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Memory - II. The Aging Brain

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Abstract

Memory problems have reached historically high concerns. Numerous signs have been identified to tell apart the signs of normal versus abnormal memory changes, even when memory itself can be impacted by dozens of different variables. Brains do change over time and it is of paramount importance to differentiate between normal and pathological changes. In this Article, I initially analyze normal brain changes for older adults and dwell at length on memory and aging. I further discuss changes for selected few types of memory. Possible causes of memory issues with aging are then explored including clinical, psychological, and lifestyle factors. Current theories on memory loss are examined. I review current research vistas on the mechanisms of age-related memory loss and formulate approaches to preserving memory ability. I also look into causes of cognitive decline with age and suggest some helpful steps to take to forestall memory decline. Because the vast potential of the human brain becomes especially clear in the domain of memory, I finally remark on the most captivating instances of superior memory ability displayed by so-called "super-agers" and "memory savants, champions, and athletes".

Abbreviations

AAMI: Age-associated memory impairment; ACIAP: Atttention deficit, Contiguity, Inhibitory control decline, Attentional resources limitation, Processing; AD: Alzheimer's disease; ADD: AD dementia; ADH: Associative deficit hypothesis; ARMI: Age-related memory impairment; DSB: (DNA) Double-strand break; HSAM: Highly superior autobiographical memory; MCI: Mild cognitive impairment; SSB; (DNA) Single-strand break.

Keywords

Autobiographical memory; Episodic memory; Implicit memory; Kinesthetic memory; Long-term memory; Memory and aging; Memory decline; Memory loss theories; Procedural memory; Prospective memory; Semantic memory; Short-term memory; Working memory.

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Forgetfulness is common and happens to most people, including memory champions. Distraction, fatigue, depression, anxiety, absent-mindedness, and many other factors may contribute to it. Fortunately, most episodes of forgetfulness are simply temporary and not a harbinger of Alzheimer's disease (AD) or other memory disorder. Such episodes are frequently linked to situational factors and normal age-related changes. For most people, mental flexibility starts to become a bit less efficient with each passing decade from the late 20s onward, and memory starts to decline in the late 30s, so it is common to notice more memory problems with age.

Memory problems have reached historically high concerns

However, because memory impacts nearly every aspect of daily life, and because the rate of AD and other memory disorders also increases with age, it becomes important to distinguish between normal age-related memory changes and signs of a memory disorder. In the U.S. and other Western countries, this focus has surged in recent years as their population of older adults has reached historically high levels. Examples abound in the U.S.:

• **2011 survey by the Metropolitan Life Insurance:** It showed that America's 76 million baby boomers feared AD only second to cancer.

• **2015 U.S. Aging survey:** It found that 35% of people over age 60 (about 23 million people) were concerned about memory loss.

• **2017 West Health Institute survey:** It found that memory loss was the top concern of adults over age 60.

• The Alzheimer's Association (AA) refers to AD as "the defining disease of the baby boomers," and estimates that 10 million baby boomers will eventually have AD (representing a significant increase from the 5.4 million Americans who currently have the disease).

Prediction of memory degradation

How do we begin to tell apart the signs of normal versus abnormal memory changes when memory itself can be impacted by dozens of different variables? While numerous signs have been identified, the following may signal a potential memory problem:

- **Current memory is notably weaker than previous levels:** This is evidenced by increasing forgetfulness for well-known, frequently used information. Such forgetting goes well beyond related "brain blips".

- **Increasing forgetfulness for recent events:** For example, conversations, activities, and appointments.

- **New difficulty managing daily tasks due to memory problems:** For example, forgetting whether medications have been taken or having paid the bills.

The above is especially the case if it does not appear to be explained by a known medical, emotional, or situational issue. For example, some people experience temporary memory problems due to stress, lack of sleep, medication side effects, thyroid issues, or other medical problems, and memory bounces back after the underlying issue is corrected.

Note that forgetting childhood memories and other "remote" information from many years ago is not a common early sign of a memory problem (though it may occur in the later stages of a memory disorder), and waiting for this type of memory problem can result in a delay in seeking help.

- **Others have noticed that memory is worsening:** It is not uncommon for someone with a memory problem to not be fully aware of it, because they may not remember their own forgetfulness. Often, those with whom we spend the most time are the first to notice a memory problem, and can comment on whether it has worsened over time.

Notice that the signs above have a few commonalities. Forgetfulness may be a potential problem if it:

- **Reflects a notable decline from previous levels.**
- **Does not improve when potential contributing factors are addressed** (and often worsens over time).
- **Involves forgetfulness for well-known information.**
- **Impairs performance of well-known tasks.**
- **Is noticeable to others.**

It is important to understand that brains change over time, and it is helpful to be able to distinguish normal changes from those that require medical and psychological attention.

What brain changes are normal for older adults?

Although new neurons develop throughout our lives, our brains reach their maximum size during our early twenties and then begin very slowly to decline in volume. Blood flow to the brain also decreases over time. Fortunately, many studies have shown that the brain remains capable of regrowth and of learning and retaining new facts and skills throughout life, especially for people who get regular exercise and frequent intellectual stimulation. Although there are tremendous differences among individuals, some cognitive abilities continue to improve well into older age, some are constant, and some decline.

Is it typical to forget things as one ages?

Changes in the ability to remember are normal, even in the absence of dementia or other condition, and memory loss is a common concern among older adults. Declines in certain types of memory (such as working memory and episodic memory) mean that a person might occasionally forget the word they had intended to say or where they left a frequently used object. Other forms of memory, including semantic memory (knowledge about the world) and procedural memory, seem to be less affected by normal aging.

At what age does memory decline?

Memory ability, at least for some kinds of memory (such as working memory), can begin to gradually decline as early as age in the twenties or thirties, with downward trends extending into later life. Research indicates that episodic memory ability (memory for experiences) tends to decrease after age 60. For some individuals, memory is preserved to a greater extent and for longer.

Some types of memory improve or stay the same

It is well known that some forms of memory ability tend to become less sharp with age. Just like other parts of the body, the brain also changes with age, with accompanying differences in the ability to recall information. But not everyone experiences such declines to the same degree as they get older, and some forms of memory (such as the memory for familiar physical tasks) seem largely unhindered by age.

Semantic memory (the ability to recall concepts and general facts that are not related to specific experiences) continues to improve for many older adults (see Article I in this series). For example, understanding the concept

that clocks are used to tell time is a simple example of semantic memory. This type of memory also includes vocabulary and knowledge of language. In addition, procedural memory (the memory of how to do things, such as how to tell time by reading the numbers on a clock) typically stays the same.

Other types of memory decline somewhat

Episodic memory is the memory which captures the "what," "where," and "when" of daily lives. Both episodic and longer term memory decline somewhat over time.

Other types of brain functions that decrease slightly or slow down include:

- Information processing and learning something new.
- Doing more than one task at a time and shifting focus between tasks.

Memory and aging

Age-related memory loss, sometimes described as "normal aging" is qualitatively different from memory loss associated with types of dementia such as Alzheimer's disease dementia (ADD), and has a different brain mechanism. It is believed to originate in the dentate gyrus, whereas AD is believed to originate in the entorhinal cortex.

Mild cognitive impairment

Mild cognitive impairment (MCI) is a condition in which people face memory problems more often than that of the average person their age. These symptoms, however, do not prevent them from carrying out normal activities and are not as severe as the symptoms for AD. Symptoms often include misplacing items, forgetting events or appointments, and having trouble finding words.

MCI is the transitional state between cognitive changes of normal aging and AD. Several studies have indicated that individuals with MCI are at an increased risk for developing AD, ranging from 1% to 25% per year. In one study, 24% of MCI patients progressed to AD in two years and 20% more over three years, whereas another study indicated that the progression of MCI subjects was 55% in four and a half years. Some patients with MCI, however, never progress to AD.

Studies have also indicated patterns that are found in both MCI and AD. Much like patients with AD, those with MCI have difficulty accurately defining words and using them appropriately in sentences when asked. While MCI patients had a lower performance in this task than the control group, AD patients performed worse overall. The abilities of MCI patients stood out, however, due to their ability to provide examples to make up for their difficulties. AD patients failed to use any compensatory strategies and therefore exhibited the difference in use of episodic memory and executive functioning.

Normal aging

Normal aging is associated with a decline in various memory abilities in many cognitive tasks; the phenomenon is known as 'age-related memory impairment' (ARMI) or 'age-associated memory impairment' (AAMI).

The ability to encode new memories of events or facts and working memory show a decline in both cross-sectional and longitudinal studies. Studies comparing the effects of aging on episodic memory, semantic memory, short-term memory and priming find that episodic memory is especially impaired in normal aging and some types of short-term memory are also impaired. The deficits may be related to impairments seen in the ability to refresh recently processed information.

Changes in certain memory types

Some types of memory noted for their decline with aging are further elaborated upon below.

Implicit or procedural memory

Typically, implicit or procedural memory shows no decline with age.

Episodic memory

Episodic memory is supported by networks spanning frontal, temporal, and parietal lobes. The interconnections in the lobes are presumed to enable distinct aspects of memory, whereas the effects of grey matter lesions have been extensively studied, less is known about the interconnecting fiber tracts. In aging, degradation of white matter structure has emerged as an important general factor, further focusing attention on the critical white matter connections.

Exercise affects many people young and old. For the elderly, especially those with AD or other diseases that affect the memory, when the brain is introduced to exercise, the hippocampus is likely to retain its size and improve its memory.

It is also possible that the years of education a person has had and the amount of attention they received as a child might be a variable closely related to the links of aging and memory.There is a positive correlation between early life education and memory gains in older age. This effect is especially significant in women.

In particular, associative learning, which is another type of episodic memory, is vulnerable to the effects of aging, as has been demonstrated across various study paradigms. This has been explained by the 'associative deficit hypothesis' (ADH), which states that aging is associated with a deficiency in creating and retrieving links between single units of information. This can include knowledge about context, events or items. The ability to bind pieces of information together with their episodic context in a coherent whole has been reduced in the elderly population. Furthermore, the older adults' performances in free recall involves temporal contiguity to a lesser extent than for younger people, indicating that associations regarding contiguity become weaker with age.

Three reasons have been speculated as to why older adults use less effective encoding and retrieval strategies as they age:

1. **The "disuse" view:** It states that memory strategies are used less by older adults as they move further away from the educational system.

2. **The "diminished attentional capacity" hypothesis:** It means that older people engage less in self-initiated encoding due to reduced attentional capacity.

3. **The "memory self-efficacy" view:** It indicates that older people do not have confidence in their own memory performances, leading to poor consequences. It is known that patients with AD and patients with semantic dementia both exhibit difficulty in tasks that involve picture naming and category fluency. This is tied to damage to their semantic network, which stores knowledge of meanings and understandings.

One phenomenon, known as "senior moments", is a memory deficit that appears to have a biological cause. When an older adult is interrupted while completing a task, it is likely that the original task at hand can be forgotten. Studies have shown that the brain of an older adult does not have the ability to re-engage after an interruption and continues to focus on the particular interruption unlike that of a younger brain. This inability to multi-task is normal with aging and is expected to

become more apparent with the increase of older generations remaining in the work field.

For super-aged people, a biological explanation for memory deficits in aging includes a post-mortem examination of five brains of elderly people with better memory than average. It was found that these individuals had fewer fiber-like tangles of tau protein than in typical elderly brains. However, a similar amount of amyloid plaque was found.

More recent research has extended established findings of age-related decline in executive functioning, by examining related cognitive processes that underlie healthy older adults' 'sequential performance'. Sequential performance refers to the execution of a series of steps needed to complete a routine. An important part of healthy aging involves older adults' use of memory and inhibitory processes to carry out daily activities in a fixed order without forgetting the sequence of steps that were just completed while remembering the next step in the sequence.

A 2009 study examined how young and older adults differ in the underlying representation of a sequence of tasks and their efficiency at retrieving the information needed to complete their routine. Findings from this study revealed that when older and young adults had to remember a sequence of eight animal images arranged in a fixed order, both age groups spontaneously used the organizational strategy of 'chunking' to facilitate retrieval of information.

However, older adults were slower at accessing each chunk compared to younger adults, and were better able to benefit from the use of memory aids, such as verbal rehearsal to remember the order of the fixed sequence. Results from this study suggest that there are age differences in memory and inhibitory processes that affect people's sequence of actions and the use of memory aids could facilitate the retrieval of information in older age.

Working memory

Working memory involves the manipulation and use of information that is being obtained to complete a task. It declines as the aging process progresses. Working memory plays a role in the comprehension and production of speech.

Table 1 summarizes some known facts about memory decline with normal aging:

Memory type	Fate with normal aging	Brain region affected
Autobiographical	o Declines somewhat o Decreases after age 60	
Episodic	o Declines somewhat o Decreases after age 60; preserved to a greater extent and for longer for some individuals	o Supported by networks spanning frontal, temporal, and parietal lobes. o Degradation of white matter medial-temporal regions, which contain the hippocampi
Implicit	o No decline o Less affected than working and episodic memories	
Kinesthetic		
Long-term	o Declines somewhat	
Procedural	o No decline	
Prospective		
Semantic	o Continues to improve or stays the same for many adults o Less affected than working and episodic memories	
Sensory		

- Auditory (or echoic) - Haptic - Olfactory - Visual spatial (or iconic)		
Short-term - Active - Working	o Somewhat impaired o Little decline for other types of short-term memory o Semantic knowledge (e.g. vocabulary) improves with age o Enhancement seen in memory for emotional events maintained with age. o Declines. Primary reason for decline in a variety of cognitive tasks and in comprehension and production of speech	

Table 1: Fate of various types of memory with normal aging

Possible causes of memory issues with aging

The causes for memory issues and aging are still unclear, even after the many theories have been tested. It is still difficult to determine exactly how each aspect of aging affects the memory and aging process. However, it is known that the brain shrinks with age due to the expansion of ventricles, restricting the room in the head. Unfortunately, a solid link between the shrinking brain and memory loss has not been established due to not knowing exactly which area of the brain has shrunk and what the importance of that area truly is in the aging process. Attempting to recall information or a situation that has happened can be very difficult since different pieces of information of an event are stored in different areas. During recall of an event, the various pieces of information are pieced back together again and any missing information is unconsciously filled up by our brains, which can account for ourselves receiving and believing false information.

Memory lapses can be both aggravating and frustrating but they are due to the overwhelming number of information that is being taken in by the brain. Issues in memory can also be linked to several common clinical, psychological, and physical causes (listed below), some of which may be reversible. For example, the following common conditions can lead to memory problems:

- **Clinical factors:**
  Blood clots in the brain
  Chronic conditions (heart disease, diabetes, etc.)
  Dehydration
  Infections
  Medication side effects.
  Thyroid imbalance
  Vitamin B12 deficiency

- **Psychological factors:**
  Anxiety
  Depression
  Psychological stress

- **Lifestyle factors:**
  Changes due to traumatic events (accidents, head injuries, past abuse, loss of loved ones, etc.)
  Chronic alcoholism
  Insufficient water drinking
  Poor nutrition
  Substance abuse

It is important to discuss these and other possible causes of memory problems with a medical professional and to have a complete medical workup. Also, a psychologist

may perform a complete neuropsychological evaluation to rule out anxiety, depression, or other psychological stresses and to test for cognitive changes. Taking care of body and mind with appropriate medication, doctoral check-ups, and daily mental and physical exercise can prevent some of these memory issues. There is a possibility that the damage to the brain makes it harder for a person to encode and process information that should be stored in long-term memory. There is support for environmental cues being helpful in recovery and retrieval of information.

Memory loss theories

Is it typical to forget things as one ages?

Changes in the ability to remember are normal, even in the absence of dementia or another condition, and memory loss is a common concern among older adults. Declines in certain types of memory (such as working memory and episodic memory) mean that a person might occasionally forget the word they had intended to say or where they left a frequently used object. Other forms of memory, including semantic memory (knowledge about the world) and procedural memory, seem to be less affected by normal aging.

At what age does memory decline?

Memory ability, at least for some kinds of memory (such as working memory), can begin to gradually decline as early as age twenties or thirties, with downward trends extending into later life. Research indicates that episodic memory ability (memory for experiences) tends to decrease after age 60. Yet these are averages; for some individuals, memory is preserved to a greater extent and for longer.

Six theories have been advanced in attempts to explain memory loss. A helpful mnemonic is ACIAP, which encompasses several effects (Atttention deficit; Contiguity; Inhibitory control decline; Attentional resources limitation; Processing).

1. Attention deficit effect

In the 'associative deficit theory' of memory, access to the memory performance of an elder person is attributed to their difficulty in creating and retaining cohesive episodes.

2. Contiguity effect

Tests and data show that as people age, the contiguity effect (stimuli that occur close together in the associated time) starts to weaken. This is supported by the associative deficit theory of memory. The supporting research shows that greater age is associated with lower hit and greater false alarm rates, and also a more liberal bias response on recognition tests even after controlling for sex, education, and other health-related issues

3. Inhibitory control decline

Older people have a higher tendency to make outside intrusions during a memory test. This can be attributed to the inhibition effect that causes participants to take longer time in recalling or recognizing an item, and also subjects them to making more frequent errors. For instance, in a study using metaphors as the test subject, older participants rejected correct metaphors more often than literally false statements.

Inhibitory control may account for the decline seen in working memory that prevents the suppression of irrelevant information in working memory and, correspondingly, the limited capacity for relevant information. Less space for new stimuli may be attributed to the declines seen in individuals' working memory as they age.

As we age, deficits are seen in the ability to integrate, manipulate, and reorganize the contents of working

memory in order to complete higher level cognitive tasks such as problem-solving, decision- making, goal-setting, and planning. More research must be completed in order to determine what the exact cause of these age-related deficits in working memory are. It is likely that many or all of the above theories (associated deficit, contiguity, inhibition, memory decline, attentional resources limitation, processing speed, and inhibitory control) may play a role in these age-related deficits. The brain regions that are active during working memory tasks are also being evaluated, and research has shown that different parts of the brain are activated during working memory in younger adults as compared to older adults.

4. Attentional resources limitation effect

Another theory that is being examined to explain age-related declines in working memory is that there is a 'limit in attentional resources' seen with aging. Older individuals are less capable of dividing their attention between two tasks so that tasks with higher attentional demands are more difficult to complete due to a reduction in mental energy. Tasks that are simple and more automatic, however, see fewer declines with aging. Working memory tasks often involve divided attention, thus, they are more likely to strain the limited resources of aging individuals.

5. Processing speed effect

Speed of processing information decreases significantly and is then responsible for the inability to use working memory efficiently as we age. As processing slows, cognitive tasks that rely on quick processing speed become more difficult.

Working memory decline effect

Working memory demonstrates great declines during the aging process and less capacity to hold information. There have been various theories offered to explain why these changes may occur, which include:

- Fewer attentional resources;
- Slower speed of processing;
- Less capacity to hold information;
- Lower degree of integration and manipulation of information because the products of earlier memory processing are forgotten before the subsequent products; and
- Lack of inhibitory control.

All of these theories offer strong arguments, and it is likely that the decline in working memory is due to the problems cited in all of these areas.

Mechanisms research

Age-related memory loss has been associated with several possible mechanisms. Here the following two mechanisms are emphasized.

Deficiency of the RbAp48 protein

In 2010, experiments that have tested for the significance of the under-performance of memory for an older adult group as compared to a young adult group, hypothesized that the associated memory deficit with age could be linked with a physical deficit. It can be explained by the inefficient processing in the medial-temporal regions – an important region for episodic memory containing the hippocampi, which are crucial in creating memory association between items. It is to be noted that age-related memory loss is believed to originate in the dentate gyrus, whereas AD is believed to originate in the entorhinal cortex.

Oxidative DNA damage

During normal aging, oxidative DNA damage in the brain accumulates in the promoters of genes involved in learning and memory, as well as in genes involved in neuronal survival. It includes DNA single-strand breaks

(SSBs), which can give rise to DNA double-strand breaks (DSBs). DSBs accumulate in neurons and astrocytes of the hippocampus and frontal cortex at early stages and during the progression to AD, a process that could be an important driver of neurodegeneration and cognitive decline.

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Preserving memory ability

Can memory be protected as people grow older?

While a person may not be able to prevent decreases in memory ability entirely, experts have studied various steps one can take to increase one's odds of maintaining a sharp memory into older age. There are also techniques for working around common memory issues if they arise.

What are some strategies for preserving memory ability?

Adopting aspects of a generally health-promoting lifestyle—such as a healthy diet, routine physical activity, and plenty of sleep—may help maintain memory as one ages. So might playing cognitively challenging games, such as chess, cards, and crossword puzzles, or exercising one's mind in other ways.

How can one manage normal, age-related memory loss?

Reducing stress and getting enough sleep could be helpful. Other ways to compensate for forgetfulness include organizing objects (such as car keys) so that their locations are always the same, making an extra effort to concentrate when taking in information to be remembered, minimizing distractions, and using simple memory aids such as planners, calendars, written lists, and reminder notes. In some cases, it may be worth considering medications to enhance memory.

Some helpful steps to take to forestall memory decline

Because memory can be impacted by dozens of factors, the warning signs noted above do not definitely indicate a memory disorder is present, Rather, they suggest that helpful steps may be taken, such as:

- **Discussing memory concerns with a health-care provider:** This may lead to a "work-up" to investigate possible contributing factors, which may include:

  ◦ Laboratory tests to measure thyroid, vitamin, and other metabolic levels;
  ◦ Analysis of possible medication side effects;
  ◦ Brief memory screening (which provides a basic measure of thinking skills, though usually not enough detail to make a diagnosis or detect

subtle memory problems);

◦ A neuropsychological evaluation which statistically analyzes memory, attention, visual functioning, reasoning, strategy formation, and other skills (i.e., the "software" of the brain) to determine if memory problems are present and how best to treat them; and
◦ Possible neuroimaging (e.g., head CT or brain MRI) to evaluate the "hardware" of the brain.

- **Cardiovascular exercising:** Multiple studies have shown that the most powerful treatment for mild memory problems is cardiovascular exercise, which can slow the rate of memory loss and even improve memory. Exercise also increases the density of brain tissue in the hippocampus (a core memory processing area) and the frontal lobes. Exercise can also slow the rate of memory loss for those who already have moderate AD.

  Given that AD-related brain changes can start 10-30 years prior to diagnosis (in the late-onset variant, where symptoms begin after age 65), and given that there is no treatment to stop the progression of AD, it is most advantageous to exercise proactively. However, it is never too late to begin exercising.

- **Increasing neuronal density:** Increasing the number and density of neuronal pathways in the brain by building "cognitive reserve" has been shown to help the brain compensate for AD-related changes, and may even prohibit AD symptoms from being expressed!

Whether or not forgetfulness is a "brain blip" or a sign of a potential memory problem, it is never too late to start building better brain health.

Extraordinary memory abilities

The vast potential of the human brain becomes especially clear in the domain of memory. The most captivating instances of superior memory ability may be few and far between—e.g., the savant who memorizes a library's worth of books, the otherwise regular person who cannot help but remember what she did 10 years ago today, etc. But such cases show that, at its outer reaches, memory capacity can be far more immense than it is for most of us on even our most lucid day.

Hyperthymesia, savants, and photographic memory

- **Hyperthymesia:** A condition that leads people to be able to remember an abnormally large number of their life experiences in vivid detail. Some awe-inspiring individuals develop highly unusual abilities to remember particular kinds of information−personal experiences, historical facts, musical compositions, or others. These powers of memory can arise in the absence of extensive training, and the cause is often unclear. They can also appear in people who are otherwise intellectually ordinary or who show deficits in other areas of cognitive functioning.

- **Highly superior autobiographical memory (HSAM):** This is another name for hyperthymesia - the ability to remember far more about one's own life than is typical, including details of personal experiences and when they occurred. Someone with HSAM would likely be able to recount what h/she personally did, what the weather was like, or what the top news was on a randomly chosen date many years ago. H/she may also be able to recall the exact dates on which various events occurred. However, people with HSAM do not show such unusual memory for all kinds of information, their autobiographical memory is not perfect, and they may not stand out on other

cognitive characteristics.

- HSAM is thought to be very rare. As of the mid-2010s, according to an expert report, fewer than 100 people with HSAM ability had been found.

- **Memory champion:** Someone who can accomplish impressive feats of memory not because of a radical difference in cognitive functioning relative to other people, but through training and the use of techniques for enhancing memory. The examples of these memory champions suggest that even relatively ordinary minds can take memory to extraordinary levels. Some of the feats performed by memory champions include memorizing long strings of digits, series of random words, sequences of cards in decks, and names and faces. Memory champions regularly set new world records: In 2019, for example, a contender memorized a sequence of 335 random words in 15 minutes. Another memorized 1,168 digits in the same amount of time.

- **Memory athlete:** Someone who participates in memory competitions, which can involve a variety of tests of memory ability. Competitors train their ability to recall information with the aid of mental techniques called mnemonics. Memory sport includes international competitions (the World Memory Championships launched in 1991) as well as national and lower-level contests.

Conclusions and take-aways

- Forgetfulness is common and happens to most people, including memory champions. Distraction, fatigue, depression, anxiety, absent-mindedness, and many other factors may contribute to it.

- Most episodes of forgetfulness are simply temporary and not a harbinger of AD or other memory disorder. Such episodes are frequently linked to situational factors and normal age-related changes.

- Because memory impacts nearly every aspect of daily life, and because the rate of AD and other memory disorders also increases with age, it becomes important to distinguish between normal age-related memory changes and signs of a memory disorder. To do so, helpful steps may be taken, such as: Discussing memory concerns with a health-care provider; cardiovascular exercising: and increasing the number and density of neuronal pathways in the brain by building “cognitive reserve”.

- Brains change over time, and it is helpful to be able to distinguish normal changes from those that require medical and psychological attention.

- Although new neurons develop throughout life, brains reach their maximum size during the early twenties and then begin very slowly to decline in volume. Blood flow to the brain also decreases over time.

- The brain remains capable of regrowth and of learning and retaining new facts and skills throughout life, especially for people who get regular exercise and frequent intellectual stimulation.

- Some types of memory improve or stay the same. Semantic memory (which also includes vocabulary and knowledge of language) continues to improve for many older adults. In addition, procedural memory typically stays the

same.

- Other types of memory (episodic and longer term memory) decline somewhat over time.

- Other types of brain functions that decrease slightly or slow down include: Information processing and learning something new; doing more than one task at a time and shifting focus between tasks.

- Age-related memory loss, sometimes described as "normal aging" is qualitatively different from memory loss associated with types of dementia such as Alzheimer's disease, and has a different brain mechanism. It is believed to originate in the dentate gyrus, whereas AD is believed to originate in the entorhinal cortex.

- Mild cognitive impairment is the transitional state between cognitive changes of normal aging and Alzheimer's disease.

- Normal aging is associated with a decline in various memory abilities in many cognitive tasks. Studies comparing the effects of aging on episodic memory, semantic memory, short-term memory and priming found that episodic memory is especially impaired in normal aging and some types of short-term memory are also impaired.

- One type of episodic memory (source information) declines with old age. This deficit may be related to declines in the ability to bind information together in memory during encoding and to retrieve those associations at a later time.

- Typically, implicit or procedural memory shows no decline with age. Episodic memory is supported by networks spanning frontal, temporal, and parietal lobes. In aging, degradation of white matter structure has emerged as an important general factor, further focusing attention on the critical white matter connections.

- For the elderly, especially those with Alzheimer's or other diseases that affect the memory, when the brain is introduced to exercise, the hippocampus is likely to retain its size and improve its memory.

- There is a positive correlation between early life education and memory gains in older age. This effect is especially significant in women.

- Associative learning, another type of episodic memory, is vulnerable to the effects of aging has been explained by the associative deficit hypothesis, which states that aging is associated with a deficiency in creating and retrieving links between single units of information. This can include knowledge about context, events or items.

- Three reasons have been speculated as to why older adults use less effective encoding and retrieval strategies as they age: The "disuse" view, the "diminished attentional capacity" hypothesis, and the "memory self-efficacy" view.

- One phenomenon, known as "senior moments", is a memory deficit that appears to have a biological cause. This inability to multi-task is normal with aging and is expected to become more apparent with the increase of older generations remaining in the work field.

- Superaged people have fewer fiber-like tangles of tau protein than in typical elderly brains but a similar amount of beta-amyloid plaque.

- An important part of healthy aging involves older adults' use of memory and inhibitory processes to carry out daily activities in a fixed order without forgetting the sequence of steps that were just completed while remembering the next step in the sequence.

- Working memory involves the manipulation and use of information that is being obtained to complete a task. It declines as the aging process progresses and plays a role in the comprehension and production of speech.

- The causes for memory issues and aging are still unclear. It remains difficult to determine exactly how each aspect of aging affects the memory and aging process. However, it is known that the brain shrinks with age due to the expansion of ventricles, restricting the room in the head. Unfortunately, a solid link between the shrinking brain and memory loss has not been established.

- Memory lapses are due to the overwhelming number of information that is being taken in by the brain. Issues in memory can also be linked to several common clinical, psychological, and physical causes, some of which may be reversible.

- Six theories have so far been advanced in attempts to explain memory loss: Associative deficit effect; contiguity effect; inhibition and inhibitory control effect; working memory decline effect; attentional resources limitation effect; processing speed effect; and inhibitory control effect.

- Age-related memory loss has been associated with several possible mechanisms, including particularly deficiency of the RbAp48 protein and oxidative DNA damage, which includes DNA single-strand breaks that can give rise to DNA double-strand breaks. DSBs accumulate in neurons and astrocytes of the hippocampus and frontal cortex at early stages and during the progression to Alzheimer's disease, a process that could be an important driver of neurodegeneration and cognitive decline.

- The vast potential of the human brain becomes especially clear in the domain of memory. The most captivating instances of superior memory ability may be few and far between.

- Hyperthymesia is a condition that leads people to be able to remember an abnormally large number of their life experiences in vivid detail. These powers of memory can arise in the absence of extensive training, their cause is often unclear, and they can appear in people who are otherwise intellectually ordinary or who show deficits in other areas of cognitive functioning.

- Highly superior autobiographical memory is the ability to remember far more about one’s own life than is typical, including details of personal experiences and when they occurred. A memory champion can accomplish impressive feats of memory not because of a radical difference in cognitive functioning relative to other people, but through training and the use of techniques for enhancing memory. A memory athlete is someone who participates in memory competitions, which can involve a variety of tests of memory ability.

- Whether or not forgetfulness is a “brain blip” or a sign of a potential memory problem, it is never too late to start building better brain health.

Sidebar - What causes cognitive decline with age

The mental process of thinking, learning, remembering, being aware of surroundings, and using judgment changes as we age. As nerve cells and synapses in the brain alter over time, the ability to quickly process information and make decisions declines. For most people, the decline is gradual, starting at around the age of 50. However, this slight drop in processing speed and working memory is generally accompanied by improvements in cumulative knowledge well into old age.

The S-nitrosylation process

A new study, in mice, suggests that alterations in a brain protein may impair synaptic plasticity (the ability of nerve cells to modify the strength of their connections), leading to memory decline. Another mice study suggests that we can help delay age-related cognitive decline, and how social interaction, cognitive training, and physical exercise activate an enzyme that improves the functioning of nerve cells and synapses, resulting in enhanced cognitive performance.

In two other studies, researchers investigated CaM kinase II (CaMKII), an enzyme that is involved in, among other processes, synaptic plasticity and the transmission of nerve impulses across synapses. By altering this brain protein, they mimicked the cognitive effects that occur during normal aging. They suggested that nitric oxide (NO) affects the action of CaMKII and that a process called S-nitrosylation, which relies on NO, modifies CaMKII.

The reduced nitrosylation of CaMKII causes a reduction in synaptic localization of CaMKII, which happens during normal aging, memory, and learning abilities are impaired. Put simply, a reduction in NO slows down the movement of nerve impulses across the connections between nerve cells, which may cause cognitive decline.

Lifestyle and cognitive decline

Researchers have long known that a healthy lifestyle (positive experiences such as social interactions, physical exercise, intermittent fasting, cognitive training, and critical thinking) is essential for optimal brain health throughout life and is associated with a slower rate of memory decline in adults with normal cognition. What is not known is how exactly these lifestyle factors have their effect.

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