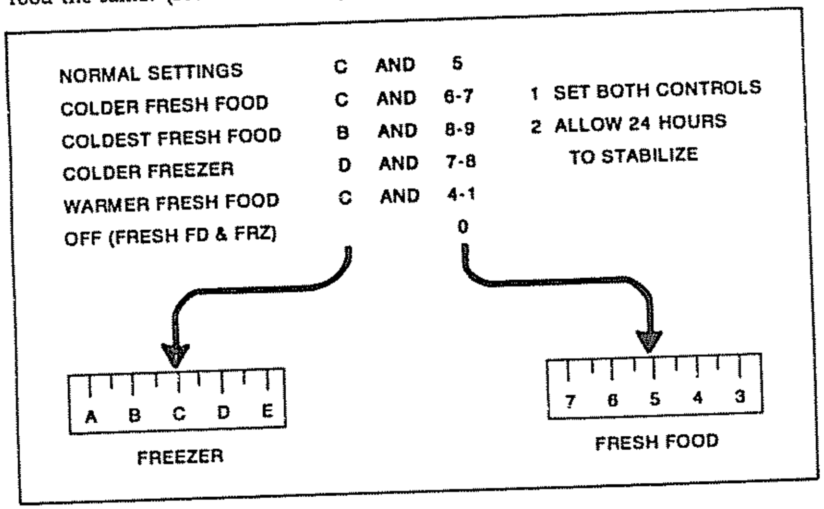
A good conceptual model allows us to predict the effects of our actions. Without a good model we operate by rote, blindly; we do operations as we were told to do them; we can't fully appreciate why, what effects to expect, or what to do if things go wrong. As long as things work properly, we can manage.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

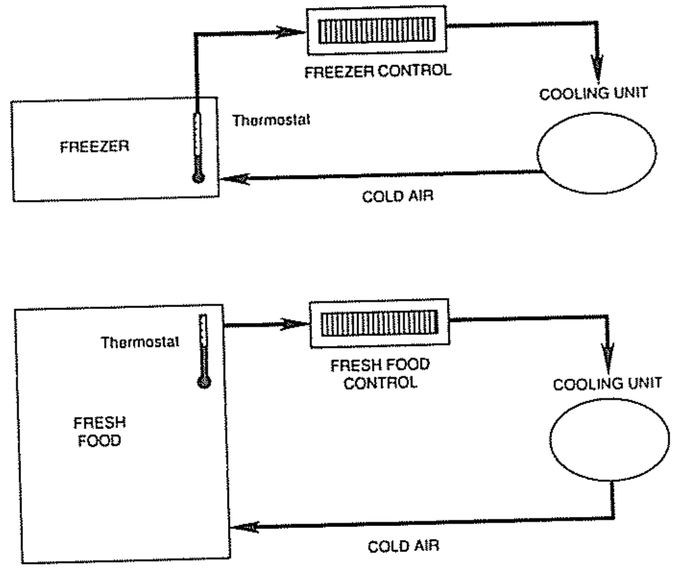
For everyday things, conceptual models need not be very complex. After all, scissors, pens, and light switches are pretty simple devices. There is no need to understand the underlying physics or chemistry of each device we own, simply the relationship between the controls and the outcomes. When the model 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?

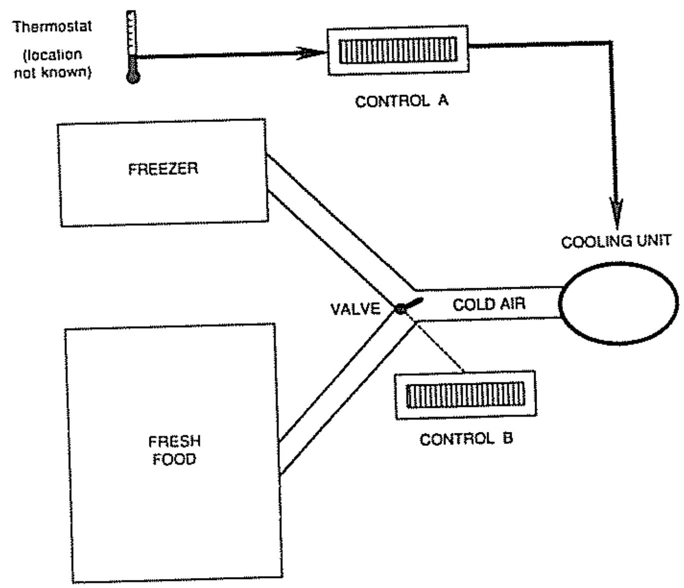
You try it. Figure 1.8 shows the instruction plate from inside the refrigerator. Now, suppose the freezer is too cold, the fresh food section just right. You want to make the freezer warmer, keeping the fresh food constant. Go on, read the instructions, figure them out.

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.)





1.9 Two Conceptual Models for My Refrigerator. The model *A* (above) is provided by the system image of the refrigerator as gleaned from the controls and instructions; *B* (below) is the correct conceptual model. The problem is that it is impossible to tell in which compartment the thermostat is located and whether the two controls are in the freezer and fresh food compartment, or vice versa.

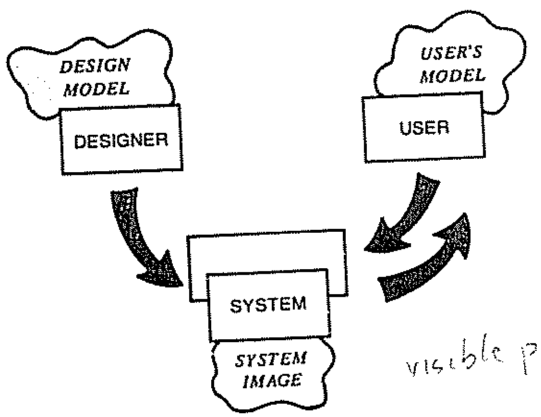


Oh, perhaps I'd better warn you. The two controls are not independent. The freezer control affects the fresh food temperature, and the fresh food control affects the freezer. And don't forget to wait twenty-four hours to check on whether you made the right adjustment, if you can remember what you did.

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."

"Hello," I answer, "who is this?"

"Who is this?" I hear in reply, "you called me."

"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?

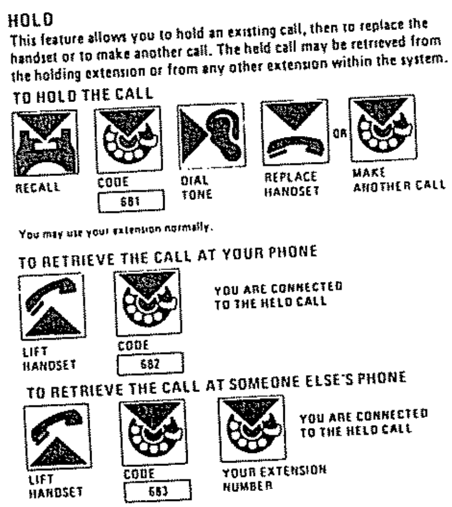
The modern telephone did not happen by accident: it was carefully designed. Someone—more likely a team of people—invented a list of features thought desirable, invented what seemed to them to be plausible ways of controlling the features, and then put it all together. My university, focusing on cost 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

1.11 British Telecom Telephone. This was in my office at the Applied Psychology Unit in Cambridge, England. It certainly looks simple, doesn't it?

1.12 Two Ways to Use Hold on Modern Telephones. Illustration *A* (below left) is the instruction manual page for British Telecom. The procedure seems especially complicated, with three 3-digit codes to be learned: 681, 682, and 683. Illustration *B* (below right) shows the equivalent instructions for the Ericsson Single Line Analog Telephone installed at the University of California, San Diego. I find the second set of instructions easier to understand, but one must still dial an arbitrary digit: 8 in this case.



CALL HOLD/CALL PARK
With party on line
- Press R key
- Listen for recall dial tone (three beeps and dial tone)
- Hang up handset

TO RETRIEVE FROM SAME PHONE
- Lift handset; you are connected to the call

TO RETRIEVE FROM ANOTHER PHONE
- Lift handset
- Dial extension where call was parked; listen for busy tone
- Dial 8; you are connected to the call

NOTE: Call will remain parked for 3 minutes before re-ringing

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."[6]

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 tem-
perature 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 map-
pings, natural relationships, between the controls and the things con-
trolled. Single controls often have single functions. There is good feed-
back. 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-

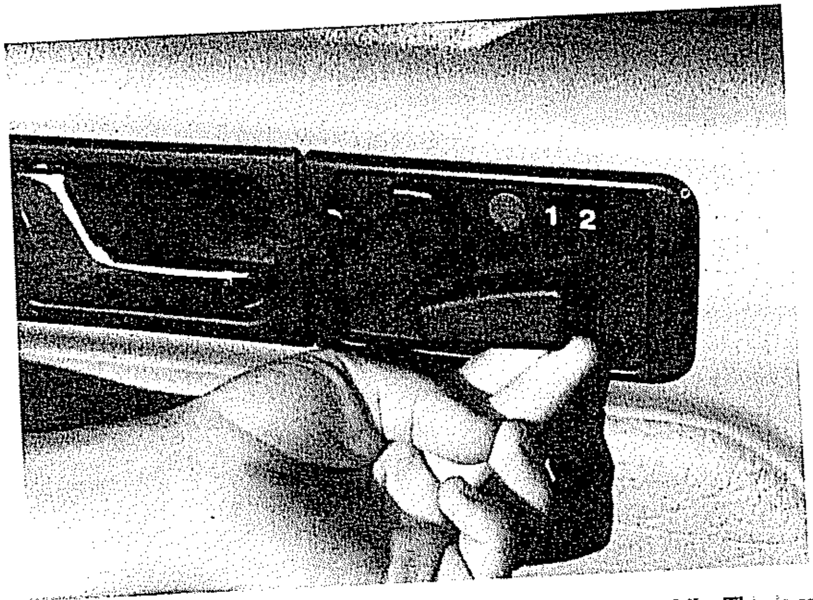
bility acts as a good reminder of what can be done and allows the control to specify how the action is to be performed. The good relationship between the placement of the control and what it does makes it easy to find the appropriate control for a task. As a result, there is little to remember.

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-



1.13 Seat Adjustment Control from a Mercedes-Benz Automobile. This is an excellent example of natural mapping. The control is in the shape of the seat itself: the mapping is straightforward. To move the front edge of the seat higher, lift up on the front part of the button. To make the seat back recline, move the button back. Mercedes-Benz automobiles are obviously not everyday things for most people, but the principle doesn't require great expense or wealth. The same principle could be applied to much more common objects.

phone system, press and release the "recall" button (the button on the handset), then dial 60, then dial the number you called.

There are several problems here. First, the description of the function is relatively complex—yet incomplete: What if two people set up callback at the same time? What if the person does not come back until a week later? What if you have meanwhile set up three or four other functions? What if you want to cancel it? Second, the action to be performed is arbitrary. (Dial 60. Why 60? Why not 73 or 27? How does one remember an arbitrary number?) Third, the sequence ends with what appears to be a redundant, unnecessary action: dialing the number of the person to be called. If the phone system is smart enough to do all these other things, why can't it remember the number that was just attempted; why must it be told all over again? And finally, consider the lack of feedback. How do I know I did the right action? Maybe I disconnected the phone. Maybe I set up some other special feature. There is no visible or audible way to know immediately.

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.

1.14 The Front/Rear Speaker Selector of an Automobile Radio. Rotating the knob with the pictures of the speaker at either side makes the sound come entirely out of the front speakers (when the knob is all the way over to one side), entirely out of the rear speakers (when the knob is all the way the other way), or equally out of both (when the knob is midway). Which way is front, which rear? You can't tell by looking. While you're at it, imagine trying to manipulate the radio controls while keeping your eyes on the road.

The control should be mounted so that it moves forward and backward. If that can't be done, rotate the control 90° on the panel so that it moves vertically. Moving something up to represent forward is not as natural as moving it forward, but at least it follows a standard convention.

In fact, we see that both the car and the telephone have easy functions and difficult ones. The car seems to have more of the easy ones, the telephone more of the difficult ones. Moreover, with the car, enough of the controls are easy that I can do almost everything I need to. Not so with the telephone: it is very difficult to use even a single one of the special features.

The easy things on both telephone and car have a lot in common, as do the difficult things. When things are visible, they tend to be easier

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 "sidetone") 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 telephone: one to change the display, one to accept the option on display. Of course, the telephone would be slightly more expensive. The tradeoff is cost versus usability.[7]

layer of criteria of quality

Pity the Poor Designer

Designing well is not easy. The manufacturer wants something that can
be produced economically. The store wants something that will be
attractive to its customers. The purchaser has several demands. In the
store, the purchaser focuses on price and appearance, and perhaps on
prestige value. At home, the same person will pay more attention to
functionality and usability. The repair service cares about maintaina-
bility: how easy is the device to take apart, diagnose, and service? The
needs of those concerned are different and often conflict. Nonetheless,
the designer may be able to satisfy everyone.

A simple example of good design is the $3\frac{1}{2}$-inch magnetic diskette
for computers, a small circle of "floppy" magnetic material encased in
hard plastic. Earlier types of floppy disks did not have this plastic case,
which protects the magnetic material from abuse and damage. A sliding
metal cover protects the delicate magnetic surface when the diskette is
not in use and automatically opens when the diskette is inserted into
the computer. The diskette has a square shape: there are apparently
eight possible ways to insert it into the machine, only one of which is
correct. What happens if I do it wrong? I try inserting the disk side-
ways. Ah, the designer thought of that. A little study shows that the
case really isn't square: it's rectangular, so you can't insert a longer side.
I try backward. The diskette goes in only part of the way. Small protru-
sions, indentations, and cutouts prevent the diskette from being in-
serted backward or upside down: of the eight ways one might try to
insert the diskette, only one is correct, and only that one will fit. An
excellent design.

Take another example of good design. My felt-tipped marking pen
has ribs along only one of its sides; otherwise all sides look identical.
Careful examination shows that the tip of the marker is angled and
makes the best line if the marker is held with the ribbed side up, a
natural result if the forefinger rests upon the ribs. No harm results if
I hold the marker another way, but the marker writes less well. The ribs
are a subtle design cue—functional, yet visibly and aesthetically unob-
trusive.

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, devices 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 complexity 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 antenna, one for the radio frequency, one for intermediate frequencies, and controls for both sensitivity and loudness. Later radios were simpler 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 control 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 countdown 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 operations 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 making 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 manageable.

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 following 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*

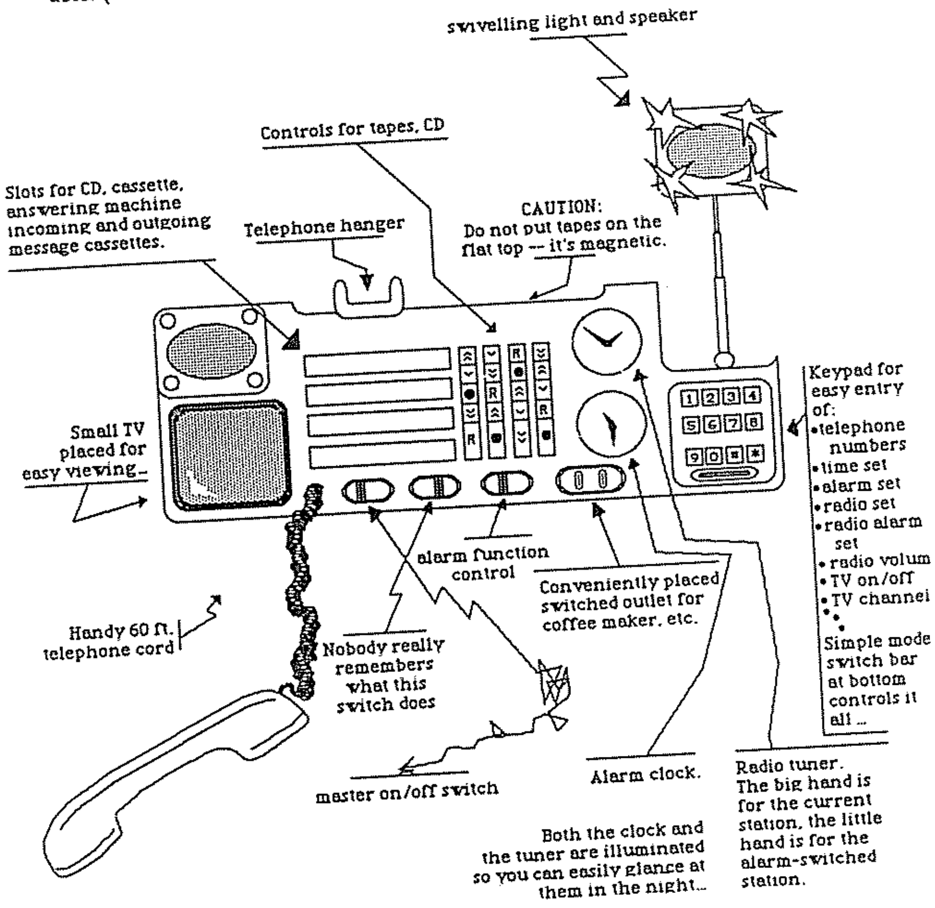
The company is trying to decide whether to include a small (two-inch screen) TV set and a switched electric outlet that can turn on a coffee maker or toaster.

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.

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]

CHAPTER FOUR

KNOWING WHAT TO DO

"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?"[1]

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.

Problems occur whenever there is more than one possibility. If there is only one part that can be operated and only one possible action to do, there will be no difficulty. Of course, if the designer has been too clever, hiding all the visible clues, the user may believe there are no alternatives and not even know how to begin.

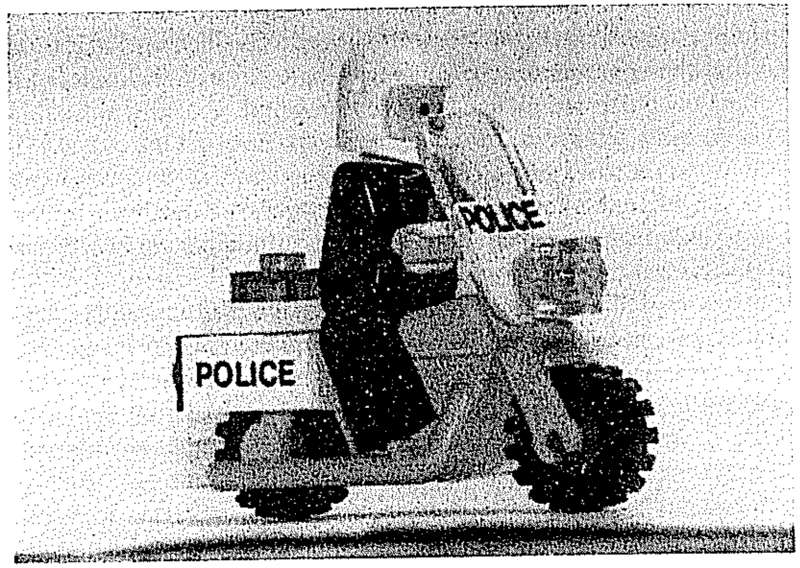
When we encounter a novel object, how can we tell what to do with it? Either we have dealt with something similar in the past and transfer old knowledge to the new object, or we obtain instruction. In these cases, the information we need is in the head. Another approach is to use information in the world, particularly if the design of the new object has presented us with information that can be interpreted.

How can design signal the appropriate actions? To answer the question we build upon the principles discussed in chapter 3. One important set of signals comes through the natural constraints of objects, physical constraints that limit what can be done. Another set of signals comes from the affordances of objects, which convey messages about their possible uses, actions, and functions. A flat plate affords pushing, an empty container affords filling, and so on. Affordances can signal how an object can be moved, what it will support, and whether anything will fit into its crevices, over it, or under it. Where do we grab it, which parts move, and which parts are fixed? Affordances suggest the range of possibilities, constraints limit the number of alternatives. The thoughtful use of affordances and constraints together in design lets a user determine readily the proper course of action, even in a novel situation.

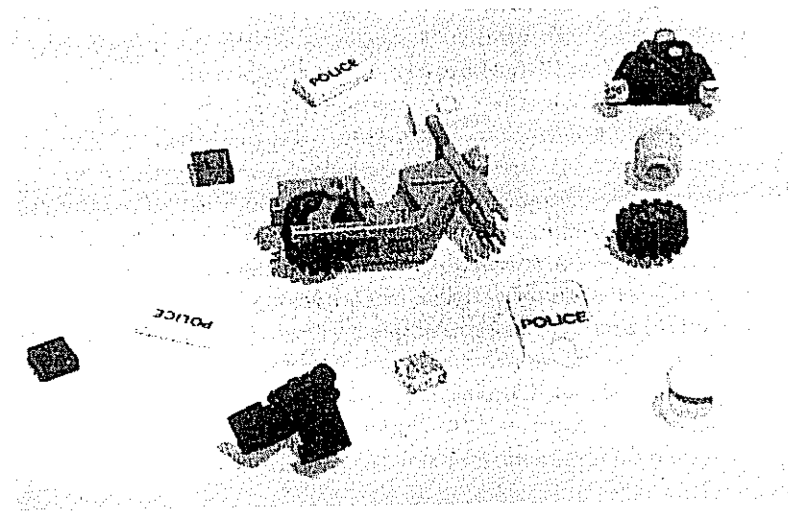
A Classification of Everyday Constraints

To understand the operation of constraints better, I did some simple experiments. I asked people to put things together from the parts given them; they had never seen the finished structure, and they were not even told what they should be constructing.[2] Let me illustrate with one of the examples: building a motorcycle from a Lego set (a children's construction toy).

The Lego motorcycle (figure 4.1) is a simple toy constructed of thirteen parts, some rather specialized. Of the thirteen parts, only two are alike—rectangles with the word *police* on them. One other piece is a blank rectangle of the same size. Three other pieces match in size and shape but are different colors. So there are two sets of three pieces in



4.1 **Lego Motorcycle.** The toy is shown assembled and in pieces. The thirteen parts are so cleverly constructed that even an adult can put them together. The design exploits constraints to specify just which pieces fit where. Physical constraints limit alternative placements. Semantic and cultural constraints provide the necessary clues for further decisions. For example, semantic constraints stop the user from putting the head backward on the body and cultural constraints dictate the placement of the three lights (the small rectangles, which are red, blue, and yellow).



which any of the three pieces are interchangeable, except for the semantic or cultural interpretation of the resulting construction. It turns out that the appropriate role for every single piece of the motorcycle is unambiguously determined by a set of physical, semantic, and cultural constraints. This means that people could construct the motorcycle without any instructions or assistance, although they had never seen it assembled. In this case, construction is entirely natural, if the builder knows about motorcycles and about the cultural assumptions that serve to constrain the placement of parts.

Affordances of the pieces were important in determining just how they fit together. The cylinders and holes characteristic of Lego suggested the major construction rule. The sizes and shapes of the parts suggested their operation. Physical constraints limited what parts would fit together. Other types of constraints also operated: all in all there were four different classes of constraints—physical, semantic, cultural, and logical. These classes are apparently universal, appearing in a wide variety of situations, and sufficient.

physical / semantic / cultural / logical > constraints

PHYSICAL CONSTRAINTS

eg safety overlocks

Physical limitations constrain possible operations. Thus, a large peg cannot fit into a small hole. The motorcycle windshield would fit in only one place, with only one orientation. The value of physical constraints is that they rely upon properties of the physical world for their operation; no special training is necessary. With the proper use of physical constraints there should be only a limited number of possible actions—or, at least, desired actions can be made obvious, usually by being especially salient.

Physical constraints are made more effective and useful if they are easy to see and interpret, for then the set of actions is restricted before anything has been done. Otherwise, the physical constraint prevents the wrong action from succeeding only after it has been tried. The Lego windshield was sometimes tried in the wrong orientation first; the design could have made the correct position more visible. The everyday door key can be inserted into a vertical slot only if the key is held vertically. But this still leaves two possible orientations. A well-designed key will either work in both orientations or provide a clear physical signal for the correct one. Good automobile door keys are made so that orientation doesn't matter. A poorly designed car key can

keys into slot + turn versus button to push

be yet another of those minor frustrations of everyday life—not so minor, perhaps, when you're standing outside the car in a storm with both arms full of packages.

SEMANTIC CONSTRAINTS

Ride face forward

Semantic constraints rely upon the meaning of the situation to control the set of possible actions. In the case of the motorcycle, there is only one meaningful location for the rider, who must sit facing forward. The purpose of the windshield is to protect the rider's face, so it must be in front of the rider. Semantic constraints rely upon our knowledge of the situation and of the world. Such knowledge can be a powerful and important clue.

↓ knowledge of world AND human ends

CULTURAL CONSTRAINTS

Some constraints rely upon accepted cultural conventions, even if they do not affect the physical or semantic operation of the device. One cultural convention is that signs are meant to be read; for the motorcycle, the pieces with the word *police* on them have to be placed right side up. Cultural constraints determine the locations of the three lights, which are otherwise physically interchangeable. Red is the culturally defined standard for a stop light, which is placed in the rear. White or yellow (in Europe) is the standard color for headlights, which go in front. And a police vehicle often has a blue flashing light on top.

Each culture has a set of allowable actions for social situations. Thus, we know how to behave in a restaurant, even one we have never been to before. This is how we manage to cope when our host leaves us alone in that strange room, at that strange party, with those strange people. And this is why we sometimes feel frustrated, so incapable of action, when we are confronted with a restaurant or group of people from an unfamiliar culture, where our normally accepted behavior is clearly inappropriate and frowned upon. Cultural issues are at the root of of many of the problems we have with new machines: there are as yet no accepted conventions or customs for dealing with them.

Those of us who study these things believe that guidelines for cultural behavior are represented in the mind by means of schemas, knowledge structures that contain the general rules and information neces-

eg orange cones

sary for interpreting situations and for guiding behavior. In some stereotypical situations (for example, in a restaurant), the schemas may be very specialized. Cognitive scientists Roger Schank and Bob Abelson have proposed that in these cases we follow "scripts" that can guide the sequence of behavior. The sociologist Ervin Goffman calls the social constraints on acceptable behavior frames, and he shows how they govern behavior even when a person is in a novel situation or novel culture. Danger awaits those who deliberately violate the frames for a culture.[3]

Next time you are in an elevator, stand facing the rear. Look at the strangers in the elevator and smile. Or scowl. Or say hello. Or say, "Are you feeling well? You don't look well." Walk up to random passersby and give them some money. Say something like, "You make me feel good, so here is some money." In a bus or streetcar, give your seat to the next athletic-looking teenager you see. The act is especially effective if you are elderly, or pregnant, or disabled.

LOGICAL CONSTRAINTS

In the case of the motorcycle, logic dictated that all the pieces should be used, with no gaps in the final product. The three lights of the Lego motorcycle presented a special problem for many people. They could use the cultural constraint to figure out that the red was the stop light and should go in the rear, that the yellow was the headlight and should go in the front, but what about the blue? Many people had no cultural or semantic information that would help them place the blue light. For them, logic provided the answer: only one piece left, only one possible place to go. The blue light was logically constrained.

Natural mappings work by providing logical constraints. There are no physical or cultural principles here; rather there is a logical relationship between the spatial or functional layout of components and the things that they affect or are affected by. If two switches control two lights, the left switch should work the left light, the right switch the right light. If the lights are mounted one way and the switches another, the natural mapping is destroyed. If two indicators reflect the state of two different parts of a system, the location and operation of the indicators should have a natural relationship to the spatial or functional layout of the system. Alas, natural mappings are not often exploited.

Applying Affordances and Constraints to Everyday Objects

The characteristics of affordances and constraints can be applied to the design of everyday objects, much simplifying our encounters with them. Doors and switches present interesting examples, for poor design causes unnecessary problems for their users. Yet the common problems have simple solutions, which properly exploit affordances and natural constraints.

THE PROBLEM WITH DOORS

In chapter 1 we encountered the sad story of my friend who was trapped between sets of glass doors at a post office, trapped because there were no clues to the doors' operation. When we approach a door, we have to find both the side that opens and the part to be manipulated: in other words, we need to figure out what to do and where to do it. We expect to find some visible signal for the correct operation: a plate, an extension, a hollow, an indentation—something that allows the hand to touch, grasp, turn, or fit into. This tells us where to act. The next step is to figure out how: we must determine what operations are permitted, in part using the affordances, in part guided by constraints.

Doors come in amazing variety. Some open only if a button is pushed, and some don't appear to open at all, having neither buttons, nor hardware, nor any other sign of their operation. The door might be operated with a foot pedal. Or maybe it is voice operated, and we must speak the magic phrase. *("Open Simsim!")* In addition, some doors have signs on them: pull, push, slide, lift, ring bell, insert card, type password, smile, rotate, bow, dance, or, perhaps, just ask. Somehow, when a device as simple as a door has to come with an instruction manual—even a one-word manual—then it is a failure, poorly designed.

Appearances deceive. I have seen people trip and fall when they attempted to push open a door that worked automatically, the door opening inward just as they attempted to push against it. On most subway trains, the doors open automatically at each station. Not so in Paris. I watched someone on the Paris Métro try to get off the train and fail. When the train came to his station, he got up and stood patiently plates mean push ; knobs turned ; buttons pushed

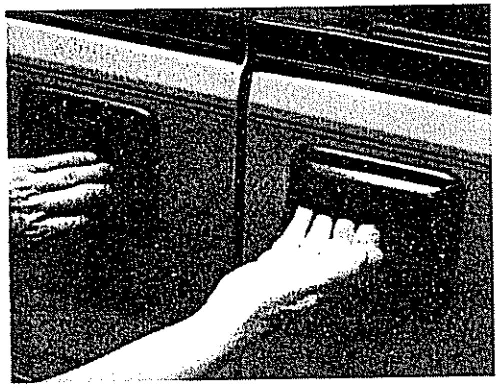
in front of the door, waiting for it to open. It never opened. The train simply started up again and went on to the next station. In the Métro, you have to open the doors yourself by pushing a button, or depressing a lever, or sliding them (depending upon which kind of car you happen to be on).

Consider the hardware for an unlocked door. It need not have any moving parts: it can be a fixed knob, plate, handle, or groove. Not only will the proper hardware operate the door smoothly, but it will also indicate just how the door is to be operated: it will exhibit the proper affordances. Suppose the door opens by being pushed. The easiest way to indicate this is to have a plate at the spot where the pushing should be done. A plate, if large enough for the hand, clearly and unambiguously marks the proper action. Moreover, the plate constrains the possible actions: there is little else that one can do with a plate except push. Unfortunately, even this simple clue is misused. Doors that should be pulled or slid sometimes have plates (figure 4.2). Doors that should be pushed sometimes have both plates and knobs or a handle and no plate.

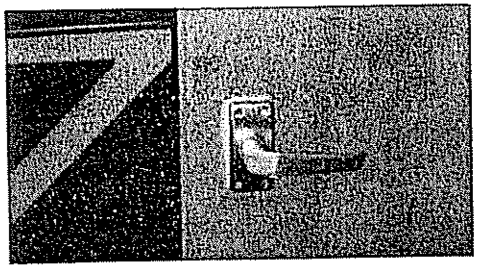
The violation of the simple use of constraints on doors can have serious implications. Look at the door in figure 4.3 *A*: this fire exit door has a push bar, a good example of an unambiguous signal to push, and a good design (required by law in the United States) because it forces proper behavior when panicked people press against a door as they attempt to flee a fire. But look again. On which side should you push? There is no way of knowing. Add some paint to the part that is to be pushed, or fasten a plate over it (figure 4.3 *B*): these provide strong cultural signals to guide the action properly. Push bars offer strong physical constraints, simplifying the task of knowing what to do. The use of cultural constraints simplifies the task of figuring out where to do it.

Some hardware cries out to be pulled. Although anything that can be pulled can also be pushed, the proper design will use cultural constraints so that the signal to pull will dominate. But even this can be messed up. I have seen doors with a mixture of signals, one implying push, the other pull. I have watched people passing through the door of figure 4.3 (*A*). And they had trouble, even people who worked in the building and who therefore used the door several times every day.

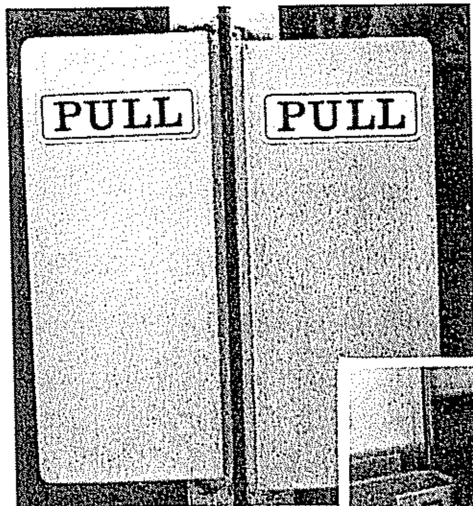
Sliding doors seem to present special difficulties. In fact, there are several good ways to signal the operation of a sliding door unambiguously. For example, a vertical slit in the door can be used in only one



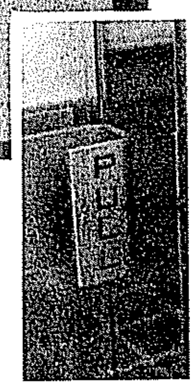
4.2 The Design of Doors. The doors at the left show two excellent examples of design: different handles, side by side on the same automobile, each neatly signaling its proper operation. The vertical placement of the lever on the handle to the left causes the hand to be held in a vertical plane, signifying a slide. The horizontal placement of the lever on the door handle to the right, coupled with the overhang and indentation that neatly afford entrance by the hand, signifies a pull. Two different types of doors, adjacent to one another, and yet there is no confusion between them.

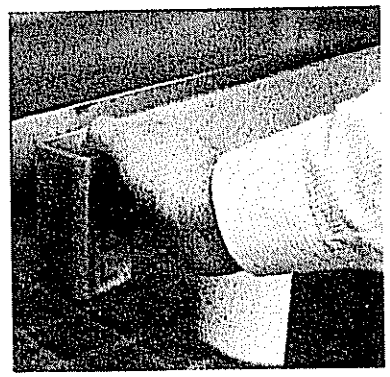


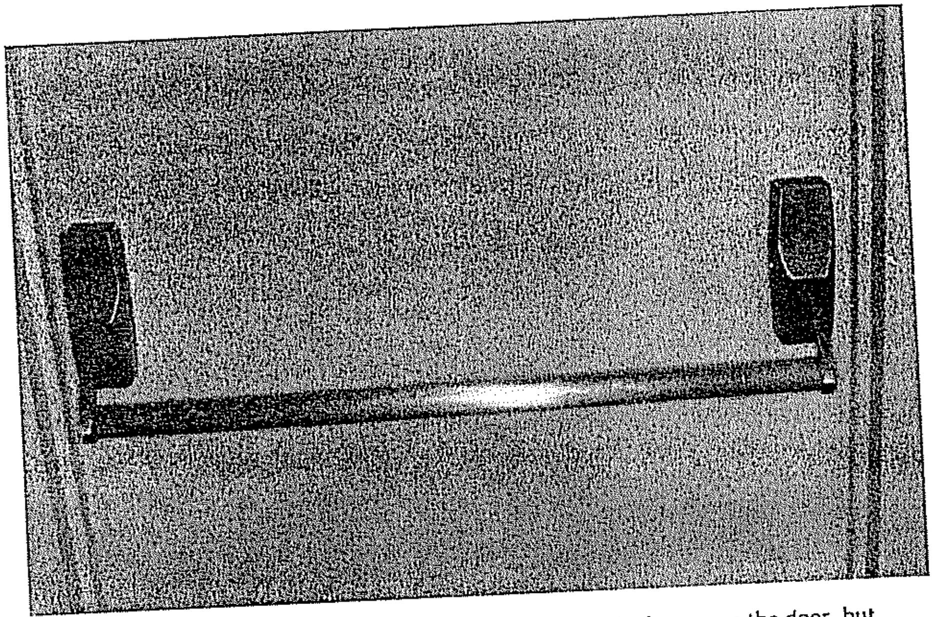
The handle depicted at the left shows inappropriate signals. This form of handle clearly marks grasp, twist, or pull—except that this particular door slides: a classic case of inappropriate design.



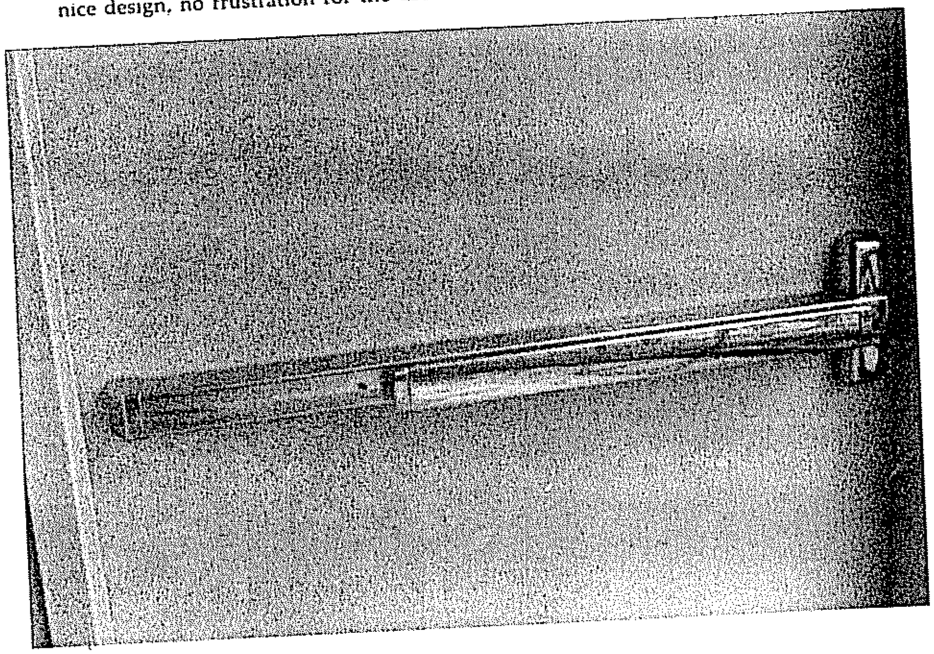
At left and below are photographs of hardware for doors that open by being pulled. The large plates at the left are a signal to push, but in fact the door is supposed to be pulled: no wonder the door needs the signs. The simple U-shaped brackets below is a much better design, but they are ambiguous enough that a sign still seems to be needed. Contrast with the two handles at the top, neither of which needs a sign yet is always operated properly. If a door handle needs a sign, then its design is probably faulty.







4.3 Doors in Two Commercial Buildings. Pushing the bar opens the door, but on which side do you push? Bar *A* (above) hides the signal, making it impossible to know on which side to push. A frustrating door. Bar *B* (below) has a flat plate mounted on the side that is to be pushed; this is a naturally interpreted signal. A nice design, no frustration for the user.



way: the fingers are inserted and the door slid. The location of the slit specifies not only where to exert the force but also in which direction. The critical signal is any depression in the door large enough for the fingers to fit into, but without an overhang. Similarly, any projection will also work, as long as it neither has an overhang nor is appropriate for being grasped with the hand. On a properly designed door, the fingers can exert pressure along the sides of the depression or projection—needed for sliding—but they can't pull or twist. I have seen elegant sliding doors, aesthetically pleasing, yet with clear signals to the user—in a conference room in Italy, on a door on a Métro train in Paris, on some Scandinavian furniture. Yet more often, it seems, sliding doors are built with the wrong signals, with clumsy hardware in positions that jam the fingers. Sliding doors somehow challenge the designer to get them wrong.

Some doors have appropriate hardware, well placed. The outside door handles of most modern automobiles are excellent examples of design. The handles are often recessed receptacles that simultaneously indicate the place and mode of action: the receptacle cannot be used except by inserting the fingers and pulling. Horizontal slits guide the hand into a pulling position; vertical slits signal a sliding motion. Strangely enough, the inside door handles for automobiles tell a different story. Here, the designer has faced a different kind of problem, and the appropriate solution has not yet been found. As a result, although the outside door handles of cars are often excellent, the inside ones are often difficult to find, hard to figure out how to operate, and difficult to use.

Unfortunately, the worst door hardware is found where we spend most of our time: at home and in the office. In many cases, the choice of hardware appears haphazard, used for convenience (or profitability). Architects and interior designers seem to prefer designs that are visually elegant and win prizes. This often means that a door and its hardware are designed to merge with the interior: the door may barely be visible, the hardware merges with door, and the operation is completely obscure. From my experience, the worst offenders are cabinet doors. It is sometimes not even possible to determine where the doors are, let alone whether and from where they are slid, lifted, pushed, or pulled. The focus on aesthetics may blind the designer (and the purchaser) to the lack of usability.

A particularly frustrating design is that of the door that opens outward by being pushed inward. The push releases the catch and ener-

gizes a spring, so that when the hand is taken away the door springs open. It's a very clever design, but most puzzling to the first-time user. A plate would be the appropriate signal, but designers sometimes do not wish to mar the smooth surface of the door. I have such a latch in the glass door of the cabinet in which I store phonograph records. You can see through the door, and it is obvious that there is no room for the door to open inward; to push on the door seems contradictory. New and infrequent users of this door usually reject pushing and open it instead by pulling, which often requires them to use fingernails, knife blades, or more ingenious methods to pry it open.

THE PROBLEM WITH SWITCHES

At any lecture I give, my first demonstration needs no preparation. I can count on the light switches of the room or auditorium to be unmanageable. "Lights please," someone will say. Then fumble, fumble, fumble. Who knows where the switches are and which lights they control? The lights seem to work smoothly only when a technician is hired to sit in a control room somewhere, turning them on and off.

The switch problems in an auditorium are annoying, but similar problems in airplanes and nuclear power plants are dangerous. The controls all look the same. How do the operators avoid the occasional mistake, confusion, or accidental bumping against the wrong control? Or misaim? They don't. Fortunately, airplanes and power plants are pretty robust. A few errors every hour are not important—usually.

One type of popular small airplane has identical-looking switches for flaps and landing gear right next to one another. You might be surprised to learn how many pilots, while on the ground, have decided to raise the flaps and instead raised the wheels. This very expensive error happened frequently enough that the National Transportation Safety Board wrote a report about it. The analysts politely pointed out that the proper design principles to avoid these errors have been known for thirty years. Why were those design errors still being made?

Basic switches and controls should be relatively simple to design well. But there are two fundamental difficulties. The first is the grouping problem, how to determine which switch goes with which function.

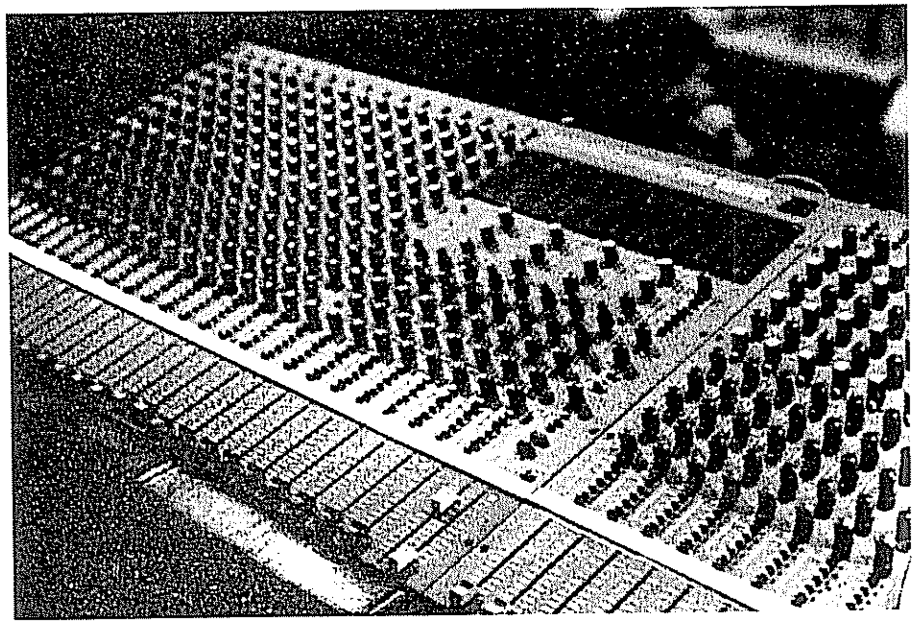
The second is the mapping problem. For example, when there are many lights and an array of switches, how can you determine which switch controls which light?

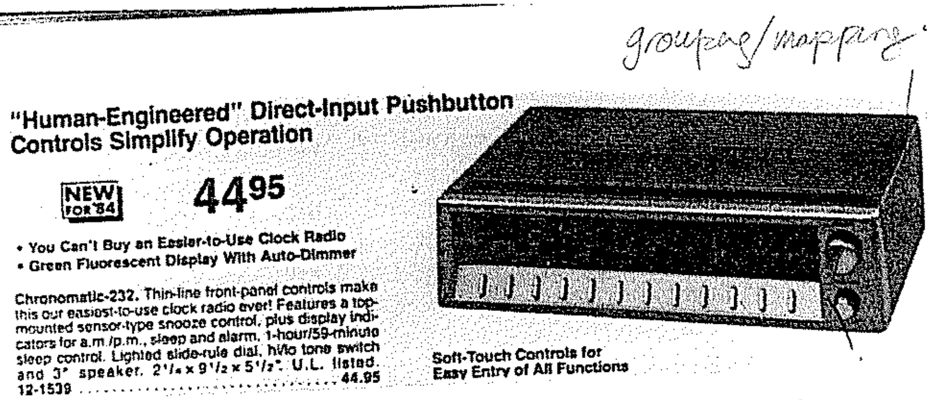
The switch problem becomes serious only where there are many of them. It isn't a problem in situations with one switch, and it is only a minor problem where there are two switches. But the difficulties mount rapidly with more than two switches at the same location. Multiple switches are more likely to occur in offices, auditoriums, and industrial locations than in homes (figure 4.4).

WHICH SWITCH CONTROLS WHICH FUNCTION?

Switches for unrelated functions are often placed together, usually with no distinguishing marks to help the user know which switch controls which function. Designers love rows of identical-looking switches. The switches look good, are easy to mount, are inexpensive to build, and please the aesthetic sensibilities of the viewer. But they

4.4 **Typical Audio Mixing Control.** This picture was taken in an auditorium in England. Fortunately, errors on panels like these are seldom serious, often not even noted.





4.5 A Clock Radio, "Human Engineered" to Simplify Operation. Note the row of identical-looking switches. (Copyright Tandy Corporation. Used with permission.)

make it easy to err. With identical switches all in a row, it is difficult to distinguish the switch for the coffee maker from the switch to the central power for the computer. Or the set-the-time switch from the turn-off-the-radio switch (figure 4.5). Or the landing gear switch from the flap control switch.

Consider my car radio: twenty-five controls, many apparently arbitrary. All tiny (so that they will fit the limited space available). Imagine trying to use the radio while driving at high speed, at night. Or in winter when wearing gloves, so that the attempt to push one button succeeds in pushing two, or the attempt to turn the loudness control also adjusts the tone control. You should be able to use things in the dark. A car radio should be usable with a minimum of visual cues. But the radio designers probably designed it in the laboratory, with little or no thought about the car, or the driver. For all I know the design won a prize for its visual aesthetics.

It should go without saying that controls that cause trouble should not be located where they can be operated by accident, especially in the dark, or when the person is trying to use the device without looking. It should go without saying, but in fact, it is necessary to say it.

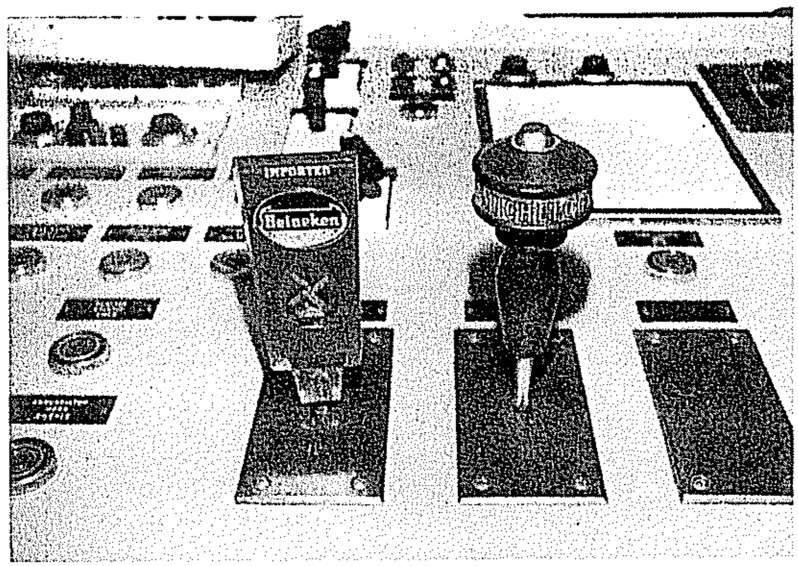
There is a simple, well-known solution to the grouping problem: set the switches for one set of functions apart from the switches that control other functions. Another solution is to use different types of switches. The solutions can be combined. To solve the problem with the airplane flap and landing gear switches, separate the switches and don't line them up in a row. Also use shape coding: a tire-shaped switch

can control the landing gear, and the flap switch can be a long, thin rectangle—the shape of a flap. Putting controls in different locations makes it less likely that a misaimed hand will throw the wrong switch. And using shape coding means that a potential error may be caught and that the correct switch can be found by feel alone (figure 4.6). That's how to solve this first problem, now let us turn to the other one.

HOW ARE THE SWITCHES ARRANGED?

With the lights in a room, you know that all the switches control lights. But which switch controls which light? Room lights are usually organized in a two-dimensional structure and they are usually horizontal (that is, they are on the ceiling or, if they are lamps, they are placed along the floor or on tables). But switches are usually arranged in a one-dimensional row mounted on the wall, a vertical surface. How can a one-dimensional row of switches map onto a two-dimensional array of lights? And with the switches being mounted on the wall and the

4.6 Make the Controls Look and Feel Different. The control-room operators in a nuclear power plant tried to overcome the problem of similar-looking knobs by placing beer-keg handles over them. This is good design, even if after the fact; the operators should be rewarded. (From Seminara, Gonzales, & Parsons, 1977. Photograph courtesy of Joseph L. Seminara.)



lights being on the ceiling, you have to do a mental rotation of the switches to get them to conform to the lights. The mapping problem is unsolvable with the current structure of switches.

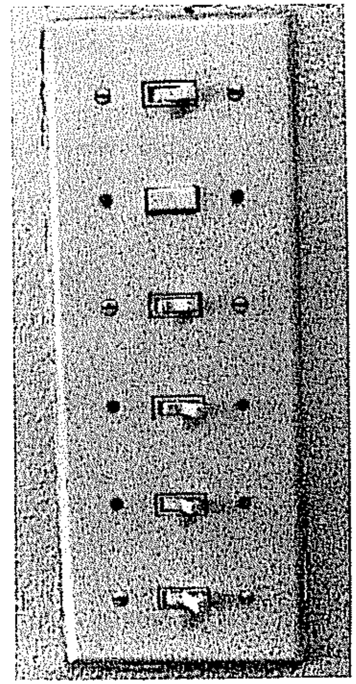
Electricians usually try to lay out the switches in the same order as the lights they control, but the mismatch in the spatial arrangement of the lights and the switches makes it difficult, if not impossible, to produce a full natural mapping. Electricians have to use standard components, and the designers and manufacturers of those standard components worried only about fitting the proper number of switches into them safely. Nobody thought about how the lights were to be arranged or how the switches ought to be laid out.

My house was designed by two brash young architects, award winning, who, among other things, liked neat rows of light switches. We got a horizontal row of four identical switches in the front hall, a vertical column of six identical switches in the living room. "You will get used to it," the architects assured us when we complained. We never did. Finally we had to change the switches, making each one different. Even so we made lots of mistakes.

In my psychology laboratory, the lights and their switches were located in many different places, yet most people wanted to control the lights upon entering the area. The area is large, with three major hallways and approximately fifteen rooms. Moreover, this floor of the building has no windows, so it is dark unless the lights are turned on.

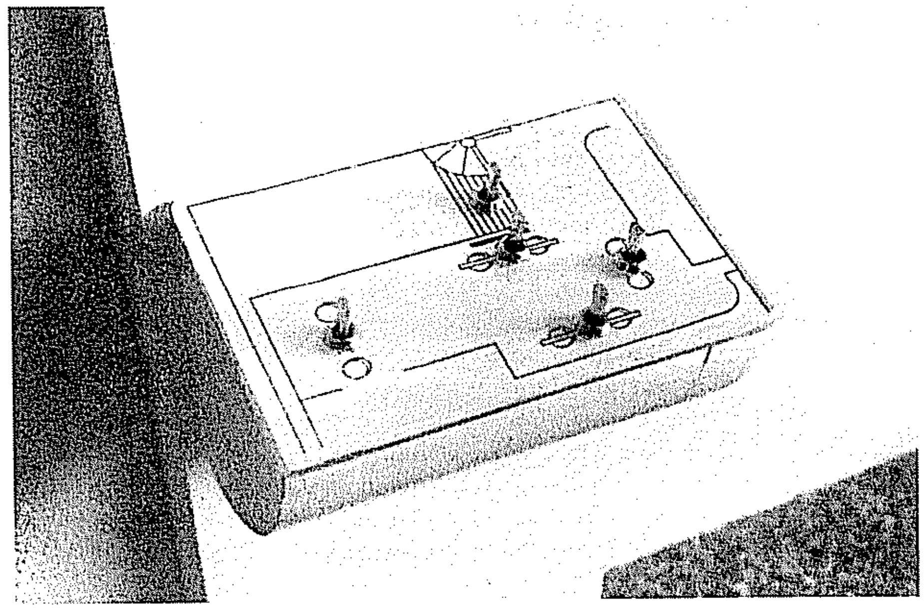
If light switches are placed on the wall, there is no way they can exactly correspond in position to the placement of the lights. Why place the switches flat against the wall? Why not redo things? Why not place the switches horizontally, in exact analogy to the things being controlled, with a two-dimensional layout so that the switches can be placed on a floorplan of the building in exact correspondence to the areas that they control? Match the layout of the lights with the layout of the switches: the principle of natural mapping. In my laboratory, as in my home, the solution was to construct a simple switchplate that mirrored the physical arrangement of the area, with small light switches placed in relevant locations.[4] Figure 4.7 shows the situation at my home, and figure 4.8 shows what we did at the laboratory.

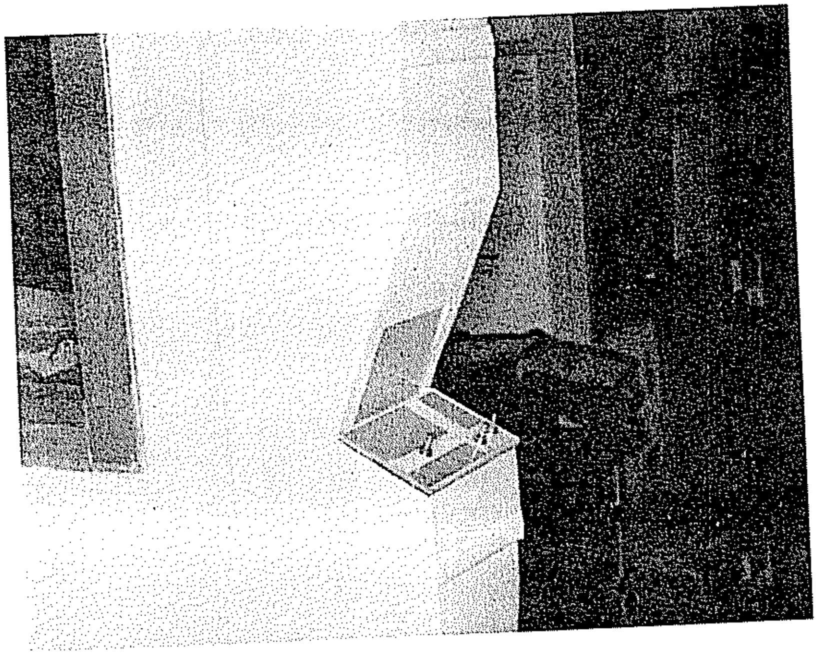
How well do the new switch arrangements work? Quite well, I am happy to report. One laboratory user sent me the following note:



4.7 The vertical array of six switches at the right is what our architects provided to control the lights in our odd-shaped living room. We could never remember which switch did what.

The photograph below shows our solution: switches arranged to match the room layout. (One more switch, for a projection screen, will be mounted on the vertical plate just above the light switches. The switch panel was constructed for the author by David Wargo.)





4.8 The original layout of switches in my laboratory had the light switches scattered. We put all the switches in one convenient location, arranged on a floor plan of the laboratory. (The switch panel was constructed by David Wargo.)

"You know, I actually kind of like those new switches now—they seem easy to use, and it's nice to have all the switches in one location when you first walk in. You can just sort of swipe at them on your way past and light up the area you want—very quick. So while I was worried they wouldn't be advantageous for the experienced user, I was wrong."

Can the new switches be used everywhere? Probably not. But there is no reason they couldn't be widely adopted. There are a series of technical problems still to be addressed: builders and electricians need standardized components. How about making up standard light switch boxes, made to be mounted *on* the wall (instead of *in* the wall as they are today), where the switches are mounted on the top of the box, on the horizontal surface. And on the top, make up a matrix of supports so that there can be free, relatively unrestricted placement of the switches in whatever pattern best suits the room. Use smaller switches

if necessary. Maybe get rid of those standardized light plates. The matrix design would require drilling holes differently for each room, but if the switches were designed to fit into standard sized circular or rectangular holes, the holes could be drilled or punched quite easily.

My suggestion requires that the switch box stick out from the wall, whereas today's boxes are mounted so that the switches are flush with the wall. Some might consider my solution ugly. Well, then, indent the boxes, placing them *in* the wall. After all, if there is room inside the wall for the existing switch boxes, there is also room for an indented horizontal surface. Or mount the switches on a little pedestal, or on a ledge.

Visibility and Feedback

So far we have concentrated upon constraints and mappings. But for knowing what to do there are other relevant principles, too, especially visibility and feedback:

1. *Visibility.* Make relevant parts visible.
2. *Feedback.* Give each action an immediate and obvious effect.

When we use a novel object, a number of questions guide our actions:

- Which parts move; which are fixed?
- Where should the object be grasped? What part is to be manipulated? What is to be held? Where is the hand to be inserted? If it is speech sensitive, where does one talk?
- What kind of movement is possible: pushing, pulling, turning, rotating, touching, stroking?
- What are the relevant physical characteristics of the movements? With how great a force must the object be manipulated? How far can it be expected to move? How can success be gauged?
- What parts of the object are supporting surfaces? How much size and weight will the object support?

The same kinds of questions arise whether we are trying to decide what to do or attempting to evaluate the results of an action. In examining the object, we have to decide which parts signify the state of the object and which are solely decorative, or nonfunctional, or part of the background or supports. What things change? What has changed over the previous state? Where should we be watching or listening to detect any changes? The important things to watch should be visible and clearly marked; the results of any action should be immediately apparent.

MAKING VISIBLE THE INVISIBLE

The principle of visibility is violated over and over again in everyday things. In numerous designs crucial parts are carefully hidden away. Handles on cabinets distract from some design aesthetics, and so they are deliberately made invisible or left out. The cracks that signify the existence of a door can also distract from the pure lines of the design, so these significant cues are also minimized or eliminated. The result can be a smooth expanse of gleaming material, with no sign of doors or drawers, let alone of how those doors and drawers might be operated. Electric switches are often hidden: many electric typewriters have the on/off switch hidden underneath; many computers and computer terminals have the on/off switch in the rear, difficult to find and awkward to use;[5] and the switches that control kitchen garbage disposal units are often hidden away, sometimes nearly impossible to find.

Many systems are vastly improved by the act of making visible what was invisible before. Consider the VCR.

> "UMPTEEN-DAY-UMPTEEN-EVENT PROGRAMMING. *Because time-shifting is so popular, manufacturers and retailers play up a VCR's ability to record automatically. The typical VCR can record four events (video jargon for programs) over a 4-day span. . . .*
>
> *"It's one thing to know that a VCR can record eight events in 14 days. It's quite another to make the machine behave. You have to go through a tedious series of steps to tell the VCR when to start recording, what channel to record, how long to run the tape, and so on.*
>
> *"Some VCR's are much easier to program than others. . . . Best of all, we think, is a feature called on-screen programming. Commands that appear on the TV screen help you enter the time, date, and channel of the program you want to tape."*[6]

As the quotation from *Consumer Reports* indicates, the act of setting up these units to do the recording is horribly complex and difficult. The same article later warns that if you are not careful in your selection,

"you could wind up with a VCR that brings out fear and loathing whenever you try to change the channel resets or set it up to record a program when you are away." It does not take much examination to discover the reason for the difficulties: there is no visual feedback. As a result, users (1) have trouble remembering their place in the lengthy sequence of required steps; (2) have trouble remembering what next needs to be done; and (3) cannot easily check the information just entered to see if it is what was intended, and then cannot easily change it, if they decide it is wrong.

The gulfs both in execution (the first two problems) and in evaluation (the last problem) are significant for these VCRs. Both can be bridged by the use of a display. Displays often cost money and take up room, which is why designers hesitate to use them, but in the case of a VCR, a display device is usually already available: the TV set. And, indeed, those VCRs that can be programmed through the use of an on-screen TV display are much easier to use. Visibility makes all the difference.

NOTHING SUCCEEDS LIKE A GOOD DISPLAY

Over and over again we find unwarranted complexity that could be avoided were the device to contain a good display. With the modern telephone (see chapter 1), a display that could prompt the user through the series of steps required for programming would make the difference between a valuable, usable system and a next-to-useless one. So, too, with any device of complexity, whether it be the washing machine, microwave oven, or office copying machine. Nothing succeeds like visual feedback, which in turn requires a good visual display.

WHAT CAN BE DONE?

New technologies, especially the inexpensive microprocessors available today (the heart of the computer) make possible the incorporation of powerful and intelligent systems even in simple, everyday things, from toys to kitchen appliances to office machines. But new capabilities must be accompanied by appropriate displays, also now relatively inexpensive. I asked the students in one of my classes to generate some possibilities for adding visibility to everyday devices. Here are some of them:

- *Display the song titles for compact discs.* Why not take advantage of the storage capacity of an audio compact disc (CD) and have it display not only the number of the song or track (as it now does) but also the title? Each title could be accompanied by other information, such as performers, composer, or playing time. Thus, in programming the CD, you could select by name rather than by number, and you would always know what you were hearing.

- *Display the names of television programs.* If each television station would also broadcast its station identification and the title of the current program, the viewer who tuned in during the middle of a show could easily find out what it was. The information could be sent in computer-readable format during the retrace interval (the time that the beam is off the screen).
- *Print the cooking information for foods on the food package in computer-readable form.* This is a scheme for bypassing the need to make things visible. The cooking of frozen foods often requires several different cooking times, waiting times, and heat settings. The programming is complex. If the cooking information were on the package in machine-readable form, one could put the food in the microwave oven, pass a scanner over the printed information, and let the oven program itself.

USING SOUND FOR VISIBILITY

Sometimes things can't be made visible. Enter sound: sound can provide information available in no other way. Sound can tell us that things are working properly or that they need maintenance or repair. It can even save us from accidents. Consider the information provided by:

- The click when the bolt on a door slides home
- The "zzz" sound when a zipper works properly
- The "tinny" sound when a door doesn't shut right
- The roaring sound when a car muffler gets a hole
- The rattle when things aren't secured
- The whistle of a tea kettle when the water boils
- The click when the toast pops up
- The increase in pitch when a vacuum cleaner gets clogged
- The indescribable change in sound when a complex piece of machinery starts to have problems

Many devices do use sound, but only for signals. Simple sounds, such as buzzers, bells, or tones. Computers use bleeping, whining, and

clicking sounds. This use of sound is valuable and serves an important function, but it is very limited in power: it is as if the use of visual cues were limited to different colored, flashing lights. We could use sound for much more communciation than we do.

These days computers produce several sounds, and keypads, microwave ovens, and telephones beep and burp. These are not naturalistic sounds; they do not convey hidden information. When used properly, a beep can assure you that you've pressed a button, but the sound is as annoying as informative. Sounds should be generated so as to give information about the source. They should convey something about the actions that are taking place, actions that matter to the user but that would otherwise not be visible. The buzzes, clicks, and hums that you hear while a telephone call is being completed are one good example: take out those noises and you are less certain that the connection is being made.

Bill Gaver, who has been studying use of sound in my laboratory, points out that real, natural sound is as essential as visual information because sound tells us about things we can't see, and it does so while our eyes are occupied elsewhere. Natural sounds reflect the complex interaction of natural objects: the way one part moves against another; the material of which the parts are made—hollow or solid, metal or wood, soft or hard, rough or smooth. Sounds are generated when materials interact, and the sound tells us whether they are hitting, sliding, breaking, tearing, crumbling, or bouncing. Moreover, sounds differ according to the characteristics of the objects, according to their size, solidity, mass, tension, and material. And they differ with how fast things are going and how far away from us they are.

If they are to be useful, sounds must be generated intelligently, with an understanding of the natural relationship between the sounds and the information to be conveyed. Sounds on artificial devices should be as useful as sounds in the real world. Gaver has proposed that sound could play an important role in computer-based applications. Here, rich, naturalistic sounds could serve as auditory icons, caricatures of naturally occurring sounds that could provide information about the concepts being represented not easily conveyed in other ways.[7]

You have to be very careful with sound, however. It easily becomes cute rather than useful. It can annoy and distract as easily as it can aid. One of the virtues of sounds is that they can be detected even when attention is applied elsewhere. But this virtue is also a deficit, for sounds are often intrusive. Sounds are difficult to keep private unless the intensity is low or earphones are used. This means both that neighbors may be annoyed and that others can monitor your activities. The use of sound to convey information is a powerful and important idea, but still in its infancy.

Just as the presence of sound can serve a useful role in providing feedback about events, the absence of sound can lead to the same kinds of difficulties we have already encountered from a lack of feedback. The absence of sound can mean an absence of information, and if feedback from an action is expected to come from sound, silence can lead to problems.

I once stayed in the guest apartment of a technological institute in the Netherlands. The building was newly completed, with many interesting architectural features. The architect had gone to great lengths to keep the noise level low; the ventilation system could not be heard. In similar fashion, the ventilation for the room came and went through invisible slots in the ceiling (so I am told; I never did find them).

All was fine until I took a shower. The bathroom seemed to have no ventilation at all, so everything became wet, then eventually cold and clammy. There was a switch in the bathroom that I thought might be the control for an exhaust fan. When I pushed the switch, a light on it came on and stayed on. Further pushing had no effect.

I noticed that whenever I returned to the apartment after an absence, the light would be off. So each time I entered the apartment, I went into the bathroom and pushed the button. By listening closely, I could hear a slight "thump" in the distance the first time the button was depressed. I decided it was some kind of signal. Perhaps it was a call button, summoning the maid, or the janitor, or maybe even the fire department (though no one showed up). I did also consider that it might control a ventilation system, but I could hear no flow of air. I examined the inside of the entire bathroom with care, trying to find an air inlet. I even got a chair and a flashlight and examined the ceiling. Nothing.

At the end of my stay, the person driving me to the airport, explained that the button controlled the exhaust fan. The fan was on as long as the light was on, and it turned off, automatically, in about five minutes. The architect was very good at disguising the ventilation system and at keeping the noise level down.

Here is a case where the architect was too successful: the feedback was clearly lacking. The light was not enough—in fact, it was quite misleading. Noise would have been welcome. It would have signaled that there really was ventilation.

CHAPTER FIVE

TO ERR IS HUMAN

"LONDON—An inexperienced computer-operator pressed the wrong key on a terminal in early December, causing chaos at the London Stock Exchange. The error at stockbrokers Greenwell Montagu led to systems staff working through the night in an attempt to cure the problem."[1]

People make errors routinely. Hardly a minute of a normal conversation can go by without a stumble, a repetition, a phrase stopped midway through to be discarded or redone. Human language provides special mechanisms that make corrections so automatic that the participants hardly take notice; indeed, they may be surprised when errors are pointed out. Artificial devices do not have the same tolerance. Push the wrong button, and chaos may result.

Errors come in several forms. Two fundamental categories are slips and mistakes. Slips result from automatic behavior, when subconscious actions that are intended to satisfy our goals get waylaid en route. Mistakes result from conscious deliberations. The same processes that make us creative and insightful by allowing us to see relationships between apparently unrelated things, that let us leap to correct conclusions on the basis of partial or even faulty evidence, also lead to error.

NOTES

CHAPTER ONE: The Psychopathology of Everyday Things

1. Reprinted by permission of the *Wall Street Journal.* © Dow Jones & Co., Inc., 1986. All rights reserved.

2. W. H. Mayall (1979), *Principles in design*, 84.

3. The notion of affordance and the insights it provides originated with J. J. Gibson, a psychologist interested in how people see the world. I believe that affordances result from the mental interpretation of things, based on our past knowledge and experience applied to our perception of the things about us. My view is somewhat in conflict with the views of many Gibsonian psychologists, but this internal debate within modern psychology is of little relevance here. (See Gibson, 1977, 1979.)

4. D. Fisher & R. Bragonier, Jr. (1981), *What's what: A visual glossary of the physical world.* The list of the eleven parts of the sink came from this book. I thank James Grier Miller for telling me about the book and lending me his copy.

5. Biederman (1987) shows how he derives the number 30,000 on pages 127 and 128 of his paper, "Recognition-by-components: A theory of human image understanding," *Psychological Review, 94,* 115–147.

6. I thank Mike King for this example (and others).

7. More complex systems have already been successfully built. One example is the speech message system that recorded phone calls for later retrie-

val, built by IBM for the 1984 Olympics. Here was a rather complex telephone system, designed to record messages being sent to athletes by friends and colleagues from all over the world. The users spoke a variety of languages, and some were quite unfamiliar with the American telephone system and with high technology in general. But by careful application of psychological principles and continual testing with the user population during the design stage, the system was usable, understandable, and functional. Good design is possible to achieve, but it has to be one of the goals from the beginning. (See the description of the phone system by Gould, Boies, Levy, Richards, & Schoonard, 1987.)

CHAPTER TWO: The Psychology of Everyday Actions

1. Unfortunately, blaming the user is imbedded in the legal system. When major accidents occur, official courts of inquiry are set up to assess the blame. More and more often the blame is attributed to "human error." The person involved can be fined, punished, or fired. Maybe training procedures are revised. The law rests comfortably. But in my experience, human error usually is a result of poor design: it should be called system error. Humans err continually; it is an intrinsic part of our nature. System design should take this into account. Pinning the blame on the person may be a comfortable way to proceed, but why was the system ever designed so that a single act by a single person could cause calamity? An important book on this topic is Charles Perrow's *Normal accidents* (1984). I cover human error in detail in chapter 5.

2. This example is taken from White & Horwitz's (1987) technical report on "ThinkerTools," their system for teaching children physics, in part to overcome the beliefs in naive physics which are otherwise so strong.

3. The subject of naive views is treated at length in many reviews. The relationship between Aristotle's physics and modern naive physics is developed in McCloskey's (1983) *Scientific American* article, "Intuitive physics."

4. The valve theory of the thermostat is taken from Kempton (1986), a study published in the journal *Cognitive Science.*

5. Some thermostats are designed to anticipate the need to turn on or off. They avoid a common problem: the temperature in a cooling house continues to drop after the thermostat has turned on the furnace, and the temperature of a heating house continues to rise after the thermostat has turned off the furnace, due to the heat already in the system. The "intelligent" thermostat turns off or on a little before the desired temperature is reached.

6. National Transportation Safety Board (1984), *Aircraft accident report—Eastern Air Lines, Inc., Lockheed L-1011, N334EA, Miami International Airport, Miami, Florida, May 5, 1983.*

7. Surprisingly little is known about the nature of action sequences. Th[e] most relevant book to what I am describing is *Plans and the structure of behavior* by Miller, Galanter, and Pribram (1960). The GOMS (Goals, Operators Methods, and Selection) model of Card, Moran, and Newell (1983) is more recent and more relevant to applications. My work is described in more detail in Norman (1986). Sanders (1980) has reviewed a host of experimental studies that supports this breakdown of the sequence into sever[al] stages. A fair amount of work on a theory of action is being done by socia[l] psychologists. On the whole, this is a rich, unexplored area, worthy o[f] much study.

8. The story of these gulfs and the initial analyses came about from research performed with Ed Hutchins and Jim Hollan, then part of a joint research team between the Naval Personnel Research and Development Center and the University of California, San Diego. The work examined the development of computer systems that were easier to learn and easier to use and, in particular, of what has been called direct manipulation computer systems. I return to this in chapter 6. The initial work is described in the chapter "Direct manipulation interfaces" in the book *User centered system design* (Hutchins, Hollan, & Norman, 1986).

CHAPTER THREE: Knowledge in the Head and in the W[orld]

1. Many people are responsible for the development of these demonstrations. I do not know who first pointed out the problems with remembering the letter-number matchup on the telephone. Nickerson & Adams (1979) and Rubin & Kontis (1983) showed that people could neither recall nor recognize accurately the pictures and words on American coins. Jonathan Grudin did the demonstration of the typists' apparent lack of knowledge of the keyboard (unpublished study).

2. Thomas Malone, now at the MIT School of Business Administration, examined how people organize their work on their office desks. His studies of the importance of physical organization are often cited as justification for the frequent use of the desktop metaphor in some computer systems, especially the Xerox Star and the Apple Lisa and Macintosh (the Apple machines were derived from the Xerox Star; Malone was working for Xerox at the time he did his studies). See Malone's (1983) paper "How do people organize their desks: Implications for designing office automation systems."

3. I take this result from the work of Rubin & Kontis (1983), who attempted to determine the mental representation (the memory schema) that their students had for American coins.

4. Stanley Meisler, *Times* staff writer, in the *Los Angeles Times,* Dec. 31, 1986. Copyright 1986, *Los Angeles Times.* Reprinted by permission.

The change from an arbitrary mapping to a partial mapping to a full natural mapping reduces the number of alternatives from 24 to 4 to 1 and reduces the information theory content from 8 to 4 to 0 bits, respectively.

17. Despite the importance of reminding from both the practical and the theoretical point of view, little is known about it. Reminds, of course, occur in a number of different ways. One form of reminding occurs entirely internally, as when a thought or an experience "reminds" one of another thought or experience. As far as I know, only Roger Schank has written about it (in his book *Dynamic memory,* 1982). Another form of reminding comes from external cues: for example, as when seeing a clock reminds one of the time and of a task that needs to be done (or worse, that can no longer be done). Another form of reminding—the type I have been discussing—is deliberately invoked or set up, as when one tries to set up physical cues on one day of tasks that are to be done during another. We treat some of these issues in the chapters by Cypher and by Miyata and Norman in Norman & Draper (1986), *User centered system design.*

CHAPTER FOUR: Knowing What to Do

1. Letter to newspaper advice columnist Ellie Rucker, *Austin* [Texas] *American-Statesman.* Aug. 31, 1986. Reprinted by permission.

2. The results of my experiments are reminiscent of studies of chess masters who were allowed only ten seconds to examine a chess board with a configuration from the middle of a real game before being asked to reconstruct the board from memory. They did so very accurately. Novices reconstruct the board poorly. But show an illegal (or illogical) combination of those very same chess pieces to a master and a novice, and they perform about equally poorly. The expert has learned so much of the structure of the game that numerous natural and artificial constraints come into play, automatically ruling out all sorts of configurations and reducing what has to be remembered to a manageable amount. The novice does not have sufficient internal knowledge to make use of these constraints. Similarly, when faced with the illegal or illogical configuration, the expert's constraints and prior knowledge are no longer useful (see Chase & Simon, 1973).

3. See Schank & Abelson's (1977) *Scripts, plans, goals, and understanding* or Goffman's (1974) book *Frame analysis,* on social structures and conventions.

4. We had to overcome a number of technical problems to improve the mapping. The lights were already installed, and it was not possible to redo the wiring. We modified some light dimmers so that they could be used as controls for remotely located lights. The choice of electrical switches was also limited. Ideally, we would have made parts especially for our purpose. Still, the experiment has been remarkably successful. In this work, I relied heavily on the electrical and mechanical ingenuity of Dave Wargo, who actually did the design, construction, and installation of the switches.

5. The reason for the awkward location of the switch is cost. One designer wrote me: "I fought the good battle to get the on/off switch to the front of the terminal. I lost the argument both times. The hardware engineers costed the front mounted switch at about $10 (about $30 to the consumer), plus the potential for the power to contaminate some nearby circuits." Those prices seem high to me, but this designer was speaking of professional equipment, where the terminal probably costs in the thousands of dollars. Here is the standard tradeoff of cost versus usability. What price are you willing to pay for usability? Does the cost really have to be that high? What if the switch had been designed to be on the front from the very beginning, as opposed to having to be moved after the rest of the layout had been completed?

6. Copyright 1987 by Consumers Union of United States, Inc., Mount Vernon, NY 10553. Excerpted by permission from *Consumer Reports,* Jan. 1987.

7. See Gaver (1986).

CHAPTER FIVE: To Err Is Human

1. *InfoWorld,* Dec. 22, 1986. Reprinted by permission.

2. See Sherry Turkle's (1984) analysis in her book *The second self.* The book is mostly about the impact of computers on people's lives, especially on the children who have grown up with daily, continual contact with machines—the "hackers" of the world. Turkle also presents an analysis of the changes that information-processing views of the human mind have made to our interpretation of Freud. All around, it is an intriguing and important book.

3. Unless otherwise noted, all the examples in this section were collected by me, primarily from the errors of myself, my research associates, my colleagues, and my students. Everyone diligently recorded their slips, with the requirement that only the ones that had been immediately recorded would be added to the collection. Many were first published in Norman (1980 and 1981).

4. The term "capture error" was invented by Jim Reason of Manchester, England (Reason, 1979). Reason has written widely on slips and other mishaps. I recommend as a good review of his work the book *Absent minded? The psychology of mental lapses and everyday errors* (Reason & Mycielska, 1982).

5. Reason (1979).

6. A simple introduction to schema theory can be found in my book *Learning and memory* (Norman, 1982).

reading for everyone involved in the design and operation of large-scale plants and systems.

It should come as no surprise to learn that I think that three excellent essays on the role model provided by architecture as well as the importance of social factors can be found in the chapters by Bannon, Brown, and Hooper in my *User centered system design*. An excellent treatment of the social aspects of design is provided by Sommer (1983) in his *Social design: Creating buildings with people in mind* (which I quote from extensively in chapter 6).

My work has been heavily influenced by Simon, especially by his ideas developed in *The sciences of the artificial* (1981), which, among other things, pointed out that much of the complexity of our behavior reflects the complexity of the world, not of our thought processes. In part I am complementing that argument, arguing that through design the world can be made simpler. A second, related idea was Simon's introduction of the concept of "satisficing," for which he argued that we do not necessarily examine all the alternatives available to us and choose the optimum, but rather we tend to minimize mental effort and take the first one that seems satisfactory.

Computers, of course, play an ever increasing role in modern design, both as tools for the design process and as the object of design. Smith, Irby, Kimball, Verplank, & Harslem (1982) present an excellent description of the design of a computer system (the Xerox Star) that heavily emphasized usability and understandability: this is recommended reading for people interested in computer systems. (The Star was not a commercial success, but later versions have been more successful; the design principles and philosophies were taken over by the Apple Computer Corporation and have accounted for the success of the Macintosh.) Ted Nelson (1981) presents an engaging description of the possible future of machines in his *Literary machines* (and other volumes). Illuminating discussions of the importance of the social context in which tools are used are provided in two new, important studies: Winograd and Flores (1986), *Understanding computers and cognition: A new foundation for design:* and Suchman's (1987) *Plans and situated actions: The problem of human-machine communication.*

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