7

Applying the Redundancy Principle

EXPLAIN VISUALS WITH WORDS IN AUDIO OR TEXT: NOT BOTH

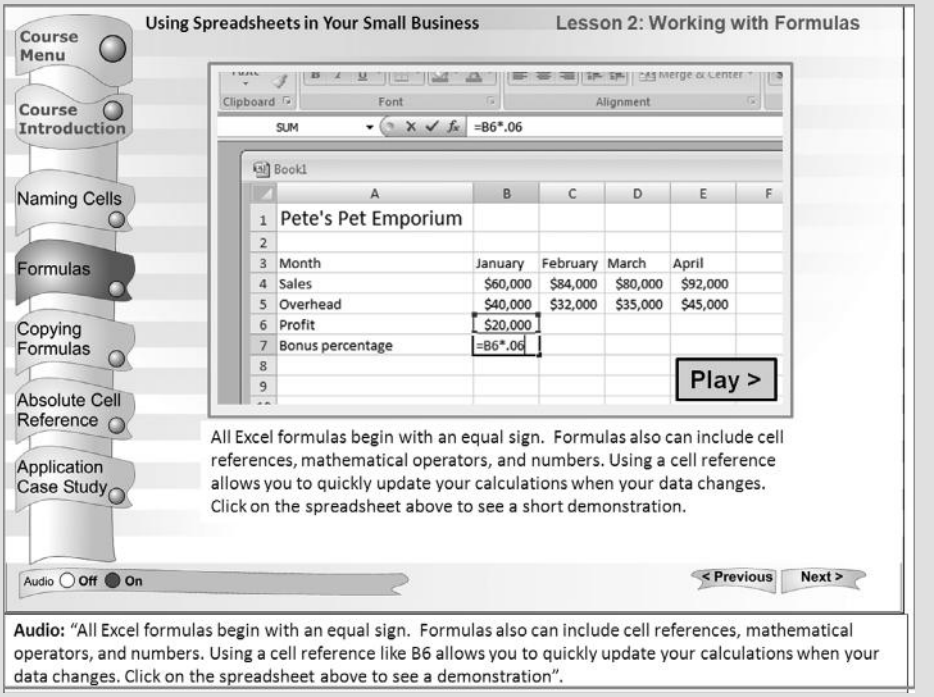
WHAT'S NEW IN THIS CHAPTER

SOME e-LEARNING DESCRIBES graphics using words in both on-screen text and audio narration in which the audio repeats the text. We call this technique *redundant* on-screen text because the printed text (the on-screen text) is redundant with the spoken text (the narration or audio). In this chapter, we summarize empirical evidence that people learn better from concurrent graphics and audio than from concurrent graphics, audio, and on-screen text. In this chapter we update research and theory that has appeared since the previous edition of this book, but the overall message remains the same: In general, do not add printed text to a narrated graphic. The psychological advantage of presenting words in audio alone is that you avoid overloading the visual channel of working memory. There are also certain situations that benefit from the use of redundant on-screen text, which we call *boundary conditions*. We describe those here as well, including new boundary conditions discovered since the previous edition.

DESIGN DILEMMA: YOU DECIDE

Now that the Excel e-learning design team has decided to add relevant visuals, as described in Chapter 4, their focus is on how best to explain those visuals. Reshmi, the instructional designer, recommends explaining visuals with a combination of text and audio: "I've reviewed the latest storyboards and I'm concerned. We know some people have visual learning styles and some are auditory learners so we need to accommodate both. Also 508 compliance requires us to accommodate learners who have visual and hearing deficits. So we have to provide words in a visual format with on-screen text and also in an auditory format with narration of that text. That way we cover all our bases!" Figure 7.1 shows one of Reshmi's revised storyboards.

Figure 7.1. Visual Described by On-Screen Text and Narration.



Audio: "All Excel formulas begin with an equal sign. Formulas also can include cell references, mathematical operators, and numbers. Using a cell reference like B6 allows you to quickly update your calculations when your data changes. Click on the spreadsheet above to see a demonstration".

Charlene, the graphic artist who has been contracted to help with visuals, protests: "We've discussed this issue before and we decided to go with audio narration to describe the visuals. I've designed large visuals and there is no screen real estate

reserved for lengthy text passages!" Based on your experience or intuition which options are best:

A. Communicate words in both on-screen text and audio narration to accommodate different learning styles and to meet 508 compliance.

B. Explain visuals with audio alone to promote best learning per the modality principle described in Chapter 6.

C. Let the learner select either audio or text as part of the course introduction.

D. Not sure which options are correct.

Redundancy Principle 1: Do Not Add On-Screen Text to Narrated Graphics

If you are planning a multimedia program consisting of graphics (such as animation, video, or even static pictures or photos) explained by narration, should you also include on-screen text that duplicates the audio? We explore this question in this section.

Based on research and theory in cognitive psychology, we recommend that you avoid e-learning courses that contain redundant on-screen text presented at the same time as on-screen graphics and narration. Our reason is that learners might pay so much attention to the printed words that they pay less attention to the accompanying graphics. When their eyes are on the printed words, learners cannot be looking at the on-screen graphics. In addition, learners may try to compare and reconcile on-screen text and the narration, which requires cognitive processing extraneous to learning the content. For example, Figure 7.2 shows a screen from a lesson on ammunition safety that uses video to illustrate an explosion. Note that the on-screen text is the same as the narration, so we call it *redundant* on-screen text. In contrast, Figure 7.3 shows a screen from an animated demonstration of how to use a new computerized telephone system. The procedural steps are narrated with audio. Note the absence of on-screen text that duplicates the narration.

Figure 7.2. Graphics Explained Using Identical Text and Audio Narration.

Audio: "This energy is used to do several possible things such as propel something such as a bullet or an artillery projectile or burst open an ammunition item containing a chemical filler."

Figure 7.3. Graphics Explained Using Audio Alone.

Audio: While Bill is talking to Don, Julie calls with a question. Bill knows that Julie needs to talk to Sally in the Art Department and decides to transfer her while he is talking to Don.

Psychological Reasons for the Redundancy Principle

There is a common belief that some people have visual learning styles, while others have auditory learning styles. Therefore, it seems that words should always be presented in both spoken and printed form so learners can choose the presentation format that best matches their learning preferences. We call this idea the *learning styles hypothesis* because it plays on the common sense argument that instruction should be flexible enough to support different learning styles. Accommodating different learning styles may seem appealing to e-learning designers who are fed up with the "one-size-fits-all" approach and to clients who intuitively believe there are visual and auditory learners.

The learning styles hypothesis is based on the information acquisition theory of multimedia learning, which holds that learning consists of receiving information. In our Design Dilemma section, the multimedia lesson illustrated in Figure 7.1 provides three delivery routes for information—by pictures (in the illustrations), by spoken words (in the narration), and by written words (in the on-screen text). In contrast, you could drop the third route and describe graphics with words in audio—but not with words both in audio and on-screen text. According to the information acquisition theory, three ways of delivering the same information is better than two, especially if one or two of the routes do not work well for some learners. Therefore, the information acquisition theory predicts that students will learn more deeply from multimedia presentations when redundant on-screen text is included rather than excluded.

The learning styles view—and the information acquisition theory upon which it is built—seems to make sense, but let's look a little deeper. What's wrong with the information acquisition theory? Our major criticism is that it makes unwarranted assumptions about how people learn. For example, it assumes that people learn by adding information to memory, as if the mind were an empty vessel that needs to be filled with incoming information.

Another major problem with the learning styles view is that it is not supported by the available research evidence. In a recent review of the scientific research evidence on adapting instruction to learning styles, Pashler, McDaniel, Rohrer, and Bjork (2008) were unable to find evidence that visualizers learn better with visual forms of instruction and verbalizers learn better with verbal modes of instruction. The lack of empirical support for the learning styles view

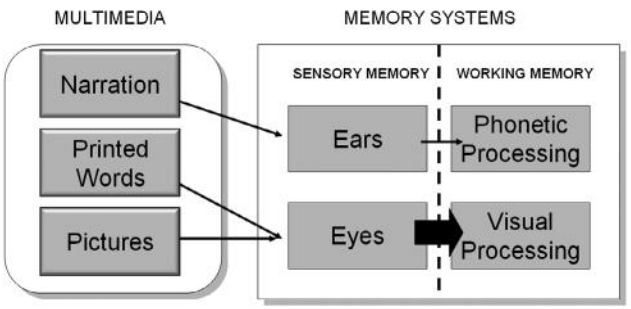
led them to conclude: "The contrast between the enormous popularity of the learning-styles approach within education and the lack of credible evidence for its utility is, in our opinion, striking and disturbing" (p. 117).

In contrast to the information acquisition view, the cognitive theory of multimedia learning is based on the assumptions that (1) all people have separate channels for processing verbal and pictorial material, (2) each channel is limited in the amount of processing that can take place at one time, and (3) learners actively attempt to build pictorial and verbal models from the presented material and build connections between them. These assumptions are consistent with theory and research in cognitive science and represent a consensus view of how people learn.

According to the cognitive theory of multimedia, adding redundant on-screen text to a multimedia presentation could overload the visual channel. For example, Figure 7.4 summarizes the cognitive activities that occur for a presentation containing animation, narration, and concurrent on-screen text. As you can see, the animation enters the learner's cognitive system through the eyes and is processed in the visual/pictorial channel, whereas the narration enters the learner's cognitive system through the ears and is processed in the auditory/verbal channel. However, the on-screen text also enters through the eyes and must be processed (at least initially) in the visual/pictorial channel. Thus, the limited cognitive resources in the visual channel must be shared in processing both the animation and the printed text. If the pace of presentation is fast and learners are unfamiliar with the material, learners may experience cognitive overload in

Figure 7.4. Overloading of Visual Channel with Graphics Explained by Words in Audio and Written Text.

Adapted from Mayer, 2001a.



the visual/pictorial channel. As a result, some important aspects of the animation may not be selected and organized into a mental representation.

Now, consider what happens when only narration and animation are presented. The animation enters through the eyes and is processed in the visual/pictorial channel, whereas the narration enters through the ears and is processed in the auditory/verbal channel. The chances for overload are minimized, so the learner is more able to engage in appropriate cognitive processing. Thus, the cognitive theory of multimedia learning predicts that learners will learn more deeply from multimedia presentations in which redundant on-screen text is excluded rather than included.

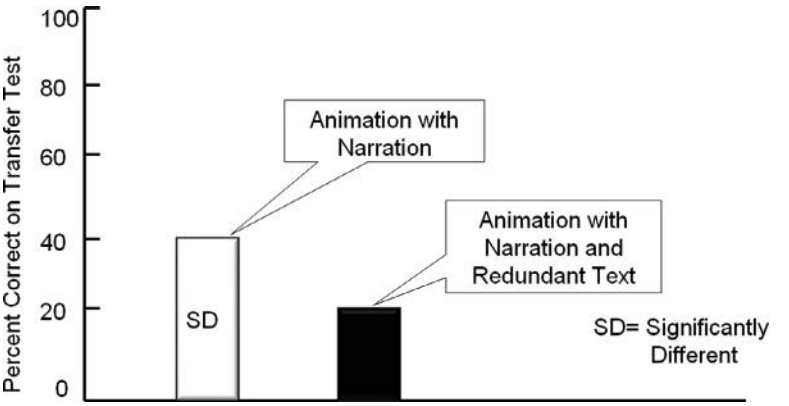
Mayer and Moreno (2003) and Mayer (2005b) describe another potential problem with adding redundant on-screen text. Learners may waste precious cognitive resources in trying to compare the printed words with the spoken words as they are presented. We refer to this wasted cognitive processing as *extraneous cognitive processing*. According to the cognitive theory of multimedia learning, learners have limited cognitive capacity, so if they use their cognitive capacity to reconcile printed and spoken text, they can't use it to make sense of the presentation.

Evidence for Omitting Redundant On-Screen Text

Several researchers have put these two competing predictions to a test. In a set of studies (Craig, Gholson, & Driscoll, 2002; Mayer, Heiser, & Lonn, 2001; Moreno & Mayer, 2002a), some students (non-redundant group) viewed an animation and listened to a concurrent narration explaining the formation of lightning. Other students (redundant group) received the same multimedia presentation, but with concurrent, redundant on-screen text. In this series of four comparisons, students in the non-redundant group produced more solutions (ranging between 43 to 69 percent more) on a problem-solving transfer test than did students in the redundant group. The median effect size was greater than 1, which is considered to be large. Figure 7.5 shows the results from one of these studies.

Kalyuga, Chandler, and Sweller (1999, 2000) provide complementary evidence. One group (non-redundant) received training in soldering (that is, techniques for joining metals) through the use of static diagrams presented on

Figure 7.5. Better Learning When Visuals Are Explained by Audio Alone.
From Moreno and Mayer, 1999a.



a computer screen along with accompanying speech, whereas another group (redundant group) received the same training along with on-screen printed text duplicating the same words as the audio. On a problem-solving transfer test involving troubleshooting, the non-redundant group outperformed the redundant group—producing an effect size of .8 in one study and greater than 1 in another. Kalyuga, Chandler, and Sweller (2004) found similar results in three additional experiments involving technical trainees learning how to set controls on power machinery for cutting. In this case, simply presenting the text after presenting the narration resulted in better test performance than presenting them at the same time, yielding a median effect size of .8.

More recently, Jamet and Le Bohec (2007) presented an eleven-minute online slide presentation on human memory that consisted of illustrations with auditory explanation (non-redundant group) or the same lesson with onscreen text that was presented either sentence-by-sentence sequentially along with the narration (sequential redundant text group) or all at once on each slide (full text redundant group). The lesson was fast-paced and under system control. On a subsequent transfer test, the non-redundant group performed much better than the redundant groups, with effect sizes in the medium to large range (.72 for sequential text and .63 for full text).

Finally, Moreno and Mayer (2002b) also found a redundancy effect within the context of an educational computer game both when played on a desktop

computer and within a virtual reality version using a head-mounted display. An on-screen agent explained the mechanics of plant growth using speech or speech and on-screen text while an animation was presented. Although students who received animation and narration performed better on subsequent tests than did students who learned with animation, narration, and on-screen text, the effect sizes were much smaller—approximately .2, which is considered a small effect. Perhaps students were better able to ignore some of the on-screen text in the game environment, although it was still a mild detriment to learning.

Mayer (2005b) refers to this result as a *redundancy effect* to reflect the idea that adding redundant on-screen text to narrated graphics tends to hurt learning. Overall, these kinds of results support the conclusion that, in some cases, less is more. Because of the limited capacity of the human information processing system, it can be better to present less material (graphics with corresponding narration) than more material (graphics with corresponding narration and printed text). Some important boundary conditions for obtaining the redundancy effect are that the multimedia lesson is fast-paced, the words are familiar, and a lot of words are presented on the screen. In other words, the negative effects of redundancy will be most evident when the multimedia program is system-controlled, includes words familiar to the target audience, and incorporates a lot of on-screen text, as shown in Figure 7.1.

Redundancy Principle 2: Consider Adding On-Screen Text to Narration in Special Situations

Are there any situations in which e-learning courses would be improved by adding redundant on-screen text? Although we recommend omitting redundant on-screen text in most e-learning programs, consider using it in special situations that will not overload the learner's visual information processing system, such as when:

- There is no pictorial presentation (for example, when the screen contains no animation, video, photos, graphics, illustrations, and so on),
- There is ample opportunity to process the pictorial presentation (for example, when the on-screen text and corresponding graphics

are presented sequentially or when the pace of presentation is sufficiently slow), or

- The learner must exert much greater cognitive effort to comprehend spoken text than printed text (for example, for learners who are not native speakers or who have specific learning disabilities, or when the verbal material is long and complex or contains unfamiliar key words).
- Only a few selected key words are presented next to the element in the graphic they describe.

REDUNDANT ON-SCREEN TEXT: WHEN TO LOSE IT AND WHEN TO USE IT

Avoid narrating on-screen text when:

Words and pictures are presented simultaneously at a fast pace

Consider narrating on-screen text when:

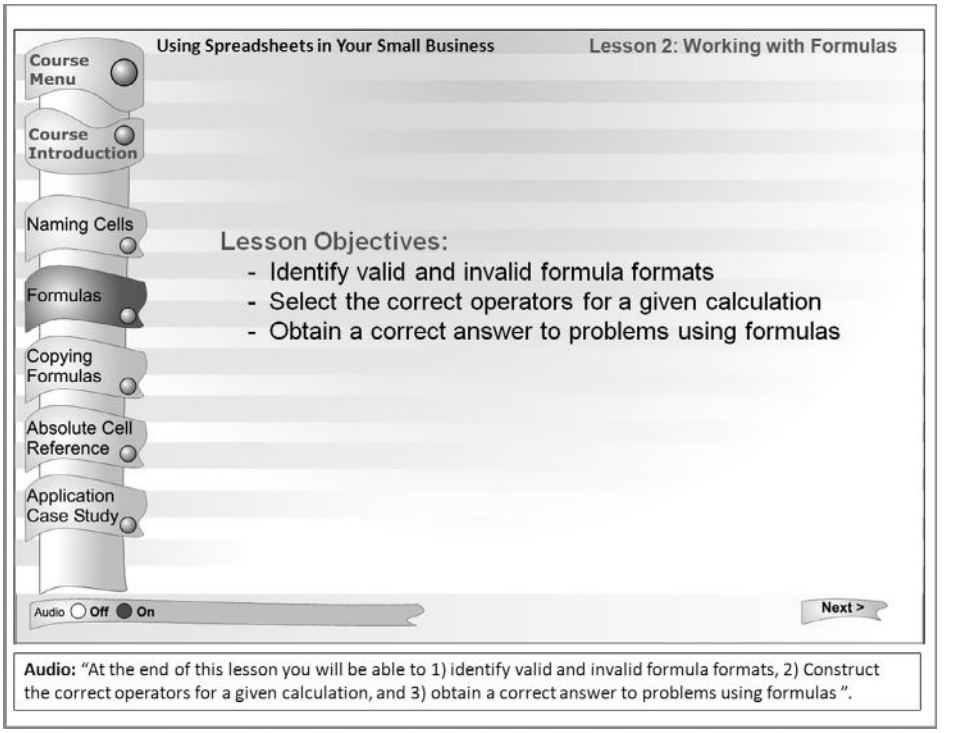
There are no pictures
The learner has ample time to process the pictures and words
The learner is likely to have difficulty processing spoken words
A few key words are presented next to the corresponding part of the picture

For example, Figure 7.6 is an introductory screen that presents the learning objectives of a multimedia lesson. Since there are no graphic illustrations, narration of the objectives presented in text on the screen should not depress learning. As described in Chapter 6, situations in which learners need to refer to information over time (such as directions to exercises) are best presented as text alone.

Psychological Reasons for Exceptions to the Redundancy Principle

The major exceptions to the redundancy principle occur in special situations in which on-screen text either does not add to the learner's processing demands or actually diminishes them. For example, consider the situation

Figure 7.6. When No Visuals Are Present, Content Can Be Presented with Text and Redundant Narration.



in which an instructional presentation consists solely of spoken words with no graphics—such as in a podcast. In this case, information enters through the ears so the verbal channel is active, but the visual channel is not active. Now, consider what happens in the learner's cognitive system when you use redundant on-screen text, for example, presented as text on a computer screen using the same words as the narration. In this case, spoken words enter through the ears and text words enter through the eyes, so neither channel is overloaded. Using dual modes of presentation can be helpful when the spoken material may be hard to process, or if seeing and hearing the words provides a benefit (such as learning a technical subject or a foreign language).

Similarly, consider a situation in which the lesson is presented at a slow pace or is under learner control. For example, presenting concurrent

narration, on-screen text, and static graphics under learner control is less likely to cause cognitive overload in the visual channel, because the learner has time to process all of the incoming material. Similarly, printing unfamiliar technical terms on the screen may actually reduce cognitive processing because the learner does not need to grapple with decoding the spoken words. Finally. printing a few key words next to the corresponding part of graphic can aid cognitive processing by directing the learner's attention—a technique than is called *signaling* (Mayer, 2005b, 2009).

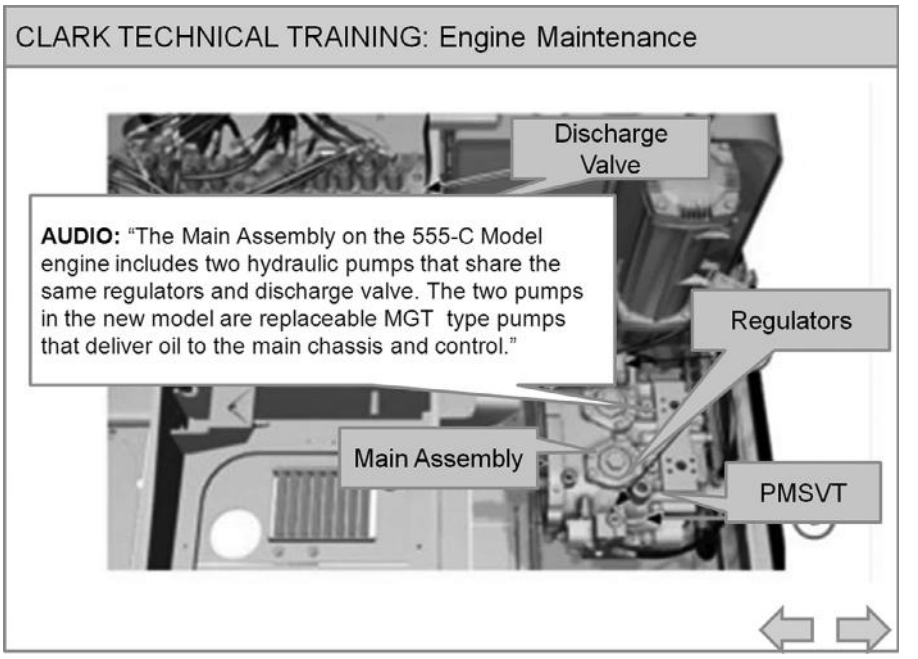
Evidence for Including Redundant On-Screen Text

In the first section of this chapter, we summarized research in which people learned less about the process of lightning formation when the presentation included animation with redundant on-screen text than when the presentation included animation with concurrent narration alone. In this section, we explore special situations in which adding redundant on-screen text has been shown to help learning.

Research shows that in certain situations learners generate approximately three times as many correct answers on a problem-solving transfer test from presentations containing concurrent spoken and printed text than from spoken text alone (Moreno & Mayer, 2002a). In these studies there were no graphics on the screen and thus the visual system was not overloaded. In another study, the animation presentation was broken into a series of sixteen short animation clips, with each clip preceded by a corresponding sentence. Thus, the learner sees and hears a sentence, then views ten seconds of animation corresponding to it, then sees and hears the next sentence, then views ten seconds of corresponding animation, and so on. In this way, the learner can view the animation without any interference from printed text. In this situation, learners who received redundant on-screen text and spoken text generated an average of 79 percent more correct answers on a problem-solving test than learners who received only spoken text (Moreno & Mayer, 2002a). Of course, this choppy sequential presentation is somewhat unusual and therefore is not likely to be applicable to most e-learning situations.

More recently, Mayer and Johnson (2008) compared the learning outcomes of students who learned about lightning formation or brakes from an online slide presentation with illustrations and narration (non-redundant) or the same lesson with each slide containing a few printed words placed next to the corresponding part of the illustration (redundant group). For example, in the first slide of the lightning passage, the voice says "Cool moist air moves over a warmer surface and becomes heated" and the redundant group also saw the text "Air becomes heated" on the slide next to wavy lines that represent moving air. In two experiments, the redundant group significantly outperformed the non-redundant group on retention and performed no worse on transfer. Based on this finding, Mayer and Johnson (2008, p. 380) called for "revising the redundancy principle" to allow for short amounts of printed text to be placed next to the corresponding part of the graphic. As an example, in Figure 7.7 a technical lesson on engine maintenance uses brief text callouts along with descriptive audio.

Figure 7.7. Use of Audio and Text Callouts Can Benefit Learning.



Based on the research and theory presented in this chapter, we offer the redundancy principle: When the instructional message includes graphics, explain the graphics with narration alone. Do not add redundant on-screen text. However, there are important boundary conditions: When there is limited graphic information on the screen or when the words are technical or the audience has language difficulties or the printed words are unobtrusive, consider the use of redundant on-screen text. As described in Chapter 6, use on-screen text without narration to present information that needs to be referenced over time, such as directions to complete a practice exercise.

Overall, the theme of this chapter is that e-learning should not add redundant on-screen text (that is, the same words that are being spoken) when attending to the text could distract the learner from viewing important graphics that are being presented at the same time. However, redundant printed and spoken words may be appropriate when there are no concurrent graphics, the text is unfamiliar to the learner, the printed words are unobtrusive, or you can use the printed words to signal where to look on the screen.

What We Don't Know About Redundancy

Research is needed to determine the situations in which the redundancy principle does not hold—including the kinds of learners, materials, and presentation methods that do not create a redundancy effect.

1. *Kinds of learners*—Does adding redundant on-screen text to a narrated graphic not hurt (or even help) non-native speakers or learners with very low prior knowledge?
2. *Kinds of material*—Does adding redundant on-screen text to a narrated graphic not hurt (or even help) when the on-screen material is technical terms, equations, or brief headings?
3. *Kinds of presentation methods*—Does adding redundant on-screen text to a narrated graphic not hurt (or even help) when the presentation pace is slow, when the presentation pace is under learner

control, when the narration precedes the on-screen text, or when the learner is given pre-training in names and characteristics of the key concepts?

It would be particularly helpful to pinpoint situations in which some form of redundancy helps learning.

DESIGN DILEMMA: RESOLVED

The Excel team members disagreed about how best to describe the visuals they decided to add. To accommodate the modality principle described in Chapter 6, they decided to use audio. But some team members wanted to also add on-screen text to accommodate different learning styles and to meet 508 compliance. The options were:

A. Communicate words in both on-screen text and audio narration to accommodate different learning styles and to give multiple learning opportunities.

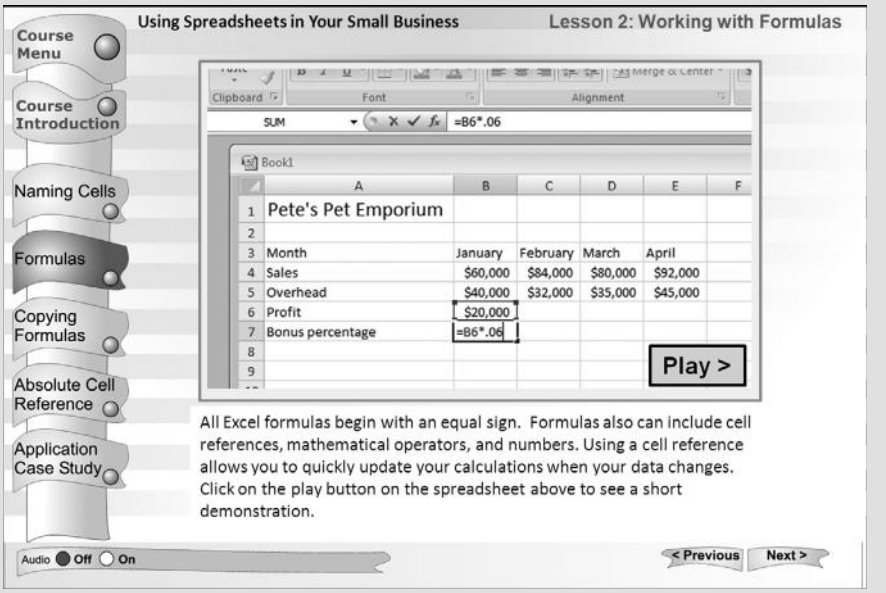
B. Explain visuals with audio alone to promote best learning per the modality principle described in Chapter 6.

C. Let the learner select either audio or text as part of the course introduction.

D. Not sure which options are correct.

It's a common misconception that learning is better from adding redundant on-screen text to audio that describes visuals. However, we have reviewed evidence in this chapter that learning is generally improved by using audio alone to describe graphics. Therefore, we select Option B. However, what about 508 compliance? We recommend that your e-learning program default to audio describing visuals. However, to accommodate learners who for various reasons may not be able to access audio, offer an "audio off" button. When the "audio off" button is activated, narration is replaced by on-screen text, as shown in Figure 7.8. In this arrangement the learner receives words in audio narration as the default but can also access words via text when audio is turned off. However they do not have the option for *both* audio narration and text of that narration.

Figure 7.8. Visual Explained by On-Screen Text When Audio Off Is Selected.



WHAT TO LOOK FOR IN e-LEARNING

- ☐ Graphics are described by words presented in the form of audio narration, not by concurrent narration and redundant text.
- ☐ On-screen text can be narrated when the screens do not include graphics.
- ☐ When language is challenging, words are presented as text.
- ☐ Short text labels are expanded with audio narration.

COMING NEXT

In the previous four chapters we have described a number of principles for best use of text, audio, and graphics in e-learning. We have seen that the appropriate use of these media elements can improve learning. However,

there are circumstances when too much of these elements can actually depress learning. In the next chapter we review how to apply the *coherence* principle to your e-learning decisions.

Suggested Readings

Jamet, E., & Bohec, O. (2007). The effect of redundant text in multimedia instruction. *Contemporary Educational Psychology, 32*, 588–598.

Mayer, R.E. (2005c). Principles for reducing extraneous processing in multimedia learning: Coherence, signaling, redundancy, spatial contiguity, and temporal contiguity. In R.E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 183–200). New York: Cambridge University Press.

Mayer, R.E., Heiser, J., & Lonn, S. (2001). Cognitive constraints on multimedia learning: When presenting more material results in less understanding. *Journal of Educational Psychology, 93*, 187–198.

Mayer, R.E., & Johnson, C.I. (2008). Revising the redundancy principle in multimedia learning. *Journal of Educational Psychology, 100*, 380–386.

Moreno, R., & Mayer, R.E. (2002a). Verbal redundancy in multimedia learning: When reading helps listening. *Journal of Educational Psychology, 94*, 151–163.

CHAPTER OUTLINE