Memory Improvement

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June 5, 2026

RECOMMENDED CITATION

mohammad looti (2026). *Memory Improvement*. PSYCHOLOGICAL SCALES. Retrieved from https://scales.arabpsychology.com/?p=38282

Memory improvement is the act of improving one's memory. It can be achieved by a variety of techniques.

History

Aristotle wrote a treatise about memory: De memoria et reminiscentia. To improve recollection, he advised that a systematic search should be made and that practise was helpful. He suggested grouping the items to be remembered in threes and then concentrating upon the central member of each triad.

Throughout history, the possession of an exceptional memory has been seen as a symbol of power and achievement. As today's research focuses on human health and longevity, studies look at memory deficits and age-related memory loss with the aim of uncovering new explanations and treatment techniques to improve memory. The knowledge gained from this research can be transferred to general memory improvement methodology and training. Neuroimaging as well as cognitive neuroscience have provided neurobiological evidence supporting holistic ways in which one can improve memory.

Experience-dependent neuroplasticity

Understanding that the brain can change through experience is the first step to improving memory. It was once thought that the adult brain was a fixed entity, however it has been found that the brain is actually a highly flexible and plastic organ that changes throughout life. Every experience, thought, emotion and behaviour that is produced causes a corresponding change in the neurocircuitry of the brain. Neural plasticity is the mechanism by which the brain encodes experience and learns new behaviours. It is also the mechanism by which the damaged brain relearns lost behaviour in response to rehabilitation. Experience-dependent neuroplasticity suggests that the brain changes in response to what it experiences. The most well known example of this is represented by London taxi cab drivers.

London Taxi Cab

London taxi cab drivers undergo extensive training for 2-4 years, learning and memorizing the layout of streets, street names and many different places within the city. Not only are they required to have this knowledge in their brain at all times, they must also find the quickest route to their customer's desired destination. After studying London taxi cab drivers, evidence showed greater grey matter volume in the posterior hippocampus, an area in the brain involved heavily in memory. The longer taxi drivers navigated in London the greater the posterior hippocampal gray matter volume. Therefore, it is suggested that there may be a capacity for plastic change in the structure of the hippocampus in healthy adult humans that can accommodate the spatial representation of a very large and complex environment. The results from the present study continue to permit the view that learning, representing, and using a spatial representation of a highly complex and large-scale environment is a primary function of the hippocampus in humans such that this brain region might adapt structurally to accommodate its elaboration. The correlation between time driving and hippocampal grey matter suggests that experience drives the changes observed.

Principles of experience-dependent neuroplasticity

Brain damage research has discovered 10 factors that may affect the outcome of rehabilitation. These principles are the result of decades of basic neuroscience research and are very useful to brain damaged individuals, but can also be used as general guidelines to help improve the memory of healthy individuals.

Neural circuits not actively engaged in task performance for an extended period of time begin to degrade. For example, in the 1960's Hubel and Wiesel found that depriving a kitten's eye of light reduced the number of neurons in the visual cortex that responded to light. This also applies to auditory deprivation, which can result in a decreased number of synapses in the cortex. It is important to note that sensory deprivation does not result in complete loss of cortical function but rather a reallocation of cortical territory. For example, if an individual follows a recipe constantly, they will begin to remember the ingredients involved and perhaps not need the assistance of the recipe anymore. However, if that individual stops making that dish for some period of time, they will forget the specifics of that recipe.

Training is a big factor in improving memory. Several studies have shown how plasticity can be induced within specific brain regions through extended training. Improvements in sensory and motor performance brought by skill training are accompanied by profound plasticity within the cerebral cortex. Rehabilitative training has also become increasingly viewed as a means of enhancing the potency of other therapeutic approaches, such as grafts of fetal tissue, provision of neuronal precursors and other treatments intended to promote restorative plasticity. This principle is essentially referring to cognitive training. (see section below) For example, improving memory is linked with engaging in activities that challenge the mind, whether it is a crossword or using your left hand to brush your teeth instead of your right (or vice versa).

In many studies, learning or skill acquisition rather than mere use, seem to be required to produce significant changes in patterns of neural connectivity. Learning-induced brain changes also show regional specificity. Specific forms of neural plasticity and associated behavioral changes are dependent upon specific kinds of experience. Therefore, specificity refers to the type of experience. Some experiences will be more specific than others and will be easier to remember. For example, memory will be more significant for a sport that you learnt how to play properly rather than just blindly playing it without prior knowledge.

Repetition of a behaviour, whether learning it for the first time or re-learning it, may be required to induce long lasting neural changes and may also help the behaviour resistant decay. The more practice an individual has with a task, the better they will perform. For example, when someone tells you his or her phone number you immediately repeat it to yourself over and over and will be more likely to remember the phone number. This is because practice reduces the amount of effort the brain needs to expend when retrieving and processing information important for the task, allowing it to be faster and more automatic. Practicing until something becomes second nature will make memory more durable, especially in situations when you are under stress and need to remember information, such as a test or even life threatening situations.

The intensity of training stimulation can also affect the induction of neural plasticity. Low-intensity stimulation can induce a weakening of synaptic responses (long-term depression), whereas higher intensity stimulation will induce long-term potentiation. In short, things that are subtle are less likely to impact memory, whereas strong experiences or even highly emotional experiences will more likely be remembered. For example, if an individual were to get into a car accident, they will surely be able to remember that experience because it is very intense and emotional.

Certain forms of plasticity appear to come before and even depend upon others, thus the nature of the plasticity observed and its behavioural relevance may depend on when one looks at the brain. In stimulation experiments, it has been seen that synaptic responses are more likely to degrade in early phases of stimulation rather than later and it has been proven that stable consolidation of memories requires time. Therefore, in order for behaviours to induce neural plasticity, timing must be correct for maximum results. For example, relating back to the phone number example seen in the principle 'repetition matters', the phone number that is trying to be remembered will be in a fragile state upon first being told. However, after practicing the phone number it will stick in the individuals mind later on.

In order for an organism to function effectively, there must be a system in place to weigh the importance of any given experience such that it can be encoded. It has been shown that there is a tendency to orient attention towards stimuli that is salient. This allows for quick detection and reaction to objects in our environment. Recently, the relationship between salience and cognitive functions such as memory have been studied and recognized. An object-place working memory test involving the memorization of objects possessing visual salience in a certain spatial location has shown to increase the ability to recall. This suggests that salience may enhance encoding and retrieval processes in memory and therefore concluding that the more important an experience is, the greater chance that it will be remembered. For example, an individual will be able to remember their wedding day much better than the day they paid their first hydro bill.

Aging results in a number of neuroplastic changes in the brain. Long-term potentiation (LTP), the increased transmission between two neurons, is said to be one of the underlying mechanisms of synaptic plastcity. Aging causes a reduction in LTP and therefore may cause a reduction in synaptic plasticity. Synaptogenesis, the formation of synapes, as well as cortical map reorganization are both also reduced with aging. Cognitive decline and age-related impairments may therefore reflect the progressive failure of plasticity processes. Although aging results in a

decrease in plasciticy, the aging brain is clearly responsive to experience and may change, even though the changes in the brain may be less profound and/or slower to occur than those observed in younger brains.
Transference refers to the ability of plasticity within one set of neural circuits to promote concurrent or subsequent plasticity. In other words, transference states that plasticity in response to one training experience can enhance the acquisition of similar behaviours. Training can not only produce plasticity in one area but it can also enhance and relate to other behaviours. For example, an individual who obtains the skills to play tennis also develops skills and coordination for other racquet sports, such as squash or badminton.
Interference or the ability of plasticity to impede new or existing plasticity within the same circuitry, which can impair learning. Some types of stimulation applied during or shortly before skill training may actually enhance motor learning, however other forms can be disruptive of learning. A negative aspect of this principle is that although therapy may benefit one skill it may interfere with the performance of another. Relating to the example above about transference, although having skills for one racquet sport may enhance skills in other racquet sports, certain factors, such as the weight of the racquet and/or ball (tennis ball, squash ball, or birdie), can interfere with these skills.

These principles strongly support the use of rehabilitative training as a tool to improve brain reorganization and functional outcome. A good way to approach these principles to improve memory is through cognitive training.

Cognitive training

Discovering that the brain can change as a result of experience has resulted in the development of cognitive training. Cognitive training involves processes that improve cognitive functioning through different kinds of brain training techniques. There are a number of studies demonstrating that training increases working memory capacity and can yield improvements in a range of important cognitive skills as well as improved cognitive functions in clinical populations with known working memory deficiencies. Other related approaches to cognitive enhancement through training include attention, speed of processing, neuro-feedback, dual-tasking and perceptual training. Cognitive training has been shown to improved cognitive abilities for up to five years. In one experiment, the goal was to prove that cognitive training would increase the cognitive functions in older adults by using three types of training (memory, reasoning and speed of processing). It was found that improvements in cognitive ability not only was maintained over time but had a positive transfer effect on everyday functioning. Therefore, these results indicate that each type of cognitive training can produce immediate and lasting improvements in each kind of cognitive ability, thus suggesting that training can be beneficial to improving memory.

Cognitive training in areas other than memory has actually been seen to generalize and transfer to memory systems. For example, the Improvement in Memory with Plasticity-based Adaptive

Cognitive Training (IMPACT) study by The American Geriatrics Society in 2009 demonstrated that cognitive training designed to improve accuracy and speed of the auditory system presented improvements in memory and attention system functioning as well as auditory functioning.

Cognitive training can occur in many different ways. Two methods related to memory improvement are known as strategy training and core training.

1. Strategy training

Strategy training is used to help individuals remember increasing amounts of information of a particular type. It involves teaching effective approaches to encoding, maintenance, and/or retrieval from working memory. The main goal of strategy training is to increase performance in tasks requiring retention of information. Studies strongly support the claim that the amount of information remembered can be increased by rehearsing out loud, telling a story with stimuli, or using imagery to make stimuli stand out. Strategy training has been used in children with Down syndrome and also in older adult populations.

2. Core training

Core training involves repetition of demanding working memory tasks.

Some core training programs involve a combination of several tasks with widely varying stimulus types. The diversity of exercises increase the chance that one of, or some combination of the training tasks, will produce desired training-related gains. A goal of cognitive training is to impact the ease and success of cognitive performance in one's daily life - not just performance in the lab. Core training can reduce the symptoms of ADHD and improve the quality of life involving patients with multiple sclerosis, schizophrenia and also, those who have suffered from stroke.

Along with these training techniques comes limitations and alternative interpretations, such as:

Expectancy/effort effects

An issue of great concern is that test score improvements may be due to participant expectations or level of investment rather than on the intentionally targeted cognitive processes. In other words, a disadvantage to studying cognitive training is expectancy bias, which is when the experimenter subconsciously influences the participants in a manner that can alter their results to their liking. Furthermore, a participants effort or lack of effort can certainly change the outcome of results. One form of expectancy bias relates to placebo effects, which is the belief that training should have a positive influence on cognition and may produce a measurable improvement on post-training performance. A "control" group may help to eliminate this bias because this group would not expect to benefit from the training.

Generalization

Researchers sometimes generalize their results, which can be misleading and incorrect. For example, working memory training studies often generalize by only using a single task but interpret the observed improvements as a broadly defined cognitive ability.

Lack of consistency

There is inconsistency in the variety of comparison groups used in working memory training. There are reported training benefits that can be impacted by the qualities of the control group. Areas of research design that can cause issues with inconsistency include: timeline of training and assessments, conditions of assessment, setting of training and the particular control groups that are used. This means that researchers must be careful in the way they present their findings.

Although cognitive training has been shown to improve memory, some considerations must be taken into account with certain results. Cognitive training may not be a practical option for many people, however studies indicate that controlling ones diet, stress level, and physical activity may improve memory.

Diet

Cognitive training may provide a way in which one can improve memory processing, but when, what and how much one eats can also directly impact one's cognitive functioning abilities. Research suggests that dietary control can specifically influence memory processing, as glucose, flavanoids, fat and calories all affect memory areas of the brain.

Glucose

Research has suggested that glucose may enhance memory processing by altering neural metabolism and neurotransmitter synthesis in the brain. Throughout the normal aging process, humans decrease in their ability to utilize glucose. Glucose is a major source of energy used by the central nervous system. It is readily transported from blood to brain, making it useful for cognitive functions such as memory. Evidence from studies on glucose and memory have indicated that glucose is involved in the regulation of memory and has also suggested that increases in glucose levels may actually enhance memory formation in both animals and humans. The influence glucose seems to have on memory regulation along with the fact that glucose utilization decreases with age, suggests that glucose may play a major role in memory deficits found in aging. Research that has been focused on minimizing memory deficits in elderly subjects has indicated that glucose can actually enhance memory in healthy young and elderly subjects, as well as subjects with Alzheimer's disease and Down syndrome. Emerging human studies support previous findings from animal studies, which illustrates that moderate increases in blood glucose levels are associated with improved memory. More specifically, a dose-response relationship for glucose effects on memory was found to represent an inverted-U, in which moderate doses enhance memory while higher doses impair it. Another way in which glucose may enhance memory other than its fundamental metabolic function is by its influence on neurotransmitters, chemical messengers in the brain. Research has shown that glucose influences the synthesis of hippocampal acetylcholine (ACh), an essential neurotransmitter in the brain. This can be witnessed by a decrease in blood glucose levels resulting in a decrease in acetylcholine synthesis in the brain. Therefore, glucose may enhance memory processes by increasing the synthesis of hippocampal acetylcholine. Seeing that glucose regulation is important in memory regulation and enhancement, maintaining a moderate increase in blood glucose levels consistently throughout the day can be a dietary intervention that helps improve memory functions. Maintaining glucose regulation can be achieved by eating meals more frequently, which provides the brain with a consistent source of high energy.

Flavonoids

Healthy fruits and vegetables

Photochemicals named flavonoids have been investigated as a dietary intervention to improve memory. Flavonoids are mainly found in plant-based foods and are known for their antioxidant activity. The main dietary groups of flavonoids are:

flavonols, found in onions, leeks and broccoli
flavones, found in parsley and celery
isoflavones, found in soybean and soya products
flavanones, found in citrus fruit and tomatoes
flavanols, which are abundant in green tea, red wine and cocoa
anthocyanidins, whose sources include red wine and berry fruits.

Human and animal research using flavonoids such as grapes, tea, cocoa, blueberries, as well as ginkgo biloba extracts, have all shown beneficial effects on mental performance. In terms of memory, emerging studies suggest flavonoids have the ability to improve human memory as they are able to enhance neuronal function, stimulate neuronal regeneration and protect existing neurons. Memory acquisition, consolidation and storage is said to be mediated by long-term potentiation (LTP). LTP is considered to be an underlying mechanism of memory and how the brain learns and maintains memories. Long-term potentiation has been seen to increase the synaptic strength between neurons as it enhances signal transmission between them and has been thought to contribute to synaptic plasticity that underlies memory formation and maintenance. Research evidence has suggested that flavonoids interact with the neuronal pathways that control long-term potentiation, consequently influencing memory and cognitive performance. In particular, flavanoids have been seen to interact with a signalling pathway that increases the expression of neurotrophins, proteins involved in the development, function and survival of neurons. Flavonoids interact with brain-derived neurotrophic factor (BDNF), a neurotrphin important in LTP as well as long-term memory because they protect neurons against oxidative and metabolic stress and have been seen to stimulate the production of new neurons in the brain, a process called neurogenesis. BDNF has been seen to be active in the hippocampus supporting its major role as a neurobiological influence on memory. Flavanol research can also be used as evidence towards improving memory as human brain-imaging studies demonstrate that when consuming flavanol-rich cocoa, there is an increase in cortical blood flow. An increase in blood flow, especially when seen in the hippocampus, is important for memory as it facilitates neurogenesis.

Fat and calories

Animal studies have shown that diets rich in saturated fats, hydrogenated fats and or cholesterol can impair cognitive performance. More specifically, observations in rats treated with high saturated fat diets provide evidence for impaired memory and hippocampal morphology. These rats produced more errors in working memory maze tasks and indicated a loss of dendritic integrity in the hippocampus as seen from reduced hippocampal staining and inflammation. Human studies on Alzheimer's disease (AD) can be used to suggest that diet may play a major role in memory. In these studies, saturated fats, cholesterol and high calorie diets have all been seen to have negative impacts on memory. Diets rich in this kind of fatty acid as well as deficient in antioxidants and vitamins have been proposed to promote the onset of the Alzheimer's disease whereas diets high in mono- and polyunsaturated fatty acids as well as omega-3 fatty acids however may decrease the risk of AD. Individuals with high cholesterol diets have also been seen to increase risk of AD, while those taking cholesterol-lowering drugs may have a decreased risk. Research on energy intake on memory has proposed that caloric restriction may improve memory by providing a protective function. Evidence can be used from epidemiologic findings that high-calorie diets increase AD risk while animal models illustrate that dietary restriction can actually improve memory by reducing the amount of neuronal damage in Alzheimer's disease. Caloric restriction has been shown to increase the resistance of neurons to dysfunction and degenerate. It can improve memory by producing brain-derived neurotrophic factor (BDNF), which has been mentioned to enhance memory by synaptic growth and protection. Although not yet completely established, data suggesting that diets low in saturated fat, cholesterol and calories may reduce the risk of AD, can not only be used as evidence towards the negative impacts these substrates may have on human memory but also may propose a protective and improving function for memory.

Emerging research on diet-brain connections provide insight into dietary influences on memory. Glucose has been seen to regulate many brain functions such as memory, therefore it is recommended to have consistent glucose regulation in one's diet. Flavonoids are suggested to be used as a dietary intervention to improve memory as they are able to enhance neuronal function, stimulate neuronal regeneration and protect existing neurons. Lastly, saturated fats, cholesterol and high-calorie diets have all been seen to be detrimental to memory function and are therefore better to be decreased in order to improve one's memory. Calories are especially advised to be reduced as caloric restriction may improve memory by providing a protective function against dysfunction and degeneration as well as the ability to increase synaptic growth via brain-derived neurotrphic factors. Overall, evidence suggest frequent, low-calorie meals, rich in flavonoids and reduced in saturated fat and cholesterol are a simple dietary intervention to help improve memory.

Stress

Research has found that chronic and acute stress have adverse effects on memory processing systems. Therefore, it is important to find mechanisms in which one can reduce the amount of stress in their lives when seeking to improve memory.

Chronic and acute stress

Chronic stress has been shown to have negative impacts on the brain, especially in memory processing systems. The hippocampus is a vulnerable and plastic region of the brain, especially during aging and repeated stress, where it has been seen to be a target of adrenal steroid stress hormones. Stress persistently elevates glucocorticoids, a class of adrenal steroid hormones which releases cortisol, a well known stress response hormone in the brain. Glucocorticoids are involved in chronic as well as acute stress and are known to have specific effects on memory. Prolonged cortisol levels, as seen in chronic stress, have been shown to result in reduced hippocampal volume as well as deficits in hippocampal-dependent memory, as seen in impaired declarative, episodic, spatial, and contextual memory performance. Even more so, it has been found that the degree of hippocampal atrophy has been strongly correlated with the degree of cortisol elevation over time. This coincides with elderly human subjects, whose years of increased cortisol levels resulted in a 14% hippocampal volume reduction and impaired hippocampus-dependent memory compared to elderly subjects with decreased or moderate cortisol levels. Chronic stress effects the structural plasticity of the hippocampus by causing atrophy, which is accompanied by hippocampal-dependent memory deficits. High exposure to stress throughout life therefore has been shown to cause death in hippocampal neurons, which can cause hippocampus-dependent memory deficits. An example can be seen again using London taxi drivers, as the anterior hippocampus was seen to decrease in volume as a result of elevated cortisol levels from stress.

Acute stress is a more commonly possessed form of stress that has been seen to have negative impacts on memory processing. Here, adrenal steroids are released and implicated in short-term and working memory processes such as selective attention, memory consolidation, as well as long-term potentiation. Animal and human studies provide evidence as they report that acute stress impairs the maintenance of short-term memory and working memory as well as aggravate neuropsychiatric disorders involved in short-term and working memory such as depression and schizophrenia. Animal studies with rats have also shown that exposure to acute stress reduces the survival of hippocampal neurons, illustrating how sensitive the brain is to even small amounts of stress. One of the roles of the central nervous system (CNS) is to help adapt to stressful environments. It has been suggested that acute stress may have a protective function however, individual differences in acute stress responsiveness may make individuals more vulnerable to their own stress hormones. Some individuals, for example, are not able to decrease or habituate their cortisol elevation, which as discussed, plays a major role in hippocampal atrophy. This over-response of the central nervous system to stress therefore causes maladaptive chronic stress-like effects to memory processing systems.

Meditation

Acute stress

The human brain has a limited capacity to process information. Because of this, there is constant competition between stimuli to become processed. Cognitive control processes such as selective attention reduce this competition by allocating where attentional resources are distributed. Attention is crucial in memory processing, as attending to an item enhances encoding and strength of memory traces. Short-term memory is especially known for its information processing limitations. It is therefore important to selectively attend to relevant information and ignore irrelevant information in order to have the greatest success at remembering. Acute stress reduces selective attention therefore reducing short-term and working memories ability to process information. Meditation is a kind of mental training of attention in which one learns how to effectively select goal-relevant information out of an array of competing irrelevant information. Studies have shown that this kind of meditative or mental training can increase the control over brain resource distribution. Even a few short days of meditation practice has been seen to produce improved attention and self-regulation. It has been suggested that such mental training may produce long-lasting changes in the brain as meditation may potentially have the ability to streghten neuronal circuits as selective attentional processes improve. Consequently, meditation may also enhance cognitive limited capacity, affecting the way in which stimuli are processed.

Chronic stress

Studies have found that meditation significantly decreases stress related cortisol secretion and may also be able to elevate brain-derived neurotrophic factor, which as discussed protects neurons against stress and stimulates the production of new neurons. Meditation practice has also been associated with physical changes in brain structure. Magnetic resonance imaging (MRI) was used with Buddhist insight meditation practitioners, who use an attentional practice named mindfulness and found an increase in cortical thickness compared to control. Meditators have also been shown to have increased volumes of the hippocampus. This research provides structural evidence that meditation practice promotes neural plasticity and experience-dependent cortical plasticity. Meditation has therefore been shown to help improve memory by decreasing the effects of acute and chronic stress on memory systems such as short-term and working memory as well as areas like the hippocampus.

Exercise

In both human and animal studies, exercise has been shown to improve cognitive performance. Research indicates that performance on encoding and retrieval tasks are improved following exercise. For instance, exercise was found to enhance acquisition and retention in various hippocampal-dependent tasks including the Morris water maze and radial arm water maze in rodent studies. When compared to sedentary animals, exercised mice showed improved performance on the radial arm water maze and displayed enhanced memory for the location of an escape platform. Likewise, human studies have shown that cognitive performance is improved when tested after exercise. The physiological arousal associated with exercise promotes speeded mental process and enhances memory storage and retrieval.

The influence of physical activity on memory performance has many practical applications. In fact, chronic exercise interventions have been found to favourably impact memory processes in older adults, as well as children.

Hippocampal Neurogenesis

Neuron

Voluntary exercise has been found to positively regulate hippocampal neurogenesis. Mice that engaged in voluntary exercise, by using a running wheel, showed an increase in neurogenesis, as well as improved performance in the Morris water navigation task. Exercise-induced increases in hippocampal neurogenesis has been proposed as an explanation for the positive influence or physical activities on memory performance. Hippocampus-dependent learning, for example, can promote the survival of newborn neurons which may serve as a foundation for the formation of new memories.

Brain-derived neurotrophic factor (BDNF) protein levels

BDNF have been implicated as an important factor in the mechanisms governing the dynamics of memory formation and storage. Exercise has been found to increase the level of BDNF protein in rats, with elevated BDNF levels corresponding with strengthened performance on memory tasks. Data also suggests that BDNF availability at the beginning of cognitive testing is related to the overall acquisition of a new cognitive task and may be important in determining the strength of recall in memory tasks.

Cerebral blood flow

Evidence suggests that administering oxygen enhances memory function. For example, adult participants who inhaled oxygen sixty seconds before the presentation of a word list, which was to be studied, showed improved recall compared to a group who did not. However, administering oxygen before the test had no effect, suggesting that increased blood oxygen saturation specifically enhances memory consolidation. It is likely that the availability of brain oxygen can limit cognitive performance if there is not enough supply to meet demand. Therefore, increasing the level of oxygen available may allow for increased neural metabolism which may result in improved memory performance. Blood oxygen saturation and heart rate are positively correlated with each other. Research has found that an increased heart rate during word recall is associated with improved memory performance. This interaction between heart rate and blood oxygen saturation is another possible reason for exercise resulting in improved memory performance.

Psychopharmacology

Nicotine

Findings from both human and animal studies have indicated that acute administration of nicotine can improve cognitive performance, particularly on tasks that require attention, including memory. However, evidence suggests that low doses of nicotine facilitate memory and high doses have no significant effect or even impair memory. Nicotine has been shown to have a positive effect on short-term episodic memory for smokers and non-smokers, decrease reaction time for working memory tasks and improve performance on prospective memory tasks. Chronic usage of low-dose nicotine in animals has been found to increase the number of neuronal nicotinic acetylcholine receptors (nAChRs) and improve performance on learning and memory tasks. The chronic nicotine-induced synaptic changes and an increase in the number of acetylcholine-containing vesicles may provide an explanation for nicotine-induced cognitive enhancement.

The effects of nicotine on memory have created interest in its potential therapeutic value. For example, short-term nicotine treatment, utilising nicotine skin patches, have shown that it may be possible to improve cognitive performance in a variety of groups such as normal non-smoking adults, Alzheimer's disease patients, schizophrenics, and adults with attention-deficit hyperactivity disorder. Similarly, evidence suggests that smoking improves visuospatial working memory impairments in schizophrenic patients, possible explaining the high rate of tobacco smoking found in people with schizophrenia.

Neurotransmitters

Epinephrine

Epinephrine, also known as adrenaline, has been associated with memory enhancement in both humans and animals. Current evidence suggests memory consolidation in particular, appears to be enhanced by the administration of epinephrine. When a person's level of epinephrine is increased after learning, epinephrine is positively correlated with improved learning, suggesting the effects of epinephrine cannot be attributed to influencing attention or perceptual processes. However, epinephrine also interacts with the level of arousal at the time of memory encoding. In addition, administering epinephrine has resulted in improvement of low arousing object recognition in rats.

Acetylcholine

As discussed, acetylcholine is an essential neurotransmitter in the brain that may be regulated by glucose levels. Research has shown that increased amounts of acetylcholine in synapses can improve working memory. These findings are attributed to the important role played by acetylcholine in the maintenance of selective attention. Other studies have shown that rats with elevated neocortical acetylcholine levels have significantly improved performance on spatial navigation tasks. Furthermore, acetylcholine is not only necessary for memory but its presence has been found to restore spatial memory in rats with damage to the nucleus basalis. Evidence that aspects of memory can be improved by action on selective neurotransmitter systems, such as the cholinergic system which releases acetylcholine, has possible therapeutic benefits for patients with cognitive disorders.

Musical training

Music playing has recently gained attention as a possible way to promote brain plasticity. Promising results have been found suggesting that learning music can improve various aspects of memory. For instance, children who participated in one year of instrumental musical training showed improved verbal memory, whereas no such improvement was shown in children who discontinued musical training. Similarly, adults with no previous musical training who participated in individualized piano instruction showed significantly improved performance on tasks designed to test attention and working memory compared to a healthy control group. Evidence suggests that the improvements to verbal, working and long-term memory associated to musical training are a result of the enhanced verbal rehearsal mechanisms musicians possess.