How does music affect emotional processing and memory function in the human brain?

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- *Memory function*
- *Dementia and Alzheimer's disease*
- *Neural pathways of emotion*

Abstract

Music is a ubiquitous part of life, from forms of expression to the enhancement of well-being and function. The goal of this review is to address the complex relationships between music and our cognitive function and emotional processing. By examining prior work in this space, this review underscores how music has these wide-ranging behavioral effects by engaging complex regions, including the amygdala, the limbic system, and reward pathways. Additionally, this review explores how music can be used to improve academic performance and as a therapeutic tool by lessening anxiety, improving memory, and slowing down the cognitive impact of neurodegenerative diseases. Finally, it also examines individual and cultural differences in music perception, showing how idiosyncratic factors can contribute to differing emotional and cognitive responses.

Introduction

The interdependence between music and the brain is a compelling subject that has caught the attention of researchers across disciplines, including neuroscientists and psychologists. Besides being a form of expression, music plays an outstanding role in engaging both cognitive and emotional functions. Specifically, music is able to change an individual's emotional state and has key bidirectional roles in both forming new memories and resurrecting past memories[25]. For instance, think of when you hear your favorite song and can't help but smile.

Therefore, this paper seeks to explore the primary question: how does music affect emotional processing and memory function in the human brain? By examining how neural systems involved in emotion and memory management engage when hearing or playing music, this paper aims to highlight the cognitive and psychological impacts. To do so, this review will explore the critical brain structures involved and use empirical and case studies, as well as real-world examples, to discuss the relationships between music and core cognitive and affective functions. The end highlights limitations and open questions, such as the role of cultural and individual differences in music perception, contradictions in research, and areas for future study. By providing this thorough review of the neural and psychological substrates that support music processing, this paper lays the groundwork for future empirical studies that bridge the gaps between music, emotion, and memory.

How the Brain Processes Music

There are multiple regions that support music processing, including both low-level sensory regions (i.e., auditory cortex) and higher-level multimodal processing regions related to emotion, memory, and attention[1]. The brain processes music hierarchically, meaning that it goes through multiple stages of processing involving both bottom-up and top-down processing until the meaning of the music comes to be understood.

To be specific, bottom-up music processing starts with sound signals that are caught by the ear and are sent to the cochlea, which converts the sounds into neural signals (see Fig. 1 for a schematic of the ear). The auditory nerves then carry the neural signals to the brainstem and thalamus for processing. After processing, the thalamus relays the information to the auditory cortex, where sound analysis continues, allowing the individual to connect it to familiar patterns, memories, or emotions[2]. To provide more detail, following the auditory cortex's basic processing, the secondary auditory areas, such as the belt regions and Wernicke's area, incorporate many other complex musical patterns like harmony and rhythm.

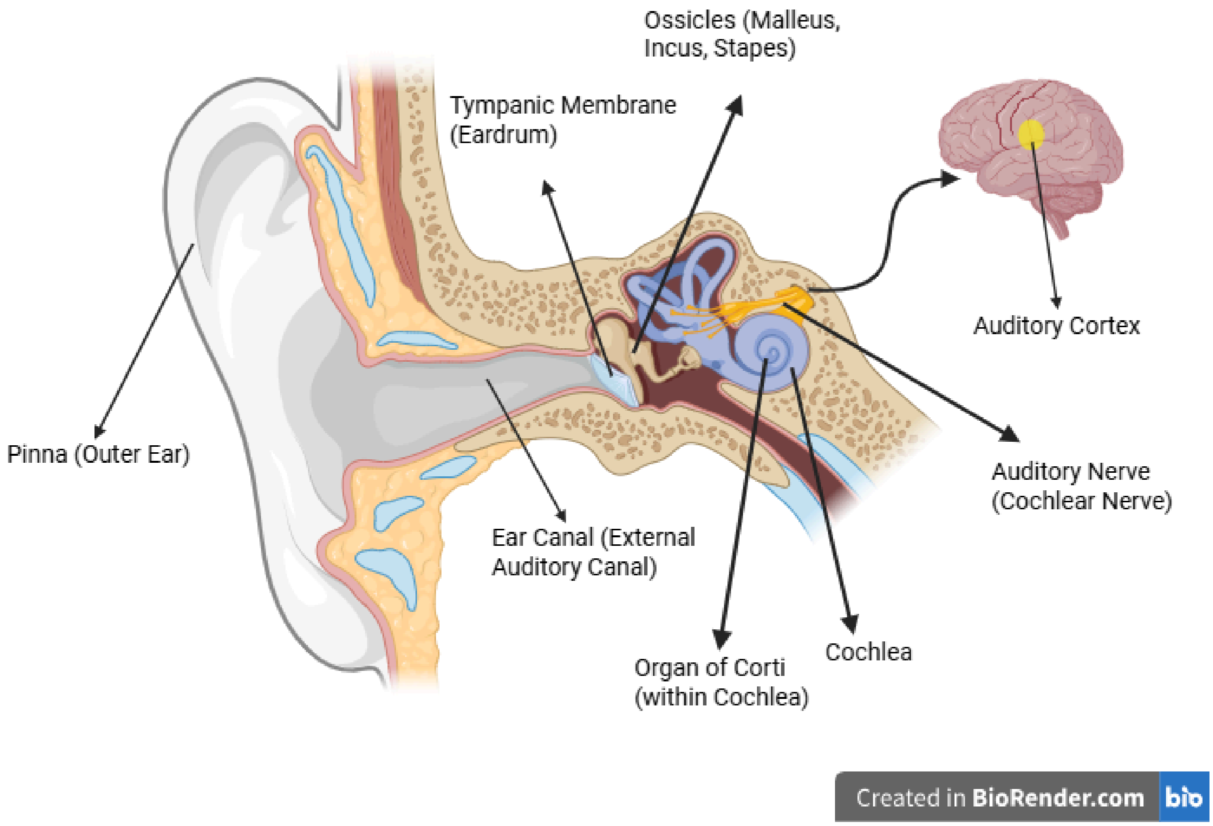

Figure 1. **Sound transduction from the ear to the cortex.** This figure shows a clear schematic of the human ear as well as the auditory pathway used to process sound. Sound enters via the pinna (outer ear) and travels down the ear canal (external auditory canal) and vibrates the tympanic membrane (eardrum). The vibrations from the tympanic membrane are transmitted through the ossicles (malleus, incus, stapes) and to the cochlea, where the sound is converted into neural signals with the help of the organ of Corti. These signals travel via the auditory nerve to their final destination, the auditory cortex, for higher-level processing (adapted from BioRender, 2025)

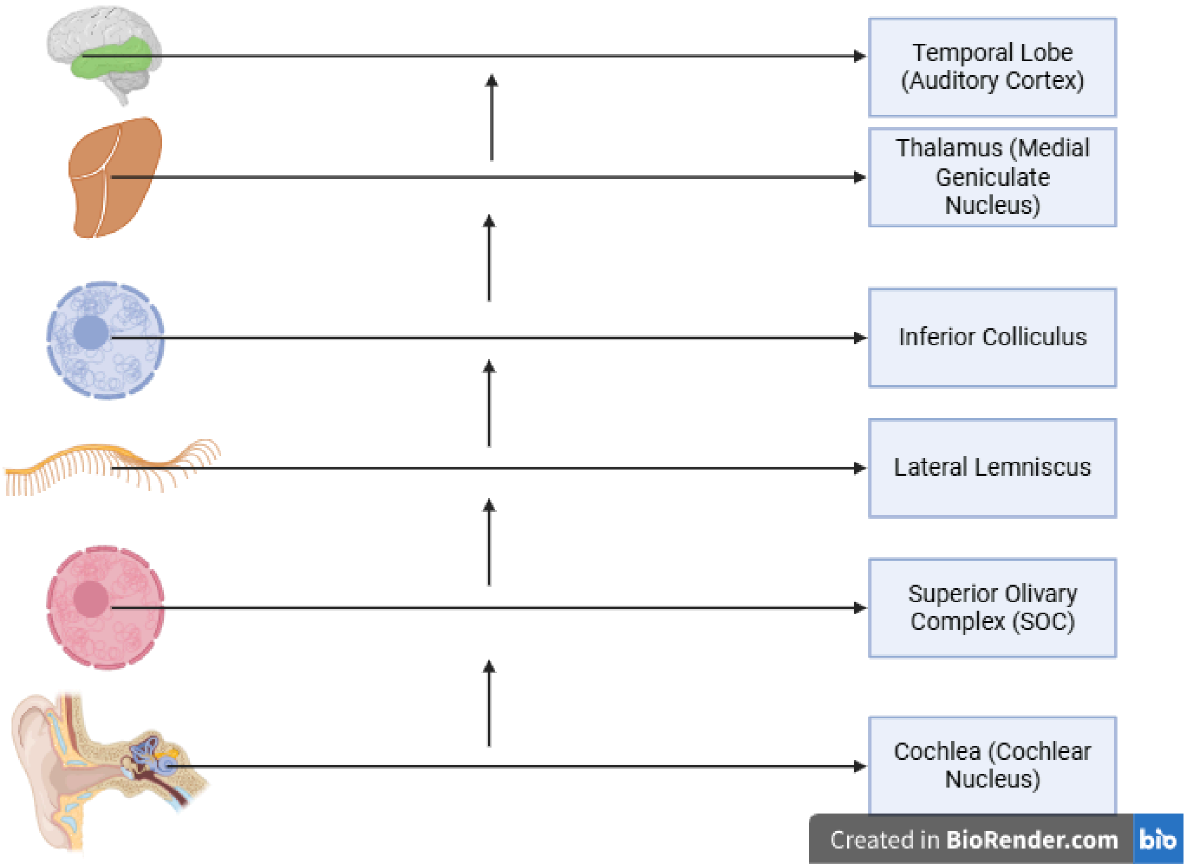

*Fig. 2. **Sound transduction pathway.***
Sound enters the cochlea, where it is later relayed to the brainstem (Superior Olivary Cortex). It travels through the midbrain (inferior colliculus, medial geniculate nucleus) to the thalamus (above the midbrain) before finally reaching the auditory cortex for higher-level processing (adapted from BioRender, 2025)

Music processing in higher-order regions supports more intricate experiences, including preferences, memory, and reward[1],[10]. For instance, the basal ganglia, a group of small structures that control voluntary movements, thinking, and reward processing, are used to interpret rhythm, which in turn helps the brain in pattern recognition[4, 5,6], interpreting regularities in information. Other related regions canonically referred to as the “reward pathway,” specifically the ventral tegmental area, are engaged when we listen to gratifying music. Furthermore, regions of the limbic system, like the amygdala and hippocampus, contribute largely to our emotional experience when listening to music[7].

The next sections will provide further detail on the role of neurotransmitters (chemical messengers) in supporting reward function before discussing the broader relationships between music, emotion, and memory and their neural correlates.

The Role of Neurotransmitters in Invoking Reward Responses to Music

All of the activity in these large brain regions is mediated by chemical messengers ("neurotransmitters") that allow neurons to communicate with each other and with other cells throughout the body[8]. Neurotransmitters hold a key role in sending signals across synapses, binding to specific receptors, and generating both inhibitory and excitatory effects throughout the nervous system. They allow for both basic functions needed for survival, such as digestion and sleep, as well as more complex functions, like movement, emotion, and cognition[8].

This paper focuses primarily on the role of a particular neurotransmitter in generating feelings of reward, pleasure, and satisfaction when listening to music. These feelings are mediated by dopamine's release in reward pathways: music listening engages the mesocorticolimbic pathway, which originates in the ventral tegmental area and includes the basal ganglia. This is where the ventral tegmental area projects dopamine to key structures, including the nucleus accumbens. The interaction between these regions is the neural basis for both reward processing and the generation of positive emotions in relation to music[9]. Generally, the release of dopamine correlates with the emotional arousal and happiness one feels in the moment[10]. This extends to music; dopamine is the principal contributor to the noticeable change in feelings experienced while listening to music[11]. Key evidence comes from a study in which participants were given a dopamine precursor (levodopa), which increased dopamine levels, or a dopamine antagonist (risperidone), which decreased dopamine levels; as seen in Fig. 3, levodopa, compared to a placebo, increased the pleasurable experience associated with music, while risperidone had the opposite effect[12].

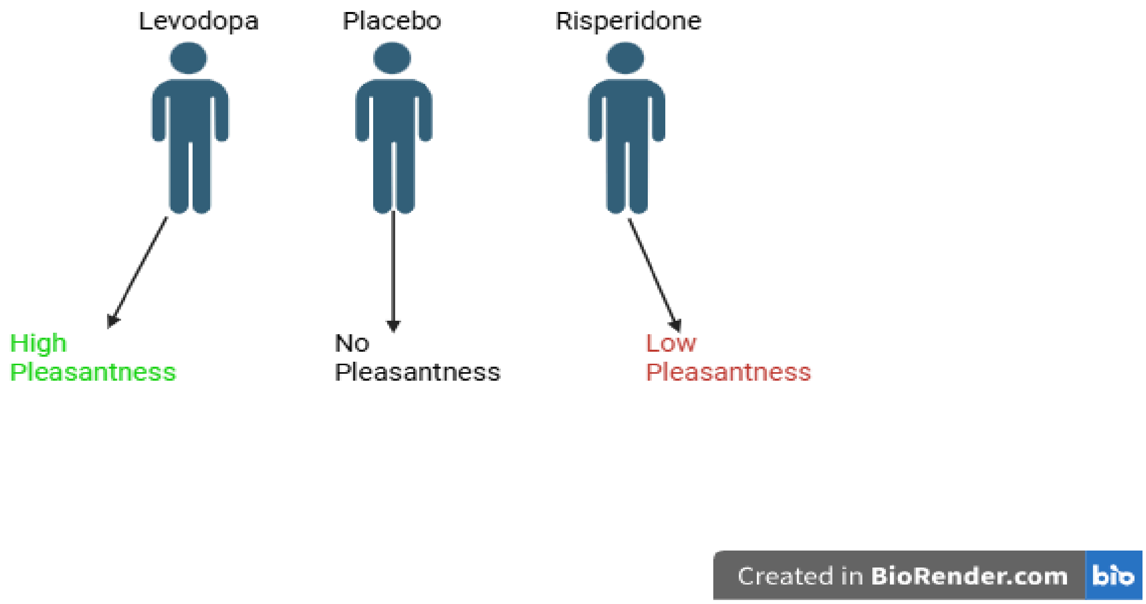

Fig. 3. **Pleasurable responses to music are influenced by dopamine levels.** This figure demonstrates that feelings of pleasure are higher when dopamine levels are higher.. Levodopa is a dopamine precursor (increases dopamine levels), and risperidone is a dopamine antagonist (decreases dopamine levels). *Adapted from Ferreri et al., (2018), BioRender (2025).*

The role of dopamine in “feeling music” is further highlighted in clinical settings. Notably, those with Parkinson’s disease (a deteriorating movement disorder caused by the loss of dopamine neurons in the ventral tegmental area and other regions) possess less of this dopaminergic response, therefore reducing their response to music[15]. Music therapy, a type of therapy that uses music to improve quality of life, reduce stress, and help accomplish goals[13], is thought to increase the dopaminergic reaction through external rhythmic cues, modulating dopamine activity, and compensating for the lack of stimulation[14], improving outcomes for those with diseases like Parkinson’s as well as dementia, or Alzheimer’s[13].

Music’s pleasurable effects stem from not only the release of dopamine in these reward pathways, but also from broader whole-brain changes. For instance, whole-brain oscillations show synchrony between our predictions of the music we are listening to and the motor responses it evokes[15]. The next section will focus on emotional responses to music more broadly.

Basic Science of Music, Emotion, and Memory

As noted, music possesses the great ability to spark and regulate human emotions, engaging many complex neural structures and psychological processes[16]. Many people across the world have emotional reactions to music; however, these reactions are often associated with individual connections and personal experiences. Evidence comes from the case study of patient Harry S. Following a brain aneurysm and the passing of his wife, Harry S. had lost much of his emotional and intellectual capabilities. However, when he performed his songs, he strongly reacted in an emotional manner, demonstrating music's ability to evoke emotions, even when other functions were impaired[17]. The neural structures engaged in music effluence include the amygdala, prefrontal cortex, and dopaminergic reward system discussed previously[18].

Research has shown that intensely pleasurable experiences to music, such as chills, named 'musical chills', are related to increased activity in the reward and emotion-related regions, namely the ventral striatum, amygdala, and prefrontal cortex[18] (see Fig. 4 for the location of these regions). Interestingly, these areas similarly respond to other pleasurable experiences like eating or social bonding, exemplifying that music taps into neural processes related to rapture or motivation.

However, there are some atypicalities where individuals seemingly have normal reward systems but do not respond to music in the way others do. One example of this is called 'music anhedonia'. People who experience music anhedonia can still decipher the harmonic pattern of music; however, there is no emotional response elicited[19]. On the other end of the scale is musicophilia, where people experience an extreme sense of pleasure or other emotions when listening to music[17]. These differences might be due to a mix of genetic, environmental, or cultural factors[20]. For instance, some proposed causes include that individuals with musicophilia may have less neural sensitivity to the reward signals induced by music *or* that, due to cultural or environmental differences, they do not develop a rewarding connection with music. There also seems to be some evidence that these unique conditions–musicophilia and music anhedonia–may also be induced by brain damage: Fletcher found that those with dementia that had more degeneration of their left posterior hippocampus but less degeneration of certain prefrontal and orbitofrontal regions had higher changes of musicophilia[21], while Martinez-Molina identified that those with musical anhedonia had reduced responses in their reward pathways[22]. This provides further evidence for the role of these reward regions in *normative* musical processing.

Nevertheless, this connection between music and the brain's reward pathways helps to explain why music generally induces idiosyncratic emotional responses across people. We know that different musical genres and tempos, types of music, and how fast the beat of the music is can elicit different emotional states. For example, faster, more upbeat music typically induces

feelings of arousal and happiness, while more melodic passages of the piece, such as the vibrato of a cello, evoke feelings of sadness, calmness, or nostalgia[16],[23] . However, music can be quite idiosyncratic, resulting from individual or cultural factors. The psychological state of the listener, such as their mood, as well as episodic memories, may modulate the emotions and effects of music on the brain, leading to individual differences[24].
The multitude of effects that music has on an individual is often related to the memories that the music evokes. Music has a unique ability to trigger autobiographical memories: memories of specific personal experiences or events[25]. Studies show that recognizable music elicits more vivid memories than other sensory cues, such as words or sounds[26]. This is because repeated patterns such as words or melodies act as mnemonic devices, allowing the brain to link these memorable parts of the song to stored memories for retrieval[26].

However, the effects of memory are much more specific than just recognizable music. In an experimental setting, music that evoked a positive connection rather than a negative one was recognized better, indicating that the emotional valence of the music directly correlates with an individual's memory retention[27]. Further, this sensory and emotional engagement has been shown to strengthen the recall and encoding of memories, especially when the music holds emotional meaning, evoking vivid mental imagery in an individual's mind[27], but more research and work are needed to fully understand it.

When it comes to memory itself, regions like the amygdala, prefrontal cortex, and hippocampus are all highly involved (see Fig. 4 for a schematic). Located deep inside the temporal lobe, the hippocampus is *necessary* to form and recall episodic memories[28]. For instance, neuroimaging studies done by Janata show that listening to familiar (as opposed to unfamiliar) music activates the medial prefrontal cortex (mPFC)[26], an area associated with a larger network of regions ("default mode network") thought to engage the storage and retrieval of autobiographical memories[28]. This is thought to occur because familiar music creates mental imagery in our minds. Adding to these neural findings, Belfi[30] conducted a study where participants listened to 30 songs and viewed 30 faces, and noted their evoked memories. The researchers discovered that 'music-evoked autobiographical memories' (MEAM) were much more graphic than the memories evoked from the faces, demonstrating that MEAMs are a stronger cue than others. Moreover, music also evokes feelings of nostalgia, allowing individuals to remember and reconnect with positive or sorrowful episodic events[31].

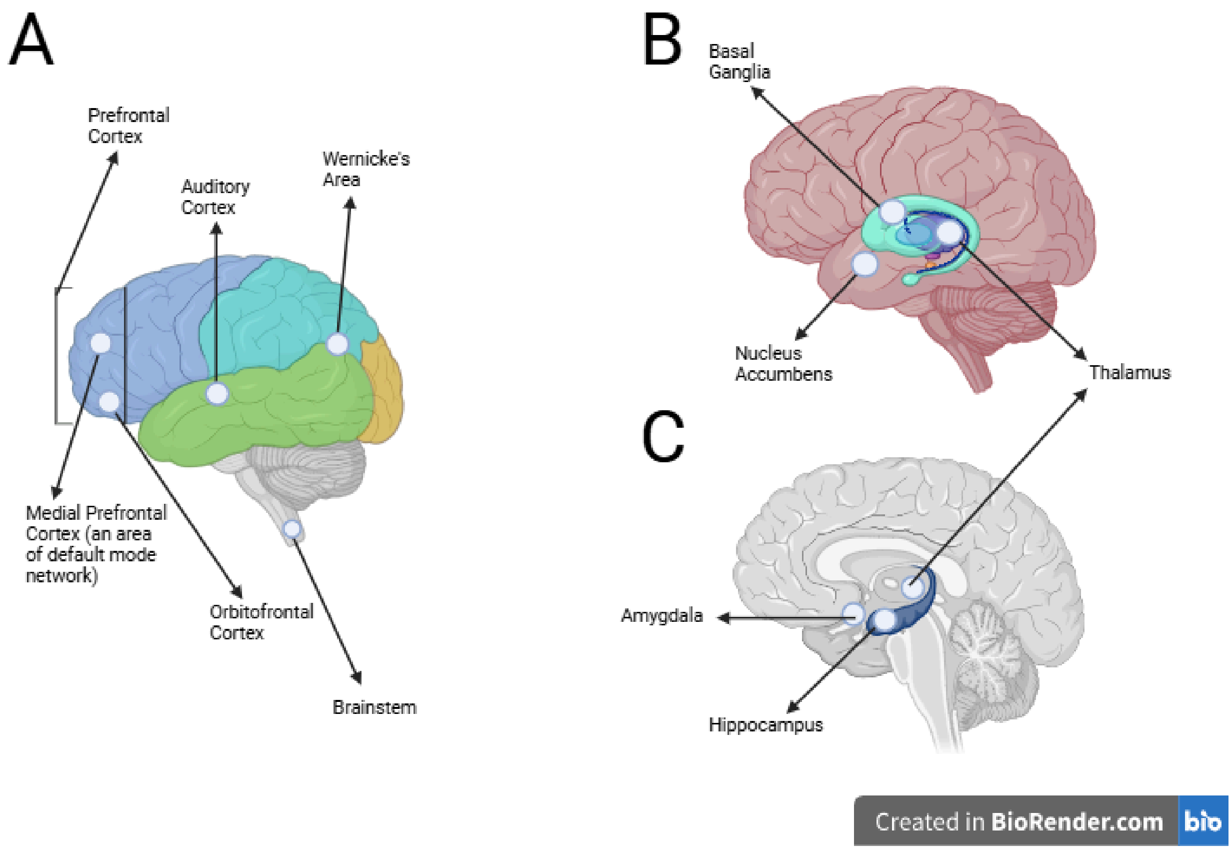

Figure 4. **Regions that support complex music functions.** This figure shows a simplified schematic of the brain, highlighting important regions involved in music processing, emotional regulation, reward, and memory formation. The figure includes auditory processing centers (auditory cortex), the thalamus, emotional and memory structures (amygdala, hippocampus), autobiographical and cognitive regions (prefrontal cortex, medial prefrontal cortex), reward regions (basal ganglia, ventral striatum, ventral tegmental area, nucleus accumbens), the motor cortico-striatal circuit (rhythm and movement timing), and the default mode network. Panel A shows a surface view (figure adapted from PikPNG). Panels B and C show medial views highlighting the basal ganglia and hippocampus/amygdala circuitry, respectively. Figures are *adapted from BioRender (2025).*

Clinical impact of music

Music's capability to activate autobiographical memories and regulate emotional states validates its usage in clinical settings. It has been shown to help individuals cope with mental pain and improve their overall well-being[36], as well as in helping anxiety-related conditions like stress. One way that music is used to help people combat anxiety is through music therapy.

As noted previously, music therapy is used to manage conditions and improve the quality of life. There are two main types of music therapy. The first one, active interventions, is when an individual takes on the role of making music with their therapist, exemplified by singing or playing an instrument[12]. The second one–receptive interventions– is when an individual listens to music and discusses it with their therapist[12]. These two types of music therapy demonstrate that music is a powerful tool that many people use to alleviate symptoms of anxiety-related conditions.

Case studies and clinical research also consistently demonstrate the effects of music on memory and well-being in those who have dementia, a disease that causes memory loss and cognitive disability, as well as Alzheimer's disease, a form of dementia. People with dementia experience a multitude of symptoms, including sleep loss, stress, and poor quality of life[37,38]. To investigate the consistency between music and memory improvement, an experiment was conducted to determine the effects of this correlation on an individual with dementia. This was a woman who was given an '8-week music-with-movement intervention'. The treatment appeared to be a success as the woman noted that it improved sleep quality, reduced depressive symptoms, and increased communication between her and her husband[39].

Broader analysis and various case studies confirm that all types of music enhance episodic memory recall, improve well-being, and decrease anxiety in patients with Alzheimer's disease[40]. Self-selected or emotionally meaningful music most effectively supplements recall in individuals with Alzheimer's, making their memories more vivid and emotionally charged than other memory cues like words or sounds[40]. These results arise from studies with different methodologies, like verbal fluency assessments (measures how quickly and accurately a person can produce words based on categories), episodic memory tests (evaluating the ability to remember specific personal events), and more, indicating their generalizability. The musical memory appears to not only support cognition, but also enhance social interactions and improve well-being for people living with Alzheimer's or dementia, providing further support to the previous study[39].

Academics

Music not only brings back prior memories, but it also has an active role in how we form memories. An example of a widely discussed real-world application dealing with the correlation between music and memory occurs in academics. Research surrounding the topic focuses on how music impacts learning, concentration, and information retention, especially in contexts like studying or classroom environments. From a research perspective, the connection between music and memory is complex and individualized. The research is mixed in suggesting whether music elevates concentration or not, and it all depends on the type of music played and other factors. One factor that determines music's effectiveness on concentration is the presence (or lack) of lyrics. Experimental studies suggest that lyrical background music can be seen as distracting[41]. This is thought to be because lyrical distractions may interfere with recall and comprehension, especially while learning through tasks that involve verbal information[41]. On the other hand, instrumental background music has the same or slightly better effects for individuals, promoting concentration and focus, with around 80% of people stating that music is therapeutic and helpful for absorbing information. It is also said that instrumental music has no lyrics and is therefore less distracting[41],[42]. Further, individuals who listen to music report high grade-point averages (GPA), a greater happiness for learning, and improved memorization[43]. An empirical article done by Christopher and Shelton[44] shows that general background music was found to be distracting; however, those with a better ‘working-memory capacity’ were less affected compared to others[44]. This shows that personal cognitive abilities also play a role in the correlation between music and academics.

These findings highlight that while music is a powerful tool for memory about academic performance, it ultimately depends on the type of music, the type of task, and individualization.

Limitations and Open Questions
While research further validates music’s association with emotion and cognition, it promotes important contradictions requiring closer analysis. Cultural differences contribute to the individuality of music perception, shaping how people from different regions around the world hear musical attributions, including pitch, rhythm, and emotionality or aesthetic. A study comparing Western listeners from America with members of the Tsimane tribe in Bolivia found that both groups can similarly differentiate tones and notes, but differ in pitch relationships, which is a big part of Western music and holds little value in Tsimane music[45]. For example, the combination of the C and F# notes is often reported as irritating to Westerners, but enjoyable to the Tsimane[45]. The authors suggest that the difference is likely from the brain’s tuning to different phonetics and sounds during critical development periods, similar to how exposure to different languages can evoke different responses[46]. This tuning impacts how sounds are processed, influencing emotional responses and memory. Furthermore, individuals from specific cultures may find it easier to recognize rhythms from their own upbringing, and synchronization to these elements of music stems from genetics and cultural factors, only increasing the listener’s individuality[47]. However, there are a few subconscious responses that are similar between every person, including facial expression or emotional reactions, demonstrating that instinctive psychological responses are integrated into culture[47]. The cultural aspect of music may also add to the individuality of a person, defining how the music is processed and how it is emotionally and cognitively outputted, providing a foundation for understanding individual differences that affect musical experience.

Beyond cultural factors, there are numerous meaningful individual differences that impact these factors that have not always been accounted for in prior research. For instance, research on music perception has identified that emotional states play an important role. Emotional states while listening to music vary widely from person to person, and can be differentiated based on a variety of factors, including the present psychological state of the listener, personality traits, music preference, and how and what the individual has learned in the past[48]. These individualized aspects of a person shape how they react to different types of music. Second, an individual's cognitive style also plays a key role in their response to music. Two dissimilar cognitive styles that hold notable differences between each other are the "empathizer", an individual who focuses on music that is easier to grasp and possesses little physiological arousal, and the "systemizer", an individual who leans towards complex music, including heavy metal, punk, or jazz[49]. Because music affects individuals personally, it becomes challenging to generalize findings, especially when studies must regulate the music used.

The individual and physiological aspects of music make listening extremely personal, making it difficult to make general, population-level conclusions in research studies that will often need to standardize the music that they are exposing the individual to. Future work should continue to take an individual differences perspective to answer these important questions. For instance, those in the field could investigate if individuals who share traits like personality type or musical preference share similar neural responses to the same piece of music in comparison to those with different traits. This experiment could involve measuring brain scans (fMRI, EEG) across various groups with alike or unlike traits while listening to the same songs, to see the similarities or differences in their responses. This would show us that individual differences change how music is processed in the brain.

Discussion

This review highlights the key relationships between music and the brain, specifically its relationship with emotional processing and memory function. Findings highlight that music engages crucial parts of the brain, including the auditory cortices, particular parts of the limbic system such as the amygdala and hippocampus, and reward systems. This engagement facilitates psychological arousal, vivid episodic memory recollection, and reward processing.

This work exemplifies how the broad effects of music can contribute to areas including mental health, therapy, and education. Music's effect on emotion and memory is not ubiquitous; however, it is extremely personalized and is differentiated based on cultural background, mood, and cognitive style. It is critical to consider the unique traits of the listener in order to have real-world applications for this research. Future work should explore these questions further in order to fully understand these relationships, which have real-world implications. For instance, in clinical settings, music therapy can be used to lessen anxiety and improve recall in patients with Alzheimer's disease or dementia, as well as general psychological well-being. In addition, educators can strategically use music to improve focus and concentration in the learning environment. Understanding the listener's musical experience and how it affects them as an individual allows for more personalized ways to improve cognitive function and emotional advancement.

Although there have been multiple advancements in music's connection to emotion and memory, the effects differ due to individual and cultural differences. Future work should examine personality and preference to better understand how individual differences shape neural responses. Investigating the associations between music and the brain can broaden our perspectives and help us progress to expand our understanding.

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