Designing with the Mind in Mind

A Simple Guide to Understanding User Interface Design Rules

Jeff Johnson

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Foreword

The design of interactive computer systems is not only an art, but, at least aspirationally, a science. Well, not a science, actually, but rather a kind of joint computer-cognitive engineering, that is, science-based techniques to create interactive systems satisfying specified requirements.

Like cars, buildings, and clothes, interactive computing artifacts can emotionally delight, exhibit style and fashion, and have social significance. There is much room for art and industrial design in making things that pop, flash, and interact. But the resulting artifacts also have to work correctly and to flow with human activity. A beautiful building whose soaring windows roast its inhabitants in the summer or whose trusses buckle in a storm is a failure. Designers need methods to put latitude, season, fenestration, volume, and circulation together to predict heating loads before building the building. They also need a stockpile of technology component solutions, like thermopane glass, blinds, overhangs, and fans to choose among as part of the standard engineering of a solution. Engineering does not replace art in a design, it makes it possible.

Engineering is hard enough for architecture; it is harder still for interactive artifacts, for the simple reason that it is easier to get a science of buildings than one of people. Providing such a supporting science and engineering has been a founding aspiration of the field of human-computer interaction. How to do it? The most basic method is by "usability testing"—watch users doing tasks, discover their difficulties, and fix these through redesign. Usability testing is useful, necessary, and inefficient. The results don't cumulate very well into a discipline anything like engineering, and it isn't very insightful about why things break. It's the cognitive equivalent of roasting the users to find the effect of the large windows. But usability testing can find many of a system's flaws. It is a feasible method, because interactive systems are often much easier to change than rebuilding a building.

Better would be to avoid many of the errors in the first place, and one method is through *design rules*. Instead of rediscovering over and over through usability testing that interfaces depending on red and green are bad for color-blind users, just make it a design rule to use color redundantly with other cues. Design rules, however, turn out to have their own problems. In practice, design rules may be ambiguous or require subtle interpretation of context or contradict other guidelines. And that brings us to the current book.

The idea of the present book is to unite design rules with the supporting cognitive and perceptual science that is at their core. This format has several merits: the psychological science is made concrete and easy to absorb by connecting to actual designs, and the design rules are made easier to adjust for context, since they are related to their deeper rationale.

Jeff Johnson is the perfect author to attempt such a book. His whole career has combined work on both the interface design side and the psychological science side. I first met him when he was on the user interface team of the Xerox Star series of products—the first commercial graphical user interface. So on the design side, he was essentially in at the beginning of GUIs. On the psychology side, he did degrees at Yale and Stanford. Putting design and psychology together, he worked on commercial interactive systems, taught at the university, and worked as a consultant. His trademark is using concrete design examples to illustrate abstract principles. In fact, he is famous for driving his points home memorably by exhibiting "blooper" examples of bad designs—and so he does in this book.

There is a third method of using science to help engineer a system that goes beyond design rules—*design models*. Jeff's book shows examples of how to use this method, too. He shows how to model the task context in terms of object and actions and how to understand real-time interaction constraints.

In sum, this is a book that advances the goal of a supporting engineering method for interactive system design. At the same time, it is a primer to understand the *why* of the larger human action principles at work—a sort of cognitive science for designers in a hurry. Above all, this is a book of profound insight into the human mind for practical people who want to get something done.

—Stuart Card

Introduction

USER-INTERFACE DESIGN RULES: WHERE DO THEY COME FROM AND HOW CAN THEY BE USED EFFECTIVELY?

For as long as people have been designing interactive computer systems, some have attempted to promote *good* design by publishing user-interface design guidelines (also called design rules). Early ones included:

- **Cheriton** (1976) proposed user-interface design guidelines for early interactive (time-shared) computer systems.
- **Norman** (1983a, 1983b) presented design rules for software user interfaces based on human cognition, including cognitive errors.
- **Smith and Mosier** (1986) wrote perhaps the most comprehensive set of user-interface design guidelines.
- **Shneiderman** (1987) included "Eight Golden Rules of Interface Design" in the first edition of his book *Designing the User Interface* and in all later editions.
- **Brown** (1988) wrote a book of design guidelines, appropriately titled *Human-Computer Interface Design Guidelines*.
- **Nielsen and Molich** (1990) offered a set of design rules for use in heuristic evaluation of user interfaces.
- **Marcus** (1991) presented guidelines for graphic design in online documents and user interfaces.

In the twenty-first century, additional user interface design guidelines have been offered by Stone *et al*. (2005), Koyani, Bailey, and Nall (2006), Johnson (2007), and Shneiderman and Plaisant (2009). Microsoft, Apple Computer, and Oracle publish guidelines for designing software for their platforms (Apple Computer, 2009; Microsoft Corporation, 2009; Oracle Corporation/Sun Microsystems, 2001).

How valuable are user-interface design guidelines? That depends on who applies them to design problems.

USER EXPERIENCE DESIGN AND EVALUATION REQUIRES UNDERSTANDING AND EXPERIENCE

Following user-interface design guidelines is not as straightforward as following cooking recipes. Design rules often describe goals rather than actions. They are purposefully very general to make them broadly applicable, but that means that their exact meaning and their applicability to specific design situations is open to interpretation.

Complicating matters further, more than one rule will often seem applicable to a given design situation. In such cases, the applicable design rules often conflict, i.e., they suggest different designs. This requires designers to determine which competing design rule is more applicable to the given situation and should take precedence.

Design problems—even without competing design guidelines—often have multiple conflicting goals. e.g.:

- bright screen *and* long battery life
- lightweight *and* sturdy
- multifunctional *and* easy to learn
- powerful *and* simple
- WYSIWIG (what you see is what you get) *and* usable by blind people

Satisfying all the design goals for a computer-based product or service usually requires tradeoffs—lots and lots of tradeoffs. Finding the right balance point between competing design rules requires further tradeoffs.

Given all of these complications, user-interface design rules and guidelines must be applied thoughtfully, not mindlessly, by people who are skilled in the art of UI design and/or evaluation. User-interface design rules and guidelines are more like *laws* than like *rote recipes*. Just as a set of laws is best applied and interpreted by lawyers and judges who are well versed in the laws, a set of user-interface design guidelines is best applied and interpreted by people who understand the basis for the guidelines and have learned from experience in applying them.

Unfortunately, with a few exceptions (e.g., Norman, 1983a), user-interface design guidelines are provided as simple lists of design edicts with little or no rationale or background.

Furthermore, although many early members of the user-interface design and usability profession had backgrounds in cognitive psychology, most newcomers to the field do not. That makes it difficult for them to apply user-interface design guidelines sensibly.

Providing that rationale and background education is the focus of this book.

COMPARING USER-INTERFACE DESIGN GUIDELINES

Table I.1 places the two best-known user-interface guideline lists side by side to show the types of rules they contain and how they compare to each other (see the Appendix for additional guidelines lists). For example, both lists start with a rule calling for consistency in design. Both lists include a rule about preventing errors. The Nielsen-Molich rule "Help users recognize, diagnose, and recover from errors" corresponds closely to the Shneiderman-Plaisant rule to "Permit easy reversal of actions." "User control and freedom" corresponds to "Make users feel they are in control." There is a reason for this similarity, and it isn't just that later authors were influenced by earlier ones.

Table I.1 The Two Best-Known Lists of User Interface Design Guidelines

Shneiderman (1987); Shneiderman and Plaisant (2009)	Nielsen and Molich (1990)
• Strive for consistency • Cater to universal usability • Offer informative feedback • Design task flows to yield closure • Prevent errors • Permit easy reversal of actions • Make users feel *they* are in control • Minimize short-term memory load	• Consistency and standards • Visibility of system status • Match between system and real world • User control and freedom • Error prevention • Recognition rather than recall • Flexibility and efficiency of use • Aesthetic and minimalist design • Help users recognize, diagnose, and recover from errors • Provide online documentation and help

WHERE DO DESIGN GUIDELINES COME FROM?

For present purposes, the detailed design rules in each set of guidelines, such as those in Table I.1, are less important than what they have in common: their basis and origin. Where did these design rules come from? Were their authors—like clothing fashion designers—simply trying to impose their own personal design tastes on the computer and software industries?

If that were so, the different sets of design rules would be very different from each other as the various authors sought to differentiate themselves from the others. In fact, all of these sets of user-interface design guidelines are quite similar if we ignore differences in wording, emphasis, and the state of computer technology when each set was written. Why?

The answer is that all of the design rules are based on human psychology: how people perceive, learn, reason, remember, and convert intentions into action. Many authors of design guidelines had at least some background in psychology that they applied to computer system design.

For example, Don Norman was a professor, researcher, and prolific author in the field of cognitive psychology long before he began writing about human-computer interaction. Norman's early human-computer design guidelines were based on research—his own and others'—on human cognition. He was especially interested in cognitive errors that people often make and how computer systems can be designed to lessen or eliminate the impact of those errors.

Similarly, other authors of user-interface design guidelines—e.g., Brown, Shneiderman, Nielsen, and Molich—used knowledge of perceptual and cognitive psychology to try to improve the design of usable and useful interactive systems.

Bottom line: user-interface design guidelines are based on human psychology.

By reading this book, you will learn the most important aspects of the psychology underlying user-interface and usability design guidelines.

INTENDED AUDIENCE OF THIS BOOK

This book is intended mainly for software development professionals who have to apply user-interface and interaction design guidelines. This of course includes interaction designers, user-interface designers, and user-experience designers, graphic designers, and hardware product designers. It also includes usability testers and evaluators, who often refer to design heuristics when reviewing software or analyzing observed usage problems.

A second audience for this book is software development managers who want enough of a background in the psychological basis for user-interface design rules to understand and evaluate the work of the people they manage.

CHAPTER

We Perceive What We Expect

1

Our perception of the world around us is not a true depiction of what is actually there. We perceive, to a large extent, what we *expect* to perceive. Our expectations—and therefore our perceptions—are biased by three factors:

- ***the past:*** our experience
- ***the present:*** the current context
- ***the future:*** our goals

PERCEPTION BIASED BY EXPERIENCE

Imagine that you own a large insurance company. You are meeting with a real estate manager, discussing plans for a new campus of company buildings. The campus consists of a row of five buildings, the last two with T-shaped courtyards providing light for the cafeteria and fitness center. If the real estate manager showed you the map shown in Figure 1.1, you would see five black shapes representing the buildings.

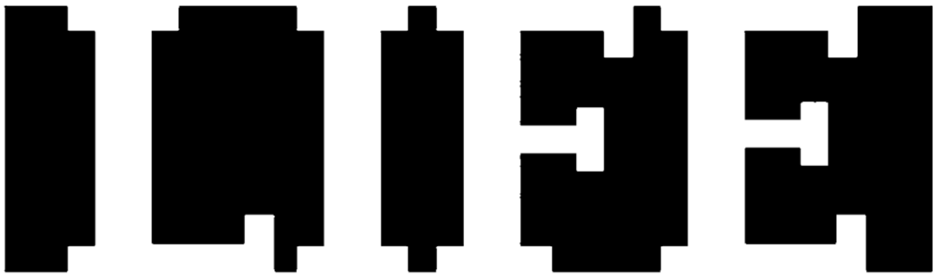

FIGURE 1.1

Building map or word? What you see depends on what you were told to see.

Now imagine that instead of a real estate manager, you are meeting with an advertising manager. You are discussing a new billboard ad to be placed in certain markets around the country. The advertising manager shows you the same image, but in this scenario the image is a sketch of the ad, consisting of a single word. In this scenario, you see a word, clearly and unambiguously.

When your perceptual system has been primed to see building shapes, you see building shapes, and the white areas between the buildings barely register in your perception. When your perceptual system has been primed to see text, you see text, and the black areas between the letters barely register.

A relatively famous example of how priming the mind can affect perception is a sketch, supposedly by R. C. James,[1] that initially looks to most people like a random splattering of ink (see Fig. 1.2). Before reading further, look at the sketch.

FIGURE 1.2

Image showing the effect of mental priming of the visual system. What do you see?

Only after you are told that it is a Dalmatian dog sniffing the ground near a tree can your visual system organize the image into a coherent picture. Moreover, once you've "seen" the dog, it is hard to go back to seeing the image as a random collection of spots.

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[1] Published in Marr D. (1982) *Vision.* W. H. Freeman, New York, NY, p. 101, Figure 3-1.

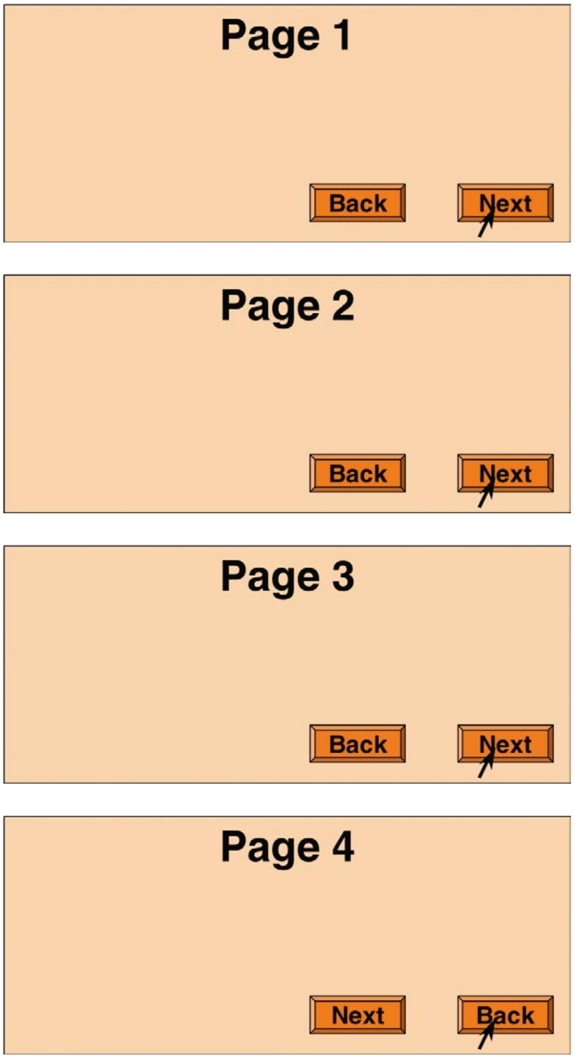

FIGURE 1.3

The "Next" button is perceived to be in a consistent location, even when it isn't.

The examples above are visual. Experience can also bias other types of perception, such as sentence comprehension. For example, the headline "New Vaccine Contains Rabies" would probably be understood differently by people who had recently heard stories about contaminated vaccines than by people who had recently heard stories about successful uses of vaccines to fight diseases.

Users of computer software and Web sites often click buttons or links without looking carefully at them. Their perception of the display is based more on what their past experience leads them to expect than on what is actually on the screen. This sometimes confounds software designers, who expect users to see what is on the screen. But that isn't how perception works.

For example, if the positions of the "Next" and "Back" buttons on the last page of a multipage dialog box[2] switched, many people would not immediately notice the switch (see Fig. 1.3). Their visual system would have been lulled into inattention by the consistent placement of the buttons on the prior several pages. Even after unintentionally going backward a few times, they might continue to perceive the buttons in their standard locations. This is why "place controls consistently" is a common user interface design guideline.

Similarly, if we are trying to find something, but it is in a different place or looks different from usual, we might miss it even though it is in plain view because experience tunes us to look for expected features in expected locations. For example, if the "Submit" button on one form in a Web site is shaped differently or is a different color from those on other forms on the site, users might not find it. This expectation-induced blindness is discussed further later in this chapter, in the section on how our *goals* affect perception.

PERCEPTION BIASED BY CURRENT CONTEXT

When we try to understand how our visual perception works, it is tempting to think of it as a bottom-up process, combining basic features such as edges, lines, angles, curves, and patterns into figures and ultimately into meaningful objects. To take reading as an example, you might assume that our visual system first recognizes shapes as letter and then combines letters into words, words into sentences, and so on.

But visual perception—reading in particular—is not strictly a bottom-up process. It includes top-down influences too. For example, the word in which a character appears may affect how we identify the character (see Fig. 1.4).

Similarly, our overall comprehension of a sentence or of a paragraph can even influence what words we see in it. For example, the same letter sequence can be

FIGURE 1.4

The same character is perceived as H or A depending on the surrounding letters.

[2] Multi step dialog boxes are called "wizards" in user interface jargon.

Fold napkins. *Polish silverware*. Wash dishes.

French napkins. *Polish silverware*. German dishes.

FIGURE 1.5

The same phrase is perceived differently depending on the list it appears in.

read as different words depending on the meaning of the surrounding paragraph (see Fig. 1.5).

This biasing of perception by the surrounding context works *between* different senses too. Perceptions in any of our five senses may affect simultaneous perceptions in any of our other senses. For example:

- What we see can be biased by what we are hearing, and *vice versa*
- What we feel with our tactile sense can be biased by what we are hearing, seeing, or smelling

Later chapters explain how visual perception, reading, and recognition function in the human brain. For now, I will simply say that the pattern of neural activity that corresponds to recognizing a letter, a word, a face, or any object includes input from neural activity stimulated by the context. This context includes other nearby perceived objects and events, and even reactivated memories of previously perceived objects and events.

Context biases perception not only in people but also in lower animals. A friend of mine often brought her dog with her in her car when running errands. One day, as she drove into her driveway, a cat was in the front yard. The dog saw it and began barking. My friend opened the car door and the dog jumped out and ran after the cat, which turned and jumped through a bush to escape. The dog dove into the bush but missed the cat. The dog remained agitated for some time afterward.

Thereafter, for as long as my friend lived in that house, whenever she arrived at home with her dog in the car, he would get excited, bark, jump out of the car as soon as the door was opened, dash across the yard, and leap into the bush. There was no cat, but that didn't matter. Returning home in the car was enough to make the dog see one—perhaps even smell one. However, walking home, as the dog did after being taken for his daily walk, did not evoke the "cat mirage."

PERCEPTION BIASED BY GOALS

In addition to being biased by our *past* experience and the *present* context, our perception is influenced by our goals and plans for the *future*. Specifically, our goals filter our perceptions: things unrelated to our goals tend to be filtered out preconsciously, never registering in our conscious minds.

For example, when people navigate through software or a Web site, seeking information or a specific function, they don't read carefully. They scan screens quickly and superficially for items that seem related to their goal. They don't simply *ignore* items unrelated to their goals; they often don't even *notice* them.

To see this, flip briefly to the next page and look in the toolbox (Fig. 1.6) for *scissors*, and then immediately flip back to this page. Try it now.

Did you spot the scissors? Now, without looking back at the toolbox, can you say whether there is a screwdriver in the toolbox too?

Our goals filter our perceptions in other perceptual senses as well as in vision. A familiar example is the "cocktail party" effect. If you are conversing with someone at a crowded party, you can focus your attention to hear mainly what he or she is saying even though many other people are talking near you. The more interested you are in the conversation, the more strongly your brain filters out surrounding chatter. If you are bored by what your conversational partner is saying, you will probably hear much more of the conversations around you.

The effect was first documented in studies of air-traffic controllers, who were able to carry on a conversation with the pilots of their assigned aircraft even though many different conversations were occurring simultaneously on the same radio frequency, coming out of the same speaker in the control room (Arons, 1992). Research suggests that our ability to focus on one conversation among several simultaneous ones depends not only on our interest level in the conversation but also on objective factors such as the similarity of voices in the cacophony, the amount of general "noise" (e.g., clattering dishes or loud music), and the predictability of what your conversational partner is saying (Arons, 1992).

This filtering of perception by our goals is particularly true for adults, who tend to be more focused on goals than children are. Children are more stimulus driven: their perception is less filtered by their goals. This characterisitic makes them more distractible than adults, but it also makes them less biased as observers.

A parlor game demonstrates this age difference in perceptual filtering. It is similar to the "look in the toolbox" exercise. Most households have a catch-all drawer for kitchen implements or tools. From your living room, send a visitor to the room where the catch-all drawer is, with instructions to fetch you a specific tool, such as measuring spoons or a pipe wrench. When the person returns with the tool, ask whether another specific tool was in the drawer. Most adults will not know what else was in the drawer. Children—if they can complete the task without being distracted by all the cool stuff in the drawer—will often be able to tell you more about what else was there.

Perceptual filtering can also be seen in how people navigate Web sites. Suppose I put you on the home page of New Zealand's University of Canterbury (see Fig. 1.7) and asked you to print out a map of the campus showing the computer science department. You would scan the page and probably quickly click one of the links that share words with the goal that I gave you: *Departments* (top left), *Departments and Colleges* (middle left), or *Campus Maps* (bottom right). If you're a "search" person, you might instead go right to the Search box (middle right), type words related to the goal, and click "Go."

FIGURE 1.6

Toolbox: Are there scissors here?

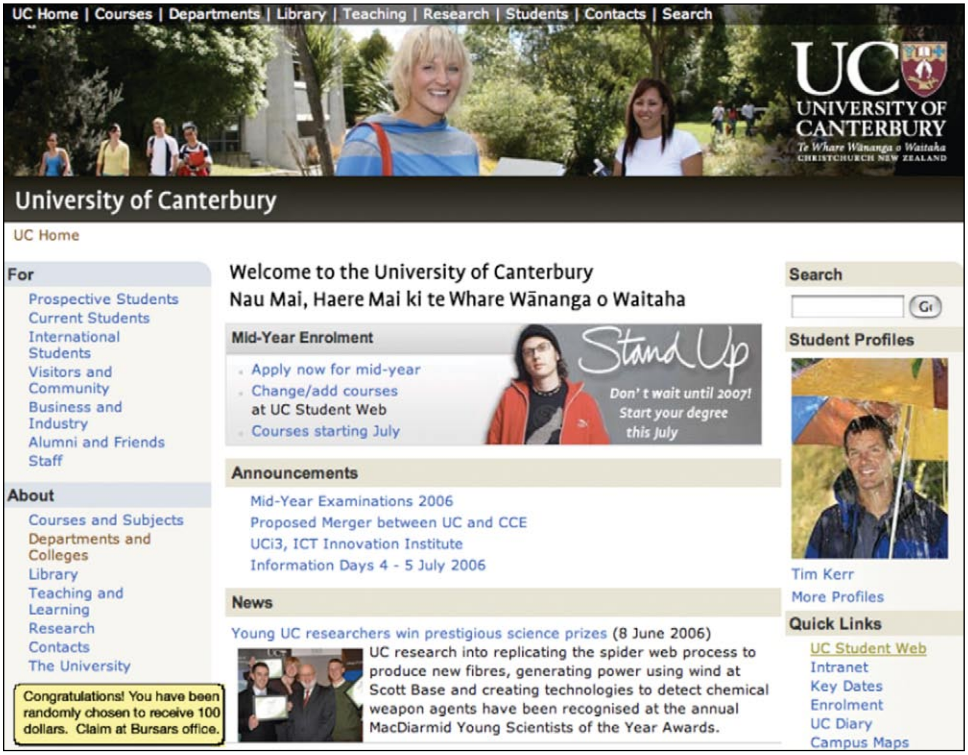

FIGURE 1.7

University of Canterbury home page: Navigating Web sites includes perceptual filtering.

Whether you browse or search, it is likely that you would leave the home page without noticing that you were randomly chosen to win $100 (bottom left). Why? Because that was not related to your *goal*.

What is the mechanism by which our current goals bias our perception? There are two:

- ***Influencing where we look.*** Perception is active, not passive. We constantly move our eyes, ears, hands, and so on, so as to sample exactly the things in our environment that are most relevant to what we are doing or about to do (Ware, 2008). If we are looking on a Web site for a campus map, our eyes and pointer-controlling hand are attracted to anything that might lead us to that goal. We more or less ignore anything unrelated to our goal.
- ***Sensitizing our perceptual system to certain features.*** When we are looking for something, our brain can prime our perception to be especially sensitive to features of what we are looking for (Ware, 2008). For example, when we are looking for a red car in a large parking lot, red cars will seem to pop out as we scan the lot, and cars of other colors will barely register in our consciousness, even though we do in some sense "see" them. Similarly, when we are trying to find our spouse in a dark, crowded room, our brain "programs" our auditory system to be especially sensitive to the combination of frequencies that make up his or her voice.

DESIGN IMPLICATIONS

All these sources of perceptual bias of course have implications for user interface design. Here are three.

Avoid ambiguity

Avoid ambiguous information displays, and test your design to verify that all users interpret the display in the same way. Where ambiguity is unavoidable, either rely on standards or conventions to resolve it, or prime users to resolve the ambiguity in the intended way.

For example, computer displays often shade buttons and text fields to make them look raised in relation to the background surface (see Fig. 1.8). This appearance

FIGURE 1.8

Buttons on computer screens are often shaded to make them look three dimensional, but the convention only works if the simulated light source is assumed to be on the upper left.

relies on a convention, familiar to most experienced computer users, that the light source is at the top left of the screen. If an object were depicted as lit by a light source in a different location, users would not see the object as raised.

Be consistent

Place information and controls in consistent locations. Controls and data displays that serve the same function on different pages should be placed in the same position on each page on which they appear. They should also have the same color, text fonts, shading, and so on. This consistency allows users to spot and recognize them quickly.

Understand the goals

Users come to a system with goals they want to achieve. Designers should understand those goals. Realize that users' goals may vary, and that their goals strongly influence what they perceive. Ensure that at every point in an interaction, the information users need is available, prominent, and maps clearly to a possible user goal, so users will notice and use the information.