Transactions on Materials, Biotechnology and Life Sciences
ISSN: 2960-1932, eISSN: 2960-2319 | Volume 8
MMTCS 2025

Effect of Music on the Brain's Memory Processes

Xinhui Wen *

Maggie L. Walker Governor's School, Richmond, United States of America

* Corresponding Author Email: jasminejjwen@gmail.com

Abstract. Extensive research has been conducted on the effects of music on memory. However, results have varied regarding the specific impacts of music on cognitive processes. This paper synthesizes predominantly positive results from research on music's impact on various brain regions and its therapeutic applications, highlighting how listening and playing music can enhance well-being and boost overall cognitive and emotional health. These findings show that music alters the neurological connections in the hippocampus, a brain region memory is most strongly associated with. Music induces structural changes in other brain areas in association with memory, like the amygdala and the prefrontal cortex, allowing individuals to remember memories better and improving memory retrieval and recall. Music therapy has emerged as an effective way to enhance memory retrieval and retention especially in individuals with memory disorders, providing a unique pathway to bring back lost memories. This research could lead to improvements in healthcare and cognitive science, particularly in exploring how different aspects of music could positively influence the neurological functions of the brain. Future developments in this field may further elucidate the therapeutic potential of music for neurological conditions.

Keywords: Memory; Music; Processing; Brain regions.

1. Introduction

Memory is a powerful tool. There are three types of memories: long-term memory, short-term memory, and sensory memory. Long-term memory is the storage of knowledge and prior events, whereas short-term and sensory memory are processed for a short time before either being forgotten or placed in long-term memory [1]. Memory must pass through both short-term and sensory memory in order to become long-term. Although these distinctions exist, all memory types interact to form an individual's overall memory system. Additionally, memory is classified into two types: declarative and procedural. Declarative, or explicit, memory is the conscious recollection of facts and events that is stored and maintained in brain regions such as the cerebellum and hippocampus. Furthermore, explicit memory is subdivided into episodic memory and semantic memory, where episodic memory is personal experiences, while semantic memory is facts and data. Implicit memory, however, is "recalled unconsciously" and stored in regions of the brain like the cerebellum and the amygdala [2]. Memory allows an individual to learn from the past, understand the present, and make predictions about the future, providing the foundation for navigating the world and forming a sense of self-identity through recalling memories and generating new thoughts.

Memory can be influenced by various factors, some of which are less obvious than others. One factor that shapes memory is music, an art that arranges sounds to produce a combination of harmony and rhythm. Research has demonstrated that not only does music trigger autobiographical memories, but the memories triggered by music can actually be distinct from those that occur naturally. These findings were more prevalent in people with disorders that impact their memories, such as Alzheimer's disease [3]. Scientists have even begun to look into music as a way to help people suffering from Alzheimer's disease through theta waves. Theta waves are brain activities that are crucial for memory formation and encoding. Studies have found that background music can increase theta waves, leading to a 20-30% improvement in the retention of event details. Other studies have shown that music is even more effective in triggering autobiographical memories than pictures or words, especially in dementia patients, as it activates brain regions associated with emotion and recall

[4]. These studies have exhibited the effects of music on neurological disorders and its significance in mitigating memory loss and facilitating memory formation.

The motivation for further combined research into this topic is from observing individuals who struggle with memory recalling, encoding, and memory formation. To be exact, individuals who experience anguish because they are unable to recall their cherished childhood memories, family inside jokes, or parts of their lost memories that would evoke warmth and joy. In knowing that there are such people who need help with their memory, music as a therapeutic intervention was proposed. Music is an especially important combination of stimuli that could improve the memory of individuals, particularly those with dementia or Alzheimer's disease. It has been shown to alleviate stress, improve attention and focus, promote relaxation, improve mood, build task endurance, and boost memory. Not only that, but music could also influence eating habits, potentially reducing food consumption when you dim the lights and soften the background music during a meal. Besides the surface-level observed effects of music on an individual's cognitive and emotional behaviors, it is plausible to hypothesize that music could even affect the neurological basis of the brain on a structural level. Thus, this paper aims to address particular aspects of memory formation in different structures of the brain and examines how these structures could be affected or altered by musical stimuli. The focus of this paper is to emphasize the relationship between music and memory through the activation of specific brain regions.

2. Memory and Music Processing

2.1. The Structural Foundation of Memory

Memory is among the most challenging and complex functions of the brain. It involves the coordinated activity of multiple regions, including the hippocampus, amygdala, and the prefrontal cortex. These areas are all crucial for memory formation, encoding, and retrieval.

The hippocampus is the most central part of the brain's memory processing. "Shaped like a seahorse" in the medial temporal lobe, the hippocampus oversees the encoding and consolidation of declarative memories which encompass general knowledge and personal experiences [5]. The hippocampus is most strongly associated with events of memory processing. It is essential for the ability to remember episodic memories, like recalling a childhood birthday party. Damage to the hippocampus reduces eye-movement-based indices of spatial and contextual memory, which shows that the hippocampus is directly activated in all different kinds of memory [6].

The amygdala is an area responsible for processing memory. It is structured like a pair of almonds and is located in front of the hippocampus in the temporal lobe. The amygdala encodes memories based on the emotional weight of the memory. Amygdala activation is enabled by the emotional arousal of the enhanced memory [7]. The stronger the emotion, particularly fear or joy, the higher retention of memory due to the interconnectivity of the amygdala and the hippocampus. Studies that used positron emission tomography (PET) and functional magnetic resonance imaging (fMRI) provided additional evidence that, during encoding, the more emotionally intense the event, the more amygdala activity occurred and the stronger the memory formation. When assessed during encoding, the combined results of the PET imaging over periods of arousal and the fMRI scan of single-item-induced amygdala activity both predicted the long-term memory of arousing stimuli [8]. The findings indicate that the amygdala plays a crucial role in memory consolidation.

The prefrontal cortex is important for higher-order cognitive functions, involving complex mental processes like memory, decision making, and problem solving. It is a highly folded region located directly behind the forehead in the frontal lobes. In particular, the medial prefrontal cortex (mPFC) plays a critical role in processing recent and short-term memories within a wide range of tasks. During the initial memory encoding, the mPFC rapidly establishes associations between contexts, events, and adaptive responses while relying on the hippocampus. Then, during consolidation, the memory is repeatedly replayed, which results in a strengthening of synapses, supporting the strength of memory

in the mPFC [9]. Thus, damage to the prefrontal cortex can impair working memory and episodic memory.

2.2. How the Brain Processes Music

Music is a complex auditory stimulus that engages multiple brain regions. First, music is processed in a pathway that ascends from the cochlea to the primary auditory cortex. From there, sound waves create neurological impulses which then travel to the brain for auditory interpretation [10]. A wide variety of features, including pitch, tempo, sound intensity, and meaning, are interpreted in the brain, and transferred to the auditory brainstem. From these brainstems, the auditory information transmits to the thalamus through the lemniscus pathway, a major sensory pathway in the central nervous system. When listening to music, even just the rhythm, the cerebellum, basal ganglia, and premotor cortex are all subsequently activated [11]. This highlights the significance of music in emotional processing. This multisensory integration makes music a powerful tool for influencing cognitive processes, including memory.

3. Music's Impact on Memory Processing of Specific Brain Regions

Music affects different aspects of memory by inducing functional and structural changes in memory-related brain regions. Studies have shown that listening or performing music causes continuous engagement of the brain which leads to changes in the brain structure and functions [11]. Additionally, studies utilizing fMRI and electroencephalography (EEG) have shown that listening to and playing music activate neural networks responsible for auditory processing, emotion regulation, and memory consolidation.

3.1. Effects of Music on the Hippocampus

Music improves long-term memory processes by creating plasticity in the hippocampus. According to a voxel-based morphometry investigation, musicians had higher gray matter density in the hippocampus than non-musicians [12]. Gray matter concentration enables the individual to process and release new information and control memory. This structural advantage supports better information processing and memory control. Musical training may also increase cognitive reserve, potentially delaying age-related memory decline. Music aids memory consolidation by creating emotional and contextual associations. Familiar songs can trigger vivid autobiographical memories, even in people with memory impairments. Listening to familiar music not only evokes emotional responses but also improves recall of specific memories that hold emotional weight to the music. Overall, music affects the hippocampus' memory function, which can in turn improve episodic memory.

3.2. Effects of Music on the Amygdala

Music's emotional impact is closely tied to the amygdala. The amygdala is highly involved in the recognition of fear. Music-induced emotions can facilitate autobiographical memory retrieval. Nostalgic songs evoke detailed personal memories by engaging the amygdala and hippocampus. Music evokes changes in the amygdala even if individuals do not have experience an intense emotional effect when listening or playing. In a study, when subjects were exposed to pleasing musical sounds, increased brain activity occurred where emotional information is integrated with cognitive processes. Dissonant music activates fear-processing regions in the amygdala [13]. Since the amygdala interacts with the hippocampus, emotionally charged music can boost the hippocampus' activity, improving long-term memory consolidation. Music-induced emotions can help retrieve autobiographical memories, improving memory through recall [14]. This emotional priming effect makes music a valuable tool for memory rehabilitation in clinical settings.

3.3. Effects of Music on the Prefrontal Cortex

Music engages the prefrontal cortex (PFC) and enhances its ability to regulate attention, process information, and strengthen memory networks. Studies have shown that musical rhythms synchronize neural activity and strengthen synaptic connections in the PFC. Thus, background music can improve working memory capacity by engaging the PFC to maintain and update information more efficiently. This synchronization may explain why music helps individuals with memory disorders, such as those with traumatic brain injury, in recovering cognitive function. Listening to music activates PFC areas that deal with executive functioning [15]. For example, the left dorsolateral prefrontal cortex during groovy music induced sensations. When listening to music, the rhythms and melodies provide a structured framework that helps the brain organize, encode, and retrieve information more effectively, aiding memory and supporting better recall.

4. Music Therapy

According to the American Music Therapy Association, music therapy is the use of music to achieve specific goals in a clinical and evidence-based manner. It utilizes music to address the physical, emotional, cognitive, and social needs of individuals. Research has increasingly shown that music can have profound impacts on people's lives and especially their memories. Familiar music serves as a pathway for people to cling to their selves and their identities. It can also serve as a template for memory retrieval and encoding. Calming music can enhance concentration and improve focused attention. Furthermore, music therapy has been shown to provide a sense of connection for patients who may feel alone or lack social connections [16].

Music therapy has demonstrated efficacy in enhancing cognitive functions, including memory, especially for individuals with dementia and Alzheimer's disease. In a study by Jacobsen and colleagues, the brain's response to music was examined using fMRI to identify regions that encode long-term musical memory. Their findings suggested that musical memory regions were well-preserved in individuals with Alzheimer's disease, explaining why musical therapy effectively retrieves verbal and musical memories in individuals, even with memory impairments [17].

5. Limitations & Future Prospects

This paper mainly focuses on the effects of music on the most important brain regions related to memory formation, processing, and encoding. However, it does not address other less direct but also functionally significant brain areas that contribute to memory processes, like the cerebellum and the basal ganglia. The paper does not show whether these areas are changed or stimulated by music, therefore the impact of music on memory is not holistic. Furthermore, this paper utilizes a combination of prior research and studies conducted in the past to address a broad hypothesis about the influence of music on memory. The reviewed studies collectively provide [YW4] evidence that music plays a beneficial role in memory processes. However, potential limitations in their methodology warrant consideration. Specifically, studies published in online repositories may exhibit reporting bias, emphasizing positive outcomes while potentially omitting nuanced or contradictory findings. Lastly, this paper does not provide original or experimental evidence that music does in fact significantly improve memory.

Future study and experimentation on the relationship between music and memory improvement could lead to many advances in healthcare and therapy. For example, continuous enhancement of fMRI and EEG technologies could enable researchers to more precisely visualize and differentiate brain regions before and after stimulation by music. This will allow researchers to understand how music specifically impacts various regions of the brain and how the neurological pathways are altered, contributing to progress in the field of neuroscience, particularly in memory retrieval and encoding processes. Additionally, improved research methodologies and technologies could enhance the ability to help patients with memory impairment, particularly those with dementia and Alzheimer's disease, by using music to bring back some of their lost memories and further research could lead to more

effective leads on repairing their damaged memories. Given the advancements in the field, research on how different genres of music could affect memory in different ways could allow musicians and scientists to personalize music playing to carry out individual memory improvements. Furthermore, longitudinal studies could be conducted to investigate the long-term effects of listening to music on elderly populations, which could provide valuable insights into cognitive aging processes and contribute to the development of music-based therapeutic approaches for aging individuals. Altogether, this goes to show that future research could lead to the use of music not just for improving memory recall in individuals with memory impairments, but even finding ways to mitigate the effects of memory loss or prolonging it in aging populations or those with neurological disorders. The implications of such research may extend beyond individuals to influence the broader fields of cognitive and therapeutic fields of science.

6. Conclusion

This paper describes some of the relationships between music and its effect on memory-related brain regions as well as how it aids individuals with memory impairments. These findings indicate that music significantly increases the grey matter in the hippocampus, thereby enhancing the cognitive processes of the brain. Music also activates the amygdala and facilitates its interaction with the hippocampus. Musical rhythms can strengthen synaptic connections in the prefrontal cortex, leading to higher levels of cognitive function like memory. This paper demonstrates that music plays a role in altering brain functions related to memory, providing substantial evidence for research on improving memory in individuals with impairments. Future research on how the brain is affected by music could lead to significant advancements in neuroscience and healthcare, particularly for individuals with dementia, Alzheimer's disease, or any type of memory-related disorders.

References

[1] N. Cowan, what are the differences between long-term, short-term, and working memory, Sci. Direct. 169 (2008) 323 - 338.

[2] S. Mujawar, J. Patil, B. Chaudhari, S. Bhore, A. Jadhav, A. Shinde, Neurobiological mechanisms and assessment, Ind. Psychiatry J. 30 (2021) 5311 – 5314.

[3] A.P. Kaiser, The cognitive characteristics of music-evoked autobiographical memories: Evidence from a systematic review of clinical investigations, WIREs Cogn. Sci. 14 (2022) e1627.

[4] A. M. Belfi, B. Karlan, D. Tranel, Music evokes vivid autobiographical memories, Routledge. 24 (2015) 1 – 11.

[5] L. R. Squire, A.J.O. Dede, Conscious and unconscious memory systems, Cold Spring Harb. Perspect. Biol. 7 (2015) a021667.

[6] J. Lisman, G. Buzsáki, H. Eichenbaum, Viewpoints: how the hippocampus contributes to memory, navigation and cognition, Nat. Neurosci. 20 (2017) 1434 – 1437.

[7] B. Roozendaal, B.S. McEwen, S. Chattarji, Stress, memory and the amygdala, Nat. Rev. Neurosci. 10 (2009) 423 – 433.

[8] B. Roozendaal, J.L. McGaugh, Memory modulation, Behav. Neurosci. 125 (2011) 797 – 824.

[9] D. R. Euston, A.J. Gruber, B.L. McNaughton, the role of medial prefrontal cortex in memory and decision making, Neuron. 76 (2013) 1057 – 1070.

[10] J. Casale, P.F. Kandle, I.V. Murray, J. Smith, L. Johnson, M. Davis, Physiology, cochlear function, StatPearls. (2023).

[11] M. T. Zaatar, K. Alhakim, M. Enayeh, R. Tamer, The transformative power of music: Insights into neuroplasticity, health, and disease, Brain Behav. Immun. Health. (2023) 100716.

[12] M. Groussard, R. La Joie, G. Rauchs, B. Landeau, G. Chételat, F. Viader, F. Desgranges, B. Eustache, when music and long-term memory interact: Effects of musical expertise on functional and structural plasticity in the hippocampus, PLoS One. 5 (2010) e13225.

[13] E. Altenmüller, S. Siggel, B. Mohammadi, A. Samii, T.F. Münte, Play it again, Sam: brain correlates of emotional music recognition, Front. Psychol. 5 (2014) 114.

[14] S. Koelsch, S. Skouras, T. Fritz, P. Herrera, C. Bonhage, M.B. Küssner, A.M. Jacobs, The roles of superficial amygdala and auditory cortex in music-evoked fear and joy, NeuroImage. 81 (2013) 49 – 60.

[15] F. A. Mansouri, N. Acevedo, R. Illipparampil, M. Fehring, A. Fitzgerald, Interactive effects of music and prefrontal cortex stimulation in modulating response inhibition, Sci. Rep. 7 (2017) 18096.

[16] M. Bleibel, A. El Cheikh, N.S. Sadier, L. Matar, H. Kassem, The effect of music therapy on cognitive functions in patients with Alzheimer's disease: a systematic review of randomized controlled trials, Alzheimers Res. Ther. 15 (2023) 65.

[17] J. H. Jacobsen, J. Stelzer, T.H. Fritz, G. Chételat, R. La Joie, and R, Turner, why musical memory can be preserved in advanced Alzheimer's disease, Brain. 138 (2015) 2438 - 2450.