Our Peripheral Vision is Poor

The previous chapter explained that the human visual system differs from a digital camera in the way it detects and processes color. Our visual system also differs from a camera in its resolution. On a digital camera’s photo sensor, photoreceptive elements are spread uniformly in a tight matrix, so the spatial resolution is constant across the entire image frame. The human visual system is not like that.

This chapter explains why:

- Stationary items in muted colors presented in the periphery of people’s visual field often will not be noticed.
- Motion in the periphery is usually noticed.

RESOLUTION OF THE FOVEA COMPARED TO THAT OF THE PERIPHERY

The spatial resolution of the human visual field drops greatly from the center to the edges. Each eye has approximately six million retinal cone cells. They are packed much more tightly in the center of our visual field—a small region called the fovea—than they are at the edges of the retina (see Fig. 6.1). The fovea is only about 1% of the retina, but the brain’s visual cortex devotes about 50% of its area to input from the fovea. Furthermore, foveal cone cells connect 1:1 to the ganglial neuron cells that begin the processing and transmission of visual data, while elsewhere on the retina, multiple photoreceptor cells (cones and rods) connect to each ganglion cell. In technical terms, information from the visual periphery is compressed (with data loss) before transmission to the brain, while information from the fovea is not. All of this causes our vision to have much, much greater resolution in the center of our visual field than elsewhere (Lindsay and Norman, 1972; Waloszek, 2005).
CHAPTER 6  Our Peripheral Vision is Poor

To visualize how small the fovea is compared to your entire visual field, hold your arm straight out and look at your thumb. Your thumbnail, viewed at arm’s length, corresponds approximately to the fovea (Ware, 2008). While you have your eyes focused on the thumbnail, everything else in your visual field falls outside of your fovea on your retina.

In the fovea, people with normal vision have very high resolution: they can resolve several thousand dots within that region—better resolution than many of today’s pocket digital cameras. Just outside of the fovea, the resolution is already down to a few dozen dots per inch viewed at arm’s length. At the edges of our vision, the “pixels” of our visual system are as large as a melon (or human head) at arm’s length (see Fig. 6.2A and B).

If our peripheral vision has such low resolution, one might wonder why we don’t see the world in a kind of tunnel vision where everything is out of focus except what we are directly looking at now. Instead, we seem to see our surroundings sharply and clearly all around us. We experience this illusion because our eyes move rapidly and constantly about three times per second even when we don’t realize it, focusing our fovea on selected pieces of our environment. Our brain fills in the rest in a gross, impressionistic way based upon what we know and expect.¹ Our brain does not have to maintain a high-resolution mental model of our environment because it can order the eyes to sample and resample details in the environment as needed (Clark, 1998).

¹Our brains also fill in the perceptual gaps that occur during saccadic eye movements, when vision is suppressed.
Resolution of the fovea compared to that of the periphery

For example, as you read this page, your eyes dart around, scanning and reading. No matter where on the page your eyes are focused, you have the impression of viewing a complete page of text, because, of course, you are. But now, imagine that you are viewing this page on a computer screen, and the computer is tracking your eye movements and knows where your fovea is on the page. Imagine that wherever you look, the right text for that spot on the page is shown clearly in the small area corresponding to your fovea, but everywhere else on the page, the computer shows random, meaningless text. As your fovea flits around the page, the computer quickly updates each area where your fovea stops to show the correct text there, while the last position of your fovea returns to textual noise. Amazingly, experiments have shown that people do not notice this: not only can they read normally, they still believe that they are viewing a full page of meaningful text (Clark, 1998).

Related to this is the fact that the center of our visual field—the fovea and a small area immediately surrounding it—is the only part of our visual field that can read. The rest of our visual field cannot read. What this really means is that the neural networks starting in the fovea, running through the optic nerve to the visual cortex, and then spreading into various parts of our brain, have been trained to read, but the neural networks starting elsewhere in our retinas cannot read. All text that we read comes into our visual system after being scanned by the central area, which means that reading requires a lot of eye movement. Of course, based on what we have already read and our knowledge of the world, our brains can sometimes predict text that the fovea has not yet read (or its meaning), allowing us to skip reading it, but that is different from actually reading.

The fact that retinal cone cells are distributed tightly in and near the fovea, and sparsely in the periphery of the retina affects not only spatial resolution but color
resolution as well. We can discriminate colors better in the center of our visual field than at the edges.

Another interesting fact about our visual field is that it has a gap—a small area in which we see nothing. The gap corresponds to the spot on our retina where the optic nerve and blood vessels exit the back of the eye (see Fig. 6.1, above). There are no retinal rod or cone cells at that spot, so when the image of an object in our visual field happens to fall on that part of the retina, we don’t see it. We usually don’t notice this hole in our vision because our brain fills it in with the surrounding content, like a graphic artist using Photoshop to fill in a blemish on a photograph by copying nearby background pixels.

People sometimes experience the blind spot when they gaze at stars. As you look at one star, a nearby star may disappear briefly into the blind spot until you shift your gaze. You can also observe the gap by trying the exercise in Figure 6.3. Some people have other gaps resulting from imperfections on the retina, retinal damage, or brain strokes that affect the visual cortex, but the optic nerve gap is an imperfection everyone shares.

**FIGURE 6.3**
To “see” the retinal gap, cover your left eye, hold this book near your face, and focus your right eye on the +. Move the book slowly away from you, staying focused on the +. The @ will disappear at some point.

**IS THE VISUAL PERIPHERY GOOD FOR ANYTHING?**

It seems that the fovea is better than the periphery at just about everything. One might wonder why we even have peripheral vision. What is it good for?

The answer is that our peripheral vision exists mainly to provide low-resolution cues to guide our eye movements so that our fovea visits all the interesting and crucial parts of our visual field. Our eyes don’t scan our environment randomly. They move so as to focus our fovea on important things, the most important ones (usually) first. The fuzzy cues on the outskirts of our visual field provide the data that helps our brain plan where to move our eyes, in what order.

For example, when we scan a medicine label for a “use by” date, a fuzzy blob in the periphery with the vague form of a date is enough to cause an eye movement that lands the fovea there to allow us to check it. If we are browsing a produce market looking for strawberries, a blurry reddish patch at the edge of our visual field draws our eyes and our attention, even though sometimes it may turn out to be radishes instead of strawberries. If we hear an animal growl nearby, a fuzzy animal-like shape in the corner of our eye will be enough to zip our eyes in that direction, especially if the shape is moving toward us (see Fig. 6.4).
That brings us to another advantage of peripheral vision: it is good at detecting motion. Anything that moves in our visual periphery, even slightly, is likely to draw our attention—and hence our fovea—toward it. The reason for this phenomenon is that our ancestors—including pre-human ones—were selected for their ability to spot food and avoid predators. As a result, even though we can move our eyes under conscious, intentional control, some of the mechanisms that control where they look are preconscious, involuntary, and very fast.

What if we have no reason to expect that there might be anything interesting in a certain spot in the periphery, and nothing in that spot attracts our attention? Our eyes may never move our fovea to that spot, so we may never see what is there.

EXAMPLES FROM COMPUTER USER INTERFACES

The low acuity of our peripheral vision explains why software and Web site users fail to notice error messages in some applications and Web sites. When someone clicks a button or a link, that is usually where his or her fovea is positioned. Everything on the screen that is not within 1–2 centimeters of the click location (assuming normal computer viewing distance) is in peripheral vision, where resolution is low. If, after the click, an error message appears in the periphery, it should not be surprising that the person might not notice it.

See Chapter 1 on how expectations bias our perceptions.
For example, at InformaWorld.com, the online publications Web site of Informa Healthcare, if a user enters an incorrect username or password and clicks “Sign In”, an error message appears in a “message bar” far away from where the user’s eyes are most likely focused (see Fig. 6.5). The red word “Error” might appear in the user’s peripheral vision as a small reddish blob, which would help draw the eyes in that direction. However, the red blob could fall into a gap in the viewer’s visual field, and so not be noticed at all.

Consider the sequence of events from a user’s point of view. The user enters a username and password and then clicks “Sign In”. The page redisplays with blank fields. The user thinks “Huh? I gave it my login information and hit Sign In, didn’t I? Did I hit the wrong button?” The user reenters the username and password, and clicks “Sign In” again. The page redisplays with empty fields again. Now the user is really confused. The user sighs (or curses), sits back in his chair and lets his eyes scan the screen. Suddenly noticing the error message, the user says “Aha! Has that error message been there all along?”

Even when an error message is placed nearer to center of the viewer’s visual field than in the above example, other factors can diminish its visibility. For example, until recently the Web site of Airborne.com signaled a login failure by displaying an error message in red just above the Login ID field (see Fig. 6.6). This error message is entirely in red and fairly near the “Login” button where the user’s eyes are probably focused. Nonetheless, some users would not notice this error message.

**FIGURE 6.5**
This error message for faulty sign-in appears in peripheral vision, where it will probably be missed.
Examples from computer user interfaces

When it first appeared. Why? Can you think of any reasons why people might not initially see this error message?

One reason is that even though the error message is much closer to where users will be looking when they click the “Login” button, it is still in the periphery, not in the fovea. The fovea is small: just a centimeter or two on a computer screen, assuming the user is the usual distance from the screen.

A second reason is that the error message is not the only thing near the top of the page that is red. The page title is also red. Resolution in the periphery is low, so when the error message appears, the user’s visual system may not register any change: there was something red up there before, and there still is (see Fig. 6.7).

**Figure 6.6**
This error message for faulty login is missed by some users even though it is not far from “Login” button.

**Figure 6.7**
A simulation of a user’s visual field while the fovea is fixed on the “Login” button.
If the page title were black or any other color besides red, the red error message would be more likely to be noticed, even though it appears in the periphery of the users’ visual field.

COMMON METHODS OF MAKING MESSAGES VISIBLE

There are several common and well-known methods of ensuring that an error message will be seen:

- **Put it where users are looking:** People focus in predictable places when interacting with graphical user interfaces (GUIs). In Western societies, people tend to traverse forms and control panels from upper left to lower right. While moving the screen pointer, people usually look either at where it is or where they are moving it to. When people click a button or link, they can usually be assumed to be looking directly at it, at least for a few moments afterward. Designers can use this predictability to position error messages near where they expect users to be looking.

- **Mark the error:** Somehow mark the error prominently to indicate clearly that something is wrong. Often this can be done by simply placing the error message near what it refers to, unless that would place the message too far from where users are likely to be looking.

- **Use an error symbol:** Make errors or error messages more visible by marking them with an error symbol, such as 

- **Reserve red for errors:** By convention, in interactive computer systems the color red connotes alert, danger, problem, error, etc. Using red for any other information on a computer display invites misinterpretation. But suppose you are designing a Web site for Stanford University, which has red as its school color. Or suppose you are designing for a Chinese market, where red is considered an auspicious, positive color. What do you do? Use another color for errors, mark them with error symbols, or use stronger methods (see below).

An improved version of the InformaWorld sign-in error screen uses several of these techniques (see Fig. 6.8).

At America Online’s Web site, the form for registering for a new email account follows the guidelines pretty well (see Fig. 6.9). Data fields with errors are marked with red error symbols. Error messages are displayed in red and are near the error. Furthermore, most of the error messages appear as soon as an erroneous entry is made, when the user is still focused on that part of the form, rather than only after the user submits the form. It is unlikely that AOL users will miss seeing these error messages.
Common methods of making messages visible

**FIGURE 6.8**
This error message for faulty sign-in is displayed more prominently, near where users will be looking.

**FIGURE 6.9**
New member registration at AOL.com displays error messages prominently, near each error.
HEAVY ARTILLERY FOR MAKING USERS NOTICE MESSAGES: USE SPARINGLY

If the common, conventional methods of making users notice messages are not enough, three stronger methods are available to user interface designers. However, these methods, while very effective, have significant negative effects so they should be used sparingly and with great care.

Pop-up message in error dialog box

Displaying an error message in a dialog box sticks it right in the user’s face, making it hard to miss. Error dialog boxes interrupt the user’s work and demand immediate attention. That is good if the error message signals a critical condition, but it can annoy people if such an approach is used for a minor message, such as confirming the execution of a user-requested action.

The annoyance of pop-up messages rises with the degree of modality. Nonmodal pop-ups allow users to ignore them and continue working. Application-modal pop-ups block any further work in the application that displayed the error, but allow users to interact with other software on their computer. System-modal pop-ups block any user action until the dialog has been dismissed.

Application-modal error pop-ups should be used sparingly, e.g., only when application data may be lost if the user doesn’t attend to the error. System-modal pop-ups should be used extremely rarely—basically only when the system is about to crash and take hours of work with it or if people will die if the user misses the error message.

On the Web, an additional reason to avoid pop-up error dialog boxes is that some people set their browsers to block all pop-up windows. If your Web site relies on pop-up error messages, some users may never see them.

Use sound (e.g., beep)

When a computer beeps, that tells its user something has happened that requires attention. The person’s eyes reflexively begin scanning the screen for whatever caused the beep. This can allow the user to notice an error message that is someplace other than where the user was just looking, such as in a standard error message box on the display. That is the value of beeping.

However, imagine many people in a cubicle work environment or a classroom, all using an application that signals all errors and warnings by beeping. Such a workplace would be very annoying, to say the least. Worse, people wouldn’t be able to tell whether their own computer or someone else’s was beeping.

In noisy work environments, e.g., factories or computer server rooms, beeps might be masked by ambient noise.

Finally, sound is muted or turned way down on some people’s computers. Therefore, signaling errors and other conditions with sound are remedies that can be used only in very special, controlled situations.
Flash or wiggle briefly

As described earlier, our peripheral vision is good at detecting motion, and motion in the periphery causes reflexive eye movements that bring the motion into the fovea. User interface designers can make use of this by wiggling or flashing messages briefly when they want to ensure that users see them. It doesn’t take much motion to trigger eye movement toward the motion. Just a tiny bit of motion is enough to make a viewer’s eyes zip over in that direction. Millions of years of evolution have had quite an effect.

However, motion, like pop-up dialog boxes and beeping, must be used sparingly. Most experienced computer users consider wiggling, blinking objects on screen to be annoying. Most of us have learned to ignore displays that blink because many such displays are advertisements. Conversely, a few computer users have attentional impairments that make it difficult for them to ignore something that is blinking or wiggling.

Therefore, if motion or blinking is used, it should be brief: it should last about a quarter- to a half-second—no longer. Otherwise, it quickly goes from an unconscious attention-grabber to a conscious annoyance.

Use them sparingly

Use all of these “heavy artillery” methods sparingly—only for critical messages. When pop-ups, sound, motion, and blinking are used frequently to attract users’ attention, a psychological phenomenon called habituation sets in. Our brain pays less and less attention to any stimulus that occurs frequently. It is like the old fable about the boy who cried “Wolf” too often: eventually, the villagers learned to ignore
his cries, so when a wolf actually did come, his cries went unheeded. Overuse of strong attention-getting methods can cause important messages to be blocked by habituation.

REI.com has an example of a pop-up dialog being used to display an error message. The message is displayed when someone who is registering as a new customer omits required fields in the form (see Fig. 6.10). Is this an appropriate use of a pop-up dialog? AOL.com (see Fig. 6.9 above) shows that missing-data errors can be signaled quite well without pop-up dialogs, so REI.com’s use of them seems a bit heavy-handed.

Examples of more appropriate use of error dialog boxes come from Microsoft Excel (see Fig. 6.11A) and Adobe InDesign (see Fig. 6.11B). In both cases, loss of data is at stake.

Computer games use sound a lot to signal events and conditions. In games, sound isn’t annoying; it is expected. Its use in games is widespread, even in game arcades, where dozens of machines are all banging, roaring, buzzing, clanging, beeping, and playing music at once. (Well, it is annoying to parents who have to go into the arcades and endure all the screeching and booming to retrieve their kids, but the games aren’t designed for parents.)

The most common use of blinking in computer user interfaces (other than advertisements) is in menu bar menus. When an action—e.g., Edit > Copy—is selected from a menu, it usually blinks once before the menu closes to confirm that the system “got” the command, i.e., that the user didn’t miss the menu item. This use of blinking is very common. It is so quick that most computer users aren’t even aware of it, but if menu items didn’t blink once, we would have less confidence that we actually selected them.

FIGURE 6.11
Appropriate pop-up error dialogs: (A) Microsoft Excel, (B) Adobe InDesign.
As an example of using motion to attract users’ eye attention, imagine that the error message on the improved InformaWorld sign-in error screen (Fig. 6.8, above) appeared, wiggled one pixel up, down, left, and right within 0.25 second (see Fig. 6.12), and then stopped to become a simple static image. Without being annoying, that would attract the users’ eyeballs, guaranteed. Because, after all, the motion in the corner of your eye might be a leopard.