# 10

## *Memory Retention and Recall Process*

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### 10.1 Introduction

Our knowledge is a collection of our experiences, which expands daily as we experience new things. The way we imbue our surroundings and ourselves with meaning depends on the knowledge and understanding we have, and this knowledge depends on our memorization of what we have learned.

In daily life, we take in new information and store it in our brain, maintaining it and recalling it depending on our needs. This happens because our brain has the capability of learning new skills and experiences, storing what has been learned and reusing the stored knowledge. These capabilities of storing and reusing experiences and skills are informally known as the human memory system. Everything we do or think depends on our memory, which is active every moment, receiving new information from our senses, updating existing knowledge using focus and attention, retrieving the stored experiences and skills, and planning for future activities that have not occurred yet. Thus far, neuroscientists have been expecting to find specific stores of memory in the brain and discover their exact location to know which type of memory lies where. Unfortunately, because of the great complexity of the human brain system (Figure 10.1 [1]), this concept has not been proved. However, some cognitive and mental functions are found in certain brain areas.

Generally, there are two different memory types—short-term and long-term memory—that store and access information differently, and many brain regions are involved in the process. Short-term memory retains information for a few seconds, and its capacity ranges from seven to nine items for a normal person. It tends to weaken as the individual's age increases. Long-term memory retains unlimited information for an infinite duration. The information could be personal events, temporal and spatial relations among these events, and real-world entities and their meaning such as symbols, words, and concepts. There are three fundamental memory processes: encoding, retention, and recall. Encoding allows converting the perceived information

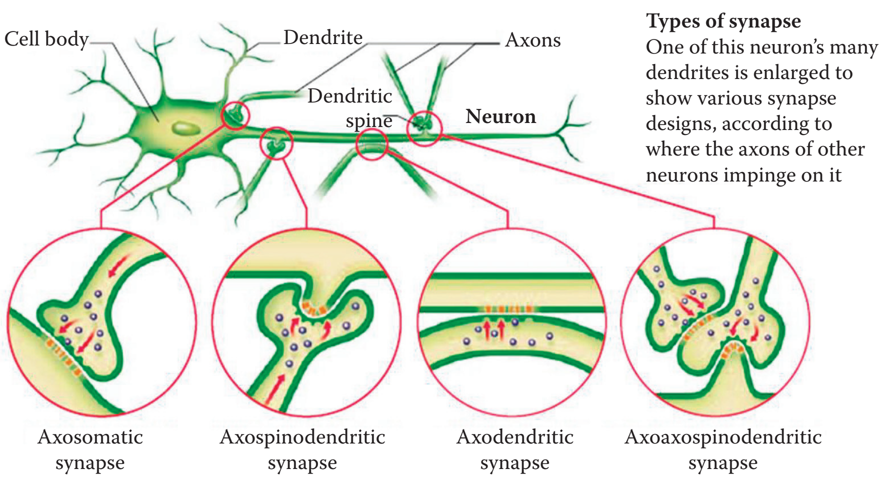


**FIGURE 10.1**
Neuronal communication in brain. (From Carter, R. et al. *The Human Brain Book*. London: Dorling Kindersley Publisher, 2009.)

of interest into a construct that can be retained in the brain. It is the first stage of creating a new memory in the brain. Retention is the storage of encoded information in the brain. Retrieval or recall is the re-accessing of retained events or information in the brain. A part of encoding or retention is memory consolidation, which stabilizes a memory trace after its initial formation. Neurologically, the consolidation process employs long-term potentiation; it strengthens the synapses by increasing the number of signals that are sent and received between the two neurons.

Scientists utilized different neuroimaging techniques to view these processes such as electroencephalography (EEG), functional magnetic resonance imaging (fMRI), magneto-encephalography (MEG), positron emission tomography (PET), etc. This chapter will focus on recent studies utilizing EEG for the two important memory processes: (1) retention and (2) recall, by focusing on their neurophysiological understanding and studying the factors that affect the retention and recall performance. The following sections will describe the traditional cognitive and memory theories of memory processes, the brain regions associated with memory functions, the neural understanding of retention and recall, applications and, finally, the conclusions.

## 10.2 Overview of Traditional Approaches

### 10.2.1 Atkinson and Shiffrin Memory Model (1968)

Richard Atkinson and Richard Shiffrin proposed a multi-store human memory model (see Figure 10.2 [2]) that divided the human memory into three distinct stores: sensory memory, short-term memory (STM), and long-term memory (LTM). This model has many limitations and has attracted much

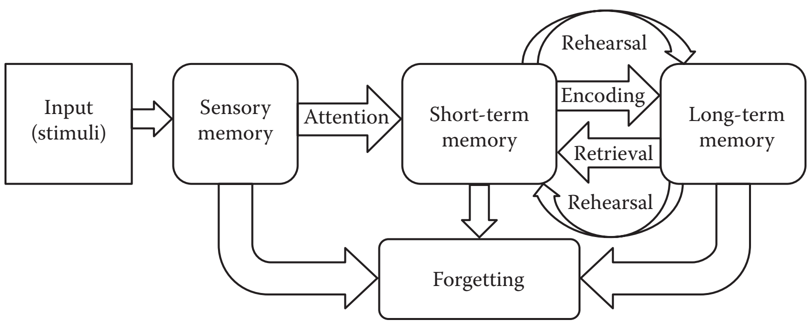


**FIGURE 10.2**
Atkinson and Shiffrin memory model. (From Atkinson, R. C. and Shiffrin, R. M. *The Psychology of Learning and Motivation*, 2, 89–195, 1968.)

criticism such as an ill-defined concept of the rehearsal buffer, presence of a single short-term store, and incorrect prediction of total recall probability in free recall [3]. However, it is still useful for researchers, who can propose new models based on this model.

### 10.2.2 Dual Coding Theory of Memory (1971)

Allan Paivio [4] developed dual coding theory in 1971. According to this theory, "human cognition is unique in that it has become specialized for dealing simultaneously with language and with nonverbal objects and events." This theory categorizes the process of intelligence and memory into two separate subsystems: verbal and nonverbal (imagery) systems. The verbal system is specialized for handling the language directly, while the imagery system is specialized for handling visual objects and events.

Although this theory was strongly criticized conceptually and was experimentally refuted, it initiated research on verbal and visual effects on memory.

### 10.2.3 Baddeley's Model of Working Memory (1974)

Alan Baddeley and G. Hitch proposed a working memory model to describe more accurately the concept and model of the short-term system in Atkinson and Shiffrin's memory model. This model consists of three main parts: (1) the central executive, (2) the phonological loop, and (3) the visuospatial sketchpad. It proposes the concept of two independent short-term memory storage subsystems: the phonological loop, for verbal information storage, and the visuospatial scratchpad, for visuospatial information storage (see Figure 10.3 [5]). The central executive controls both the subsystems and deals with cognitive tasks such as problem solving and mental arithmetic.

Baddeley and Hitch's original working memory model also attracted much criticism, which led to the exploration of the episodic buffer [6] in the original

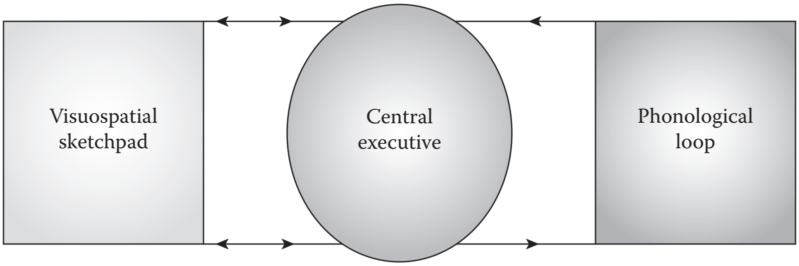


**FIGURE 10.3**
Baddeley and Hitch working memory model. (From Baddeley, A. D. and Hitch, G. Working memory. *The Psychology of Learning and Motivation*, 8, 47–89, 1975.)

WM model. However, this model is very critical to understand how the human mind manipulates and retains information during problem solving, reasoning, and thinking. Davidson et al. investigated cognitive control and executive functions for memory manipulation and inhibition in the visual switching task. They stated that "the mind has the ability to recollect plan and other things related to the present, future, and past" [7]. The episodic buffer organizes the arrangement of verbal sentences with the help of the phonological loop into a coherent sequence along with memory. For example, when people are involved in mutual dialogue, their brain responds by keeping track of what has been said, and their assumptions about what different speakers intended by their explanations.

### 10.2.4 Cognitive Load Theory (1988)

This theory took shape from the idea of working memory's limited capacity and its operations. John Sweller developed cognitive load theory [8,9] when studying problem-solving strategies. This theory is concerned with the way cognitive resources are focused and utilized while learning and solving problems. It encouraged learners to utilize working memory efficiently while solving difficult tasks. It has implications in the designing of learning material to reduce cognitive load such as multimedia content for learning.

### 10.2.5 Cognitive Theory of Multimedia Learning (1999)

Richard E. Mayer [10] proposed modality principles stating that when verbal and imagery content are presented together to a learner, they are processed along two distinct channels (see Figure 10.4). These principles are known as the cognitive theory of multimedia learning.

This theory combines several other concepts such as dual code theory, working memory limitation, connections between text-based and image-based

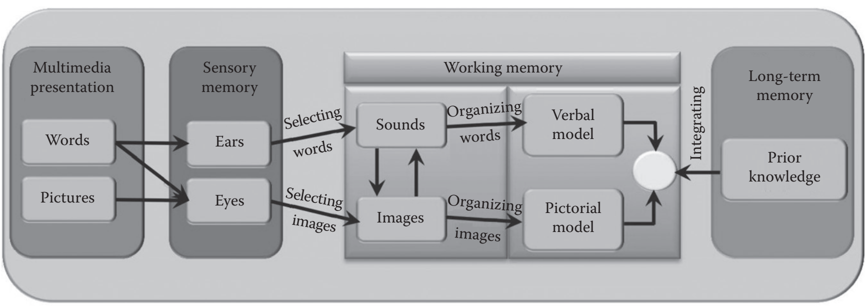


**FIGURE 10.4**
Cognitive theory of multimedia learning. (From Moreno, R. and Mayer, R. E. *Journal of Educational Psychology*, 91, 358, 1999.)

**TABLE 10.1**

Summary of Traditional Models

| Model | Main Objective | Strengths | Weaknesses |
|---|---|---|---|
| Atkinson and Shiffrin Memory Model [3] | Multi-store memory system | It provides the basis for other theories.<br>It explores the distinction between STM and LTM memory stores.<br>It emphasizes the effect of rehearsal on memory recall. | There is a lack of emphasis on unconscious processes.<br>Intermediate-level activation between STM and LTM is missing; absence of memory subsystems.<br>The effect of rehearsal is overstated. |
| Dual-coding theory of memory [4] | Verbal and nonverbal information processing | It explains human behavior and experience in terms of verbal and imagery representation. | It does not consider the likelihood of cognition being mediated by routes other than words and images. |
| Baddeley's model of working memory [11] | Concept of working memory | It is applicable in everyday experience of processing information during problem solving.<br>Rehearsal is not necessary to remember and recall all types of information. | The functions and capacity of central executive system are not clearly described and difficult to determine in practice. |
| Cognitive load theory [8] | Efficient use of working memory during problem solving | It identifies the methods to reduce extraneous cognitive load in learning.<br>It initiates research on effective instructional design strategies. | When material is presented in a way that does not relate to actual performance, then transfer of learning will be more challenging. |
| Cognitive theory of multimedia learning [10] | Learning from multimedia content | It suggests five principles for designing multimedia instructions that lead to learning that is more effective. | It is based on multimedia technology, which has a tendency to overwhelm the brain, and needs to be designed more effectively. |

representation, and transfer of information from long-term to working memory while performing any task. Table 10.1 presents a summary of these theories with their strengths and weaknesses.

## 10.3 Understanding Memory Retention and Recall

Human memory processes can be classified as the ability of the mind to understand, retain, and successfully recall information. The role of retention is to store encoded events and information, and the role of recall is to re-access the retained events and information in the mind in response to external stimuli. Although memory is achieved in multiple phases, recall is the only way to measure memory performance. How much information is encoded? How much information is retained? How much information is retrieved? What is the memory performance? All these questions can be answered in the memory recall phase by asking someone questions and recording their recall responses. The correct responses will indicate the *memory performance*, *retained information*, or amount of *encoded information*.

Memory is closely related to the learning process, which is concerned with acquiring skills or knowledge. Memory is also the representation of learning that has been acquired. Various brain parts are involved in learning and the memory formation process, and different mental and physical factors are reported that influence memory retention and recall performance. These brain areas and the factors that affect retention and recall performance are discussed in the subsequent sections.

### 10.3.1 Brain Areas Associated with Memory Functions

Many areas of the brain are associated with memory and memory processes, including the cerebral cortex of the frontal, parietal, and temporal lobes; the hippocampus; the amygdala; and the diencephalon (Figure 10.5).

Loss of the hippocampus leads to an inability to encode short-term memory to long-term memory. The causes of memory loss may be trauma, injury, stroke, disease, drugs, etc.

#### *10.3.1.1 Cerebral Cortex*

The outer covering of gray matter on the hemispheres is the cerebral cortex. It is a thin layer of tissue and covers the outer portion of cerebrum up to 5 mm. It consists of 19% of all the brain cells (approximately 86.1 (±8.1) billion neurons) [12],

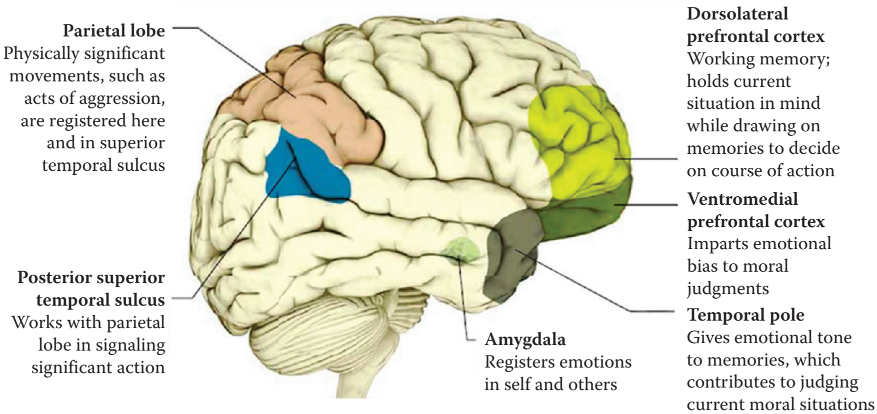


**FIGURE 10.5**
Brain regions associated with memory functions. (From Carter, R. et al. *The Human Brain Book*. London: Dorling Kindersley Publisher, 2009.)

which are organized into a complex neural network of synaptic connections and develops the distributed connections among the specialized brain system. It is divided into four lobes: the frontal, central, parietal, temporal, and occipital lobes, which are responsible for specific functions such as thinking, reasoning, decision making, perception, movement, touch, smell, vision, listening, attention, memory, and emotion. Some cortical regions are specialized for certain functions, and some cortices are associated with more complex functions, including working memory, emotion, attention, judgment, etc. The main functions of the frontal lobe include problem solving, reasoning, planning, memory, and decision making. It is experimentally proved that this lobe is primarily responsible for dealing with working memory and information processing in connection with other task-specific brain regions [11].

The parietal lobe is responsible for spatial orientation, pain and touch sensation, and cognitive functions. The posterior parietal cortex has been associated with memory retrieval, especially in episodic memory: personal experiences occurring at a certain time and place [13]. Several fMRI studies have investigated the intra-parietal sulci in memory encoding and retrieval, and their results reflected parietal activation in the memorization process and engagement of the brain attentional network [14]. Temporal lobes are involved in auditory, emotional, speech, language, learning, and memory related functions. High gamma activity in the left temporal cortical region has discriminated true from false memory responses [15] in memory retrieval tasks. The primary visual cortex in the occipital lobe is responsible for processing visual information received from the eyes through the thalamus. The entire cerebral cortex is linked directly or indirectly in memory processes: encoding, retention, and retrieval.

#### *10.3.1.2 Hippocampus*

The hippocampus is a part of the limbic system, which lies inside each temporal lobe. It is located along the upper edge of the parahippocampal gyrus. It interlocks with the dentate gyrus and forms the hippocampal–dentate complex. It is responsible for spatial navigation, particularly the encoding of new information from short-term to long-term memory, and the retrieval of long-term memories. Karlsgodt et al., [16] showed an fMRI study that used a verbal working memory test. In encoding, maintenance, and recall, a within-subject comparison of functional activation suggested that the hippocampus had a role in working memory similar to its role in long-term memory, implying that the hippocampus might be involved in overall encoding and recalling rather than just in long-term memory tasks.

#### *10.3.1.3 Amygdala*

The amygdala is an almond-shaped nuclei located in the deep anterior inferior medial temporal lobe near the hippocampus and holds 13 nuclei, each of which has other subsystems. It is associated with many functions in the

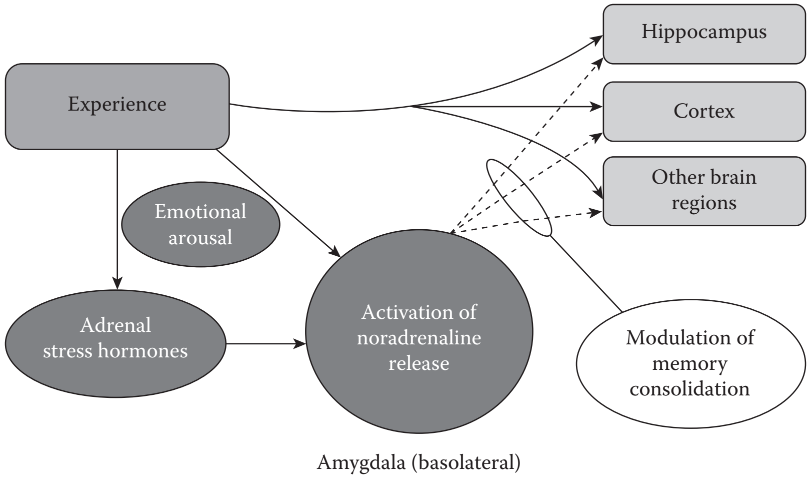


**FIGURE 10.6**
Amygdala activation modulates memory consolidation. (From McGaugh, J. L. *Trends in Cognitive Sciences*, 10, 345–347, 2006.)

brain, such as fear and anxiety, emotional and social impact of the environment, support for memory storage across multiple brain regions, and regulation of automatic responses. It consists of three classes of nuclei: baso-lateral, superficial, and centromedial. This classification is not consistent with all amygdala-anatomy-related studies. The input signals to the amygdala from the cortex, thalamus, hypothalamus, and brain stem include olfactory, somatosensory, gustatory, auditory, and visual information.

The amygdala itself is not a storage place for memory, but influences the consolidation and acquiring of memories in various learning situations in the brain, such as interactions with the hippocampus in emotional memory [17], involvement in memory storage in other brain systems [18], drug addiction memory [19], reward expectancy [20], and spatial learning [21]. Several other studies have reported that emotional arousal stimulates the amygdala and has modulatory effects on memory; for example, neuroimaging studies investigated the positive association between emotional memory retention and the amygdala activation during learning [22]. These studies clarify the role of the amygdala in memory consolidation (Figure 10.6) via projections to other brain memory system [23], especially in emotional memory.

### 10.3.2 Long-Term Potentiation and Memory Retention

In neuroscience research, it is a significant challenge to find the cellular and molecular processes involved in the process of learning and creating new memories. New information is acquired through the learning process, and memory is the route by which the acquired information is stored. Memory formation is dependent on neuronal changes at the synaptic level that allow strengthening of connections between neurons in the brain [24]. It is believed that task-dependent synaptic plasticity at the corresponding synapses during the formation of new memory is crucial and is sufficient to store information. This phenomenon of activity-dependent enhancement of synaptic transmission, which facilitates long-term information in the brain, is known as long-term potentiation (LTP). For further reading about the properties and detailed mechanism of LTP, see Ref. [25].

### 10.3.3 Factors Affecting Memory Retention and Recall

Cognitive research studies [26–28] have emphasized that retention and recall processes are related to one another and also are connected with other concepts such as learning, testing, capacity limit of memory, attention demand, and complexity of material. However, there are many other factors that affect retention and recall performance, such as attention, rehearsal, sleep, testing, mnemonics, exercise and nutrition, and reward. The conventional concept of learning and retrieval is that learning takes place during studying, while retrieval helps to assess the learned content.

#### *10.3.3.1 Attention*

As human memory has a limited capacity, it is crucial to determine the information of interest to be encoded and subsequently retained. Attention helps the brain to encode items selectively into memory. Recent studies have established a link between attention and memory processes. In an experiment, it was established that attention-directing cues can influence the collection of objects from visual memory [29]. Another study concluded that attention and memory cannot work separately [30], but it improves memory performance. Dividing attention may reduce the strength of retention. A recent study investigated long-term memory retention with full and divided attention. They found superior results with full attention as compared to divided attention during the memory recognition task [31]. A similar study examined the relationship between attention and memory processes and reported a strong association between attention and retention in working memory [32]. These studies established a strong association between attention and memory retention and the recall process.

#### *10.3.3.2 Rehearsal*

Rehearsal is the repeated reception, verbally or visually, of the same content, events, or information. According to the phonological loop model [33], verbal information is maintained in the phonological loop, but declines after a moment unless rehearsed. However, some studies have reported that rehearsal does not improve in the word length in a serial recognition memory task [34]. It can be concluded that rehearsal may not improve memory recall in each task.

#### *10.3.3.3 Sleep*

The association between sleep and memory has been studied for the last few decades, but it is now well established that sleep plays an important role in the memory consolidation process [35], which is a part of retention or the encoding process. There is electrophysiological and behavioral evidence to prove that sleep helps memory consolidation and brain plasticity. Frank and Benington [36] reviewed the role of sleep in memory consolidation and found that sleep promotes plastic changes in the brain. They divided the link between sleep and memory into three categories: sleep deprivation and memory consolidation, their correlation, and its effect on learning. Recently, Bell et al. [37] investigated the impact of sleep and spacing gap on long-term memory. Their results support the positive effects of sleep on long-term memory retention.

#### *10.3.3.4 Exercise and Nutrition*

Studies have reported the benefits of exercise in individuals whose cognitive performance is lowest [38]. The results showed that exercise improves memory performance in those individuals whose cognitive score in working memory was the lowest (see Figure 10.7).

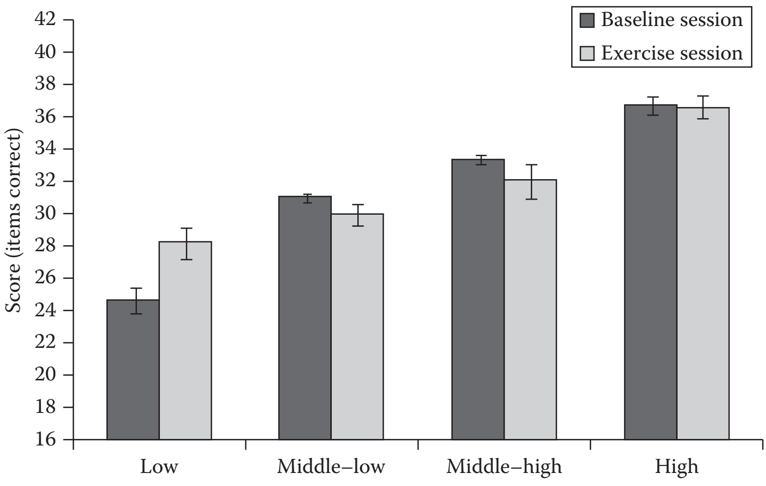


**FIGURE 10.7**
Memory performance for baseline and exercise sessions for four groups (low quartile, middle–low quartile, middle–high quartile, high quartile). (From Sibley, B. A. and Beilock, S. L. *Journal of Sport and Exercise Psychology*, 29, 783–791, 2007.)

The effects of nutrition and exercise on verbal memory were studied for type 2 diabetic old age participants, and positive results were reported. This study showed that exercise and nutrition may help memory for old adults at high risk of developing type 2 diabetes [39]. The reason for this finding may be that diet and exercise affect neurotropic elements and synaptic plasticity in the brain's regions, which are directly related to memory.

#### *10.3.3.5 Mnemonics*

Mnemonics is a mental technique that helps the brain remember information easily by associating the memories with some other keywords such as letters, images, or numbers. Several mnemonic techniques are available that help remember various pieces of information easily, including acronyms, acrostics, method of loci, chunking, rhymes and songs, stories, etc. [40].

#### *10.3.3.6 Testing Effect*

In educational systems, the theory of studying and testing is followed. Learning occurs during lectures, reading, and study groups. Tests have been designed to judge what has been absorbed or learned by studying. These tests are considered assessments or evaluations of learned knowledge. Researchers studied learning by trials of study (S) and a test (T). The critical supposition is that learning occurs through study phases, while a test simply measures what was learned in previous study phases (of STSTST … order). Recently, a study of reviewed evidence opposes this conventional perception: retrieval exercises during tests have often resulted in better learning and long-term retention than has studying [41].

In related studies, Roediger and colleagues [27,41,42] investigated the link between retention and learning with repeated testing, and they proposed that the repeated recalling of retained information led to better learning and long-term retention. In one experiment, participants were given a list of items to study under two different conditions. In one condition, the list was studied 15 times and tested 5 times, while in the other condition the list was studied 5 times and tested 15 times. A retrieval task after one week showed better learning and retention results in the repeated test condition as compared to the repeated study (see Figure 10.8).

In another study, they investigated the retention performance between repeated retrieval and single retrieval conditions. The results showed a very high improvement in the repeated retrieval condition as compared to the single retrieval condition (see Figure 10.9).

These studies explained that testing/retrieval is a powerful technique of enhancing memory retention and recall performance. The implications of these are that students should test themselves repeatedly instead of studying the content frequently. However, feedback should be included in the frequent testing technique to avoid errors.

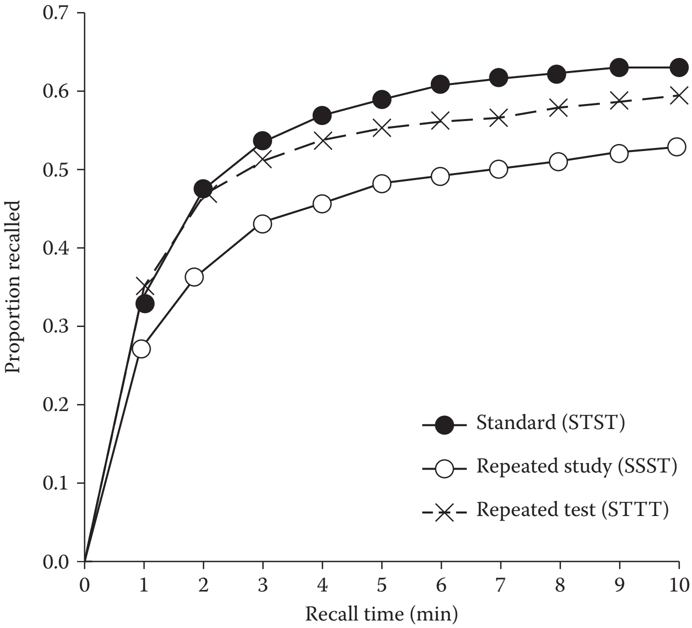


**FIGURE 10.8**
Retention performance of repeated recall versus repeated study. (From Karpicke, J. D. and Roediger, H. L., III. *Journal of Memory and Language*, 57, 151–162, 2007.)

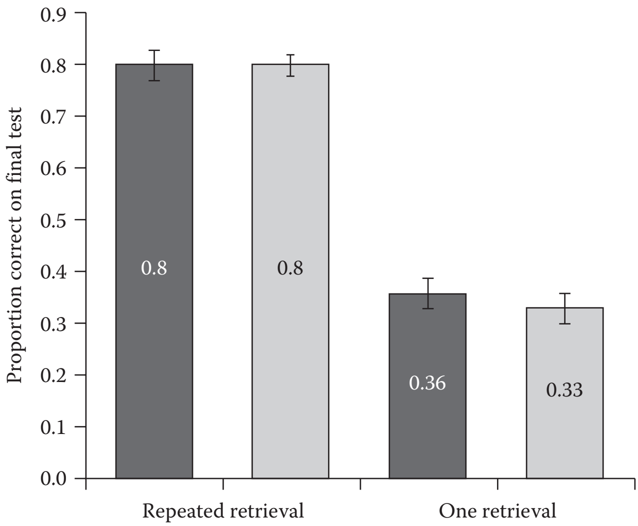


**FIGURE 10.9**
Correct memory recall performance of repeated versus single test. (From Karpicke, J. D. and Roediger, H. L., III. *Science*, 319, 966–968, 2008.)

#### *10.3.3.7 Reward*

Researchers investigated the process of reward and punishment stimuli and the neural understanding of reward processing in the brain. A recent study [43] reported that training under reward conditions results in substantial long-term retention, whereas training under neutral conditions showed a significant decline in memory gain. The research found reward-based training and learning more effective than neutral or punished conditions.

The effectiveness of all these techniques for memory retention and recall processes is experimentally proved. However, one technique may not give good results in all situations. Table 10.2 summarizes the factors that influence memory retention and recall performance with the underlying reasons.

**TABLE 10.2**

Summary of Factors Affecting Memory Retention and Recall

| Factor | Affects | Reasons |
|---|---|---|
| Attention [30] | Full attention enhances memory recall and longer retention. Partial attention results in reduced recall performance. | When attention is divided, the limited capacity of working memory cannot accommodate the desired information and the result is partial memory consolidation, which ultimately reduces recall performance. |
| Rehearsal [44] | Frequent rehearsal improves recall performance. | Frequent rehearsal strengthens the synaptic connections among the neurons involved in a certain task, and stronger synaptic connections support better subsequent information recollection. |
| Sleep [45] | Sleep promotes brain plasticity and memory consolidation. | It remains to be determined how sleep produces neuronal changes that affect the consolidation process. |
| Exercise [38] and nutrition [39] | Exercise and nutrition offer benefits for mental health and affect neurotransmitters. | Nutrition and regular exercise influence neurotrophic elements and plasticity in brain regions related to memory performance. Further, for the elderly, regular exercise and balanced nutrition prevent the brain from shrinking and maintain memory. |
| Mnemonics [40] | Mnemonics helps encode difficult-to-remember information in such a way that it becomes much easier to recall correctly. | It strengthens network interactions and makes it easy to retain and retrieve difficult information. |
| Testing effect [41] | Testing allows recalling stored information from memory. It also minimizes the errors in the recall result and helps to retain correct information. | Repeated testing allows the same neurons involved initially in learning to fire repeatedly. The neuronal networks become more stable and synchronized, and recollection of stored information becomes easy. |
| Reward [43] | Reward-based training or learning leads to better results than nonreward learning or punishment situation. | Rewards may attract more attention during a certain task and maintain neuronal connections, which result in stable memory performance. |

## 10.4 Experimental Design Issues

Various practical, theoretical, and ethical issues have been cited in the literature about memory research. Recently, common design issues of neurocognitive research have been highlighted [46,47]. Here, we summarize all the possible memory experimental design issues which are normally not given explicit importance, but are sensitive to the results of the experimental investigations.

Aim: When designing a memory experiment, the aim of the experimenter should be well defined. If the investigator is going to study the cognitive load, retention time, reaction time, recall performance, modality effect, short-term memory, long-term memory, recognition memory, and verbal or visual memory, the experiment must reflect the aim.

Task Simplicity: Although complex tasks have been used to examine cognitive load and brain processing speed, extreme complications in shorter time interval tasks may confuse the subject. It is better to avoid complexity from the experimental task and specify it as per memory type, subject health and age, and the nature of the memory.

Memory type: Researchers discriminate between memory types: short-term memory or working memory and long-term memory, on the basis of their capacity, retention length, and processing power. In memory experimental design, memory types are as essential as other experimental parameter specifications.

Memory modality: Visual and auditory are the two main memory modalities. The brain separately processes the information received from visual and auditory sources, and the capacities differ between visual memory and auditory memory. In designing an experiment, it should be considered that the experimental task with both modalities may have high cognitive load compared to the task with a single modality.

Specific Brain: Brain diseases such as Alzheimer's, brain tumor, depression, and Parkinson's affect different brain regions. Researchers have considered unusual tasks that focus on the affected brain part. If subjects are suffering from any brain disorder, the experimental task should be revised in consultation with area experts to handle the target subjects.

Subjects' characteristics: Individuals or volunteers who participate in the experiment are collectively called the sample. The individualities of a sample may be normal or patients, old or young, adolescent or children, and male or female. These individual differences need to be considered in task design to start the memory investigation.

Brain mapping method: Various brain-mapping methods are available such as EEG (invasive/non-invasive), fMRI, MEG, and PET. Each method has its own strengths and weaknesses. However, the choice of method depends on equipment availability, and the experimental design should be flexible to coordinate and overcome the limitation of the selected brain mapping method.

Predefined memory paradigm: Several predefined memory paradigms are available [47]. In order to use the existing available paradigm, one must be able to identify the memory paradigm that best reflects a subject's responses.

Experiment duration: The duration of the experimental task tends to vary depending on the study objectives. However, patients may feel anxiety while taking part in a prolonged experiment. This affects the patients' attention and interest in the experiment and eventually disturbs the desired consequences. The experimental task duration can be specified according to patients' health, the research aim, and the selected modality.

Consent: In memory research, the subject's consent is an important issue. The research study and designed task should meet the regional, legal, and ethical laws and should protect patients' well-being, mental privacy, and self-incrimination.

## 10.5 Summary

In this chapter, we have presented an overview of traditional theories of memory types and memory processes. We have focused on two important memory processes: retention and recall. The traditional theories explored short-term and long-term memory storage, working memory phenomena, verbal and nonverbal information processing, efficient use of cognitive capacity, and brain dual channels information processing of visual and verbal data. All these theories have their own distinctions. However, they are linked with each other and have important contribution in today's memory research.

Brain regions, especially the cerebral cortex, hippocampus, and amygdala have been strongly linked with memory processes. The cerebral cortex in the frontal, parietal, and temporal lobes contributes to working memory, episodic memory, and correct memory retrieval, respectively. In the medial temporal lobe, the hippocampus is the region for memory encoding and formation of new memory or transfer of information from short-term to long-term storage. The amygdala is the hub of emotional memory representation: fear, sadness, happiness, and other emotion-related events are associated with amygdala activation.

The process of long-term potentiation has a significant role in learning and new memory formation; the strong and weak memory depends on the synaptic communication network strength. Strong synaptic links have a high probability of storing new information and correct recall.

Various factors have been investigated, which have contributed to retaining more information and recall after a longer time. Many of them (such as attention, sleep, rehearsal, etc.) have been experimentally proved, such as their crucial role in utilizing the limited working memory capacity and learn more information, and transfer to long-term storage. Not all of these factors may be in support of high retention or recall. However, each of them has its own contribution in certain scenario.

In the end, various issues regarding memory experimental design were summarized. As a whole, these issues may be useful to consider in designing a memory experiment, especially for new researchers in memory research.

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