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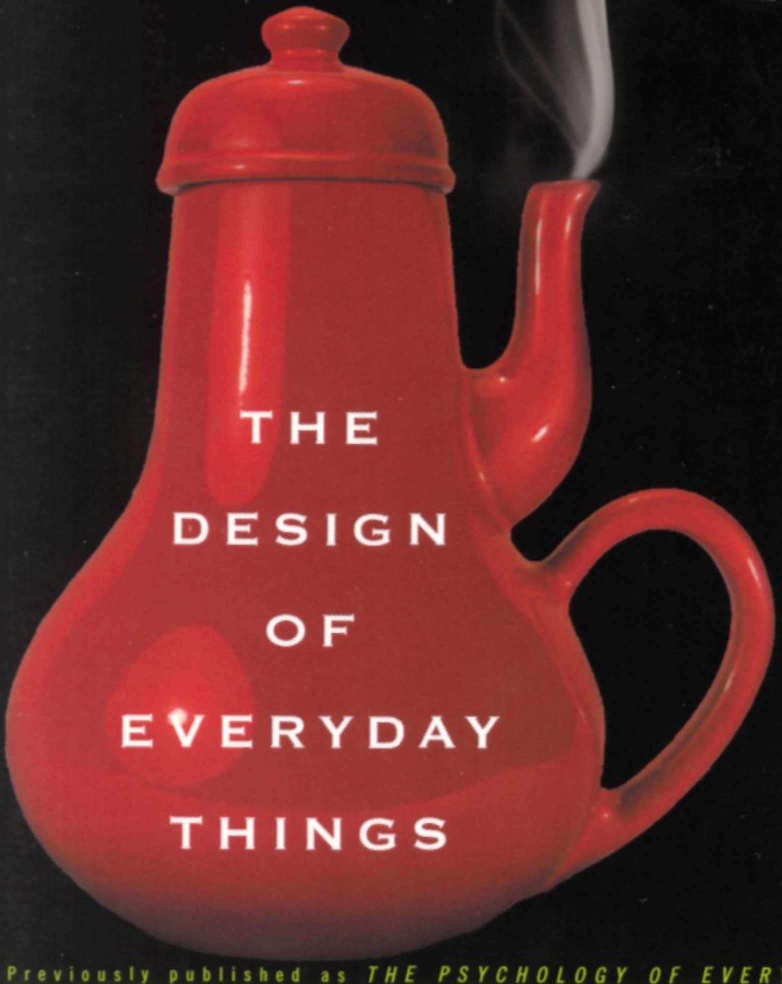


THE DESIGN OF EVERYDAY THINGS

Previously published as *THE PSYCHOLOGY OF EVERYDAY THINGS*

DONALD A. NORMAN

AUTHOR OF EMOTIONAL DESIGN

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.

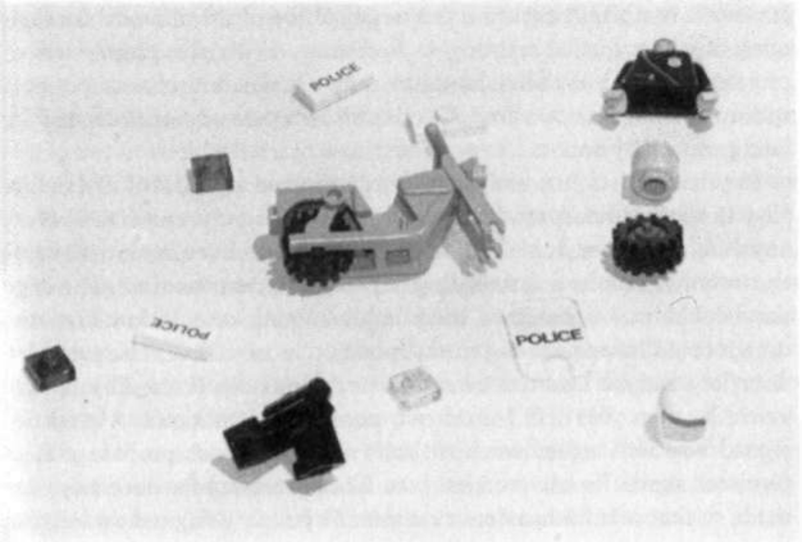
How can design signal the appropriate actions? To answer the question we build upon the principles discussed in chapter 3. One important set of signals comes through the natural constraints of objects, physical constraints that limit what can be done. Another set of signals comes from the affordances 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 CONSTRAINTS

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 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

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.

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 necessary 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 Metro try to get off the train and fail. When the train came to his station, he got up and stood patiently *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 Metro, 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).*

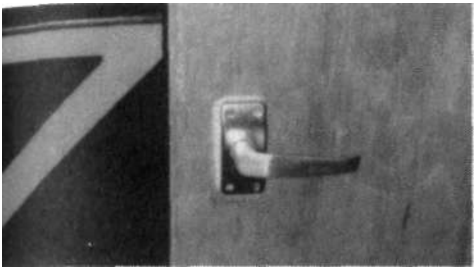
Consider the hardware for an unlocked door. It need not have any moving parts: it can be a fixed knob, plate, handle, or groove. Not only will the proper hardware operate the door smoothly, but it will also indicate just how the door is to be operated: it will exhibit the proper affordances. Suppose 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.

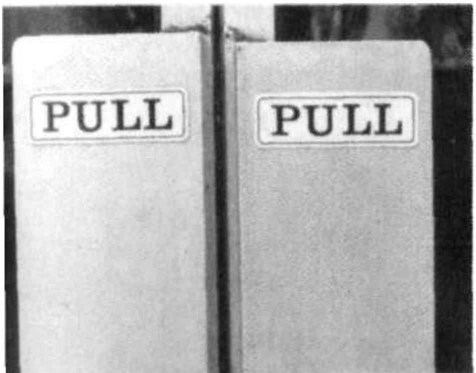
Some hardware cries out to be pulled. Although anything that can be pulled can also be pushed, the proper design will use cultural constraints so that the signal to pull will dominate. But even this can be messed up. I have seen doors with a mixture of signals, one implying push, the other pull. I have 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

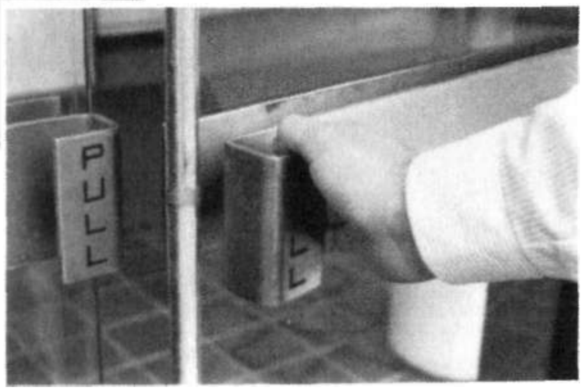
4.2 The Design of Doors. The doors at the left show two excellent examples of design: different handles, side by side on the same automobile, each neatly signaling its proper operation. The vertical placement of the lever on the handle to the left causes the hand to be held in a vertical plane, signifying 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.

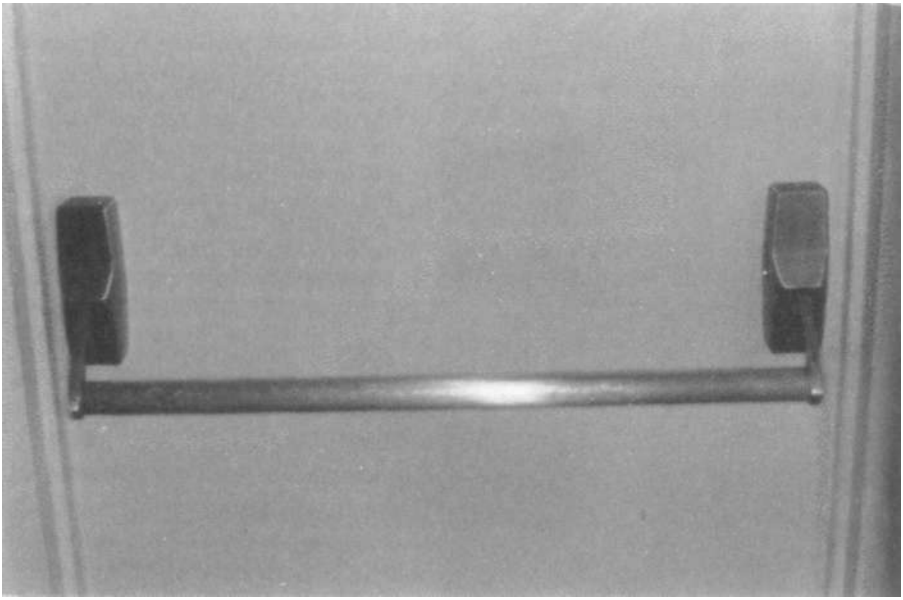


The handle depicted at the left shows inappropriate signals. This form of handle clearly marks grasp, twist, or pull—except that this particular door slides: a classic case of inappropriate design.

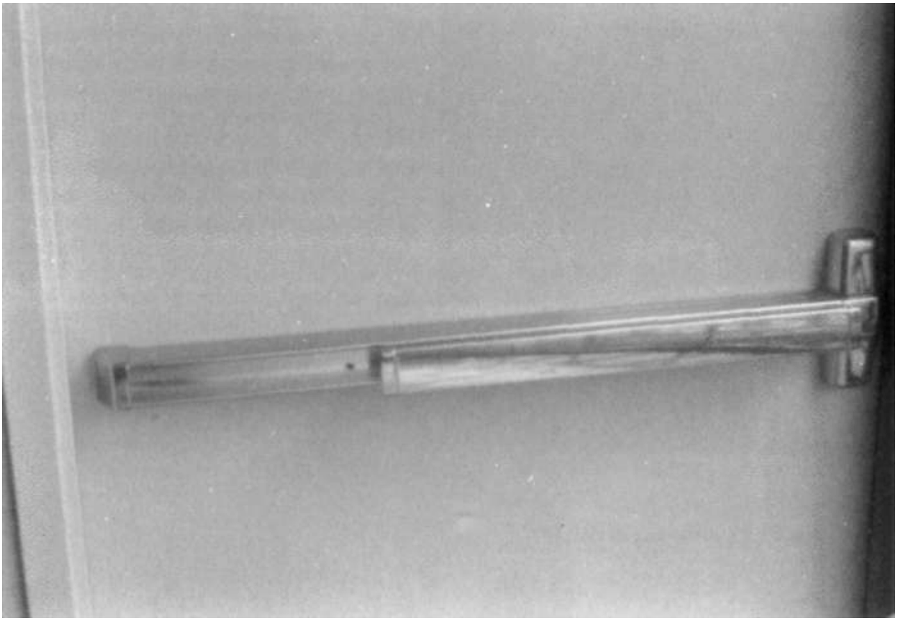


At left and below are photographs of hardware for doors that open by being pulled. The large plates at the left are a signal to push, but in fact the door is supposed to be pulled: no wonder the door needs the signs. The simple U-shaped brackets below is a much better design, but they are ambiguous enough 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 Metro 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.

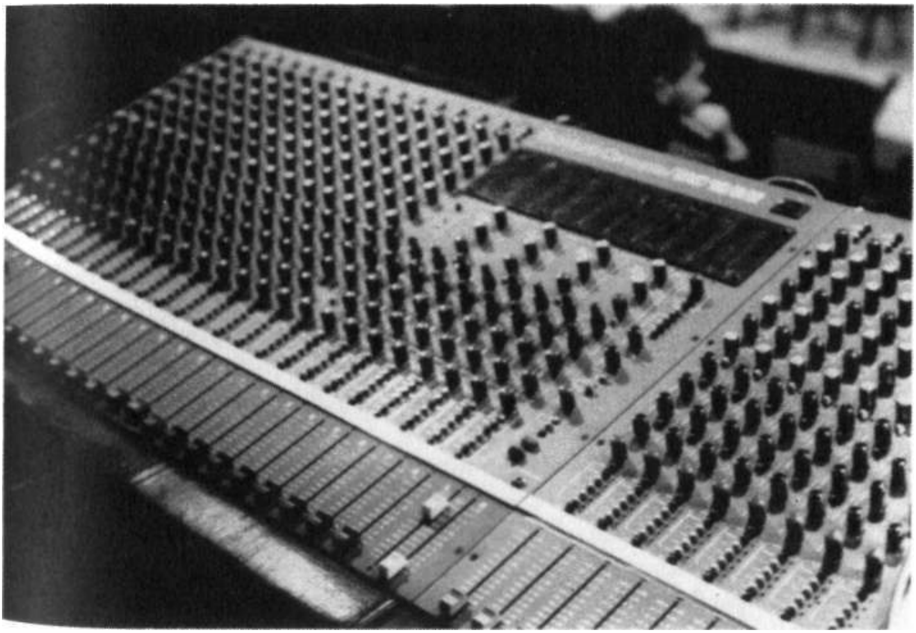
The second is the mapping problem. For example, when there are many lights and an array of switches, how can you determine which switch controls which light?

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.



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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.

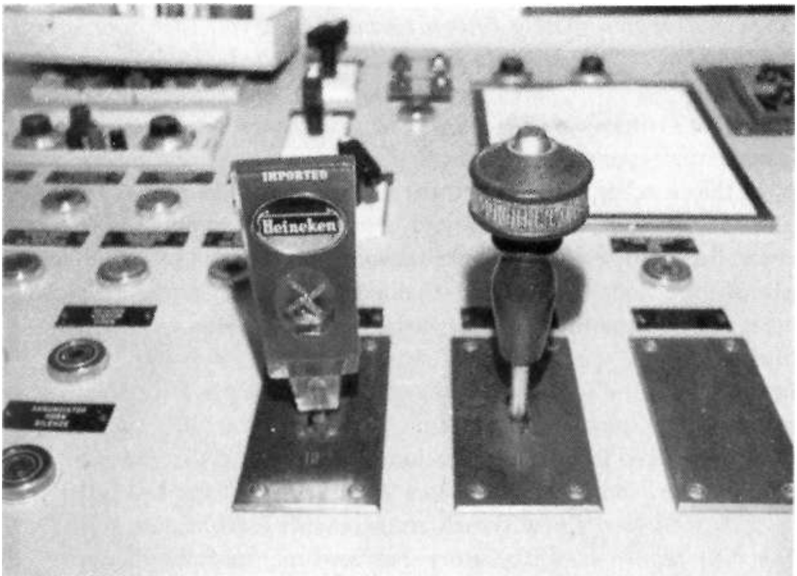
It should go without saying that controls that cause trouble should not be located where they can be operated by accident, especially in the dark, or when the person is trying to use the device without looking. It should go without saying, but in fact, it is necessary to say it.

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.

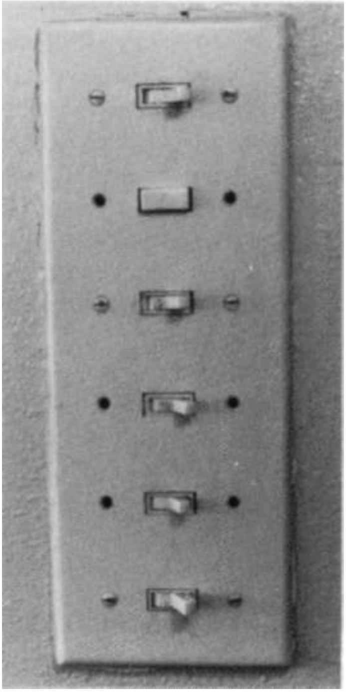
My house was designed by two brash young architects, award winning, who, among other things, liked neat rows of light switches. We got a horizontal row of four identical switches in the front hall, a vertical column of six identical switches in the living room. "You will get used to it," the architects 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.

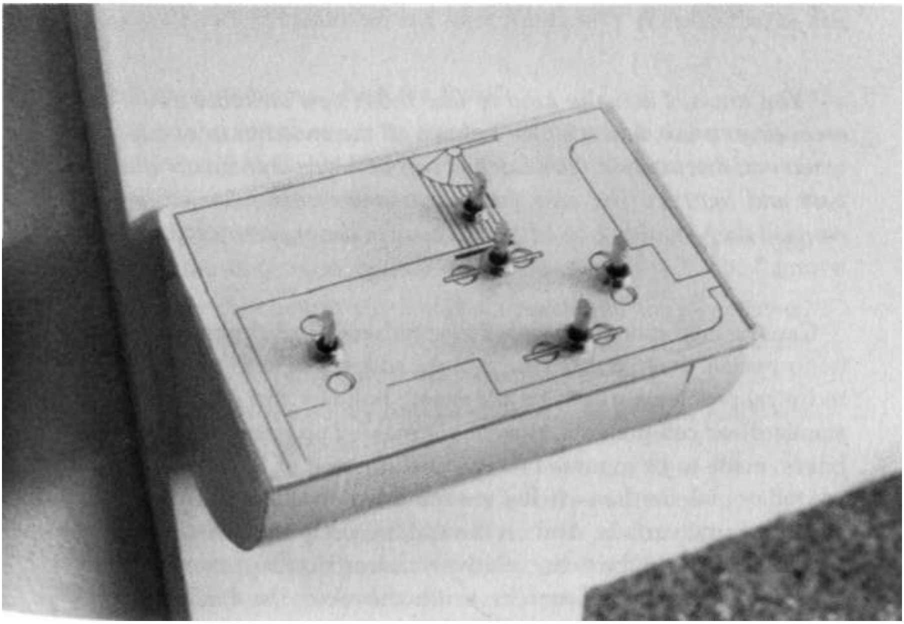
If light switches are placed on the wall, there is no way they can exactly correspond in position to the placement of the lights. Why place the switches flat against the wall? Why not redo things? Why not place the switches horizontally, in exact analogy to the things being controlled, with a two-dimensional 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.

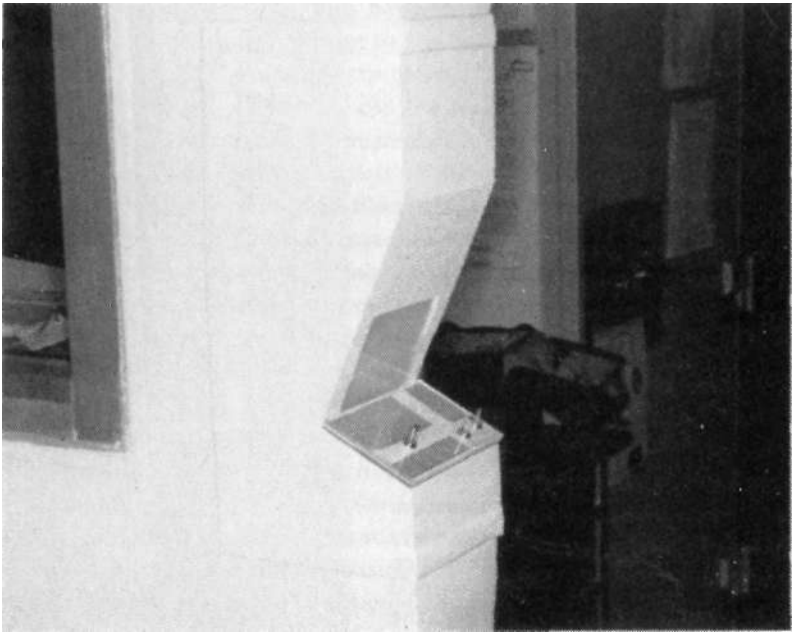
How well do the new switch arrangements work? Quite well, I am happy to report. One laboratory user sent me the following note:

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 communication 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.