CHAPTER

Our Attention is Limited; Our Memory is Imperfect

7

Just as the human visual system has strengths and weaknesses, so does human memory. This chapter describes some of those strengths and weaknesses as background for understanding how we can design interactive systems to support and augment human memory rather than burdening or confusing it. We will start with an overview of how memory works.

SHORT VS. LONG-TERM MEMORY

Psychologists historically have distinguished *short-term* memory from *long-term* memory. Short-term memory covers situations in which information is retained for very short intervals ranging from a fraction of a second up to several seconds—perhaps as long as a minute. Long-term memory covers situations in which information is retained over longer periods, e.g., minutes, hours, days, years, even lifetimes.

It is tempting to think of short-term and long-term memory as separate memory stores. Indeed, some theories of memory have considered them separate. After all, in a digital computer, the short-term memory stores (central processing unit data-registers) are separate from the long-term memory stores (random access memory or RAM, hard disk, flash memory, CD-ROM, etc.). More direct evidence comes from findings that damage to certain parts of the human brain results in short-term memory deficits but not long-term ones, or vice versa. Finally, the speed with which information or plans can disappear from our immediate awareness contrasts sharply with the seeming permanence of our memory of important events in our lives, faces of significant people, activities we have practiced, and information we have studied. These phenomena led many researchers to theorize that short-term memory is a separate store in the brain where information is held temporarily after entering through our perceptual senses (e.g., visual or auditory) or after being retrieved from long-term memory (see Fig. 7.1).

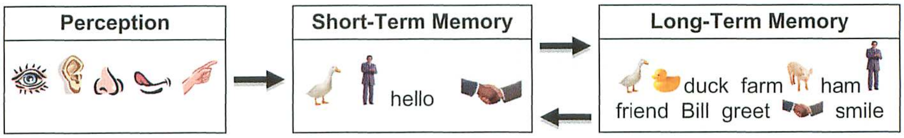


FIGURE 7.1

Traditional (antiquated) view of short-term versus long-term memory.

A MODERN VIEW OF MEMORY

Recent research on memory and brain function indicates that short- and long-term memory are functions of a single memory system—one that is more closely linked with perception than previously thought (Jonides et al., 2008).

Long-term memory

Perceptions enter through the visual, auditory, olfactory, gustatory, or tactile sensory systems and trigger responses starting in areas of the brain dedicated to each sense (e.g., visual cortex, auditory cortex), then spreading into other areas of the brain that are *not* specific to any particular sensory modality. The sensory-modality-specific areas of the brain detect only simple features of the data, such as a *dark-light edge*, *diagonal line*, *high-pitched tone*, *sour taste*, *red color*, or *rightward motion*. Downstream areas of the brain combine low-level features to detect higher-level features of the input, such as *animal*, *Uncle Kevin*, *minor key*, *threat*, or *the word "duck."*

The set of neurons affected by a perception depends largely on its features and context. The context is just as important as the features of the perception. For example, a dog barking near you when you are walking in your neighborhood stimulates a different pattern of neural activity in your brain than the same sound heard when you are safely inside your car. The more similar two perceptual stimuli are—i.e., the more features and contextual elements they share—the more overlap there is between the sets of neurons that fire in response to them.

The initial strength of a perception depends on how much it is amplified or dampened by other brain activity. All perceptions create some kind of trace, but some are so weak that they can be considered as not registered: the pattern was activated once but never again.

Memory formation consists of long-lasting and even permanent changes in the neurons involved in a neural activity pattern, which make the pattern easier to reactivate in the future.[1] Some such changes involve the release of chemicals into

[1] There is evidence that the long-term neural changes associated with learning occur mainly during sleep, suggesting that separating learning sessions by periods of sleep may facilitate learning (Stafford & Webb, 2005).

the areas around neurons that change their sensitivity to stimulation for fairly long periods of time, until the chemicals dissipate or are neutralized by other chemicals. More permanent changes consist of neurons growing and forming new connections with other neurons.

Activating a memory consists of reactivating the same pattern of neural activity that occurred when the memory was formed. Somehow the brain distinguishes initial activations of neural patterns from *re*activations—perhaps by measuring the relative ease with which the pattern was reactivated. New perceptions very similar to the original ones reactivate the same patterns of neurons, resulting in *recognition* if the reactivated perception reaches awareness. In the absence of a similar perception, stimulation from activity in other parts of the brain can also reactivate a pattern of neural activity, which if it reaches awareness results in *recall*.

The more often a neural memory pattern is reactivated, the "stronger" it becomes—that is, the easier it is to reactivate—which in turn means that the perception it corresponds to is easier to recognize and recall. Neural memory patterns can also be strengthened or weakened by excitatory or inhibitory signals from other parts of the brain.

A particular memory is not located in any specific spot in the brain. The neural activity pattern comprising a memory involves a network of neurons extending over a wide area. Activity patterns for different memories overlap, depending on which features they share. Removing, damaging, or inhibiting neurons in a particular part of the brain typically does not completely wipe out memories that involve those neurons, but rather just reduces their level of detail or accuracy by deleting features.[2] However, some areas in a neural activity pattern may be critical pathways, so that removing, damaging, or inhibiting them may prevent most of the pattern from activating, thereby effectively eliminating the corresponding memory.

Short-term memory

The processes discussed above are about long-term memory. Where is short-term memory in all of this? The answer is suggested by the word "awareness."

Short-term memory is not a *store*—it is not a *place* where memories and perceptions *go* to be worked on. More precisely, it is not a temporary repository for information just brought in from the sensory system or retrieved from long-term memory. Instead, short-term memory is a combination of phenomena arising from perception and attention.

Each of our perceptual senses has its own very brief short-term "memory" that is the result of residual neural activity after a perceptual stimulus ceases, like a bell that rings briefly after it is struck. Until they fade away, these residual perceptions are available as possible input to our brain's attention mechanisms, which integrate

[2] This is similar to the effect of cutting pieces out of a holographic image: it reduces the overall resolution of the image, rather than removing pieces of it as with an ordinary photograph.

input from our various perceptual systems and focus our awareness on some of that input. These sensory-specific residual perceptions together comprise a minor component of our short-term memory.

Also available as potential input to our attention mechanisms are long-term memories reactivated through recognition or recall. As explained above, each memory corresponds to a specific pattern of neural activity distributed across our brain. While activated, a memory pattern is a candidate for our attention.

The human brain has multiple attention mechanisms, some voluntary and some involuntary. They focus our awareness on a very small subset of the perceptions and activated long-term memories while ignoring everything else. That tiny subset of all of the available information from our perceptual systems and our long-term memories that we are conscious of *right now* is the main component of our *short-term memory*, the part that cognitive scientists often call *working memory*.

Don't think of working memory as a temporary buffer where perceptions and memories are *brought* to allow our brains to work on them. Instead, think of it as the combined *focus of attention*—the currently activated neural patterns of which we are aware. The number of items in short-term memory at any given moment is extremely limited and volatile.

What about the earlier finding that damage to some parts of the brain causes short-term memory deficits, while other types of brain damage cause long-term memory deficits? The current interpretation of that finding is that some types of damage decrease or eliminate the brain's ability to focus attention on specific objects and events, while other types of damage harm the brain's ability to store or recall long-term memories.

CHARACTERISTICS OF SHORT-TERM MEMORY

Short-term memory, as described above, is equal to the focus of our attention. Whatever is in that focus is what we are conscious of at any moment.

Right now you are conscious of the last few words and ideas you've read, but probably not the color of the wall in front of you. But now that I've shifted your attention, you *are* conscious of the wall's color, and may have forgotten some of the ideas you read on the previous page.

The primary characteristics of short-term memory are its low capacity and its volatility.

The low capacity of short-term memory is fairly well known. Many college-educated people have read about "the magical number seven, plus or minus two," proposed by cognitive psychologist George Miller in 1956 as the limit on the number of simultaneous unrelated items in human short-term memory (Miller, 1956).

Miller's characterization of the short-term memory limit naturally raises several questions.

- ***What are the items in short-term memory?*** They are current perceptions and retrieved memories. They are goals, numbers, words, names, sounds, images, odors—anything one can be aware of.
- ***Why must items be unrelated?*** Because if two items are related, they correspond to one big neural activity pattern—one set of features—and hence one item, not two.
- ***Why the fudge-factor of plus or minus two?*** Because researchers cannot measure with perfect accuracy how much people can recall, and because of differences between individuals in how much they can remember.

Later research in the 1960s and 1970s found Miller's estimate to be too high. In the experiments Miller considered, some of the items presented to people to remember could be "chunked" (i.e., considered related), making it appear that people's short-term memory was holding more items than it actually was. When the experiments were revised to disallow unintended chunking, the capacity of short-term memory was shown to be more like four plus or minus one, that is, three to five items (Broadbent, 1975).

More recent research has cast doubt on the idea that the capacity of short-term memory should be measured in whole items or "chunks." It turns out that in early short-term memory experiments, people were asked to briefly remember items (e.g., words or images) that were quite different from each other, i.e., that had very few features in common. In such a situation, people don't have to remember every feature of an item in order to recall it a few seconds later; remembering some of its features is enough. So people appeared to recall items as a whole, and therefore short-term memory capacity seemed measurable in whole items.

Recent experiments have given people items to remember that were similar, i.e., they shared features. In that situation, to recall an item and not confuse it with other items, people need to remember more of its features. In these experiments, the finding was that people remember more details (i.e., features) of some items than of others, and the items they remember in greater detail are the ones they paid more attention to (Bays and Husain, 2008). This finding suggests that the unit of attention—and therefore the capacity limit on short-term memory—is best measured in item-features rather than whole items or "chunks" (Cowan, Chen, & Rouder, 2004).

The second important characteristic of short-term memory is how volatile it is. Cognitive psychologists used to say that new items arriving in short-term memory often bump old ones out, but that way of describing the volatility is based on the view of short-term memory as a temporary storage *place* for information. The modern view of short-term memory as the current focus of attention makes it even clearer: focusing attention on new information turns it away from some of what it was focusing on.

However we describe it, information can easily be lost from short-term memory. If items in short-term memory don't get combined or rehearsed, they are at risk of having the focus shifted away from them. This volatility applies to goals as well as to the details of objects. Losing items from short-term memory corresponds to forgetting or losing track of something you were doing. We have all had such experiences, for example:

- Going to another room for something, but once there we can't remember why we came.
- Taking a phone call, and afterward not remembering what we were doing before the call.
- Something yanks our attention away from a conversation, and then we can't remember what we were talking about.
- In the middle of adding a long list of numbers, something distracts us, so we have to start over.

One way researchers have shown that short-term memory is limited in capacity and duration is to show people a picture, then show them a second version of the same picture and ask them if the second picture is the same or different from the first. Surprisingly, the second picture can differ from the first in many ways without people noticing any difference. To explore further, researchers gave people questions to answer about the first picture, affecting their goals in looking at it, and therefore what features of the picture they pay attention to. Result: people don't notice differences in features other than those their goals made them pay attention to. This is called "change blindness" (Angier, 2008).

A particularly striking example of the volatility of short-term memory comes from experiments in which experimenters holding city maps posed as lost tourists and asked local people walking by for directions. When the local person focused on the tourist's map in order to figure out the best route, two workmen—actually more experimenters—walked between the "tourist" and the advice-giver carrying a large door, and in that moment the "tourist" was replaced by another experimenter-"tourist." Astoundingly, after the door passed, over half of the local people continued helping the "tourist" without noticing any change, even when the two "tourists" differed in hair color or in whether they had a beard (Simons & Levin, 1998). Some people even failed to notice changes in gender. Conclusion: people focus on the "tourist" only long enough to determine if they are a threat or worth helping, "record" only that the person is a tourist who needs help, and then focus on the map and the task of giving directions.

A SHORT-TERM MEMORY TEST

To test your short-term memory, get a pen or pencil and two blank sheets of paper and follow these instructions:

1. Place one blank sheet of paper after this page in the book and use it to cover the next page.
2. Flip to the next page for 3 seconds, pull the paper cover down and read the **black numbers** at the top, and flip back to this page. Don't peek at other numbers on that page unless you want to ruin the test.
3. Say your phone number backward, out loud.
4. Now write down the black numbers from memory. … Did you get all of them?
5. Flip back to the next page for 3 seconds, read the **red numbers** (under the black ones), and flip back.
6. Write down the numbers from memory. These would be easier to recall than the first ones if you noticed that they are the first seven digits of *pi* (3.141592), because then they would be only one number, not seven.
7. Flip back to the next page for 3 seconds, read the **green numbers**, and flip back.
8. Write down the numbers from memory. If you noticed that they are odd numbers from 1 to 13, they would be easier to recall, because they would be three chunks ("odd, 1, 13" or "odd, seven, from 1"), not seven.
9. Flip back to the next page for 3 seconds, read the **orange words**, and flip back.
10. Write down the words from memory. … Could you recall them all?
11. Flip back to the next page for 3 seconds, read the **blue words**, and flip back.
12. Write down the words from memory. … It was certainly a lot easier recall them all because they form a sentence, so they could be memorized as one sentence rather than seven words.

3 8 4 7 5 3 9

3 1 4 1 5 9 2

1 3 5 7 9 11 13

town river corn string car shovel

what is the meaning of life

IMPLICATIONS OF SHORT-TERM MEMORY CHARACTERISTICS FOR USER INTERFACE DESIGN

The capacity and volatility of short-term memory have many implications for the design of interactive computer systems. The basic implication is that user interfaces should help people remember essential information from one moment to the next. Don't require people to remember system status or what they have done, because their attention is focused on their primary goal and progress toward it. Specific examples follow.

Modes

The limited capacity and volatility of short-term memory is one reason why user-interface design guidelines often say to either avoid designs that have *modes* or provide adequate mode-feedback. In a moded user interface, some user actions have different effects depending on what mode the system is in. For example:

- In a car, pressing the accelerator pedal can move the car either forwards, backwards or not at all, depending on whether the transmission is in drive, reverse, or neutral. The transmission sets a mode in the car's user interface.
- In many digital cameras, pressing the shutter button can either snap a photo or start a video recording, depending on which mode is selected.

- In a drawing program, clicking and dragging normally selects one or more graphic objects on the drawing, but when the software is in "draw rectangle" mode, clicking and dragging adds a rectangle to the drawing and stretches it to the desired size.

Moded user interfaces have advantages; that is why many interactive systems have them. Modes allow a device to have more functions than controls: the same control provides different functions in different modes. Modes allow an interactive system to assign different meanings to the same gestures in order to reduce the number of gestures users must learn.

However, one well-known *dis*advantage of modes is that people often make *mode-errors*: they forget what mode the system is in and do the wrong thing by mistake (Johnson, 1990). This is especially true in systems that give poor feedback about what the current mode is. Because of the problem of mode-errors, many user interface design guidelines say to either avoid modes or provide strong feedback about which mode the system is in. Human short-term memory is too unreliable for designers to assume that users can, without clear, continuous feedback, keep track of what mode the system is in, even when the users are the ones changing the system from one mode to another.

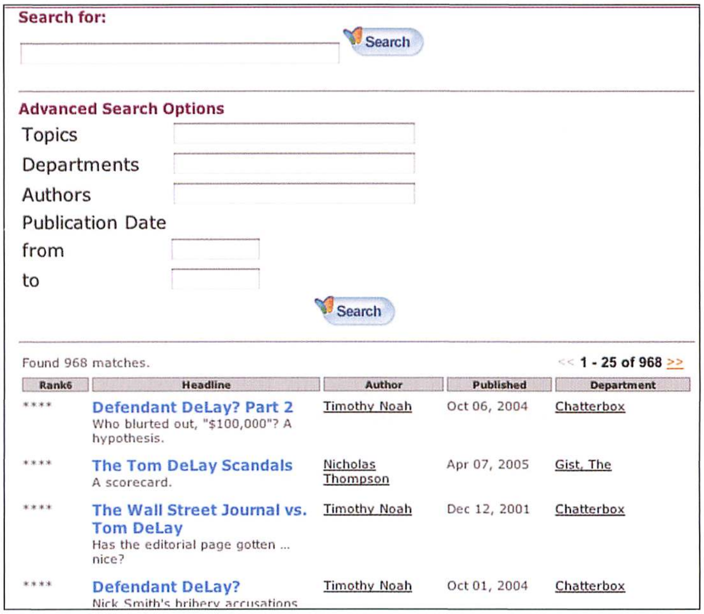
Search results

When people use a search function on a computer to find information, they enter the search terms, start the search, and then review the results. Evaluating the results often requires knowing what the search terms were. If short-term memory were less limited, people would always remember, when browsing the results, what they had entered as search terms just a few seconds earlier. But as we have seen, short-term memory is very limited. When the results appear, the person's attention naturally turns away from what they entered and toward the results. Therefore, it should be no surprise that people viewing search results often do not remember the search terms they just typed.

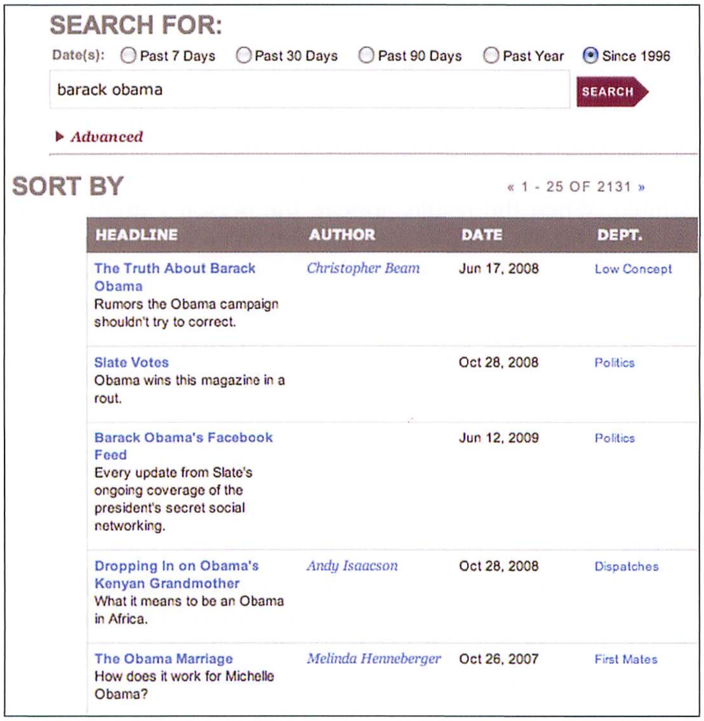
Unfortunately, some designers of online search functions don't understand that. Search-results sometimes don't show the search terms that generated the results. For example, in 2006, the search-results page at Slate.com provided search fields so users could search again, but didn't show what a user had searched for (see Fig. 7.2A). A more recent version of the site does show the user's search terms (see Fig. 7.2B), reducing the burden on users' short-term memory.

Instructions

If you asked a friend for a recipe or for directions to her home, and she gave you a long sequence of steps, you probably would not try to remember it all. You would know that you could not reliably keep all of the instructions in your short-term memory, so you would write them down or ask your friend to send them to you by email. Later, while following the instructions, you would put them where you could refer to them until you reached the goal.




(A)




(B)

FIGURE 7.2

Slate.com search results: (A) in 2007, users' search terms not shown, (B) in 2009 search terms shown.

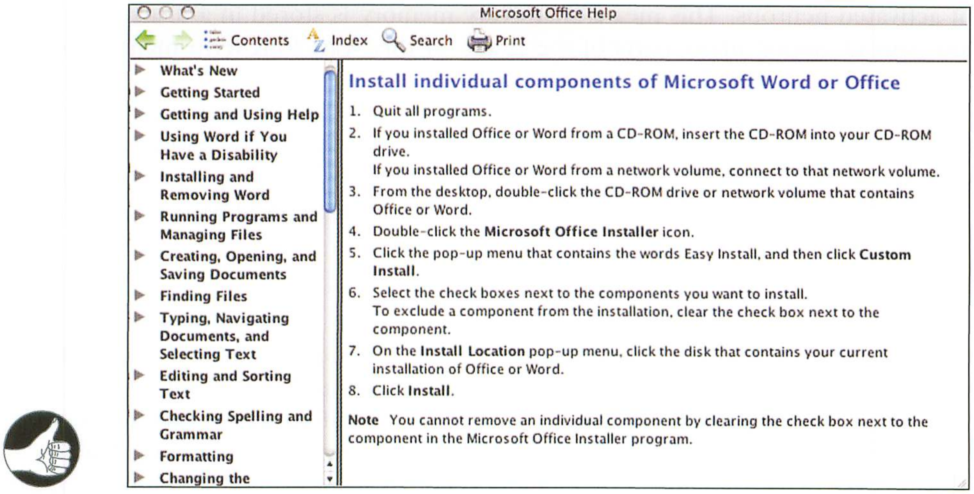


FIGURE 7.3

Instructions in Windows Help files remain displayed while users follow them.

FIGURE 7.4

Instructions for Windows XP wireless setup start by telling users to close the instructions.

Similarly, interactive systems that display instructions for multistep operations should allow people to refer to the instructions while executing them until completing all the steps. Most interactive systems do this (see Fig. 7.3), but some do not (see Fig. 7.4).

CHARACTERISTICS OF LONG-TERM MEMORY

Long-term memory differs from short-term memory in many respects. Unlike short-term memory, it actually *is* a memory store.

However, specific memories are not stored in any one neuron or location in the brain. As described above, memories, like perceptions, consist of patterns of activation of large sets of neurons. Related memories correspond to overlapping patterns of activated neurons. This means that every memory is stored in a distributed fashion, spread among many parts of the brain. In this way, long-term memory in the brain is similar to holographic light images.

Long-term memory evolved to serve our ancestors and us very well in getting around in our world. However, it has many weaknesses: it is error-prone, impressionist, free-associative, idiosyncratic, retroactively alterable, and easily biased by a variety of factors at the time of recording or of retrieval. Let's examine some of these weaknesses.

Error prone

Nearly everything we've ever experienced is stored in our long-term memory. Unlike short-term memory, the capacity of human long-term memory seems almost unlimited. Although Landauer (1986) used the average human learning rate to calculate the amount of information a person can learn in a lifetime,[3] no one has yet measured or even estimated the maximum information capacity of the human brain.

However, what is in long-term memory is not an accurate, high-resolution recording of our experiences. In terms familiar to computer engineers, one could characterize long-term memory as using heavy compression methods that drop a great deal of information. Images, concepts, events, sensations, actions—all are reduced to combinations of abstract features. Different memories are stored at different levels of detail, that is, with more or fewer features.

For example, the face of a man you met briefly who is not important to you might be stored simply as an average Caucasian male face with a beard, with no other details—a whole face reduced to three features. If you were asked later to describe the man in his absence, the most you could honestly say was that he was a "white guy with a beard." You would not be able to pick him out of a police lineup of other Caucasian men with beards. In contrast, your memory of your best friend's face includes many more features, allowing you to give a more detailed description and pick your friend out of any police lineup. Nonetheless, it is still a set of features, not anything like a bitmap image.

As another example, I have a vivid childhood memory of being run over by a plow and badly cut, but my father says it happened to my brother. One of us is wrong.

In the realm of human-computer interaction, Microsoft Word users may remember that there is a command to insert a page number, but they may not remember which menu the command is in. That specific feature may not have been recorded when the user learned how to insert page numbers. Alternatively, perhaps the menu-location feature *was* recorded, but did not reactivate with the rest of the memory when the user tried to recall how to insert a page number.

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[3] 10^9 bits, or a few hundred megabytes.

Weighted by emotions

Chapter 1 described a dog that remembered seeing a cat in his front yard every time he returned home in the family car. The dog was excited when he first saw the cat, so his memory of it was strong and vivid.

Another example: an adult could easily have strong memories of her first day at nursery school, but probably not of her tenth. On the first day, she was probably upset about being left at the school by her parents, whereas by the tenth day, being left there was nothing unusual.

Retroactively alterable

Suppose that while you are on an ocean cruise with your family, you see a whale-shark. Years later, when you and your family are discussing the trip, you might remember seeing a whale, and one of your relatives might recall seeing a shark. For both of you, some details in long-term memory were dropped because they did not fit a common concept.

A true example comes from 1983, when the late President Ronald Reagan was speaking with Jewish leaders during his first term as president. He spoke about being in Europe during World War II and helping to liberate Jews from the Nazi concentration camps. The trouble was, he was never in Europe during World War II. When he was an actor, he was in a *movie* about World War II, made entirely in Hollywood.

A LONG-TERM MEMORY TEST

Test your long-term memory by answering the following questions:

1. Was there a roll of tape in the toolbox in Chapter 1?
2. What was your *previous* phone number?
3. Which of these words were *not* in the list presented in the short-term memory test earlier in this chapter?
   city stream corn auto twine spade
4. What was your first grade teacher's name? Second grade? Third grade? …
5. What Web site was presented earlier that does not show search terms when it displays search results?

Regarding question 3: When words are memorized, often what is retained is the *concept*, rather than the exact word that was presented. For example, one could hear the word "town" and later recall it as "city."

IMPLICATIONS OF LONG-TERM MEMORY CHARACTERISTICS FOR USER INTERFACE DESIGN

The main thing that the characteristics of long-term memory imply is that people need tools to augment it. Since prehistoric times, people have invented technologies to help them remember things over long periods: notched sticks, knotted ropes, mnemonics, verbal stories and histories retold around campfires, writing, scrolls, books, number systems, shopping lists, checklists, phone directories, datebooks, accounting ledgers, oven timers, computers, portable digital assistants (PDAs), online shared calendars, etc.

Given that humankind has a need for technologies that *augment* memory, it seems clear that software designers should try to provide software that fulfills that need. At the very least, designers should avoid developing systems that *burden* long-term memory. Yet that is exactly what many interactive systems do.

Authentication is one functional area in which many software systems place burdensome demands on users' long-term memory. For example, a Web application developed a few years ago told users to change their personal identification number (PIN) "to a number that is easy … to remember," but then imposed restrictions that made it impossible to do so (Fig. 7.5). Whoever wrote those instructions seems to have realized that the PIN requirements were unreasonable, because the instructions end by advising users to write down their PIN! Never mind that writing a PIN down creates a security risk and adds yet *another* memory task: users must remember where they hid their written-down PIN.

A contrasting example of burdening people's long-term memory for the sake of security comes from Intuit.com. To purchase software, visitors must register. The site requires users to select a security question from a menu (see Fig. 7.6). What if you can't answer *any* of the questions? What if you don't recall your first pet's name, your high school mascot, or any of the answers to the other questions?

But that isn't where the memory burden ends. Some questions could have several possible answers. Many people had several elementary schools, childhood friends, or heroes. In order to register, they must choose a question and then *remember* which answer they gave to Intuit. How? Probably by writing it down somewhere. Then, when Intuit.com asks them the security question, they have to *remember* where they put the answer. Why burden people's memory, when it would be easy to let users make up a security question for which they can easily recall the one possible answer?

Such unreasonable demands on people's long-term memory counteract the security and productivity that computer-based applications supposedly provide (Schrage, 2005), as users:

- place sticky notes on or near computers or "hide" them in desk drawers
- contact customer support to recover passwords they cannot recall
- use passwords that are easy for others to guess
- setup systems with no login requirements at all, or with one shared login and password

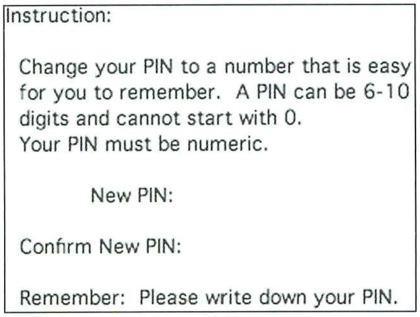

FIGURE 7.5

Instructions tell users to create an easy-to-remember PIN, but the restrictions make that impossible.

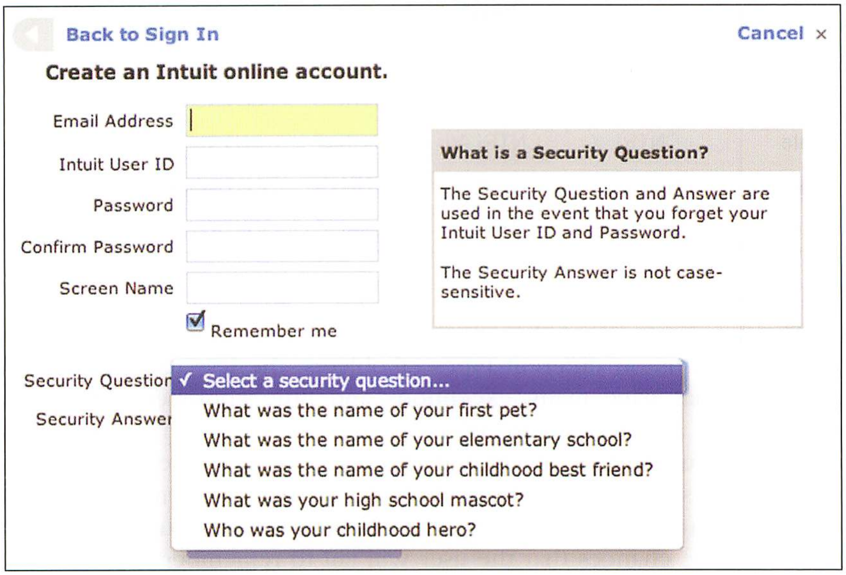

FIGURE 7.6

Intuit.com registration burdens long-term memory: users may have no unique, memorable answer for any of the questions.

The registration form at NetworkSolutions.com represents a small step toward more usable security. Like Intuit.com, it offers a choice of security questions, but it also allows users to create their own security question—one for which they can more easily remember the answer (see Fig. 7.7).

Another implication of long-term memory characteristics for interactive systems is that learning and long-term retention are enhanced by user-interface consistency.

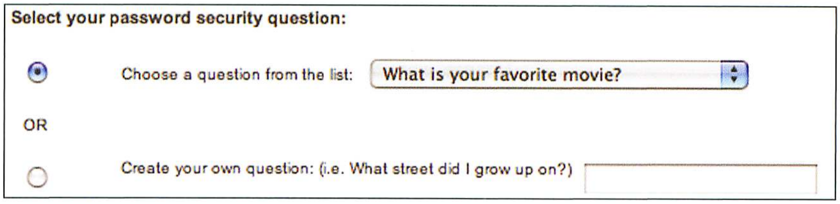

FIGURE 7.7

NetworkSolutions.com lets users create a security question if none on the menu works for them.

Table 7.1 Which UI Design will be Easiest to Learn and Remember? Which One will be Hardest?

Object	Document Editor Keyboard Shortcuts: Alternative Designs					
	Design A		Design B		Design C	
	Cut	Paste	Cut	Paste	Cut	Paste
Text	CNTRL-X	CNTRL-V	CNTRL-X	CNTRL-V	CNTRL-X	CNTRL-V
Sketch	CNTRL-X	CNTRL-V	CNTRL-C	CNTRL-P	CNTRL-X	CNTRL-V
Table	CNTRL-X	CNTRL-V	CNTRL-Z	CNTRL-Y	CNTRL-X	CNTRL-V
Image	CNTRL-X	CNTRL-V	CNTRL-M	CNTRL-N	CNTRL-X	CNTRL-V
Video	CNTRL-X	CNTRL-V	CNTRL-Q	CNTRL-R	CNTRL-E	CNTRL-R

The more consistent the operation of different functions, or the more consistent the actions on different types of objects, the less users have to learn.[4] User interfaces that have many exceptions and little consistency from one function or object to another require users to store in long-term memory many features about each function or object and its correct usage-context. The need to encode more features makes such user interfaces harder to learn. It also makes it more likely that a user's memory will drop essential features during storage or retrieval, increasing the chances that the user will fail to remember, misremember, or make other memory errors.

Consider three alternative designs for the keyboard shortcuts for Cut and Paste in a hypothetical multimedia document editor. The document editor supports the creation of documents containing text, sketches, tables, images, and videos. In Design A, Cut and Paste have the same two keyboard shortcuts regardless of what type of content is being edited. In Design B, the keyboard shortcuts for Cut and Paste are different for every type of content. In Design C, all types of content *except* videos have the same Cut and Paste keyboard shortcuts. (see Table 7.1).

[4] See also Chapter 11.

The first question is: which of these designs is easiest to learn? It is fairly clear that Design A is easiest.

The second question is: which design is hardest to learn? That is a tougher question. It is tempting to say "Design B" because that one seems to be the least consistent of the three. However, the answer really depends on what we mean by "hardest to learn."

If we mean "the design for which users will require the most time to become productive", that is certainly Design B. It will take most users a long time to learn all the different Cut and Paste keyboard shortcuts for the different types of content. But people are remarkably adaptable if sufficiently motivated—they can learn amazingly arbitrary things if, say, using the software is required for their job. Eventually—maybe in a month—users would be comfortable and even quick with Design B. In contrast, users of Design C would begin to be productive in about the same short time as users of Design A—probably a matter of minutes.

However, if we interpret "hardest to learn" as meaning "the design for which users will take the longest to be error-free," that is Design C. All the types of document content use the same shortcut keys for Cut and Paste except videos. Although users of Design C will be productive quickly, they would continue to make the error of trying to use CNTRL-X and CNTRL-V with videos for at least several months—perhaps forever.

Even though some have criticized the concept of consistency as ill-defined and easy to apply badly (Grudin, 1989), the fact is that consistency in a user-interface greatly reduces the burden on users' long-term memory. Mark Twain once wrote: "If you tell the truth, you never have to remember anything." One could also say "If everything worked the same way, you would not have to remember much." We will return to the issue of consistency in Chapter 11.