Proceedings of ICEIPI 2026 Symposium: Psychological Resilience, Motivation, and Well-Being in Educational Contexts
DOI: 10.54254/2753-7048/2026.NS35037

Secrets Behind Memory: Theories about Memories Which Relevant to Learning

Ganping Zhang

School of Psychology, Jiangxi Normal University, Nanchang, China
shanshuiheliu@126.com

Abstract. This is a review about several theories about memory, which tells us what researches and memories could involve with learning process. Ebbinghaus spaced practice effect could reduce the forgetting process, Method Of Loci (MOL) could use as a efficient memorize strategy, Levels of Processing (LOP) showed us how to process our memory more effective, Encoding Specificity Principle showed us how we encode the information we have received and what to do with improving this encoding process for a better recall performance, and research about eyewitness memory showed us that our memory is not as reliable as we thought, in fact, it can be influenced by several factors like trauma or stress. This review also includes some ideas about how to combine these classical theories with some ideal educational cases, which could suggest the educators some constructional solutions for predictable difficulties. This review also tries to discover the truth under memory theories development and possible relevance between these classical researches.

Keywords: Memory, Learning strategies, review

1. Introduction

Study, is a classical strategy to develop any personality and life-long skills of any individuals, which brings a commonplace theme? What is the most critical factor of studying? Beyond those various of studying skills, a better memorize performance could be another possible answer for the question above. From all over the world, scientists have already introduced or discovered thousands of theories to describe or explain the truth of memory. Which inspired biologists, physicians and even psychologist made their effort on discover the secret of memory.

For the recent decades, the competition between nations and its people has become sharper and hotter. A little advance beyond the competitors always become a great lead when this crossing era is approaching. Basically, the critical factor of social development can be conclude as education and economy while education could somehow determines what the quality of future development could be. This series of classical research and theories could do some help for those who has the need for improving the learning performance or needs to deal with memory problem or challenge but don't know where to start with.

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2. Ebbinghaus spaced practice effect

2.1. Definition and phenomenon

The spaced practice effect was first identified by Hermann Ebbinghaus, which suggests that active recall with increasing time intervals reduces the probability of forgetting information. From 1880 to 1885, Hermann Ebbinghaus' ran a limited, incomplete study on himself and published his hypothesis in 1885 as Memory: A Contribution to Experimental Psychology [1].

In this study, he studied the memorization of nonsense syllables and the rate of forgetting, and developed a graph called the "forgetting curve".

As soon as he came up with some basic training in increasing the strength of memory, one of the techniques he developed was spaced repetition. He discovered that the forgetting curve was flattened by every repetition and each repetition in learning increases the optimum interval before the next repetition.

2.2. Relevant researches of spacing effects

An article published by University of Illinois Press discussed the spacing effect in long-term retention tests [2]. He discovered that the spacing effect is robust for items presented twice after a 24-hour delay in testing but present in studies 4~6 times and tested after 24-hour delay.

Moreover, some research from 1993 to 2002 has shown reliable spacing effects in cued-memory tasks under incidental learning conditions, where semantic analysis is encouraged through orienting tasks [3]. However, no spacing effect was found when the target words were shallowly encoded using a graphemic study task. This suggests that semantic priming underlies the spacing effect in cued-memory tasks.

2.3. The real use of this phenomenon

In 2007, Rohrer from University of South Florida discussed the use of spaced practice in math education [4]. The study compared spaced practice with mass practice; spaced practice significantly improved performance. When students practice problems mixed randomly, they can even perform better.

In conclusion, we can randomly arrange our study schedule, and make sure the same type of knowledge can be practiced spaced. At the same time, we need to make sure each type of knowledge has been repeated four to six times every 24 hours.

3. Method of loci

Nowadays, college students have encountered many presentation tasks, which require students to finish a speech without any notes. But the slide is not always enough for students to recall what they need to say. Besides, the method of loci (MOL) is a interesting to help these students to achieve their goal.

3.1. What is MOL

Method of loci (MOL) is a strategy for memory enhancement, which uses visualizations of familiar spatial environments in order to enhance the recall of information. This method or strategy was first introduced by the ancient Romans, using this method as a mnemonic device.

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The items to be remembered in this mnemonic system are mentally associated with specific physical locations. The method relies on memorized spatial relationships to establish order and recollect memorial content. For example, you can build up a relation between your key point of your speech and the path you go to school.

3.2. The possible explanation and classical use

In a classic study in cognitive neuroscience, O'Keefe and Nadel proposed "that the hippocampus (an area of brain whose outline is like a seahorse) is the core of a neural memory system providing an objective spatial framework within which the items and events of an organism's experience are located and interrelated." [5]. This study could explain that the method of loci is somehow scientific-proved because the hippocampus is also known as the core of long-term memory. If the hippocampus could provide an objective spatial framework, then it could work if you memorize and recall something using details of places or roads connected to them.

In fiction, the detective Sherlock Holmes has been portrayed as using the Method of Loci – constructing a "memory palace" to enable his remarkable memory.

In reality, this method is extremely effective for some people in need, especially for those who participate in the World Memory Championship. For those memory champions, contestants combine this method with images so that it is possible to remember more than 1,000 digits in half an hour. For example, the "Memory Athlete" prepares hundreds of "Palaces", such as their childhood home, The path they take to work and even levels or achievements of video games. Then they would designate specific "loci" or stations in a fixed chronological order, just like Front Door, Hallway Rug and Coat rack.

3.3. Productive use

To use this method, we can follow these steps: First construct the palace, like a road to your school, or the path back to home. Second, order the stations in appropriate positions. Third, encoding, encode the material you need to remember, converting items into vivid images. Fourth, place these images in the palace. When you have to recall this information, just re-walk the route, and read out what you see.

4. Levels of processing framework

In the previous passages, we discussed how to form our memories more reliably based on study time and mental imagery. But the 'depth' at which we study information can also help us to retrieve it efficiently. The levels of processing theory explains why 'depth' matters [6].

4.1. Definition

The levels of processing model was created by Fergus I. M. Craik and Robert S. Lockhart in 1972, and describes memory recall of stimuli as a function of the depth of mental processing. It leads to a result that the deeper you process your memory, the more durable your memory trace, which means it's easier for you to recall your memory.

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4.2. Classical researches and its experimental process

In this model, Craik and Lockhart separated processing of verbal material you're trying to learn into 3 levels. The first is Structural or visual processing. At this level, humans will only focus on physical details of stimuli. For example, how to spell the word and what it looks like. The second level is phonemic processing, which means remembering the word by how the sound goes while reading it. For example, remembering that a stimulus word rhymes with another word, like tall and fall. The Third level is semantic processing. At this level, we may process the memory by encoding the meaning of the word with another similar word or making connections to some existing knowledge.

To verify this model, Craik & Tulving used an Orienting Task experiment [7]. They found some university participants and showed them a list of words. When the words showed up, there was also a set of yes/no questions designed to orient participants to process each word at different depths of processing.

The participants had to respond yes or no to the question as quickly as possible.

Structural questions: "Is the word 'table' printed in capital letters?"

Phonemic questions: "Does the word 'bird' rhyme with 'WEIGHT'?"

Semantic questions: "Would the word 'chair' fit in the sentence: 'He sat on the ____'?"

Then the participants were given an unexpected memory test. Using tests of recognition memory and free recall. In the recognition test, they presented a mixed list of old words and new words, and asked the participant to indicate which words they had studied. In the free recall test, participants were asked to write down as many words as they could remember from the earlier task.

The experiment provided strong evidence that the durability of a memory trace is a function of the depth of processing applied during encoding. Words studied in the Semantic orienting task were remembered better, on average, than words studied with shallower orienting tasks. Deeper, meaning-based processing creates richer, more stable memory traces than shallow, perceptual processing.

4.3. Educational use

Encoding new information while focusing on its meaning can help us remember it better. We can ask ourselves: What does this mean? Why is this true? How does this connect to what I already know? These three questions are an efficient way to ensure deep processing strategies, and encode information at the semantic level.

5. Encoding specificity principle

5.1. Definition

The encoding specificity principle is the general principle that matching the context in which information gets encoded with the context in which it gets retrieved can improve the retrieval of episodic memories. It was introduced by Thomson and Tulving who suggested that contextual information is encoded with memories which affects the retrieval process [8]. The context may refer to the physical location or surroundings, as well as the mental or physical state of the individual at the time of encoding.

5.2. Classical research and details

In 1971, Thompson and Tulving conducted an experiment to examine whether word recognition memory is influenced by retrieval context. They first gathered 60 college students as participants

DOI: 10.54254/2753-7048/2026.NS35037

and prepared materials of a series of to-be-remembered words (TBR words), and divided the list into three input contexts. Single-word context , weak associative pair context, and strong associative pair context. The participants were similarly divided into 3 categories, and were given a mix of old and new words for the test. For each word presented, participants had to decide whether it was an "old word" and provide a confidence rating .

The result showed that the recognition performance in the single-word input context declined when a related word was added during testing, regardless of whether the association was weak or strong. Both weak associative pair input and strong associative pair input led to the best recognition performance when the original pair remained. And every performance had decreased while removing or replacing the pair with a new associated word.

Their conclusion was that recognition memory is influenced by test context, supporting the view that "information accessibility" plays a crucial role in recognition and refuting the assumption that "recognition requires no retrieval process."

Afterwards, research shows that semantics sometimes plays a role in encoding specificity, especially when associated with the context. In 1970, Bahrick studied this hypothesis by using a paired-associate list with four types of prompts for each stimulus word [9]. Some of the prompts are semantically relevant to the stimulus and others are not. For example, for the stimulus "telephone", the prompts could be "dial" or "extension", and the previous one led to better performance. Interestingly, the word "pole" is somehow weakly related to "telephone", but it provided nearly the same benefit as the strongly related word did. Even weak semantic associates of a to-be-remembered word can serve as helpful cues, so long as they prompt the activated part of the context in which one would encounter the to-be-remembered item.

In this principle, the context of material is not only the verbal context, but also the environment, including the physical and auditory environment. In 1975 Godden and Baddeley took two groups of individuals and asked them to study and remember a list of words [10]. One group was given a list of words to study while underwater in scuba gear, while the others were studying on dry land. The experimenters then tested the groups either on water or on land, with half of the subjects staying in the same environment and the other half switching environments between encoding and test. The result illustrates that recreating the physical environment of encoding brings better testing performance. In 1998, Grant designed another experiment for the auditory environment [11]. 39 participants were asked to read the same topic one time, knowing that they would take a short test on the material afterwards. Each of them were required to wear headphones hearing moderately loud noise and the others heard nothing. Comparing the test score with different groups, Godden found that no matter what kind of tests the participants took, it is more beneficial to study and test in the same auditory environment.

5.3. Educational use and tips for students

For the goal of better memorizing and getting better test scores, we should focus on matching the memorizing context and the retrieval context. Potentially, this could mean matching almost any aspect of the context that is under your control – like the shirt you wear during studying and testing, the place you sit in the room, or the color of pen that you use. Just like the previous sections we discussed, it is better to memorize the specific material semantically, and depth of encoding strategies can be combined with encoding specificity.

Although we often cannot control our testing environment, we can potentially take steps to make our learning environment match the environment in which we will be tested. In our school life, we always take our exams under the circumstance of a quiet classroom where we can hardly hear any

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sound of noise or music. In this case, we should not study in the dining room or listen to music, because the mismatch between encoding and retrieval is harmful to test performance.

6. Discussion and classical theory about memory reliability

Most of us believe that what we see is what we remember, so that our long term memory is simply a record of our experiences. But what if our memory could be wrong? To answer this question, let's introduce a concept: eyewitness memory.

6.1. Eyewitness memory

Eyewitness memory is a person's episodic memory for a crime or other witnessed dramatic event, which is often relied upon in the judicial system. Eyewitness memory is a kind of long term memory. However, in the late 20th century, Elizabeth F. Loftus started a series of studies to find out whether eyewitness memory is not always reliable [12].

6.2. Statement from E. F. Loftus and her researches

E. F. Loftus designed a classic experiment called the false memory implantation experiment. The researchers first asked a 14-years-old teenager Chris and his older brother and his mother to join in the experiment as participants. The researcher then used the "Family Collaboration-Suggestion" approach, simulating the real-life scenario of family members reminiscing together, to increase the reliability of the case.

In the experimental procedure, The researchers first worked with Chris's brother, Jim, to fabricate three events from Chris's childhood (around age 5). Two were genuine events, which were confirmed by the mother, and one was completely fictional, lost in a shopping mall. The script for the fictional event was: "In 1981 or 1982, when Chris was 5, our family went shopping at the University City shopping mall in Spokane. Chris got lost. We panicked and searched for him, and finally found him being led down the mall by a tall, elderly man wearing a flannel shirt. Chris was crying and holding the man's hand. The man explained he had just found Chris walking around crying and was trying to help him find his parents." Each event was written on 3 cards separately.

In the following period, Jim told Chris to read each card and write down any detail about it, or just say "I don't remember." Over the next five consecutive days, Chris would read and write them down without involvement from the researchers. When the day passed, Chris gradually added more and more detail to the fake event. For example, On day 2, Emotional memory such as fear begins to appear even though he could not remember anything about this a day before. And on the day 4, sensory details emerged: "I also remember that old man's flannel shirt"

A few days later, when researchers interviewed Chris and his mother with the same method, The false memory of Chris had become remarkably rich and vivid, but his mother consistently failed to recall the fictional getting-lost event. Finally, researchers debriefed Chris, telling him one of the three events was false and asking him to guess which one but Chris guessed one of the genuine events. When told the "getting lost" event was fabricated, Chris's initial reaction was shocked and he even initially resisted accepting that it was a false memory.

This successful implantation experiment suggested the constructive nature of memory; our memory can be revised unconsciously, and even the vividness of a memory and the individual's confidence in it are not reliable indicators of the truth.

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6.3. Conclusion and its truth

False memory is a huge section of memory science, which shows that stress or trauma during an event can affect the encoding of the memory – and that what we "remember" may not be what happened. What we should know is that our memory is not as reliable as we once believed. We should always consider the possibility that some aspect of our memory is false, even if our memory for an event includes vivid details.

7. Discussions and conclusions

The theories reviewed in this paper show that memory is not a simple storage system, but a process shaped by how information is learned, processed, and later retrieved. Rather than working in isolation, these theories highlight different aspects of memory that, when considered together, provide a more complete picture of how learning can be improved.

One important theme across the research is the role of both time and depth in memory formation. The spacing effect demonstrates that distributing study over time helps reduce forgetting, while the levels of processing framework suggests that deeper, meaning-based encoding leads to more durable memory traces. Taken together, these findings imply that effective learning is not just about reviewing material repeatedly, but about engaging with it in a meaningful way over time.

Another key factor is the role of context and structure in memory retrieval. The method of loci shows how information can be organized using spatial cues, while the encoding specificity principle emphasizes that recall is often tied to the conditions present during learning. These ideas suggest that successful recall depends not only on how information is stored, but also on whether appropriate cues are available when it is needed.

At the same time, research on eyewitness memory highlights an important limitation: memory is not always reliable. Studies have shown that memories can be influenced, altered, or even fabricated over time, often without conscious awareness. This challenges the assumption that confidence or vividness guarantees accuracy. In a learning context, this means that while certain strategies can improve recall, they do not eliminate the possibility of error.

There are also practical considerations in applying these theories. Some strategies, such as the method of loci, may require additional effort and practice, while others, like encoding specificity, may be difficult to control in real-world situations. In addition, many of the studies discussed were conducted under controlled conditions, which may not fully reflect everyday learning environments that include distractions and time constraints.

Overall, the evidence suggests that no single method is sufficient on its own. Instead, a combination of approaches—such as spaced repetition, deeper processing, structured encoding, and attention to context—can be more effective in improving memory performance. At the same time, it is important to recognize the limitations of memory and to approach it with a critical perspective. Understanding both the strengths and weaknesses of memory can help learners use these strategies more effectively and realistically.

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