

Memory for the Future

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June 5, 2026

RECOMMENDED CITATION

mohammad looti (2026). *Memory for the Future*. PSYCHOLOGICAL SCALES. Retrieved from <https://scales.arabpsychology.com/?p=38227>

Memory for the future refers to the ability to use memory to picture and plan future events. It is a subcategory of "mental time travel" which Suddendorf and Corballis described to be the process that allows people to imagine both past and potential future events. Mental time travel into the future has been discovered to use the same processes as mental time travel into the past or recall. There are two ways that we can use our memory for the future. The first is by using episodic memory and is therefore named "episodic future thinking". The second is by using semantic memory, also known as "semantic future thinking". Prospective memory can be seen as a subtopic of memory for the future, as it involves remembering to carry out some action that has been previously thought of, without needing an explicit reminder. There are three distinct processes; to develop, to remember, and to remember to execute the plan in the future. Developing the plan is most linked to the topic of memory for the future. Memory for the future may be used to choose how we will remember to perform the intended action. Memory for the future is the most flexible aspect of our memory based system and comparing humans to other nonhuman animals has led researchers to the belief that it is also the most recently evolved process of the memory system. Having the ability to mentally travel forward in time is an important tool that allows humans to adapt to and prepare for future events.

Processes

Cognitive resources used

In order to use memory for the future, certain processes are required. These processes include: working memory, long term memory, declarative memory, recursion, understanding of time, inhibition of present needs, and episodic and semantic memory.

Working Memory- the manipulation of previous memories to imagine future events takes place in the working memory using the phonological loop and the visuospatial sketchpad.

Self-awareness- to realize that one's self and one's future is separate from that of other individuals.

Declarative memory- the theory of memory for the future is using memory for future needs rather than immediate needs. Declarative memory uses a top down processing method that is not recalled by stimulus. This means that one is intentionally able to think about and plan for the future, rather than spontaneously remembering when faced with a particular situation.

Time dimensions- an understanding of the distinction between past, present and future.

Inhibition of stimulus driven responses - the ability to stop oneself from being distracted by irrelevant stimuli

In order to create representations of a possible future, a mental construction of past experiences must first be created. Pieces of information learned through episodic memory can be remembered and pictured in the mind. This ability allows for the combination of the basic elements of one's past (people, places, objects, and actions) into almost limitless possible futures, which is called

recursion. Using episodic memory (the details from personal past experiences together with semantic memory (general knowledge of the world) allows for visualization of novel situations and prepare for future events.

Development of cognitive resources

Children in school

By determining the average age at which certain cognitive milestones are reached, inferences can be made about the resources that are necessary to be able to use memory for the future. Research studies have been conducted in order to try and map out this cognitive timeline. Data collected has shown that children begin to be able to use secondary representation by the age of two. Secondary representation is the ability that one has to imagine oneself doing something, directly before it happens. For example, if a child hits another child, he or she would be able to envision themselves hitting that other child before they do it. Another development at the age of two is the ability of children to create various sentences out of previously learned words, exhibiting the skill of combining elements (words) learned from their past, or recursion.. It has also been shown that two year olds can recognize themselves in the mirror, demonstrating self awareness This self awareness develops further as the child reaches between the age of three and four years, when they can understand that not only are they different from the people around them, but that other people have different representations of the world than they do.

Child exploring

Until the age of three or four, children generally have a hard time explaining the concept of yesterday and tomorrow. Atance, Meltzoff, O'Neill found that by the time children reach the age of three to four years, they begin to use language that reflects their capability of imagining themselves in possible future events. At this age, they also understand that there is no certainty in their future, rather that there are many possibilities. With this knowledge, children at the age of four are more likely to wait for a larger reward that is delayed than a smaller reward that is more immediately gratifying, exhibiting the milestone of inhibition towards immediate stimuli. For example, Thompson discovered that when given the choice of one sticker now and two stickers in the future, most children under the age of four will choose one sticker now, while the children of four years of age or older will most likely choose two stickers later.

Hudson found that by age five, children know the difference between planning for a future scenario and creating scripts of general scenarios from their semantic knowledge. Children between the ages of three to five were asked to either explain a script or create a plan for the same scenario. For example, a child would have to either explain what happens when a person goes grocery shopping or create a plan for grocery shopping. The results showed that at the age of five children

were better at planning for future needs, including the use of strategies to prevent common unexpected problems such as forgetting to bring money to the grocery store.

Physiology

Mental construction of future events has been found to share cognitive resources with mental time travel into the past. There are, however specific areas in the frontal and medial temporal lobes that are more involved in mental time travel into the future than into the past. It is important to understand the physiological processes behind memory for the future. To do this, experiments are performed based on the knowledge of the other processes behind memory for the future. For example, knowing that both episodic memory and semantic memory are involved in memory for the future, researchers would try to find activation in the systems involved in both types of memory. Conway found that episodic memory is a posterior temporo-occipital system and that semantic memory is a prefrontal anterior-temporal system.

Frontal lobes

Studies of frontal lobe activity suggest that the frontal lobes are used in remembering and imagining the future. Specifically, Addis discovered that the right frontal pole is involved in prospective memory and the construction of future events. Tulving used Functional magnetic resonance imaging studies to discover that the left frontal lobes are important in semantic memory retrieval. There have also been comparisons to non-human animals explaining that the reason many animals cannot use memory for the future is due to the smaller size of their frontal lobes and the expansion of the frontal lobes in human evolution.

Prefrontal cortex

Suddendorf and Corballis explain that the expansion of the prefrontal cortex in humans and not in many other primates could be evidence as to why many other primates cannot use memory for the future. The prefrontal cortex is an important brain region to the retrieval of episodic memory, the process of working memory, and the tracking of time, which together allows for the ability of mental time travel. It has been discovered that actions involved in obtaining future rewards can be traced to the dorsolateral prefrontal cortex and the cerebellum. There is also evidence of reorganization of the prefrontal cortex in humans throughout evolution that other non-human animals have not acquired. Brodmann area 11 (known to be involved in the projection of one's self into the future) and 47 have enlarged, decreasing the size of Area 13.

Temporal lobes

The activity of the temporal lobe in experimental studies has resulted in the evidence that the

medial temporal lobe is used in declarative memory, and that the temporal lobe is an active region in the process of remembering the past and envisioning the future along with the frontal lobes. Tulving found Functional magnetic resonance imaging studies to show that the left temporal lobe is important in semantic memory retrieval.

Hippocampal-cortical system

The hippocampal system, which is essential in retrieving memories about the past, has been shown through research to be involved when making predictions about upcoming events. Research has proven that the hippocampus and its associated cortical structures are active when people think about future events. The ability to make predictions about upcoming events is severely disrupted in individuals who have damage to the hippocampus system. The hippocampus is also a key component in the fine details perceived in the recollection of past episodes and envisioning of future events. Cohen and Eichenbaum suggest that it is the hippocampal system that permits the manipulations of stored memories into novel combinations that anticipate future events. It is this manipulation of stored memories that permits problem-solving behaviours. Johnson and Sherman suggest that expectations about the future is an incorporation of all the past events one has experienced and stored

Functional Magnetic Resonance Imaging studies have demonstrated the role of the hippocampal-cortical system in future episodic thought. It was found that the same regions are active during envisioning the future as remembering the past. In 2006 Svoboda et al. used data from twenty-four Positron Emission Tomography and fMRI studies that tested participants autobiographical memory retrieval. During the testing period in which the subjects were asked to recall these past memories, the hippocampal-cortical system was constantly active. When participants were asked to imagine future scenarios, the same hippocampal-cortical system was proven to be active. Behavioural studies have also proved that thinking about the future elicits the same behavioural properties as thinking about the past. Spzunar and McDermott conducted a study in which they tested participants in different environments. One study asked subjects to imagine future events in previously known environments as opposed to never-experienced environments. It was found that imagined future events contained significantly more detail if they were constructed on familiar environments as opposed to new ones. This shows that acts of envisioning the future rely heavily on memories from the past.

Evidence in human patients

Patients with cognitive deficits

There is a large amount of evidence for memory for the future, particularly when looking at people with different types of brain damage and disorders. Individuals who have trouble recollecting their

past are also unable to form detailed mental images of their future. Reasons for this inability can include frontal lobe damage, schizophrenia (D'Argembeau et al. forthcoming), severe depression (Williams et al. 1996), amnesia (Tulving 1985; Levine et al. 1998; Klein et al. 2002; Hassabis et al. 2007) and Alzheimer's disease.

Many frontal lobe patients have a working semantic memory system, and are able to imagine themselves in the future through this system. The problem lies in their episodic memory. A damaged episodic memory system including "episodic future thinking," causes the patient to be unable to view themselves in specific future events. For example, a patient knows that he or she will one day grow old, however if asked to envision and describe their future he or she will not be able to do so.

Patients with amnesia who are unable to explain what happened yesterday, are just as unlikely to explain what may happen tomorrow. This is due to damage to the medial temporal lobe and other structures that are associated with it, which results in an impairment in recounting recent events and learning new information. However, the global cognitive functions and procedural memory remains intact. The following three cases of patients with amnesia clearly demonstrate that the brain systems important to regular memory are crucial to using memory for the future.

K.C., a patient who had a head injury that damaged the medial temporal and frontal lobes, causing amnesia. Due to these injuries, K.C was unable to envision any events that may occur in the future. Patients with memory impairment, along with damage to the hippocampal region also often have difficulties in imagining upcoming events and new scenarios. This suggests that the memories of past events may serve as the bases for prediction and imagination.

H.M became a densely amnesic patient as a result of a bilateral resection of the hippocampus and adjacent structures in the medial temporal lobe. He could not make predictions about any events involving himself in the future (future autobiographical events). When asked to answer a question about the future, his answers either consisted of an event that had happened in the past, or he simply did not answer at all.

D.B developed amnesia following anoxia in which his hippocampus was affected. Klein and colleagues studied D.B by asking him questions about the future. D.B was incapable of answering questions regarding his own personal future but he could answer questions about the future of general things. For example he could answer questions about the future of general things including the environment and society, showing that his general knowledge was intact.

Further research conducted by Tulving, Klein et al., and Atance & O'Neill have discovered that patients who have lost their episodic memory but retained their semantic memory seemed to have lost their ability for episodic future thinking, but retained their ability for semantic future thinking. Other research has found that the reverse is true as well. These studies help to conclude that both

of these systems are responsible for the different forms of memory for the future.

Alzheimer's disease involves the degeneration of the medial prefrontal and parietal cortices, as well as lateral parietal and temporal regions, posterior temporoparietal regions, medial prefrontal, medial and lateral parietal, and medial and lateral temporal regions. These regions are important for episodic memory, which is typically one of the first things to be disrupted in patients with Alzheimer's disease. They generally have deficits in describing both past and future events, but even when they were able to somewhat envision future events, they lacked the normal episodic detail that someone without Alzheimer's disease would have. There is also evidence that older adults have the same effect as Alzheimer's patients with past and future, which is due to the fact that there is a natural degradation of the brain.

Healthy patients

There is also evidence for memory of the future in healthy individuals. Arzy, Adi-Japha and Blanke researched what is known as mental time. Their research suggests that events in human cognition are spatially mapped along an imagery mental time line. The results of this study found that the amount of time it takes for an individual to imagine themselves along a mental time line is dependant on the temporal-distance between one imagined location and the location of another imagined event. Also, studies have shown that the temporal-distance has an effect on the ability to project oneself mentally into the past or into the future. This is called the temporal-distance effect.

Williams and colleagues tested healthy individuals future memory. They manipulated past events that reduced the details of the past memory. When asked to remember subsequent future events, the imagery detail was greatly reduced. This suggests the retrieval of past events and the imagining of future events are directly correlated.

Human life

Evolution

Most processes passed on through natural selection are important for survival and allow the particular species or individual to live long enough to produce more offspring. Mental time travel is considered a crucial ability for human beings from an evolutionary stand point. This is because it offers a selective advantage by enhancing flexibility in new situations, and helps in goal setting and long term planning. Language experiments have been conducted to prove that memory has specific future oriented systems involved. Participants were given a list of either thirty planning words or thirty other words to memorize. The participants who had a list of planning words performed better when asked to recall their list.

In ancient Egypt humans buried the dead with provisions that they would need in the afterlife. Humans organized hunting parties for generations, developed agriculture and villages, and traveled great distances in the expectation of new land to colonize, which were all planned to meet future needs for survival. With the ability to predict the consequences of actions, moral laws were created, which one day grew into governed laws. If memory for the future can be led this far back into the past of humans, why and how did the process of memory for the future begin in humans?

The earliest evidence of human use of memory for the future was the construction of tools that were used more than once, it was an expectation that those tools would be needed to provide food and safety in the future.". Researchers suggested that deforestation during a cooling of the earth led to this occurrence.

Savage-Rumbaugh specifically theorize that during this time an increased support and monitoring of young was needed, which may have led to the ability of keeping several things in mind and carrying tools around for ease of use, and the ability to predict and influence the environment, rather than just react to it came to be.

Osvath and Gärdenfors theorize that the deforestation led to expanding savannahs with less vegetation (food resources) but an increase in herbivores. The larger distances faced between the source of tool materials (stones used) and killing sites led to a need for future thought.

Tooby and DeVore theorize that this deforestation exposed humans to more predation, which led them to the need of strong social cooperation and communication. The planning involved in carrying rocks to throw during hunting and for defense may have been strongly selected for, and led to the skill of creating tools that would be better at what they were intended for.

There is no hard evidence of the approximate time period in which humans began to use fire for important survival tools such as the provision of warmth, cooking, night time vision, and defense and attack. However, the time line of use is theorized to have been an accidental discovery of fire, learning to keep the fire maintained, and finally, the creation of fire for future use. As far as anyone knows, fire could have been the turning point in the evolution of using memory for the future. The Greeks may have been correct in saying that Prometheus stole fire from the heavens to give humans the powers of the gods, which set them apart from other animals-Prometheus means foresight.

It is these sorts of discoveries and creations that have led to more advanced technology, with the idea that work in the future would be easier. The ability to use memory for the future has made society what it is today. The creation of education systems and religions are examples of using memory for the future. These are dependent on the ability to remember the past and imagine the future. Humans have a large distribution on earth, and thus have the capabilities to form colonies and properly adapt to different environments across the planet. This can be led back to memory for

the future, which allows for the imagination of countless possibilities based on the past that makes humans highly adaptable when environmental patterns change.

Using memory for the future humans continue to plan for future generations. People, for the most part, try to make the Earth a better place for the generations to come. People consider future threats to the planet, whether from their own doing or from things that they cannot control, and plan accordingly to fix those problems. However, this also leads to negative results. An example can be explained by Robbie Burns in his poem *Ode to a Mouse*, in which he explains that all of these expectations may lead to the fear of the futures imagined: "But oh I cast my eye on prospects drear, and forwards tho' I canna see, I guess and fear." With the gift of foresight, humans must also suffer in the knowledge of a death that is inevitable, and create future possibilities such as the end of the Earth that we will have no control over. For example, the media continues to create films such as *2012*, *The Day After*, and *The Day After Tomorrow*.

Daily life

Humans have evolved using memory for the future it has become an important aspect of day to day life. Memory for the future is used when setting all goals in life, such as making money in future careers or winning a sporting event. Memory for the future is also used when making decisions based on the future possibilities that can be imagined. This can range from planning the details of one's lunch for tomorrow, to preparing for a job interview a week from now, to planning for a trip around the world once retired. A positive image of the future can help people set clear goals and create realistic plans to follow that allow them to fulfill these goals.

Klinger and Cox discovered that the average person spends twelve percent of their daily thoughts on events that may take place in the future. They also state that it is pleasurable to think about future success and that mental time travel into the future plays an important role in one's happiness and well-being. McLeod and Conway agree, stating that positive future thinking creates well-being in the general population. Therefore, it would be expected that unhappy individuals would have difficulties in imagining future success and positive future events. Research performed has found this to be true. Suicidally depressed individuals are unable to form detailed mental images of their future and patients with high levels of anxiety brought up more negative possibilities for the future.

Another way that memory for the future can help people in day to day life is that the anticipation of negative outcomes can help lower the effect of actual negative outcomes. This can be explained through an example of pain. Arntz, van Eck, and de Jong discovered that a mildly painful event that cannot be anticipated will end up being more painful than a considerably painful event that can be anticipated.^{#14} Electrical shocks at unpredictable intensity were more painful and had more of a negative emotional impact to participants than twenty predictable strong shocks did.

In animals

Researchers have discovered that animals are limited to their memory for the future and that this characteristic is distinctly human. Although nonhuman animals display some sort of learning capacity, there have been few significant actions performed to display a knowledge or presentation of temporally distant events. Animals may plan actions toward a goal, but do so thinking only about their current needs, rather than their future needs. This is also known as the Bischof-Köhler hypothesis, specifically stating that nonhuman animals do not have the ability to think of the future states they may have as being different from the ones they are currently experiencing. This may not be true as some animals act in a way to secure their future needs. However, these may be instinctive through behavioral predispositions.

Behavioral predispositions should not be confused with the use of memory for the future. The ancestors of a species may have been confronted with certain environmental factors which were overcome by actions of coincidence. Breeding throughout generations would create offspring that are far more likely to perform the same actions, as parents that did not perform these actions most likely passed away. Therefore, species-typical behavior was created. Such behaviours are universal to the species and are acted upon by an individual without any past experience as to why the action they are performing is meaningful. In other words, there is no mental representation of the future.

There are a few examples of memory use for the future in animals:

Food caching scrub jays

A species of corvid, the scrub jay, has been discovered to store certain food types from hours to a day in advanced of having an appetite for that food type. Researchers would randomly give scrub jays a breakfast with or without pine seeds over a period of days. The birds that had learned this pattern were more likely to store pine seeds with the anticipation that there may be breakfasts without them in the future. Their actions depend on when and where they stored what (food type), expecting certain things to happen in the future. This is not a behavioral predisposition because after researchers destroyed or stole the food items that were hidden, the scrub jays learned not to store their food. It was also discovered that they would re-hide any food items that other scrub jays had witnessed, if they themselves had previously stolen food items from another bird. This shows that they can imagine the future possibility of food theft from their own past experiences.

Bonobos and orangutans

The Bonobo and Orangutan are close evolutionary relatives of human beings. Researchers gave apes from these species a chance to experience and learn how to use a tool to obtain a reward from an obstacle. They were later allowed to select a suitable tool from the test room when the

obstacle was in view, but not accessible. Each ape was then led to a waiting room. The apes brought the tool into the waiting room and were left there for different time periods. Next they were again brought to the test room and were required to voluntarily bring the tool back into the test room upon their return. Seventy percent chose the right tool and brought it with them to the waiting room and back into the test room, with the anticipation that they would need it in future use. The apes were able to do this task with up to a fourteen hour delay. Therefore, they chose appropriate tools, saved them, and carried them around with the anticipation that they would need them in the future.

Squirrel monkeys

Experimenters have also found results of memory for the future in the squirrel monkey. In the first experiment, researchers gave squirrel monkeys the choice of four peanuts or two peanuts. Next, they were given the choice of only two peanuts and the researcher would come back with a larger reward of ten peanuts fifteen minutes later. After this experience, when given the choice of four peanuts at the present moment or two peanuts with the anticipation of ten more peanuts on the way, more of the monkeys chose two peanuts.

Another experiment gave the monkeys a choice of one or four dates, which made the squirrel monkeys thirsty. When they made the choice of four dates they had a three hour period without water. A choice of one date gave them water half an hour later, relieving the monkey's thirst much faster. Most monkeys learned from this experience, and using the memory from their past, planned for the future experience of being thirsty and chose only one date in later trials.