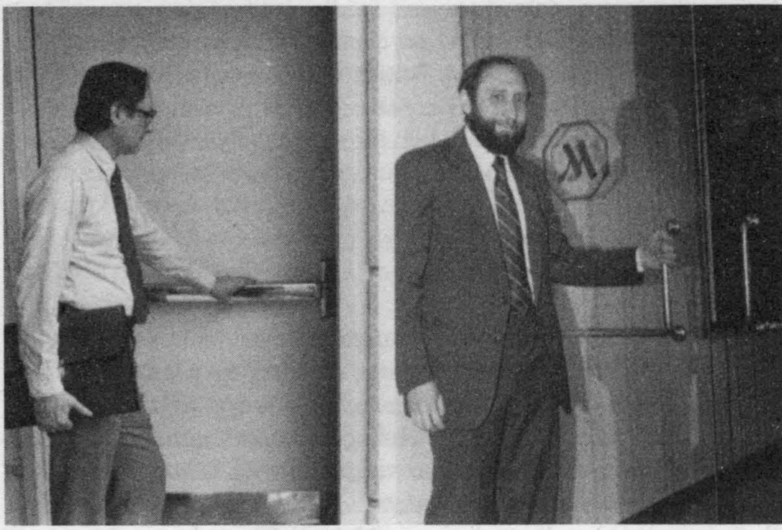
AFFORDANCES

"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]

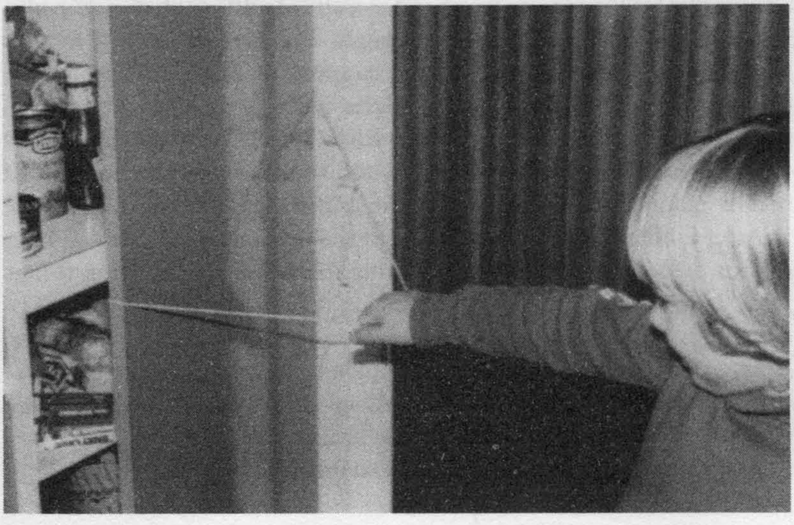
Affordances provide strong clues to the operations of things. Plates are for pushing. Knobs are for turning. Slots are for inserting things into. Balls are for throwing or bouncing. When affordances are taken advantage of, the user knows what to do just by looking: no picture, label, or instruction is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

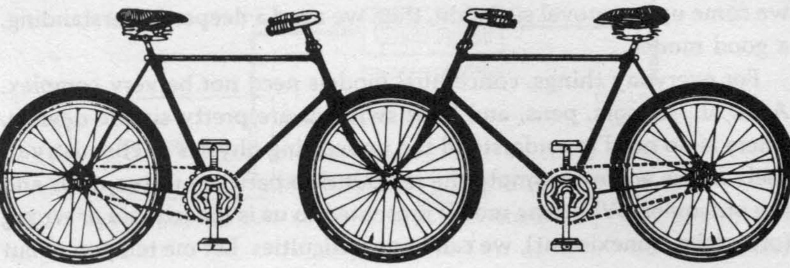
The book *What's What: A Visual Glossary of the Physical World* has more than fifteen hundred drawings and pictures and illustrates twenty-three thousand items or parts of items.[4] Irving Biederman, a psychologist who studies visual perception, estimates that there are probably "30,000 readily discriminable 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.

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,



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.

eg

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

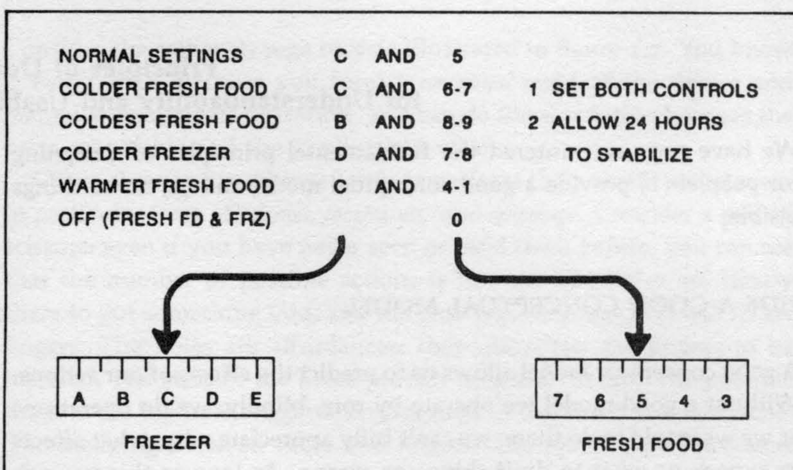
A good conceptual model allows us to predict the effects of our actions. Without a good model we operate by rote, blindly; we do operations as we were told to do them; we can't fully appreciate why, what effects to expect, or what to do if things go wrong. As long as things work properly, we can manage.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

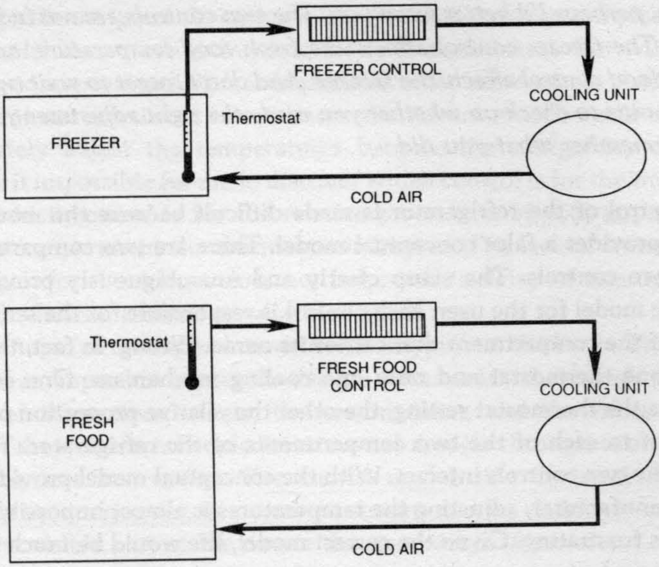
For everyday things, conceptual models need not be very complex. After all, scissors, pens, and light switches are pretty simple devices. There is no need to understand the underlying physics or chemistry of each device we own, simply the relationship between the controls and the outcomes. When the model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

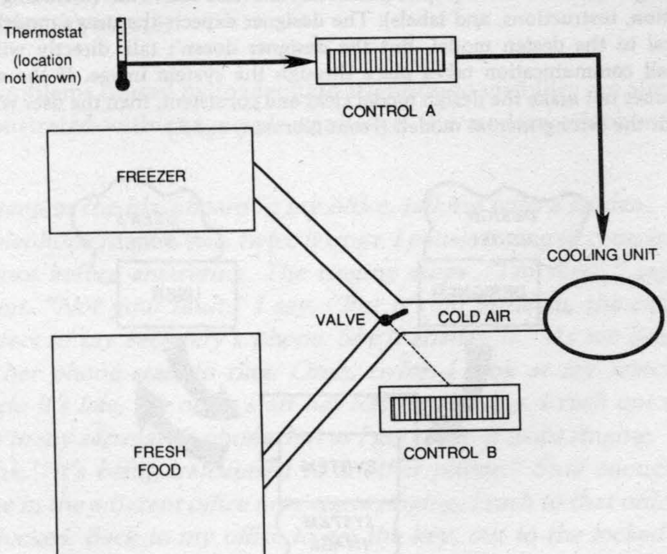
You try it. Figure 1.8 shows the instruction plate from inside the refrigerator. Now, suppose the freezer is too cold, the fresh food section just right. You want to make the freezer warmer, keeping the fresh food constant. Go on, read the instructions, figure them out.

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.

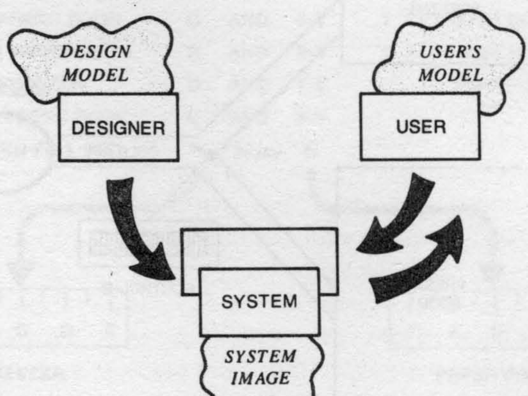


Oh, perhaps I'd better warn you. The two controls are not independent. The freezer control affects the fresh food temperature, and the fresh food control affects the freezer. And don't forget to wait twenty-four hours to check on whether you made the right adjustment, if you can remember what you did.

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.

How People Do Things: The Seven Stages of Action

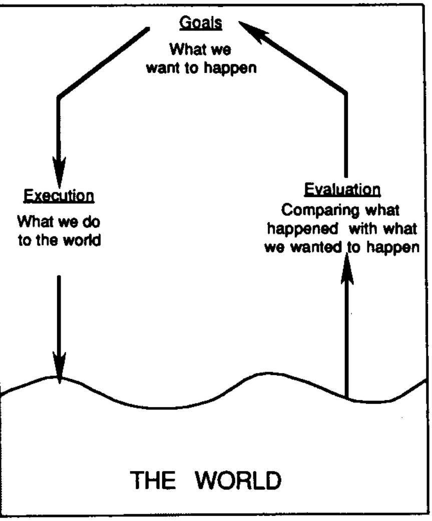
I am in Italy, at a conference. I watch the next speaker attempt to thread a film onto a projector that he has never used before. He puts the reel into place, then takes it off and reverses it. Another person comes to help. Jointly they thread the film through the projector and hold the free end, discussing how to put it on the takeup reel. Two *more people come over to help, and then another. The voices grow louder, in three languages: Italian, German, and English. One person investigates the controls, manipulating each and announcing the result. Confusion mounts. I can no longer observe all that is happening. The conference organizer comes over. After a few moments he turns and faces the audience, which has been waiting patiently in the auditorium. "Ahem," he says, "is anybody expert in projectors?" Finally, fourteen minutes after the speaker had started to thread the film (and eight minutes after the scheduled start of the session) a blue-coated technician appears. He scowls, then promptly takes the entire film off the projector, rethreads it, and gets it working.*

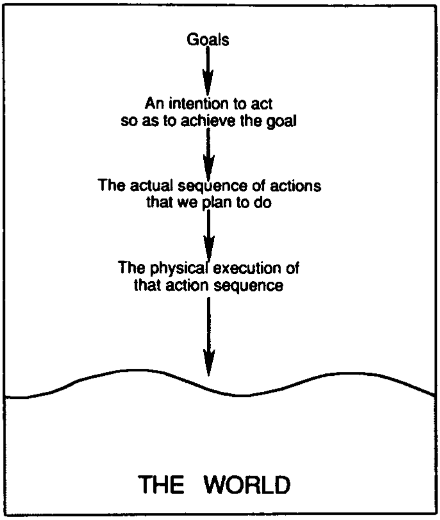
What makes something—like threading the projector—difficult to do? To answer this question, the central one of this book, we need to know what happens when someone does something. We need to examine the structure of an action.

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

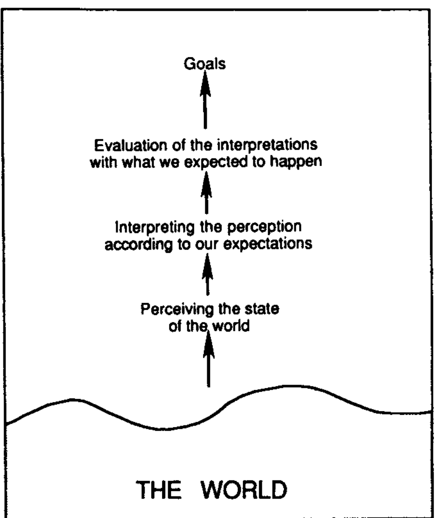
Real tasks are not quite so simple. The original goal may be imprecisely specified—perhaps "get something to eat," "get to work," "get dressed," "watch television." Goals do not state precisely what to do—where and how to move, what to pick up. To lead to actions goals must be transformed into specific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

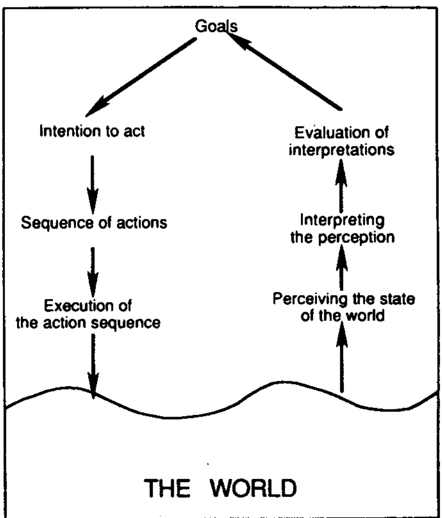
Suppose I am sitting in my armchair, reading a book. It is dusk, and the light has gotten dimmer and dimmer. I decide I need more light (that is the goal: get more light). My goal has to be translated into the intention that states the appropriate action in the world: push the switch button on the lamp. There's more: I need to specify how to move my body, how to stretch to reach the light switch, how to extend my finger to push the button (without knocking over the lamp). The goal





2.2 The Action Cycle (above left). Human action has two aspects, execution and evaluation. Execution involves doing something. Evaluation is the comparison of what happened in the world with what we wanted to happen (our goal). **2.3 Stages of Execution** (above right). Start at the top with the *goal,* the state that is to be achieved. The goal is translated into an *intention* to do some action. The intention must be translated into a set of internal commands, an *action sequence* that can be performed to satisfy the intention. The action sequence is still a mental event: nothing happens until it is *executed,* performed upon the world. **2.4 Stages of Evaluation** (below left). Evaluation starts with our *perception* of the world. This perception must then be *interpreted* according to our expectations and then compared *(evaluated)* with respect to both our intentions (from figure 2.3) and our goals. **2.5 Seven Stages of Action** (below right).
The stages of execution from figure 2.3 (intentions, action sequence, and execution) are coupled with the stages of evaluation from figure 2.4 (perception, interpretation, and evaluation), with goals common to both stages.





has to be translated into an intention, which in turn has to be made into a specific action sequence, one that can control my muscles. Note that I could satisfy my goal with other action sequences, other intentions. If someone walked into the room and passed by the lamp, I might alter my intention from pushing the switch button to asking the other person to do it for me. The goal hasn't changed, but the intention and resulting action sequence have.

The specific actions bridge the gap between what we would like to have done (our goals and intentions) and all possible physical actions. After we specify what actions to make, we must actually do them—the stage of execution. All in all, there are three stages that follow from the goal: intention, action sequence, and execution (figure 2.3).

The evaluation side of things, checking up on what happened, has three stages: first, perceiving what happened in the world; second, trying to make sense of it (interpreting it); and, finally, comparing what happened with what was wanted (figure 2.4).

There we have it. Seven stages of action: one for goals, three for execution, and three for evaluation.

- Forming the goal
- Forming the intention
- Specifying an action
- Executing the action
- Perceiving the state of the world
- Interpreting the state of the world
- Evaluating the outcome

The seven stages form an *approximate model,* not a complete psychological theory. In particular, the stages are almost certainly not discrete entities. Most behavior does not require going through all stages in sequence, and most activities will not be satisfied by single actions. There must be numerous sequences, and the whole activity may last hours or even days. There is a continual feedback loop, in which the results of one activity are used to direct further ones, in which goals lead to subgoals, intentions lead to subintentions. There are activities in which goals are forgotten, discarded, or reformulated.[7]

For many everyday tasks, goals and intentions are not well specified: they are opportunistic *rather than planned. Opportunistic actions are* *those in which the behavior takes advantage of the circumstances. Rather than engage in extensive planning and analysis, the person goes about the day's activities and performs the intended actions if the relevant opportunity arises. Thus, we may not go out of our way to go to a shop, or to the library, or to ask a question of a friend. Rather, we go through the day's activities, and if we find ourselves at the shop, near the library, or encountering the friend, then we allow the opportunity to trigger the relevant activity. Otherwise, the task remains undone. Only in the case of crucial tasks do we make special efforts to ensure that they get done. Opportunistic actions are less precise and certain than specified goals and intentions, but they result in less mental effort, less inconvenience, and perhaps more interest.*

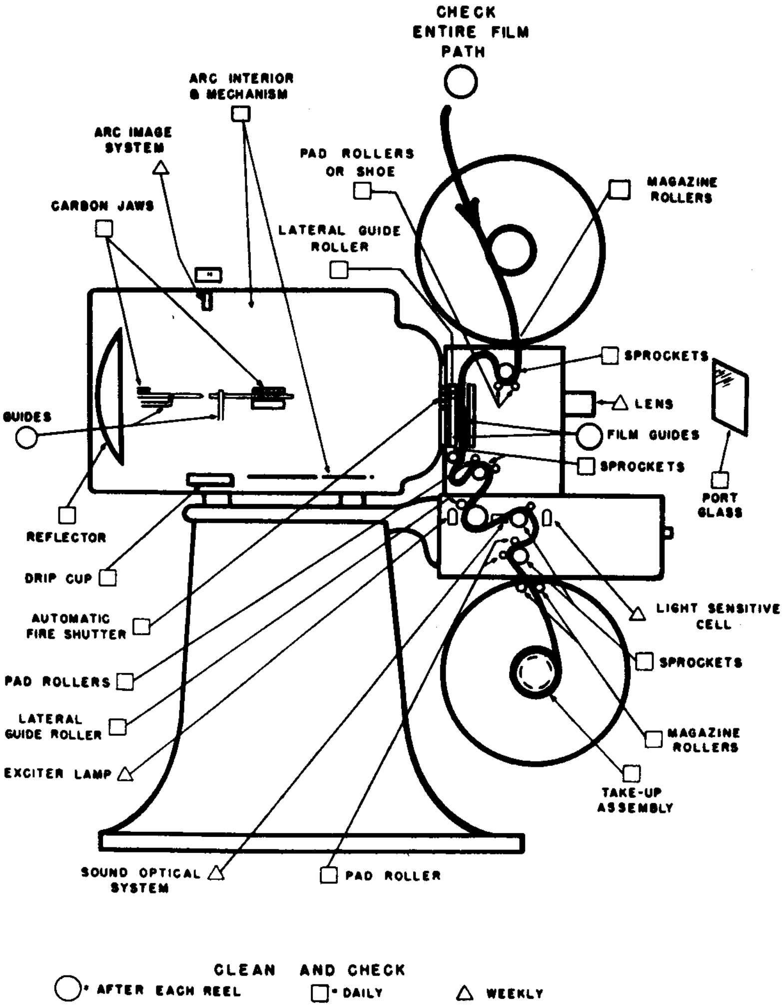
The seven-stage process of action can be started at any point. People do not always behave as full, logical, reasoning organisms, starting with high-level goals and working to achieve them. Our goals are often ill-formed and vague. We may respond to the events of the world (in what is called data-driven behavior) rather than to think out plans and goals. An event in the world may trigger an interpretation and a resulting response. Actions may be executed before they are fully developed. In fact, some of us adjust our lives so that the environment can control our behavior. For example, sometimes when I must do an important task, I make a formal, public promise to get it done by a certain date. I make sure that I will be reminded of the promise. And then, hours before the deadline, I actually get to work and do the job. This kind of behavior is fully compatible with the seven-stage analysis.

The Gulfs of Execution and Evaluation

Remember the movie projector story? People's problems threading the projector did not come from a lack of understanding of the goal or the task. It did not come from deep, subtle complexity. The difficulty lay entirely in determining the relationship between the intended actions and the mechanisms of the projector, in determining the functions of each of the controls, in determining what specific manipulation of each control enabled each function, and in deciding by the sights, sounds, lights, and movements of the projector whether the intended actions were being done successfully. The users had a problem with mappings and feedback, as they would have with the projector in figure 2.6.

The projector story is only an extreme case of the difficulties faced in the conduct of many tasks. For a surprisingly large number of everyday tasks, the difficulty resides entirely in deriving the relationships between the mental intentions and interpretations and the physical actions and states. There are several *gulfs* that separate mental states from physical ones. Each gulf reflects one aspect of the distance between the mental representations of the person and the physical com-

2.6 Threading the Movie Projector. The dark line at the right shows the path of the film. This picture doesn't tell the whole story, for the several loops of film have to be threaded just right, neither too loose nor too taut. (From *Projectionist's manual,* Department of the Army and the Air Force, May 1966.)



ponents and states of the environment. And these gulfs present major problems for users.[8]

THE GULF OF EXECUTION

Does the system provide actions that correspond to the intentions of the person? The difference between the intentions and the allowable actions is the Gulf of Execution. One measure of this gulf is how well the system allows the person to do the intended actions directly, without extra effort: Do the actions provided by the system match those intended by the person?

Consider the movie projector example: one problem resulted from the Gulf of Execution. The person wanted to set up the projector. Ideally, this would be a simple thing to do. But no, a long, complex sequence was required. It wasn't at all clear what actions had to be done to accomplish the intentions of setting up the projector and showing the film.

Self-threading projectors do exist. These nicely bridge the gulf. Or look at VCRs. They have the same mechanical problem as film projectors: the videotape has to be threaded through their mechanism. But the solution is to hide this part of the system, to put the task on the machine, not the person. So the machinery bridges the gulf. All the user has to do is to plop in the cartridge and push the start button. It's a pity the film companies are so far behind. Well, in a while it won't matter. There won't be any film, just videotape.

THE GULF OF EVALUATION

Does the system provide a physical representation that can be directly perceived and that is directly interpretable in terms of the intentions and expectations of the person? The Gulf of Evaluation reflects the amount of effort that the person must exert to interpret the physical state of the system and to determine how well the expectations and intentions have been met. The gulf is small when the system provides information about its state in a form that is easy to get, is easy to interpret, and matches the way the person thinks of the system.

In the movie projector example there was also a problem with the Gulf of Evaluation. Even when the film was in the projector, it was *difficult to tell if it had been threaded correctly. With VCRs all you have to know is whether the cartridge is properly inserted into the machine. If it isn't, usually it won't fit right: it sticks out obviously, and you know that things are not right.*

But VCRs aren't perfect, either. I remember a conference speaker who pushed the start button on the VCR and told the audience to watch the screen. No picture. She fiddled with the machine, then called for help. One, then two, then three technicians appeared on the scene. They carefully checked the power connections, the leads to the VCR, the circuits. The audience waited impatiently, giggling. Finally the problem was found: there wasn't any tape in the VCR. No tape, no picture. The problem was that once the cartridge door to that particular VCR was shut, there was no visible way to tell whether it contained a tape. Bad design. That Gulf of Evaluation sunk another user.

The gulfs are present to an amazing degree in a variety of devices. Usually the difficulties are unremarked and invisible. The users either take the blame themselves (in the case of things they believe they should be capable of using, such as water faucets, refrigerator temperature controls, stove tops, radio and television sets) or decide that they are incapable of operating the pesky devices (sewing machines, washing machines, digital watches, digital controls on household appliances, VCRs, audio sets). These are indeed the gadgets of everyday household use. None of them has a complex structure, yet many of them defeat the otherwise capable user.

The Seven Stages of Action as Design Aids

The seven-stage structure can be a valuable design aid, for it provides a basic checklist of questions to ask to ensure that the Gulfs of Evaluation and Execution are bridged (figure 2.7).

In general, each stage of action requires its own special design strategies and, in turn, provides its own opportunity for disaster. It would be fun, were it not also so frustrating, to look over the world and gleefully analyze each deficiency. On the whole, as you can see in figure 2.7, the questions for each stage are relatively simple. And these, in turn, boil down to the principles of good design introduced in chapter 1.

- *Visibility.* By looking, the user can tell the state of the device and the alternatives for action.

How Easily Can One:

Determine The Function
of the Device?

Tell What Actions Are Possible?	Tell if System is in Desired State?
Determine Mapping from Intention to Physical Movement?	Determine Mapping from System State to Interpretation?
Perform the Action?	Tell What State the System is In?

2.7 Using the Seven Stages to Ask Design Questions

- *A good conceptual model.* The designer provides a good conceptual model for the user, with consistency in the presentation of operations and results and a coherent, consistent system image.
- *Good mappings.* It is possible to determine the relationships between actions and results, between the controls and their effects, and between the system state and what is visible.
- *Feedback.* The user receives full and continuous feedback about the results of actions.

Each point provides support for one or more of the seven stages of action. The next time you can't immediately figure out the shower control in a motel or work an unfamiliar television set or stove, remember that the problem is in the design. And the next time you pick up an unfamiliar object and use it smoothly and effortlessly on the first try, stop and examine it: the ease of use did not come about by accident. Someone designed the object carefully and well.