Learning, Memory and Forgetting

This chapter and the next two focus on human memory. All three chapters deal with intact human memory, but Chapter 7 also considers amnesic patients in detail. Traditional laboratory-based research is the focus of this chapter and Chapter 7, with more naturalistic research being discussed in Chapter 8. There are important links among these different types of research. Many theoretical issues are relevant to brain-damaged and healthy individuals whether tested in the laboratory or the field. Learning and memory involve several stages. Processes occurring during the presentation of the learning material are known as encoding and involve many of the processes involved in perception. This is the first stage. As a result of encoding, information is stored within the memory system. Thus, storage is the second stage. The third stage is retrieval, which involves recovering stored information from the memory system. Forgetting (discussed at length later in the chapter) occurs when our attempts at retrieval prove unsuccessful. These various processes occur within the overall structure or architecture of the memory system. We have distinguished between architecture and process and among encoding, storage and process. Note, however, we cannot have architecture without process, or retrieval without previous encoding and storage. ARCHITECTURE OF MEMORY Many theorists distinguish between short-term and long-term memory. For example, there are enormous differences in capacity: a few items in short-term memory vs. essentially unlimited capacity for long-term memory. There are also massive differences in duration: a few seconds for short-term memory vs. up to several decades for long-term memory. The distinction between short-term and long-term memory stores is central to multi-store models. More recently, however, some theorists have proposed unitary-store models in which this distinction is much less clear-cut. Both types of models are discussed below.

Multi-store model

Atkinson and Shiffrin (1968) described the basic architecture of the memory system (see Figure 6.1): • sensory stores each modality-specific (i.e., limited to one sensory modality) and holding information very briefly; • short-term store of very limited capacity; • long-term store of essentially unlimited capacity holding information over very long periods of time. According to the multi-store model, environmental stimulation is initially processed by the sensory stores. These stores are modality-specific (e.g., vision, hearing). Information is held very briefly in the sensory stores, with some being attended to and processed further by the short-term store. Some information processed in the short-term store is transferred to the long-term store. There is a direct relationship between the amount of rehearsal in the short-term store and the strength of the stored memory trace in long-term memory. Sensory stores The visual store (iconic memory) holds visual information briefly. Sperling (1960) argued that information in iconic memory decays within about 500 milliseconds. However, this may be an underestimate. Iconic memory is very useful because the mechanisms responsible for visual perception always operate on the icon. More generally, the existence of iconic memory increases the time for which visual information is available to us (e.g., when reading). It has typically been assumed that iconic memory is preattentive, meaning it does not depend on attention. This assumption was accepted by Atkinson and Shiffrin (1968) – in Figure 6.1, attention occurs only after information has been held in the sensory stores. Recent evidence suggests this assumption is incorrect. Persuh et al. (2012) found storage of information in iconic memory was severely disrupted if participants engaged in an attentionally demanding task at the same time. There is further discussion of iconic memory in Chapter 16. Echoic memory, the auditory equivalent of iconic memory, holds auditory information for a few seconds. In everyday life, suppose someone asked you a question while your mind was elsewhere. Perhaps you replied, “What did you say?” just before realising you know what had been said. This “playback” facility depends on the echoic store. Ioannides et al. (2003) measured brain activation when tones were presented. The duration of echoic memory was longer in the left hemisphere than the right (maximum of five seconds vs. two seconds, respectively). This hemispheric difference probably reflects the dominance of the left hemisphere in language processing.

There are sensory stores associated with each of the other senses (e.g., touch, taste). However, they are less important than iconic and echoic memory and have attracted much less research.

Short-term memory

Short-term memory has very limited capacity. Consider digit span: participants listen to a random digit series and then repeat the digits back immediately in the correct order. There are also letter and word spans. The maximum number of items recalled without error is typically about seven (Miller, 1956). There are two reasons for rejecting seven items as the capacity of short-term memory. First, we must distinguish between items and chunks, which are “groups of items that have been collected together and treated as a single unit” (Mathy & Feldman, 2012, p. 346). Memory span involves a random series of items and so the number of chunks corresponds to the number of items. In contrast, suppose you were given the following letters on a letter-span task: PSYCHOLOGY. There are ten letters but only one chunk and so your recall would be perfect (hopefully!). Second, estimates of short-term memory capacity are often inflated because participants' performance depends on rehearsal and long-term memory.

The concept of a "chunk" is rather vague. Mathy and Feldman (2012) argued that people process a string of items by compressing them into the smallest possible number of distinct sequences or chunks. The number of chunks so defined that were recalled immediately in order was three or four. A similar capacity limit has been obtained in several other studies. Chen and Cowan (2009) presented participants with chunks consisting of single words or pairs of words learned previously. Rehearsal was prevented by articulatory suppression (saying "the" repeatedly). Only three chunks were recalled in the absence of rehearsal. Within the multi-store model, it is assumed that all items have equal importance. However, this is an oversimplification (Nee and Jonides, 2013). Suppose several items are presented, followed very rapidly by another, a probe item. Participants decide whether the probe item corresponds to any of the list items. Response to the probe is faster when it corresponds to the most recently rehearsed item than when it corresponds to any of the other items (McElree, 2006). Thus, the item within short-term memory that is the current focus of attention has a privileged position. How is information lost from short-term memory? Two main answers have been proposed. First, information may decay over time in the absence of rehearsal. Second, there may be interference. This interference could come from items on previous trials and/or from information presented during the retention interval. Berman et al. (2009) claimed that interference is more important than decay. Short-term memory performance on any given trial was disrupted by words presented on the previous trial. Suppose this disruption effect occurred because the words from the previous trial had not decayed sufficiently. If so, disruption would have been greatly reduced by increasing the time interval between trials. In fact, increasing the intertrial interval had no effect on performance. However, the disruption effect was largely eliminated when interference from previous trials was reduced. Campoy (2012) pointed out that Berman et al.'s (2009) research was limited. Their experimental design did not allow them to observe any decay occurring within 3.3 seconds of an item being presented. Campoy discovered there were strong decay effects at time intervals shorter than 3.3 seconds. Thus, decay occurs mostly at short retention intervals and interference at longer ones. Is short-term memory distinct from long-term memory? If they are separate, there should be some patients with impaired long-term memory but intact short-term memory and others showing the opposite pattern. This would produce a double dissociation (see Glossary). The findings are generally supportive. Patients with amnesia (discussed in Chapter 7) have severe long-term memory impairments, but typically have intact short-term memory (Spiers et al., 2001). A few brain-damaged patients have severely impaired short-term memory but intact long-term memory. For example, KF had no problems with long term learning and recall but had a very small digit span (Shallice & Warrington, 1970). Subsequent research indicated that his short-term memory problems focused mainly on recall of letters, words or digits rather than meaningful sounds or visual stimuli (e.g., Shallice & Warrington, 1974). Evaluation The multi-store approach has various strengths and has had enormous influence. It is still widely accepted (but see below) that there are important conceptual distinctions between three kinds of memory stores. Several kinds of experimental evidence provide strong support for the crucial distinction between short-term and long-term memory. However, the strongest evidence probably comes from brain-damaged patients having impairments only to short-term or long-term memory. What are the model's limitations? First, it is very oversimplified. It is assumed the short-term and long-term stores are both unitary, that is, each store always operates in a single, uniform way. Shortly we will discuss an approach in which the single short-term store is replaced with a working memory system consisting of four components. In similar fashion, there are several long-term memory systems (see Chapter 7). Second, it is assumed the short-term store acts as a gateway between the sensory stores and long-term memory (see Figure 6.1). This is incorrect, because the information processed in short-term memory has already made contact with information in long-term memory (Logie, 1999). Consider our ability to rehearse "IBM" as a single chunk in short-term memory. We can do this only because we have previously accessed relevant information in long term memory. Third, Atkinson and Shiffrin (1968) assumed that information in short-term memory represents the "contents of consciousness". This implies that only information processed consciously can be stored in long-term memory. However, implicit learning (learning without conscious awareness of what has been learned) appears to exist and leads to long-term memory (see later in the chapter). Fourth, the assumption that all items within short-term memory have equal status is incorrect. In fact, the item currently receiving attention can be accessed more rapidly than the other items in short-term memory (McElree, 2006). Fifth, it was assumed that most information is transferred to long-term memory via rehearsal. This greatly exaggerates the role of rehearsal – only a small fraction of the information we have stored in long-term memory was rehearsed during learning.

Unitary-store model

Jonides et al. (2008) argued that the multi-store model should be replaced by a unitary-store model. According to the unitary-store model, "STM [short term memory] consists of temporary activations of LTM [long-term memory] representations or of representations of items that were recently perceived" (Jonides et al., 2008, p. 198). Such representations are especially likely to occur when they are the focus of attention. Atkinson and Shiffrin (1968) emphasised the differences between short-term and long-term memory, whereas advocates of the unitary-store approach focus on the similarities. There are certainly close links between short-term and long-term memory. For example, word span is approximately seven words if the words are random. However, it can be 20 words if the words form sentences (Simon, 1974). This enhanced word span involves forming large chunks (integrated units), which depends heavily on long-term memory. How can unitary-store models explain amnesic patients having essentially intact short-term memory but severely impaired long-term memory? Jonides et al. (2008) argued that they have special problems in forming novel relations (e.g., between items and their context) in both short-term and long-term memory. Amnesic patients perform well on short-term memory tasks because such tasks typically do not require storing relational information. Thus, amnesic patients should have impaired short-term memory performance on tasks requiring relational memory. According to Jonides et al. (2008), the hippocampus and surrounding medial temporal lobes (damaged in amnesic patients) are crucial for forming novel relations. Multi-store theorists assume these structures are much more involved in long-term than short-term memory. However, unitary-store models predict the hippocampus and medial temporal lobes would be involved if a short-term memory task required forming novel relations.

Findings

Much relevant research involves amnesic patients with damage to the medial temporal lobes including the hippocampus (although other brain areas can be damaged). As predicted by the unitary-store approach, such patients often perform poorly on memory tasks with a fairly brief interval between study and test (Jeneson & Squire, 2012). In one study (Hannula et al., 2006), scenes were presented and then repeated exactly or with one object having been moved spatially. Amnesic patients with hippocampal damage and healthy controls decided whether each scene had been viewed previously. Amnesic patients performed worse than controls even with a very short retention interval, suggesting the hippocampus is needed even for relational short-term memory. However, long-term memory may have been involved in the Hannula et al. study. Jeneson et al. (2011) used a similar task (but with reduced memory load to minimise the involvement of long-term memory). Amnesic patients (all with hippocampal damage) had comparable memory performance to controls. Thus, the hippocampus is not essential for good relational short-term memory. Several neuroimaging studies have reported hippocampal involvement in short-term memory (Jeneson & Squire, 2012). However, it has generally been unclear whether hippocampal activation was due in part to encoding for long-term memory. An exception was a study by Bergmann et al. (2012), who assessed short-term and long-term memory for word pairs. The key evidence related to brain activation when short-term memory for word pairs was successful but subsequent long-term memory was not. Learning of these word pairs was not associated with hippocampal activation.

Clarification of the brain areas involved in short-term memory was obtained by Race et al. (2013). They assessed face recognition memory with an eight-second retention interval in amnesic patients and healthy controls. Patients with brain damage limited to the hippocampus had intact memory performance, whereas those with more extensive damage to the medial temporal lobes had impaired memory performance (see Figure 6.2).

Evaluation

As predicted by unitary-store models, activation of part of long-term memory typically plays an important role in short-term memory. There is also some (controversial) support for the notion that forming novel relations in short-term memory may involve the hippocampus. More promisingly, related areas of the medial temporal lobes may be involved in short-term as well as long-term memory (Race et al., 2013). What are the limitations of the unitary-store approach? First, it is oversimplified to argue that short-term memory is only activated long-term memory. We can manipulate activated long-term memory in flexible ways going well beyond simply activating part of long-term memory. Two examples are backward digit recall (recalling digits in the opposite order to the one presented) and generating novel visual images (Logie & van der Meulen, 2009). Second, most studies on amnesic patients suggest hippocampal involvement is far greater in long-term memory than short-term memory. Such findings are more consistent with the multi-store approach than the unitary-store approach. Third, the findings of neuroimaging studies are not supportive of the unitary-store approach. There is little evidence of hippocampal involvement when attempts are made to separate out short-term and long-term memory processes (e.g., Bergmann et al., 2012).