Figure 1-5, *that occur on every trial, a set of stages that completely account for mental processing*. Importantly, the order of the stages was treated as fixed on the grounds that each stage provides a result that is used for the next one. More to the point, this assumption implies that one and only one stage can be done at a time, which may not be the case in reality. The influence of the computer analogy is very clear here. Computers have achieved high speeds of operation, but are largely serial processors: They do operations one by one, in a sequential order. And yet there is no *a priori* reason to expect that human cognition has this quality in all situations.

The second assumption is that the stages were **independent and nonoverlapping**. That is, *any single stage was assumed to finish its operation before the next stage could begin, and the duration of any single stage had no bearing or influence on the others*. Thus, at the beginning of a trial, encoding starts, completes its operations, and passes its result to the search stage. Then and only then could the search stage begin, followed after its completion by the decision and response stages. With these assumptions, the total time for a trial could be interpreted as the sum of the durations for each stage; because mental processes take time and because each stage is a separate, the total time could be viewed as the sum of the times for all the individual stages. In our earlier example, then, the 50-ms differences between ROBIN, MOTOR, and OFFICE were attributed to the search stage.

PARALLEL PROCESSING As research has been done, evidence has accumulated that casts doubt on the assumptions of serial, nonoverlapping stages of processing. Instead, there is some evidence that multiple mental processes can operate *simultaneously*—which is termed **parallel processing**. One example involves typing. Salthouse (1984) did a study of how skilled typists type and how performance changes with age. His data argued for a four-process model; the input stage encoded the to-be-typed material, a parsing stage broke large reading units (words) into separate characters, a translation stage transformed the characters into finger movements, and an execution stage triggered the keystrokes. Significantly, his evidence indicated that these stages operate in parallel: While one letter is typed, another is translated into a finger movement, and the input stage is encoding upcoming letters, even as many as eight characters in advance of the one being typed. Moreover, older adults counteracted the tendency toward slower finger movements by increasing their "look ahead" span at the upcoming letters (see Townsend & Wenger, 2004, for a thorough discussion of serial versus parallel processing).

In moving away from the simpler computer analogy, the cognitive science approach embraced the ideas that cognition needs to be understood with some reference to the brain. An important lesson we have learned from neuroscience is that the brain shows countless ways in which different cognitive components and processes operate simultaneously, in parallel. Furthermore, there is now ample neurological evidence that different regions of the brain are more specialized for different processing tasks, such as encoding, responding, memory retrieval, and controlling the stream of thought (Anderson, Qin, Jung, & Carter, 2007).

CONTEXT EFFECTS A second difficulty with the early assumptions of sequential stages and nonoverlapping processes arose when **context effects** were taken into account. A simple example of this is the speedup in deciding—that you are faster to decide MOTOR is a word if you have seen MOTOR recently (see "repetition priming" in Chapters 6 and 7). A more compelling demonstration comes from work on lexical ambiguity—the fact that many words have more than one meaning. As an example, Simpson (1981) had people do a modified lexical decision task, judging letter strings such as DUKE or MONEY (or MANTY or ZOOPLE) after they had read a context sentence. When the letter string and sentence were related—for instance, "The vampire was disguised as a handsome count," followed by DUKE—the lexical decision on DUKE was faster than normal. The reason involved priming (see Chapters 6 and 7), the idea that concepts in memory become activated and hence easier to process. In this case, because the context sentence primed the royalty sense of the word *count*, the response time to DUKE was speeded up.

This was an issue for earlier cognitive models because there was no mechanism to account for priming. Look again at Figure 1-5; is there any component that allows a context sentence to influence the speed of the processes? No, you need a meaning-based component to keep track of recently activated meanings that would speed up the search process when meanings matched but not when they were unrelated.

Let's look more deeply at the influence of context on cognition. Information that is active in long-term memory, for example, can easily have an effect *right now* on sensory memory, the input stage for external stimuli. Here is a simple example:

> As you read a sentence or paragraph, you begin to develop a feel for its meaning. Often you understand well enough that you can then skim through the rest of the material, possibly reading so rapidly that lower-level processes such as proofreading and noticing typograpical errors may not function as accurately as they usually do. *Did you see the mistake?*

What? Mistake? If you fell for it, you failed to notice the missing *h* in the word *typographical*, possibly because you were skimming but probably because the word *typographical* was expected, predictable based on meaning. You may have even "seen" the missing *h* in a sense. Why? Because your understanding of the passage, its meaningfulness to you, may have been strong enough that the missing *h* was supplied by your long-term memory.

We call such influences **top-down** or **conceptually driven processing** *when existing context or knowledge influences earlier or simpler forms of mental processes.* It's one of the recurring themes in cognition (see Table 1-2). For another example, adapted from Reed (1992), read the following sentence:

FINISHED FILES ARE THE RESULT OF YEARS OF SCIENTIFIC STUDY COMBINED WITH THE EXPERIENCE OF MANY YEARS.

Now, read it a second time, counting the number of times the letter F occurs.