11-2021

Proactive Interference Caused By Repeated Use Of Memory Palace

Xuan Wei
xuan.wei@siu.edu

PROACTIVE INTERFERENCE CAUSED BY REPEATED USE OF
MEMORY PALACE

by

Xuan Wei

B.S., Lanzhou University, 2014
M.S., University of Illinois at Chicago, 2016

A Research Paper
Submitted in Partial Fulfillment of the Requirements for the
Master of Science

Department of Psychology
in the Graduate School
Southern Illinois University Carbondale
December 2021

RESEARCH PAPER APPROVAL

PROACTIVE INTERFERENCE CAUSED BY REPEATED USE OF MEMORY PALACE

by

Xuan Wei

A Research Paper Submitted in Partial

Fulfillment of the Requirements

for the Degree of

Master of Science

in the field of Psychology

Approved by:

Reza Habib, Ph.D.

Graduate School
Southern Illinois University Carbondale
November 12, 2021

TABLE OF CONTENTS

CHAPTER 1

INTRODUCTION

It isn't uncommon for one to bemoan a subpar memory, or to wish for a photographic memory to improve study or professional efforts. In fact, there exists a small group of individuals who can remember a massive amount of detailed information very quickly and accurately, including recalling the number pi to over ten thousand digits (Raz et al., 2009). The 2019 World Memory Champion, Ryu Song I, took one hour to memorize 4,629 random digits and 30 minutes to memorize 7,485 binary digits, breaking the number marathon world record. The techniques Ryu Song I and many other grandmasters of memory adopted to achieve these incredible feats of memorization are called mnemonics.

A record number of people have recently plunged into mnemonic technique fever and have begun engaging in this mental sport. Even young children compete fiercely with adults and spare no effort in breaking records. Ryu Song I is a high school student from North Korea and reported using an innovative method that combines human five-sense imagery during the 2019 World Memory Competition. Other well-known memory champions such as Alex Mullen, Jonas von Essen, and Nelson Dellis, Yanjaa, suggest that a good mental state, healthy lifestyle, fusing emotions with the materials to be remembered, and spending less time on electronic devices help in winning memory competitions (Tobias & Wehlisch, 2018).

Visual mnemonic techniques have been widely acknowledged as effective devices to encode and retrieve information in human memory (Verhaeghen, Marcoen, & Goossens, 1993), but the method of loci, also known as the memory palace, is considered to be the most powerful mnemonic method involving imagery (Moè & De Beni, 2005). This particular technique can dramatically improve memory thanks to its merging with another strong type of human memory, spatial memory. The underlying principle is that humans are better at remembering images and locations than abstract concepts like words or numbers (Foer, 2011, pp. 89-106).

In examining memory, two questions are often addressed: (1) Do memory champions have an extremely high IQ? (2) Do memory champions' brain structures differ anatomically from those of ordinary people? The fact is, the brains of memory champions are indistinguishable from the average person's brain, as proved by MRI scans of many memory champions and control subjects, performed by neuroscientist Eleanor Maguire from University College London (2003). Grandmasters of memory, Ed Cook and Lukas Amsüss, also claim that memory champions are actually average individuals with average IQs based on collected IQ data (Foer, 2011, pp. 37-40).

However, there exists one distinct phenomenon when these superior memorizers are using the method of loci, whether they are recalling numbers, faces, or something else. Ninety percent of mental athletes' MRI scans show that, when utilizing the memory palace, the activations of the medial parietal cortex, retrosplenial cortex, and the right posterior hippocampus are involved (Maguire et al., 2003). During resting periods, memory champions and control groups exhibit no specific regional brain differences, but memory champions' brain connections are different from control participants. After control participants began practicing memorization with the method of loci for six weeks, distributed functional brain network connectivity began to emulate brain network organization held by memory champions (Dresler et al., 2017).

The number of neurons in an average human brain has been identified to be on the order of 100 billion (1011) and there are many more neuroglia to support and protect the neurons. Simulations have suggested that the human brain's memory storage capacity is limitless. In a paper by Yingxu Wang, a cognitive model was created of the brain, and a set of mathematical and computational algorithms determined that human memory capacity is on the order of 108432 bits (Wang, Liu, & Wang, 2003). One petabyte is 815 bits, and 108432 is a mathematically infinite number.

However, having a large memory capacity does not protect against memory interferences. Memory interference is a phenomenon in which some information interferes with the retrieval of other information. Many have encountered memory interference, causing unnecessary difficulty in their studies or professional life. For example, even a trivial act like changing one's phone number can cause one type of memory interference, proactive interference. In this case, recalling the new phone number becomes difficult because of the inclination to recite the old phone number. Even world memory champions have reported encountering proactive and retroactive interferences when recalling information.

Many seek to enhance their memory to improve academic or professional performance. The following chapter will first provide a general review of the human memory mechanism and forgetting mechanism. It will then introduce memory championship and mnemonic techniques, including three of the most popular and beneficial mnemonic techniques using imagery. It will also evaluate these three beneficial mnemonic techniques and discuss why the method of loci is superior and prevails among memory competitors.

CHAPTER 2

LITERATURE REVIEW

Memory

Memory is an imprint of past events and experiences. In other words, it is the retention of information that can be recalled at a later time. Memory can be understood as three overlapping processes of encoding, storage, and retrieval. It is difficult to precisely define or draw a line between these three processes because when encoding, storage, and retrieval begin and end is still not fully understood (Roediger III, Dudai, & Fitzpatrick, 2007, pp. 13-34).

Encoding refers to the initial registration or learning of information, which is necessary for any kind of later memory performance, especially when trying to retrieve information. On a physiological level, encoding of information from sensory stimuli comprises a neural mechanism called long-term potentiation that causes depolarization and modifies synaptic transmission between neurons directly or indirectly in different brain regions (Jensen & Lisman, 2005; Levy & Steward, 1983). Long-term potentiation (LTP) describes changes in the efficacy of synaptic transmission due to repeated experience with particular stimuli. LTP can be achieved by enhancing the postsynaptic response to the release of neurotransmitters (Volianskis, Collingridge, & Jensen, 2013). Neurons responsible for encoding memories exist mainly in the cortex and hippocampus (Yassa & Reagh, 2013). Encoding is the important first step in formulating new memory because it is a process of transferring information to long-term memory.

Consolidation is the process where stabilization of recent-memorized knowledge or information occurs. In other words, consolidation is the process where the brain converts experiences into memories. Long-term memory in the context of synaptic consolidation refers to the storage and recall of information lasting for at least 24 hours (Dudai, 2004). It is assumed that structural and chemical changes in the nervous system are involved in this process, for example, an increase of synaptic connections of neurons (Urcelay & Miller, 2008, pp. 53-73).

An alternative view questions the function of consolidation as post-encoding stabilization of memory. The role of consolidation from this view is to facilitate the accessibility of information after being encoded and stored immediately upon presentation (Roediger III, Dudai, & Fitzpatrick, 2007, pp. 123-143). Other psychologists hold the view that consolidation takes place every time memory is retrieved and is referred to as reconsolidation (Alberini, 2005). Reconsolidation occurs when previously consolidated memories become labile due to reactivation of the memory trace (Sara, 2000). Each time a memory is recalled, it is then re-encoded by a similar, but not identical set of neurons (Shapiro & Eichenbaum, 1999). Accessing memories helps make them stronger, but the re-encoding influences subtle details, and certain aspects of the memory may be strengthened, weakened, changed, and even lost depending on which neurons are activated (Yassa & Reagh, 2013). From the physiological perspective, memories are not stored in a static state but then can be retrieved with perfect accuracy. Instead, previously consolidated memories are changed and restabilized every single time they are accessed (Elsey & Kindt, 2017).

Retrieval is the mental process to recall or access stored information. Its success is affected by whether the encoding environment matches the test environment. Therefore, if the retrieval cue is in the corresponding environment in which information was encoded, retrieval is less likely to fail (Tulving & Thomson, 1973). Existing knowledge supports memory, and association creates more retrieval pathways. Repeatedly accessing a memory can extend its duration; memories that are recalled often are more likely to be retrieved successfully. This explains why repetition while remembering leads to better recall (Goldstein, 2019, pp. 192-203).

In summary, memory is the means by which organisms retain information of experience through the mental processes of encoding, consolidation, and retrieval. Encoding changes the form of the information so that it can be stored in the memory system; consolidation transfers the short-term memory into long-term memory; retrieval takes the information out of the long-term memory. These three intertwined steps altogether endow people with the ability to take, store, and recall information.

Forgetting

Although long-term memories can be remembered for many decades, they are susceptible to forgetting. It's not difficult to observe that people can forget already learned information as time goes by, no matter what methods are employed to aid the recall. Forgetting takes place when people cannot retrieve information despite the physical memory trace still existing in the brain. In this case, people forget because of the loss of access to the stored information rather than a complete loss of the stored information. Another plausible theory about the occurrence of forgetting is that the original memory might have been simply decayed or changed (Roediger III, Dudai, & Fitzpatrick, 2007, pp. 317-335).

Reasons that cause memory failure can be summarized into four categories: encoding failure, decay, amnesia (retrograde vs. anterograde), and retrieval failure. Encoding failure happens when the brain fails to store the information or create an initial encoding. Because the premise of forgetting is that information needs to be consolidated first, encoding failure and anterograde amnesia do not meet the description of forgetting. In encoding failure and anterograde amnesia, an item is not initially registered or learned. Thus, these two types of memory failure cannot be regarded as resulting from forgetting.

The trace decay theory of forgetting was developed from Hermann Ebbinghaus' research on forgetting curves, which demonstrates that memories decay over time, leading to forgetting. As the first to design an experiment to investigate learning and memory, Ebbinghaus studied learning as it occurred rather than after the fact. His method was to first create a pool of 2,300 nonsense syllables, which are meaningless and couldn't be influenced by prior learning. Then he chose a subset from the pool, usually consisting of 12 nonsense syllables, to memorize. After starting the experiment, the first step was to look at each syllable for a fraction of a second, then pause for 15 s after going through the entire list, then repeat until he could recall all items in the list without error. He kept track of how many times he needed to study the list until he achieved mastery of the list. Once he mastered the list, he would repeat this process to relearn the list at various time intervals. He recorded the number of exposures it took to relearn the list. The dependent measurement is called savings and equals the number of times he needed to study the list originally to achieve mastery minus the number of times he needed to study the list to relearn it. Therefore, savings reflects a reduction in the time investment required to relearn the information compared to the initial learning process (Ebbinghaus, 1885).

From the experiment, Ebbinghaus found out that forgetting is most rapid after the first few hours but relatively slow after that. The forgetting curve from his research also shows that after day five, the remaining knowledge is less than 20 % with an extremely low forgetting rate, and a very small percent of information still remains no matter how many more days pass. Ebbinghaus also developed the concept of overlearning, which refers to rehearsing newly acquired information or skills after initial mastery. He came to the conclusion that overlearning can reduce forgetting from the experiment. Another outcome of his interpretation of the experiment is that it's easier to remember things that have meanings. Based on the data, it took him 10 times longer to learn nonsense syllables as syllables taken from prose (Ebbinghaus, 1913).

Retrieval failure can also lead to forgetting, sometimes as a consequence of intervening factors. In fact, interference from overlapping memories is one of the main contributors to forgetting. Interference occurs when some memories interfere with the retrieval of other memories, especially when recalling similar materials that compete with one another. Interference can cause people to forget previously learned information and inhibit them in their future learning (Darby & Sloutsky, 2015).

There are two types of interference effects: proactive interference and retroactive interference. Proactive interference occurs when memory for previously learned information attenuates the learning of new information. Usually, older memories are more often rehearsed and more strongly consolidated, thus, it is often easier to recall previously learned information than information learned recently. Retroactive interference, on the other hand, occurs when learning of new information attenuates memory for previously learned information. This type of interference has a negative impact on the retention of old knowledge, making it more difficult to recall things that have been previously learned (Darby & Sloutsky, 2015).

To demonstrate the role of delay and number of intervening items on memory retrieval, Keppel and Underwood (1962) presented participants meaningless three-letter consonant trigrams (for example, HTP) with retention being measured after 3, 9, and 18 seconds. When the number of trigrams was three, the occurrence of forgetting the first trigram was less than the occurrence of forgetting the second or third one. But there was no difference between the occurrence of forgetting the second and third trigram, regardless of the time interval length. Proactive interference with the memory for new consonants occurred because memory for the earlier consonants had transferred to long-term memory. When the number of trigrams was increased to six, the occurrence of forgetting also increased. Therefore, they concluded that forgetting is a function of both the number of presented items and the length of the time interval (Keppel & Underwood, 1962).

In another study investigating interference in the retention of a word list, two major sources of interference in long-term memory were examined. One is the previously learned letter-sequence habit developed during the normal language learning process. For example, the well-established letter-sequence habit makes a random trigram such as JQB difficult to learn. These habits also interfere with the trigrams falling on sequential association during the retention test. The other is unit-sequence interference, which refers to the interference on sequential associations between units. Each trigram is regarded as a unit. Two groups of participants were asked to remember a 12-item list of words or trigrams measured with a 30-second retention interval. The experimental group also needed to memorize another list whereas the control group did not need to. The results showed that the control group performed better than the experimental group in recalling the first list. The measurements of errors due to letter-sequence and unit-sequence interference also revealed both sources of inference during the retention interval. The conclusion is the information received recently interferes with the information earlier learned, and that the rate of forgetting is related to letter-sequence and unit-sequence interference (Underwood & Postman, 1960).

People can recall information from recent or past selectively, but how proactive and retroactive interference effect recalling target information is not well understood. To investigate the problem of selecting target information in the presence of proactive and retroactive interference, experiments were conducted on participants by asking them to search on a target list of words either preceded by (proactive) or followed by (retroactive) another list. The dependent measurement took the proportion of items recalled, number of intrusion output, and recall latency as attributes of the targeted memory. Participants were first randomly assigned into three groups, then they memorized either one of the two lists or both lists, and then they recalled one of the lists or both lists. The data showed that compared to only remembering and recalling only one of the lists, remembering both lists and then recalling either of the two lists resulted in a lowered proportion of recall, a higher number of intrusion output, and longer recall latencies. This suggested that there exists both proactive and retroactive interference when recalling either list 1 or list 2 when the task is to remember both lists (Unsworth, Brewer, & Spillers, 2013).

Primary causes of memory failures, like encoding failure, decay, and interference, are related to one another. When encoding multiple memories with shared features, memory retrieval would be more difficult due to the interference caused by the overlap. On the other hand, encoding without any shared characteristics makes a single memory more difficult to retrieve because there are fewer connections and retrieval paths to the item (Anderson, 2003; Levy & Anderson, 2002). Memory failure is frustrating, but a small group of people have the ability to quickly remember much more information for a very long period. They are the memory masters.

Memory Championship

World memory championship is an organized memory sport in which competitors memorize as much information as possible within a given period. Designed to explore the limits of human cognition and improve memorizing efficiency, the World Memory Sports Council hosted the first world memory championship in 1991. Anyone is allowed to join the memory championship. There are four age groups in the memory championship competition, children 12 years of age and younger, a junior group with 13-17-year-olds, an adult group with participants between 18 and 59 years of age, and a senior group consisting of adults 60 and above. Kids and juniors are allowed to choose to compete in the adult groups. The event consists of ten different disciplines, including memorizing numbers, cards, words, images, etc. The memory champion selected each year receives the highest score summing up these ten disciplines' scores. The statistics of the world memory championship have shown that memory competitors have been creating new records each year and that the record-breakers' age tends to decrease ("World Records", 2016).

Grand Master of Memory is a title awarded to people who can memorize 1,000 random digits in an hour, the order of 10 decks of cards in an hour, and the order of one deck of cards in under two minutes (Day & Chambers, 2008). These three requirements need to be achieved at competitions officially approved and arbitrated by the World Memory Sports Council (WMSC). Titles "international grandmaster" (IGM) and "international master" (IMM) correspond to other levels of difficulties. By November 2016, there were 22 international grandmasters, 154 grandmasters, and 149 international masters in the world. The vast majority of these individuals are of Chinese origin ("World Records", 2016).

Tony Buzan, the founder of the world memory championship, believes that the teaching methods in schools are ineffective due to too much information being presented but no training on ways to retain it. He has been promoting the use of mnemonics in schools since 1970. Mnemonics refers to any memory technique that helps information be retained and retrieved from human memory. Some educators hold the opposite view, however. They argue that mnemonics prevent understanding of information since using mnemonics allows people to remember information accurately and pass tests without understanding the knowledge conceptually (Mastropieri, Scruggs, & Fulk, 1990; Scruggs et al., 1987). Others argue that parents are not encouraged to teach children to take mnemonics training from an early age, which might hinder their learning and comprehension abilities.

Mnemonics

Mnemonics delays the forgetting of information through the use of elaborative rehearsal, recovery cues, and visualization to improve the efficiency of memory storage and retravel. Elaborative rehearsal proves more successful in encoding compared to maintenance rehearsal because the processing of maintenance rehearsal is shallow, thinking about one piece of information repeatedly. In elaborative rehearsal, on the other hand, information processing is deep when thinking about the meaning and making associations. The origin of elaborative rehearsal can be traced to the levels of processing model proposed by Craik and Lockhart in 1972. Craik and Lockhart believe that the depth of information processing is positively correlated to the ability to recall it (Craik & Lockhart, 1972). The basic idea suggested by levels of processing theory is that the deeper information is processed, the stronger a memory trace is. The way that memory was associated in the first place is closely related to how vivid the memory will be (Goldstein, 2019, pp. 196-198). However, shallow encoding does not imply encoding failure and elaborative encoding does not ensure successful retrieval. People can still remember information successfully that has relied on shallow encoding and fail to remember information that has been subjected to elaborative encoding, depending on the nature of the test.

Retrieval cues are stimuli that aid memory retrieval. They assist people to access memories stored in long-term memory and bring them into conscious awareness. The presence of retrieval cues can make recalling information much easier. Retrieval cues can be internal (for example, feelings) and external (for example, smell).

Mnemonics aids learning and remembering by facilitating the creation of associations between to be remembered items and prior stored knowledge, leaving a deeper impression or more meaningful comprehension to aid in retrieval (Zimbardo, Johnson, & Weber, 2006). The are several types of mnemonic techniques. Examples of non-imagery mnemonics include music mnemonics, model mnemonics, and note organization mnemonics. Imagery-based mnemonic techniques include the link method, pegword, and method of loci.

All memory champions reported using a mnemonic technique, the most common being the method of loci (Goldman, 2017). While mnemonics are viewed as useful for aiding memory, research indicates that the results are mixed with some studies demonstrating a benefit of using mnemonics and others failing to find a mnemonic advantage. For example, Dunlosky et al. (2013) examined the relative utility of 10 different techniques to help improve students' learning. Dunlosky and colleagues found that using mnemonic devices was found to be of surprisingly low utility compared to other learning techniques such as repeating and practicing (Dunlosky et al., 2013). In another study of memorizing categoric words, one group used the pegword mnemonic technique (see below) while the other group did not use any mnemonic devices. The result showed that the recall performance of the pegword group was poorer than the other group (Reddy & Bellezza, 1986).

In a study assessing the effectiveness of mnemonics, 1468 college students were presented with 12 mnemonic techniques and asked whether or not they used mnemonics on an exam. For two questions from the exam, there was no statistically significant difference in mnemonic use for students who answered correctly and those who did not. But for the other questions on the exam, students who answered correctly were more likely to report using a mnemonic technique (Mocko et al., 2017), thus demonstrating the effectiveness of mnemonics in aiding test performance. Twenty studies on 669 students with learning disabilities, emotional and behavioral disorders, or mild developmental disabilities showed that mnemonics improved memory, measured by the recall of word definitions or factual information. These findings demonstrate that mnemonic techniques can improve academic performance across educational settings, student ages, and disabilities (Fulk, 1994; Bulgren, Schumaker, & Deshler, 1994; Wolgemuth, Cobb, & Alwell, 2008).

The inconsistency among the results of these and other studies about mnemonics is partially caused by the fact that the treatment groups cannot master mnemonics within a short time without enough practice (Radović & Manzey, 2019). In one study conducted by Campo and Gonzale, four experiments were conducted to evaluate the effectiveness of one of the mnemonic techniques, the keyword method, on two groups of adolescents and adults. The results from all the experiments showed that rote memory was more effective compared to the keyword method, one of the mnemonic techniques. The ineffectiveness of the keyword method was attributed to the lack of training by the treatment group (González & Amor, 2003).

What makes some mnemonics hard to master is the requirement to form mental/visual images of the to-be-remembered information. The process of imagery makes remembering something even more time-consuming at the beginning (Qureshi et al., 2014).

Imagery

Imagery refers to experiencing a sensory impression without the presence of sensory input. There exist two ways of experiencing visual images: 1) nerve impulses traveling from the retina to the brain areas responsible for vision can create images; 2) in the absence of visual stimuli, images can be formed or recreated in the mind by visual imagery (Goldstein, 2019, pp. 323-325). Besides visual imagery, other types of sensory imagery include auditory imagery, gustatory imagery, tactile imagery, and olfactory imagery, which engage the senses of hearing, taste, touch, and smell, respectively (Schifferstein, 2009). Much more research on mental imagery has been done in the visual domain than any other sensory modalities since visual imagery has been widely used in mnemonics because vision is the most important and complex sense (Hutmacher, 2019). However, the other four mental imageries involving human senses have also shown their capacity in improving memory (Darwin, Turvey, & Crowder, 1972; Shih, Dubrowski, & Carnahan, 2009).

The mechanism by which imagery improves memory is believed to occur through the generation of more vivid, stronger links with other information during encoding that can increase correct memory and decrease false memory (Ishai & Sagi, 1995; Oliver, Bays, & Zabrucky, 2016). Some research indicates that visual imagery is most effective when the images of the objects or information are connected in an interactive way, and especially in a bizarre way (Besken & Mulligan, 2021). However, research conducted by Wollen and his coworkers (1972) contradicted these findings by demonstrating that as long as the images were associated with something else, bizarreness did not enhance memory. Studies by Senter and Hoffman (1976) underscored Wollen's result that bizarreness is a nonessential variable in imagery for mnemonic purposes. Recent data show that as the number of images increases, the effect of bizarreness in improving memorization becomes more important. More recent reflections on mnemonic techniques indicate that the more bizarre the visualization, the more stable and longer-lasting the stored information can be (McDaniel & Einstein, 1986; Cornoldi & de Beni, 1988; Toyota, 2002). Earlier attempts to prove the superiority of bizarreness likely failed, at least in part, due to the use of inexperienced participants (Hauck, Walsh, & Kroll, 1976).

Imagery has been employed in many types of visual mnemonic devices, such as the link method, pegword, and the method of loci. It serves as the major non-spatial process of the method of loci. The limitation of solely using imagery to remember information is that it is difficult for people to recall the pictures or the information in a specific sequence – even if the number of items is less than a dozen – as indicated by the results from Wollen and Sente; almost half of the 12 images were forgotten.

The link method

The link method can be seen as the easiest and quickest way to remember any list of information by linking the information one by one. It functions similar to a metal chain: one item is connected to the next, and all of them are joined into one strand. The word link in the link method refers to associations; this mnemonic technique improves memory by converting information into vivid images and then linking the images of two or more objects with each other instead of associating the objects randomly. Recall proceeds by starting with the very first image and the chain or link continues until the end.

The link method is often used to memorize short lists of items like shopping lists and to-do lists, in which each item can be associated or connected with the next. It can also be used to remember the names of people in formal and informal situations, topics to be included in a presentation or a speech, lists of instructions, etc. Moreover, the method can help students to study by memorizing different unrelated information (Einstein & McDaniel, 1987).

Two variants exist to the link method. First, the chain-link method, also known as the word train technique, aims to connect all objects from the list via mental images. This includes a series of object pairs in the list that are juxtaposed. Second, the story method, also known as the continuous technique, intends to create a continuous story that links images of all objects together in a sequence based on the list (Bremer, 2011).

Remembering a short list using the chain-link method can be accomplished in two steps: first, two items in the list that are next to each other can be linked; second, a visual association between those items is created by putting the images together, such as one on top of the other. The entire list can be learned by moving through the list, linking each item to the next.

The story method can be employed by linking all items together and highlighting them with a memorable story. The strength of the images and the flow of the story provide the cues for retrieval. Since the power of the story can compensate for the lack of creativity, a large amount of creativity is not required. This method requires two procedures: one of creating a story and one of linking the images. Inserting oneself into the story adds power. Brain imaging research proves that imagining a threat lights up almost the same brain regions as experiencing the threat; imagination can be as effective as reality (Reddan, Wager, & Schiller, 2018). Becoming part of the story yields feelings and emotions that are attached to what happened. One should accordingly work to create sensory perceptions as well, such as smell, noises, or the feelings of the objects after the brain has already received the mental picture when constructing the story.

In summary, the chain-link method links a series of pairs of items like a chain whereas the continuous technique uses the link of the items together with a memorable story to feature them. With strong associations, retrieval of to-be-remembered items is enhanced. Each method has its own advantages. The chain-link method allows lists to be memorized in a sequence within a surprisingly short amount of time, the key is to focus on any of the two items at one time. Its advantage over the story method is its potential to form an open doubly linked list that can be transversed backward or forward (Ziganov & Kozarenko, 2000). The link method can be used for any number of different lists an infinite number of times. And the link method is easy to perform without much training; people can remember lists for days without practicing the list. As long as the mental picture is clear, making a mistake is very rare (Kozarenko, 2005).

Pegword

Pegword was invented by Henry Hudson in the mid-1600s and has become one of the most popular mnemonic approaches to remembering lists of items (Higbee, 1977). This mnemonic technique can be learned one time then used repeatedly to remember different lists of items. The peg in the peg system, such as numbers from 1 to 10 or ABCs, is already known and easy to remember. These numbers or letters can associate information, then mental pictures for the associated information can be created (Bower, 1970). The principle of pegword is that people never forget how to count from one to ten or how to recite their ABCs, so they can attach other things that are new to each item. In other words, a peg system can be perceived as a wardrobe that contains many hooks on which to hang clothes. The hangers themselves never change, but the clothes which are hung up on them can be different. The advantage of this technique is that it is straightforward, and people can start using it immediately once the peg system is created. The important point is that this method is based on associating two things and no more. The peg system can be used to remember lists of numbered items, such as ideas, concepts, or topics to be covered in a speech or a presentation. It also applies to remembering short, medium, or long numbers, such as dates, telephone numbers, and information for examinations (Harris & Blaiser, 1997).

The peg memory system has numerous variations, but they all have the same procedures: The first step in building a peg system is to learn the peg list (the code) of the system. If using the alphabet system, words starting with letters A through Z can serve as cues to trigger the recall. If using numbers from 1 to 10, a simple list of rhythming words corresponding to the numbers or a list of the number-shape images can act as pegs on which to hang the information (Harris & Blaiser, 1997). People can easily memorize the code by pegging them on these ordered structures to be remembered. The second step in implementing pegword is to apply the code. Take a list of things to be memorized and then apply the code by creating mental associations between items to be remembered and codes that are already known from the peg list. The more vivid and action-oriented the association, the easier it will be to remember. Creating a memorable narrative for the images of associations like the link method is optional. Ultimately, one must memorize then recall. When replaying the images or following logically from one scenario of the story to the next, all items in the right order can be retrieved (Delprato, & Baker, 1974).

Two popular peg systems are the alphabet peg system and the number peg system. The alphabet system can be further dived into the celebrity peg method (a list of celebrity names), the animal word peg method (a list of words based on animal names), the body part method (a list of body parts), or the sing-along method (a list of familiar songs). The number peg system has two alternatives: the number rhyme system and the number shape system. The most widely known pegword system is the number rhyme system (Holliman, 2009).

The number rhyme system employs a simple list of rhyming words to substitute or function as the numbers. Each number word pair acts as a peg on which to hang the information. Before using the number rhyme pegword strategy, the corresponding rhyming words of the numbers must be memorized. Then, each item must be associated with the corresponding “peg” object and individual images formed (Bower, 1970). Below is an example of the rhyming pegword system consisting of ten objects serving as the "pegs" on which to "hang" the items to be remembered:

one is a gun, two is s shoe, three is a tree, four is a door, five is a hive,

six is sticks, seven is heaven, eight is a gate, nine is wine, ten is a hen.

After memorizing the rhyming list of words corresponding to numbers, the words associate with something to be memorized in a creative way. The rhyming word and number pair serve as a memory cue when recalled. For example, if remembering the same list above with the rhyming system, the first item is a chicken. Think of the image of a chicken being shot by a gun and blood splattering everywhere. When memorizing the second item, milk, create an image of a shoe used as a container for milk, dripping milk on the floor continuously. And the third item is a potato; imagine a tree that grows potatoes. The fourth item is broccoli; imagine a door painted with broccoli. The fifth item is an egg; imagine a hive that contains eggs from the size of a quail egg to the size of an ostrich egg (Holliman, 2009).

However, this kind of rhythmic word of numbers can only be used to remember at most eleven items if including the corresponding rhyming word hero for the number zero. Starting at eleven, the rhythm can no longer be applied since seven and eleven, and thirteen to nineteen have the same ending pronunciation. Thus, an alternative number peg method was created to remember more items. For this peg word method, instead of using rhyming, images looking like the shape of numbers are utilized, which is also known as the number shape system.

Pegword is a robust and resilient mnemonic device to remember a sufficient amount of information, but its limitation is also observable. The alphabet peg system can be used to remember a list of up to 26 items, and the number shape system up to 100 items. Whereas the method of loci can be used to remember hundreds of thousands of pieces of information. One grandmaster of memory remembered two hundred items just by using his own body parts.

Method of Loci

The method of loci, also known as the memory palace, has been utilized for centuries. It is the most popular and efficient memory enhancement device used to remember large amounts of information by coupling visual imagery and spatial memory. As indicated in its name, loci is the Latin word for places. Through visualizations that place information to be remembered in familiar spatial environments, it becomes a learning strategy toolbox to boost the retention of material over a long duration (Gross et al., 2014). The contemporary usage of the method of loci has vast diversity, from learning exam material to foreign languages, to remembering poetry, presentations, or speeches. People can learn faster while forgetting less, and creating vivid imaginary pictures instead can make learning more enjoyable. This method is helpful in effectively forming long-term memory of the material.

History of the Method of Loci

The origin of the Method of Loci is attributed to Greek poet Simonides in the 5th century BC. Simonides was invited to sing a victory ode at a banquet in Thessaly for a boxer celebrating victory. The banquet host, Scopus, had hired Simonides, who not only sang his poem praising the boxer, but also included Castor and Pollux who were boxing and athletics demigods. After Simonides performed his poetry, Scopus refused to pay in full and only paid half the promised fee. He even went so far as to mock Simonides, instructing him to collect the other half of the payment from Castor and Pollux whom he had praised so highly.

Shortly afterward, a banquet servant delivered a message to Simonides that two young men wanted to speak to him outside. Simonides went out to the street, but no one was there. As he searched the street for the young men, the banquet hall roof fell in and the entire building collapsed, killing everyone inside. Greek mythology says the two young men who disappeared were Castor and Pollux themselves, and had come from heaven to honor Simonides by saving his life.

Simonides worked to help the authorities identify the bodies inside the banquet hall, but the building's collapse was so catastrophic that the bodies were unrecognizable. He assisted by employing the loci method to remember the name of each person based on their location around the table, and placed names on bodies to facilitate proper funeral ceremonies and burial rituals for the victims. This tale marks the beginning of the memory palace, which was supposedly developed and later extended by Simonides (Yates, 1966). The memory palace was adopted and then widely used in the ancient Roman and Greek rhetorical treatises in medieval times through the Renaissance, prior to the extensive spread of the printing press.

Steps of Creating a Memory Palace

Creating a functional memory palace to remember a large amount of information like memory champions do may seem like an unachievable task. But, it simply requires persistent practice with memorizing a small to vast amount of material. There are only three crucial steps to building a memory palace: 1) visualizing information that is to be remembered, 2) storing that image in a real or imaginary location, and 3) mentally making a journey through those locations in the palace to recall the information. Images and places are the two basic keys in this technique (Holliman, 2009).

A Man Who Remembered Too Much

In *The Mind of a Mnemonist*, the author, A. R. Luria studied a man designated with S, who had vast memory and could remember almost everything. Here are a few of his original words of how he perceived the world (Luria, 1968, p. 25):

"I can't escape from seeing colors when I hear sounds. What first strikes me is the color of someone's voice. Then it fades off... for it does interfere."

S could perceive any tone, noise, or voice as a visual image. In most experiments to examine his memory, like remembering numbers, addresses, the Russian alphabetical table, he remembered everything by converting everything into visual images. However, in a test of producing a long list of words, he omitted four words "pencil", "egg", "banner", and "blimp". And he explained (Luria, 1968, p. 36):

"I put the image of the pencil near a fence... the one down the street, you know. But what happened was that the image fused with that of the fence and I walked right on past without noticing it. The same thing happened with the word egg. I had put it up against a white wall and it blended in with the background. How could I possibly spot a white egg up against a white wall? Now take the word blimp. That's something gray, so it blended in with the gray of the pavement... Banner, of course, means the Red Banner. But, you know, the building which houses the Moscow City Soviet of Worker's Deputies is also red, and since I'd put the banner close to one of the walls of the building, I just walked on without seeing it..."

Likewise, suppose putting broccoli on a tree (the third rhyming word for number three) in the above the peg number rhyme system. People likely won’t remember what exactly they hung on the tree because the broccoli cannot stand out from the tree.

One of the most important rules for effective memorization is known as the von Restorff effect, according to which, things that stand out from their peers are more memorable. In other words, people are more likely to remember things that stand out (Parker, Wilding, & Akerman,1998). If something stands out for being a different shape, size, color, or in some other way significantly characteristically different from the other items around it, it becomes easier to recall (von Restorff, 1933). Therefore, if people want to remember something, make it stand out.

As was indicated, S used the mnemonic technique method of loci. However, S's impressive memory failed him in his career as a journalist because he had trouble distinguishing the trivial from the important. He could not ignore the small details not worth keeping, and he was not able to hold any job for a long time (Luria, 1968, pp. 38-40; Foer, 2011, pp. 20-40).

Among different mnemonic techniques, the link method is regarded as the fastest way to remember information. This is especially useful when people are in a pinch and want to remember a list of information, as this method allows them to jump into the linking system without any preparation or building any memory palaces. Alternatively, the method of loci takes months or even years of practice for people to master (Schacter, 2001). However, the link method not only requires the generation of images for each item, but also requires connections between subsequent images, which can be done in several ways, such as the images touching each other, interacting with each other, or causing affecting each other, whatever makes it memorable depending for the individual. One of the prominent caveats of this technique is that if one of the links is lost, the rest of the images could be lost forever as well. Therefore, it is not the best technique to ensure that all the information is remembered, and it is risky to adopt this method in a memory competition.

The reason that the method of loci thrives is that it combines the two effective processes for forming long-lasting memories: visual imagery and spatial memory. As was indicated by 2014 Nobel Prize winner in physiology, John O'Keefe, it is in living organisms' nature that cells in the hippocampus form spatial representations of the environment and help animals to guide the direction (O'Keefe, 1979). Studies show that people using the method of loci perform better in tests than those who use other mnemonic techniques (Roediger, 1980). Once it is mastered, the method of loci can be used to maximize memory performance.

Interference in Mnemonics

Many powerful mnemonic techniques use mental visualization, and the key to being better at any mnemonic is to really use imagination. Tony Buzan claimed that the World Memory Championship is more a test of creativity than memory (Foer, 2011, pp. 196-209). Some approaches can boost the effectiveness, like exaggerating the association, creating dynamic images, substituting, and being ridiculous. According to memory experts, they use both sides of their brains. Possessing a dirty mind when creating pictures also aids in stronger memory because evolution has programmed human brains to consider two things superiorly interesting and memorable: sex and jokes. Jokes about sex are particularly exciting (Foer, 2011, pp. 89-105). Here is an example of how to remember a phrase from the book Moonwalking with Einstein: cottage cheese. Imagine Claudia Schiffer swimming in a tub of cottage cheese and dripping with dairy. It is crucial to remember or visualize the image using multiple senses, because the more vivid the image is, the more likely it adheres to its locus. However, a problem arises with the vivid images that have been created.

In the book Moonwalking with Einstein, Joshua Foer wrote:

"*In order to actively clean palaces for memory sports, some mental athletes do not talk with people three weeks before the competition.*"

But according to Alex Mullen, a three-time world memory champion, he never makes an active effort to erase "ghost images" on the loci he wants to reuse. Resting palaces that he will use in competition for more than a week before the event is sufficient to let any old images fade (Mullen, 2017).

It has been suggested that the repeated use of the same loci may create both proactive and retroactive interference. In the research on exploring possible interference using the same mind palace, 105 university students were assigned either to a loci group or a control group. All the students learned three lists of pairs of nouns, with the loci group using the same mind palace three times for each list. The results showed that while the mind palace improved performance on all the tasks compared to the control group, the performance of recall on the final task was not as good as the previous recall due to retroactive interference (Cornoldi & de Beni, 1988).

But for memory competitors, retroactive interference does not affect the competitors' performance as much as proactive interference, since the information to be tested is all given at the match. In most competitions, whoever can remember and recall more newly given information wins. Therefore, proactive interference has higher priorities to be overcome compared to retroactive interference.

Based on the definition and cause of memory interference, interference could be reduced by encoding memories in an unrelated way so that similar pieces of information do not overlap. New memories can be retrieved more effortlessly with less interference from old memories and vice versa (Chanales et. al., 2019). However, this cannot be the solution for most memory competitors to reduce memory interference. If their prioritized mnemonic technique is the method of loci, no matter how distinctively they encode old and new information, both will eventually attach to the same spot in their memory palace, which is the essential cause of the interference problem for a memory palace. Mnemonic techniques using just visualization without locations could solve the memory interference at some level, but their limitations will cause other problems to arise.

REFERENCES

Alberini, C. M. (2005). Mechanisms of memory stabilization: Are consolidation and reconsolidation similar or distinct processes? *Trends in Neurosciences, 28*(1), 51–56. https://doi.org/10.1016/j.tins.2004.11.001

Anderson, M. C. (2003). Rethinking interference theory: Executive control and the mechanisms of forgetting. *Journal of Memory and Language, 49*(4), 415–445. https://doi.org/10.1016/j.jml.2003.08.006

Besken, M., & Mulligan, N. W. (2021). The bizarreness effect and visual imagery: No impact of concurrent visuo-spatial distractor tasks indicates little role for visual imagery. *Journal of Experimental Psychology: Learning, Memory, and Cognition.* Advance online publication. https://doi.org/10.1037/xlm0001038

Bower, G. H. (1970). Imagery as a relational organizer in associative learning. *Journal of Verbal Learning & Verbal Behavior, 9*(5), 529–533. https://doi.org/10.1016/S0022-5371(70)80096-2

Bremer, B. (2011). *The Manual: A Guide to the Ultimate Study Method*. Fons Sapientiae Publishing

Bulgren, J. A., Schumaker, J. B., & Deshler, D. D. (1994). The effects of a recall enhancement routine on the test performance of secondary students with and without learning disabilities. *Learning Disabilities Research & Practice, 9*(1), 2–11.Campos, A.,

Chanales, A. J. H., Dudukovic, N. M., Richter, F. R., & Kuhl, B. A. (2019) Interference between overlapping memories is predicted by neural states during learning. *Nat Commun 10*, 5363. doi:10.1038/s41467-019-13377-x

Cornoldi, C., & de Beni, R. (1988). Weaknesses of imagery without visual experience: The case of the total congenital blind using imaginal mnemonics. In M. Denis, J. Engelkamp, & J. T. E. Richardson (Eds.), *Cognitive and neuropsychological approaches to mental imagery* (pp. 393–401). Martinus Nijhoff Publishing.

Craik, F. I., & Lockhart, R. S. (1972). Levels of processing: A framework for memory research. *Journal of Verbal Learning & Verbal Behavior, 11*(6), 671–684. https://doi.org/10.1016/S0022-5371(72)80001-X

Darby, K. P., & Sloutsky, V. M. (2015). The cost of learning: Interference effects in memory development. *Journal of Experimental Psychology: General, 144*(2), 410– 431. https://doi.org/10.1037/xge0000051

Darwin, C. J., Turvey, M. T., & Crowder, R. C. (1972). An auditory analogue of the Sperling partial report procedure: Evidence for brief auditory storage. *Cognitive Psychology, 3*(2), 255–267. https://doi.org/10.1016/0010-0285(72)90007-2

Day, C., & Chambers, P. (2008). *The Mind Sport of Memory 2008 Yearbook*. Filament Publishing.

Delprato, D. J., & Baker, E. J. (1974). Concreteness of peg words in two mnemonic systems. *Journal of Experimental Psychology, 102*(3), 520–522. https://doi.org/10.1037/h0035888

Dresler, M., Shirer, W. R., Konrad, B. N., Müller, N., Wagner, I. C., Fernández, G., Czisch, M., & Greicius, M. D. (2017). Mnemonic Training Reshapes Brain Networks to Support Superior Memory. *Neuron, 93*(5), 1227–1235.e6. https://doi.org/10.1016/j.neuron.2017.02.003

Dudai, Y. (2004). The neurobiology of consolidations, or, how stable is the engram? *Annu Rev Psychol, 55*, 51-86.

Dunlosky, J., Rawson, K. A., Marsh, E. J., Nathan, M. J., & Willingham, D. T. (2013). Improving students' learning with effective learning techniques: Promising directions from cognitive and educational psychology. *Psychological Science in the Public Interest, 14*(1), 4–58. https://doi.org/10.1177/1529100612453266

Ebbinghaus, H. (1885). *Über das Gedächtnis*. Leipzig: Dunker.

Ebbinghaus, H. (1913). *Memory: A contribution to experimental psychology*. (H. A. Ruger & C. E. Bussenius, Trans.). Teachers College Press. https://doi.org/10.1037/10011-000

Einstein, G. O., McDaniel, M. A., & Lackey, S. (1989). Bizarre imagery, interference, and distinctiveness. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15*(1), 137–146. https://doi.org/10.1037/0278-7393.15.1.137

Elsey, J. W. B. & Kindt, M. (2017). Tackling maladaptive memories through reconsolidation: From neural to clinical science. *Neurobiol Learn Mem, 142*(Pt A), 108-117.

Foer, J. (2011). *Moonwalking with Einstein: The art and science of remembering everything*. New York: Penguin Press.

Fulk, B.M. (1994). Mnemonic keyword strategy training for students with learning disabilities. Learning Disabilities Research & Practice, 9, 179–185.

Goldman, B. (2017). Memory lane: How using landmarks boosts memorization ability. https://stanmed.stanford.edu/2017spring/mnemonic-system-called-method-of-loci-enables-anyone-to-be-a-memory-athlete.html

Goldstein, E. B. (2011). *Cognitive psychology: Connecting mind, research, and everyday experience*. Australia: Wadsworth Cengage Learning.

González, M. A., & Amor, A. (2003). Limitations of the Mnemonic-Keyword Method. *Journal of General Psychology, 130*(4), 399–413. https://doi.org/10.1080/00221300309601166

Gross, A. L., Brandt, J., Bandeen-Roche, K., Carlson, M. C., Stuart, E. A., Marsiske, M., & Rebok, G. W. (2014). Do older adults use the method of loci? Results from the ACTIVE study. *Experimental aging research*, *40*(2), 140–163. https://doi.org/10.1080/0361073X.2014.882204

Harris, L. J., & Blaiser, M. J. (1997). Effects of a Mnemonic PEG System on the Recall of Daily Tasks. *Perceptual and Motor Skills*, *84*(3), 721–722. https://doi.org/10.2466/pms.1997.84.3.721

Hauck, P. D., Walsh, C. C., & Kroll, N. E. (1976). Visual imagery mnemonics: Common vs. bizarre mental images. *Bulletin of the Psychonomic Society*, *7*(2), 160–162. https://doi.org/10.3758/BF03337151

Higbee, K. L. (1977). *Your memory: How it works and how to improve it.* Prentice-Hall.

Holliman, C. (2009). *The Mnemonics Book: 30 Ways in 30 Days to Maximize Your Memory*. Professional Press

Hutmacher, F. (2019). Why is there so much more research on vision than on any other sensory modality? *Frontiers in Psychology, 10,* Article 2246. https://doi.org/10.3389/fpsyg.2019.02246

Ishai, A., & Sagi, D. (1995). Common mechanisms of visual imagery and perception. *Science, 268*(5218), 1772–1774. https://doi.org/10.1126/science.7792605

Jensen, O., & Lisman, J. E. (2005). Hippocampal sequence-encoding driven by a cortical multi-item working memory buffer. *Trends in Neurosciences, 28*(2), 67–72. https://doi.org/10.1016/j.tins.2004.12.001

Keppel, G., & Underwood, B. J. (1962). Proactive inhibition in short-term retention of single items. *Journal of Verbal Learning & Verbal Behavior, 1*(3), 153–161. https://doi.org/10.1016/S0022-5371(62)80023-1

Kozarenko, V. (2005). Giordano Memorization System.

Levy, B. J., & Anderson, M. C. (2002). Inhibitory processes and the control of memory retrieval. *Trends in Cognitive Sciences, 6*(7), 299–305. https://doi.org/10.1016/S1364-6613(02)01923-X

Levy, W.B., & Steward, O. (1983). Temporal contiguity requirements for long-term associative potentiation/depression in the hippocampus. *Neuroscience, 8*, 791-797.

Luria, A.R. (1968). *The mind of the mnemonist*. Harvard University Press.

Maguire, E. A., Valentine, E. R., Wilding, J. M., & Kapur, N. (2003). Routes to remembering: The brains behind superior memory. *Nature Neuroscience, 6*(1), 90–95. https://doi.org/10.1038/nn988

Mastropieri, M. A., Scruggs, T. E., & Fulk, B. M. (1990). Teaching abstract vocabulary with the keyword method: Effects on recall and comprehension. *Journal of Learning Disabilities, 23*(2), 92–96, 107. https://doi.org/10.1177/002221949002300203

McDaniel, M. A., & Einstein, G. O. (1986). Bizarre imagery as an effective memory aid: The importance of distinctiveness. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 12*(1), 54–65. https://doi.org/10.1037/0278-7393.12.1.54

Mocko, M., Lesser L. M., Wagler A. E., & Francis W. S. (2017). Assessing effectiveness of mnemonics for tertiary students in a hybrid introductory statistics course. *J Stat Educ, 25*(1), 2–11. https://doi.org/10.1080/10691898.2017.1294879

Moè, A., & De Beni, R. (2005). Stressing the Efficacy of the Loci Method: Oral Presentation and the Subject-generation of the Loci Pathway with Expository Passages. *Applied Cognitive Psychology, 19*(1), 95–106. https://doi.org/10.1002/acp.1051

Mullen, A. (2017). Why I Never Erase Old Memory Palaces. https://mullenmemory.com/memory-palace/erasing-memory-palaces

Murre, J. M., & Dros, J. (2015). Replication and Analysis of Ebbinghaus' Forgetting Curve. *PloS one, 10(*7), e0120644. https://doi.org/10.1371/journal.pone.0120644

O'Keefe, J. (1979). A review of the hippocampal place cells. *Progress in Neurobiology, 13*(4), 419-439. doi:10.1016/0301-0082(79)90005-4.

Oliver, M. C., Bays, R. B., & Zabrucky, K. M. (2016). False memories and the DRM paradigm: Effects of imagery, list, and test type. *Journal of General Psychology, 143*(1), 33–48. https://doi.org/10.1080/00221309.2015.1110558

Parker, A., Wilding, E., & Akerman, C. (1998). The von Restorff effect in visual object recognition memory in humans and monkeys: The role of frontal/perirhinal interaction. *Journal of Cognitive Neuroscience, 10*(6), 691–703. https://doi.org/10.1162/089892998563103

Qureshi, A., Rizvi, F., Syed, A., Shahid, A., & Manzoor, H. (2014). The method of loci as a mnemonic device to facilitate learning in endocrinology leads to improvement in student performance as measured by assessments. *Advances in physiology education, 38*(2), 140–144. https://doi.org/10.1152/advan.00092.2013

Radović, T., & Manzey, D. (2019). The Impact of a Mnemonic Acronym on Learning and Performing a Procedural Task and Its Resilience Toward Interruptions. *Front Psychol,10*:2522. doi: 10.3389/fpsyg.2019.02522.

Raz, A., Packard, M. G., Alexander, G. M., Buhle, J. T., Zhu, H., Yu, S., & Peterson, B. S. (2009). A slice of pi : an exploratory neuroimaging study of digit encoding and retrieval in a superior memorist. *Neurocase*, *15*(5), 361–372. https://doi.org/10.1080/13554790902776896

Reddan, M. C., Wager, T. D., & Schiller, D. (2018). Attenuating Neural Threat Expression with Imagination. *Neuron*, *100*(4):994-1005.e4. doi: 10.1016/j.neuron.2018.10.047.

Reddy, B. G., & Bellezza, F. S. (1986). Interference between mnemonic and categorical organization in memory. *Bulletin of the Psychonomic Society*, *24*(3), 169– 171. https://doi.org/10.3758/BF03330539

Roediger, H. L., Dudai, Y., & Fitzpatrick, S. M. (2007). *Science of memory: Concepts*. Oxford: Oxford University Press.

Sara, S. J. (2000). Retrieval and reconsolidation: toward a neurobiology of remembering *Learning & Memory*, *7*(2), 73–84. doi:10.1101/lm.7.2.73.

Schacter, D. L. (2001). *The seven sins of memory: How the mind forgets and remembers*. Boston: Houghton Mifflin.

Schifferstein, H. N. J. (2008). Comparing mental imagery across the sensory modalities. *Imagination, Cognition and Personality*, *28*(4), 371–388. https://doi.org/10.2190/IC.28.4.g

Scruggs, T. E., Mastropieri, M. A., McLoone, B. B., Levin, J. R., & Morrison, C. R. (1987). Mnemonic facilitation of learning disabled students' memory for expository prose.

Journal of Educational Psychology, *79*(1), 27–34. https://doi.org/10.1037/0022-0663.79.1.27

Senter, R. J., & Hoffman, R. R. (1976). Bizarreness as a nonessential variable in mnemonic imagery: A confirmation. *Bulletin of the Psychonomic Society*, *7*(2), 163–164. https://doi.org/10.3758/BF03337152

Shapiro, M. L., & Eichenbaum, H. (1999). Hippocampus as a memory map: Synaptic plasticity and memory encoding by hippocampal neurons. *Hippocampus, 9*(4), 365-84.

Shih, R.H., Dubrowski, A., & Carnahan, H. (2009). Evidence for haptic memory. *World Haptics 2009 - Third Joint EuroHaptics conference and Symposium on Haptic Interfaces for Virtual Environment and Teleoperator Systems*, 145-149.

Tobias, J. & Wehlisch, C. (2018). Memory Games. https://www.netflix.com/title/81105525

Toyota, H. (2002). The Bizarreness Effect and Individual Differences in Imaging Ability. *Perceptual and Motor Skills*, *94*(2), 533–540. https://doi.org/10.2466/pms.2002.94.2.533

Tulving, E., & Thomson, D. M. (1973). Encoding specificity and retrieval processes in episodic memory. *Psychological Review, 80*(5), 352–373. https://doi.org/10.1037/h0020071

Underwood, B. J., & Postman, L. (1960). Extraexperimental sources of interference in forgetting. *Psychological Review, 67*(2), 73–95. https://doi.org/10.1037/h0041865

Unsworth, N., Brewer, G., & Spillers, G. J. (2013). Focusing the search: Proactive and retroactive interference and the dynamics of free recall. *Journal of Experimental Psychology: Learning Memory and Cognition, 39*(6), 1742-1756. https://doi.org/10.1037/a0033743

Urcelay, G. P., & Miller, R. R. (2008). *Learning and memory: A comprehensive reference*. Volume 1. Amsterdam: Elsevier.

Verhaeghen, P., Marcoen, A., & Goossens, L. (1992). Improving memory performance in the aged through mnemonic training: A meta-analytic study. *Psychology and Aging, 7*(2), 242–251. https://doi.org/10.1037/0882-7974.7.2.242

Volianskis, A., Collingridge, G. L., & Jensen, M. S. (2013). The roles of STP and LTP in synaptic encoding. *PeerJ*. https://doi.org/10.7717/peerj.3

von Restorff, H. (1933). Über die Wirkung von Bereichsbildungen im Spurenfeld [The effects of field formation in the trace field]. *Psychologische Forschung [Psychological Research] (in German). 18*(1): 299–342. doi:10.1007/BF02409636.

Wang, Y., Liu, D., & Wang, Y. (2003). Discovering the Capacity of Human Memory. *Brain and Mind, 4*(2):189-198. https://doi.org/10.1023/A:1025405628479

Word Record, (2016). http://www.world-memory-statistics.com/disciplines.php

Wolgemuth, J. R., Cobb, R. B., & Alwell, M. (2008). The effects of mnemonic interventions on academic outcomes for youth with disabilities: A systematic review. *Learning Disabilities Research & Practice, 23*(1), 1–10. https://doi.org/10.1111/j.1540-5826.2007.00258.x

Wollen, K. A., Weber, A., & Lowry, D. H. (1972). Bizarreness versus interaction of mental images as determinants of learning. *Cognitive Psychology, 3*(3), 518–523. https://doi.org/10.1016/0010-0285(72)90020-5

Yassa, M. A., & Reagh, Z. M. (2013). Competitive trace theory: A role for the hippocampus in contextual interference during retrieval. *Frontiers in Behavioral Neuroscience, 7,* Article 107. https://doi.org/10.3389/fnbeh.2013.00107

Yates, F. A. (1966). *The art of memory*. Chicago: University of Chicago Press.

Zimbardo, P.G., Johnson, R.L., & Weber, A. L. (2006). *Psychology: Core Concepts*. Boston: Allyn and Bacon.

Ziganov, M. A., & Kozarenko, V. (2000). Mnemonics - All Secrets of Super Memory.

VITA

Graduate School
Southern Illinois University

Xuan Wei

xuan_wei@hotmail.com

Lanzhou University
Bachelor of Science, Chemistry, June 2014

University of Illinois at Chicago
Master of Science, Chemistry, May 2016

Research Paper Title:
Proactive Interference Caused by Repeated Use of Memory Palace

Major Professor: Reza Habib, Ph.D.