**Cognitive Information Processing**

The theory (or theories) of cognitive information processing, at least the classical version of it we discuss, focuses on computers as models of human thought processes. The approach breaks down complex cognitive processes, such as reading, into simpler ones that can be studied somewhat independently from the larger processes in which they are embedded. Sparked by the Cognitive Revolution against behaviorism in the 1950s, which included a devastating critique of Skinner’s Verbal Behaviors by Noam Chomsky (1959), information processing, with its descendant, cognitive science, remains one of the two dominant paradigms in research on the psychology of reading today.

In early information-processing theory, the human mind was viewed as consisting of different functions, similar to the different parts of a computer. Different scholars use slightly different versions of the information-processing model, but the main parts and how they are thought to work are pretty similar. You may want to refer to Figure I.1 as we discuss the various elements of this theory:

Sensory register (also called sensory input or the sensory memory) is the gateway for all information coming into the mind. In a computer, the sensory memory would be connected to such input devices as the keyboard, mouse, modem, and disk drive. In human beings, the sensory memory takes in information from our senses: sight, hearing, touch, taste, and smell. The sensory memory can take in a great deal of information, but the impression made by a stimulus on the sensory memory is very fleeting, a few seconds or mere milliseconds long depending on the sense, unless the sensory impression is passed on to working memory. It is in the sensory register that the graphic input from text is processed.

Because the sensory memory can take in many more pieces of information than the working memory can deal with, attention controls which information from the sensory memory transfers into working memory. Directing attention in computers is just a matter of pushing a button to bring up a different program or screen, but attention in humans is much more complex. Some attention patterns originate in the sensory memory itself—loud noises, unexpected movements, and other novel, potentially dangerous stimuli draw our attention automatically; the human nervous system is “hardwired” to pay attention to such stimuli as a matter of survival. Other times, certain stimuli attract attention because they are related to something that is currently engaging working memory (e.g., once you start reading a good novel, it is easy to focus your attention on it and shut out other stimuli), or because they are associated in long-term memory with something either pleasant or upsetting (e.g., consider how quickly you notice a friend’s, or an enemy’s, face in a crowd). Finally, you can use your executive control to focus attention on certain stimuli deliberately, such as when you search for particular information in a textbook being used in a class.

Working memory is sometimes also called short-term memory because information disappears from working memory within 20–30 seconds if attention is not focused on it. Working memory in humans is parallel to the random-access memory (RAM) in a computer, with one important difference. Whereas many computers today have several gigabytes of RAM (which means they can work with several billion bits of information at the same time), we humans can work with only five to nine separate pieces of information simultaneously on the “desktop” of our working memory. This difference is one reason computers can calculate so much faster than humans (although, as you will discover, we have other advantages).

Humans use a number of different processes to deal with these severe limitations to working memory. One of the simplest is maintenance rehearsal, which involves repeating information over and over to keep it fresh in memory (much as you might repeat a phone number you have looked up in order to remember it until you can get to a phone). We need our working memories to build and update our current understanding of the text as we read. We notice difficulty with our working memories when there are lots of characters and places to keep track of, causing us to lose track of the identity of a pronoun we have encountered in a text. Children may demonstrate difficulties with their working memories when they try to string together long sequences of sounds as they sound out words in a text.

Perhaps the biggest space-saving function in working memory is that of automaticity. Once we have learned to do something very well, we have practiced it to the point that it takes up very little working memory; that is, we have made its retrieval automatic. Without automaticity, we could never do all the very complex activities involved in daily life, from driving to reading to even walking or talking—without automaticity, we literally could not walk and chew gum at the same time! In reading, automaticity is a central concept around which many of our activities operate. We can quickly recognize words, quickly interpret the grammatical relationships in a sentence, and quickly retrieve relevant information from our experience to be used in interpreting text. In addition to the main part of working memory, sometimes called the central executive, it seems likely that there are at least two subcomponents: the phonological loop, which holds and rehearses sounds and words and is obviously involved in word decoding, and the visual–spatial scratchpad, whereupon visual images can be briefly stored and manipulated. Both of these elements are crucial to the act of reading.

Long-term memory is like the hard drive on your computer, but this is where we humans have a huge advantage. First of all, no matter how big your computer’s hard drive is, your human long-term memory is larger; in fact, no one has ever found the limits of the storage capacity in human long-term memory. Second, although all information originally enters long-term memory after being processed through working memory, just as information has to be processed through RAM to get to the hard drive on a computer, information in human long-term memory is not stored in hierarchical pathways the way it is on our computers. Instead, it is stored in organized, interconnecting, cross-connecting, and ever-changing networks. The information from your long-term memory is brought to bear when you are reading a text, and it is used in an ongoing way as the meaning of the text unfolds and is updated as comprehension occurs. Executive control is the part of your mind that chooses goals and decides on strategies for reaching them.

An important skill that enhances executive control functioning is metacognition, or the ability to reflect upon and control your own thinking. Young children are not very metacognitive; they often are not aware of what they know and don’t know or how they learn best. They are not very good at being strategic as they read. As we get older, we can get better at monitoring our understanding if we reflect on our own learning and thinking—that is, by knowing when we have understood something we have read, for example, and when we need to go back over it to gain a better understanding. The value of metacognitive reflection is one reason good reading teachers instruct children not only to read the various materials they will encounter, but also to reflect on and discuss them. The more metacognitive children become, the better they can use and add to the information and skills they acquire. Today few cognitive psychologists would hold to the classical version of information-processing theory that we have presented here.

Certainly, one main lesson that emerged from the past few decades of research in cognitive psychology is how interactive and less stage-like cognition is than what we have just described. However, we still see remnants of the “mind as computer” analogy that drove much of the early theorizing from this theoretical standpoint in the current use of computer modeling to test theories found in cognitive-science approaches to reading. Throughout this book you will notice how important the information processing model of thought is to the study of reading. Concepts generated from this approach—such as attention, working memory, automatization, long-term memory, semantic networks, and metacognition—will come up repeatedly as we progress from explanations of emergent and early word reading all the way through the study of reading comprehension. We will see that this cognitive-science approach to reading psychology has become very interdisciplinary, seeking theoretical input from the fields of psychology, artificial intelligence, cognitive neuroscience, linguistics, and education. To a great extent, the cognitive information-processing approach has been useful to classroom teachers by providing guidance in identifying the workings of a particular aspect of reading that they are teaching. It can help provide insight into problems particular children may be having. It can help them answer many questions, such as: “Do the children in my classroom have the long-term memory concepts required for reading this particular book?” “Is this child’s word reading automatic and accurate enough so as not to gobble up working memory resources and interfere with comprehension?” “Is the sound identification process and rehearsal process engaged by the phonological loop operating optimally to help this child pair sound to print?”