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Resiliency of Musical Memory Networks in Alzheimer’s Disease Patients

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ABSTRACT

This paper examines the resilience of musical memory regions in the brain throughout the progression of Alzheimer’s disease. Alzheimer’s disease is the most widespread neurodegenerative disease and is globally projected to affect 153 million people by 2050. While memory loss is one of the main symptoms of Alzheimer's, recent research has shown that some forms of memory remain relatively preserved throughout the disorder’s progression. This paper reviews studies that use neuroimaging techniques, such as MRI, fMRI, PET, and EEG, to track how the brain changes with age, and then more specifically, how the brain progresses through Alzheimer’s disease. The paper then reviews studies on musical memory networks and the specific brain regions that are activated when processing music. Interestingly, these regions of the brain involved with musical memory, which include the right hippocampus, medial and superior temporal lobes, the caudal anterior cingulate cortex (cACC), and the ventral pre-supplementary motor area (ventral pre-SMA), correspond with the regions that are some of the last to degenerate in Alzheimer’s, namely the cingulate cortex, frontal areas, and parts of the temporal lobe. This endurance may help explain why patients with later stages of Alzheimer’s can recognize familiar songs and respond emotionally to music. Understanding these mechanisms can help researchers, caregivers, and patients explore music-based therapies that are non-pharmacological and accessible. In the context of a neurodegenerative disease like Alzheimer’s, these insights show that music, and possibly personalized music, can be a tool to improve the mood, memory, and quality of life of patients.

Keywords*: neurodegenerative diseases, Alzheimer’s disease, music therapy, musical memory, accessible dementia care, non-pharmacological therapy, intervention, functional magnetic resonance imaging (fMRI), regional brain vulnerability, amyloid-beta, cognitive memory, brain function*

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INTRODUCTION

Globally, Alzheimer's disease accounts for 60–80% of all dementia cases, affecting about 55 million individuals, and is projected to grow to 153 million individuals by 2050 (Matziorinis & Koelsch, 2022). This large increase is mainly due to population growth and population aging (Nichols et al., 2022).

In the United States alone, about 6.9 million people aged 65 and older are living with Alzheimer's dementia today (Alzheimers Dement., 2024). Alzheimer's is already the seventh leading cause of death in the U.S., with deaths increasing by more than 140% since 2000. In 2024, the U.S. was expected to spend around $360 billion on health care, long-term care, and hospice services for patients with dementia (Alzheimers Dement., 2024). These growing numbers show why it is so important to understand the disease better and find ways to prevent or slow it down. Since there is still no cure to stop dementia once it starts, researchers use brain scans such as MRI (to look at the brain's structure), fMRI (to see brain activity), PET scans (to see how the brain uses energy), and EEG (to measure brain waves) to figure out what is happening inside the brain as this disorder progresses.

Accessible and cost-effective, music therapy can be utilized anywhere. It is a practical option for helping people with dementia. This paper will begin by explaining what neurodegeneration is and how researchers use neuroimaging techniques to track Alzheimer-related changes in the brain. Then, research on how musical memory works in healthy adults will be discussed, followed by similar research in Alzheimer's patients that shows how musical memory regions, like the caudal anterior cingulate cortex and ventral pre-supplementary motor area, stay intact longer than other parts of the brain as the disorder progresses. After that, a review of behavioral and imaging evidence for music therapy will be presented, showing how personalized and active music interventions boost brain connectivity and improve thinking skills. Finally, a discussion will follow on how these findings support the use of music therapy to slow cognitive decline. By analyzing fMRI data on musical memory in Alzheimer's disease, this paper argues that the brain areas responsible for musical memory are the last to be affected by Alzheimer's, which helps explain why music therapy is an effective and nonpharmacologic intervention that can reduce cognitive decline in people with Alzheimer's and other memory disorders.

LITERATURE REVIEW

Alzheimer's Disease in the Brain

Alzheimer's disease is a neurodegenerative disease that is the most widespread cognitive disorder among the elderly (Matziorinis & Koelsch, 2022), and it can begin years before any signs of symptoms. It is

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characterized by the neuropathological features of the accumulation of amyloid-β (amyloid-beta) peptide in amyloid plaques and tau protein in neurofibrillary tangles (Matziorinis & Koelsch, 2022). As the disorder progresses, atrophy, which is the deterioration of brain tissue and neural structures, spreads across multiple regions of the brain. However, some areas are mostly spared, which include auditory areas and pre-supplementary motor areas (pre-SMA) (Matziorinis & Koelsch, 2022; Veitch et al., 2018). Clinical symptoms of Alzheimer's disease involve a decline in cognition, memory, and speech production, as well as behavioral and psychological symptoms of dementia (BPSD), including depression, anxiety, and sleep disorders (Matziorinis & Koelsch, 2022). Individuals who have a family history or other risk factors have an increased risk of developing Alzheimer's disease later in life. Since there is currently no cure, early detection and treatments that delay progression are crucial. Neuroimaging techniques such as structural MRI (sMRI), functional MRI (fMRI), positron emission tomography (PET) targeting specifically amyloid-β and tau, and electroencephalography (EEG) provide scientists insights into the mechanisms of Alzheimer's disease and potential therapies (Reiman & Jagust, 2012).

What is Neurodegeneration?

Neurodegeneration is defined as the ongoing and irreversible process of structural and functional loss in neurons, leading to the deterioration of brain regions, and ultimately, to various neurodegenerative diseases (Zeydan & Kantarci, 2023). Neurodegenerative diseases encompass Alzheimer's disease, the most common cause of dementia, as well as other forms of dementia such as frontotemporal degeneration and dementia with Lewy bodies (Frisoni et al., 2010). Although the exact cause of Alzheimer's remains unknown, aging is the greatest risk factor. Neuroimaging techniques such as structural MRI, PET imaging for amyloid-beta and tau deposition, and emerging modalities like ultra-field MRI and functional MRI are predominantly used and provide valuable insights into this process of degeneration (Zeydan & Kantarci, 2023). For the study of Alzheimer's disease specifically, structural imaging has become important for clinical assessment. Detected by high-resolution MRI, brain atrophy, particularly in medial temporal regions such as the hippocampus, is correlated with amyloid-beta deposition, tau protein deposition, and neuropsychological decline, and is a diagnostic marker for Alzheimer's disease at the mild cognitive impairment stage (Frisoni et al., 2010; Reiman & Jagust, 2012). With this general framework in mind, it is important to examine how the brain changes with age, distinguishing normal aging from the processes that underlie Alzheimer's disease.

How the Brain Changes with Age

As the brain ages, it goes through microscopic changes that are different from the severe damage seen in neurodegenerative diseases such as Alzheimer's. Esiri (2007) found that aging surprisingly does not cause as much neuron loss as scientists once thought. Instead, aging is more often marked by a decrease in the size of neurons, especially in the dendrites and axons, which are branches in the neuron that are responsible for receiving and transmitting information, respectively (Esiri, 2007; Goaillard et al., 2020). This shrinking is a result of several factors, including damage from free radicals (which is caused by both internal body mechanisms and external factors, such as air pollutants) and imbalances in calcium levels (Esiri, 2007; Machlin & Bendich, 1987; Tvrdá & Benko, 2020). In addition, genetic and environmental influences can change how brains age, making certain groups of neurons more vulnerable than others. Lockhart and DeCarli (2014) further explain the physical changes that occur in healthy aging. Two of the most common changes are the thinning of the brain's outer layer, the cortex, and shrinkage in the hippocampus, a region important for memory. These changes are closely connected to the memory and thinking skills that often decline with age (Lockhart & DeCarli, 2014).

In contrast to the gradual and slightly variable changes to normal aging, Alzheimer's disease causes more severe damage to the brain. One major difference is seen in the brain's default mode network (DMN), a group of connected regions that is active when the brain is at rest and is crucial for memory and thinking. In normal brain function, the DMN deactivates when a person switches from rest to an active cognition task, such as solving a problem or doing a task that requires attention. However, studies using resting-state fMRI have found that in Alzheimer's patients and aging individuals, the DMN does not deactivate properly, especially during memory tasks, and loses its coordination even in the earlier stages of the disease. As Alzheimer's progresses, the connectivity within the DMN becomes increasingly disrupted (Brier et al., 2012; Reiman & Jagust, 2012). In particular, the DMN overlaps with regions where amyloid-beta plaques tend to build up, which show brain tissue shrinkage and lower energy use, key signs of Alzheimer's progression (Reiman & Jagust, 2012). Even though normal aging does lead to reductions in cortical thinning and hippocampal volume, these changes are more prominent and severe in Alzheimer's. Fjell et al.'s 2014 study found that frontotemporal regions, areas part of the DMN and known for their high degree of plasticity, are especially at risk. This suggests that while some decline in these regions involving the DMN may be normal as the brain ages, they are likely to become more affected by Alzheimer's than other parts of the brain (Fjell et al., 2014).

The Progression of Alzheimer's Disease, Regional Vulnerability, and Underlying Mechanisms

Alzheimer's disease develops in a complex way, with different parts of the brain changing at different times. Benzinger et al.'s (2013) research has shown that as Alzheimer's progresses, amyloid-beta plaques build up, the brain's use of glucose decreases, and neurons begin to shrink or die. However, these changes do not happen evenly across all brain regions. For example, in people with autosomal dominant Alzheimer's, a form of Alzheimer's caused by a mutation, amyloid plaques can appear as early as 15 years before symptoms begin; yet, not all areas show reduced function or shrinkage at the same time. Some areas, like the precuneus and posterior cingulate, might even show a brief period of increased metabolism before declining, while the hippocampus tends to lose its activity earlier than other regions (Benzinger et al., 2013). The amyloid cascade hypothesis (a theory suggesting that the deposition of amyloid-beta in the brain is the primary cause of Alzheimer's) explains this pattern by proposing that when the brain cannot balance the production and removal of these amyloid-beta proteins, harmful plaques and tau tangles form and build up (Gordon et al., 2014; Karran & De Strooper, 2016). The level and timing of these changes are different among brain regions, which means some areas are affected earlier and more severely than others (Gordon et al., 2014).

Long-term MRI and PET studies help researchers understand the order in which these changes occur. MRI scans have shown that atrophy, or brain shrinkage, starts in the hippocampus and amygdala. Afterward, the middle temporal gyrus becomes affected, followed by the entorhinal cortex and parahippocampal gyrus, and finally, the damage extends to the striatum and thalamus, and then the middle frontal, cingular, parietal, insular cortices and pallidum (Du et al., 2004; Li et al., 2010; Planche et al., 2022). Notably, a meta-analysis conducted by Pusparani et al. (2025) showed that the left hippocampus experienced greater atrophy and decline than the right hippocampus. PET scans provide more evidence about tau protein tangles; structures linked to cell and nerve damage. Tau tangles first appear in the transentorhinal and entorhinal areas (Berron et al., 2021; Kaufman et al., 2018). Interestingly, the spread of tau tangles does not always match up with the timing and distribution of brain atrophy. This discrepancy suggests that other factors, such as nerve connections, might also contribute to brain shrinkage seen in Alzheimer's disease (Berron et al., 2021). Knowing this connection is important for developing treatments that stop harmful protein build-up and better understand how the brain changes in Alzheimer's.

These findings together show that Alzheimer's disease causes severe and region-specific brain damage that is more drastic than the changes in normal aging. Some regions in the brain, which will be investigated later in this literature review through the lens of musical memory, may remain relatively intact until the later stages of Alzheimer's.

MUSICAL MEMORY IN THE BRAIN

Music has a unique way of triggering memories, especially in individuals with Alzheimer's disease or other neurodegenerative conditions. Musical memory involves how the brain stores and processes music-related information, and scientists have been studying which parts of the brain are responsible for this for a long time. One of the first major discoveries came from Penfield and Perot (1963), who used electrodes to stimulate the brain and found that the temporal cortex might play an important role in how people form and remember musical memories (Penfield & Perot, 1963, as cited in Jacobsen, 2015). The brain uses several different networks, not just one, to encode musical experiences. Long-term musical memory includes both explicit and implicit forms. Explicit memory is conscious, meaning that a person knows that they are remembering something, and helps them remember facts and experiences. Explicit memory is then broken down into episodic memory (recalling personal musical experiences, such as when and where a person heard a song) and semantic memory (remembering general knowledge about the music, such as the song name or genre). On the other hand, implicit memory is unconscious, meaning that a person does not realize they are using memory, but the brain draws on past experiences, such as playing an instrument, to carry out tasks (Baird & Samson, 2009; Vanstone & Cuddy, 2009; Vanstone et al., 2012). In a study that examined musical memory in 12 patients with moderate to severe Alzheimer's and 12 healthy older adults, Vanstone and Cuddy (2009) found that familiar melodies can bring back personal memories quite vividly, even in individuals with Alzheimer's as their other memory functions decline. This suggests that these familiar melodies can trigger episodic and semantic memory. However, as some Alzheimer's patients performed at levels comparable to healthier adults, others showed partial preservation, and a few exhibited almost complete loss of musical memory (Vanstone & Cuddy, 2009). Vanstone et al. (2012) further explored this, revealing that the more familiarity a person had with a song, the stronger the connection between episodic and semantic memory became. Music naturally activates multiple memory systems at once, and increased engagement and familiarity may help preserve memory function in people with Alzheimer's more, even when other cognitive abilities decline.

Neuroimaging Evidence of Music Processing

Neuroimaging studies have revealed that multiple brain regions work together to support musical memory and recognition. Using neuroimaging techniques such as fMRI and PET scans, researchers have identified specific areas of the brain involved in the processing of music. Watanabe et al.'s (2008) study used fMRI scans to explore which brain areas are activated when people successfully retrieve musical memories, choosing newly composed music as stimulus so there would be no influence on familiarity. They found strong activity in the right hippocampus, left inferior frontal gyrus (IFG), and anterior parts of the bilateral temporal lobes. The right hippocampus showed stronger activation than the left, emphasizing the importance of the right side of the brain in musical memory and the overall involvement of the right hemisphere in nonverbal memory, which helps with remembering the emotional parts of music (Watanabe et al., 2008). In contrast, the left IFG activation was correlated to the mental effort in retrieving music, suggesting that the left hemisphere may be involved in the mental effort to recall music rather than storing the memory itself (Watanabe et al., 2008). The medial prefrontal cortex (MPFC) also plays a key role as music triggers emotion and autobiographical memories. Janata (2009) also used fMRI scans to examine the brain activity in healthy young adults listening to songs from their childhood. This study found that the dorsal medial prefrontal cortex (located towards the top part of the MPFC) became more active depending on how personally meaningful the music was, linking music with autobiographical memories. The dorsal MPFC works with the right hippocampus to bring together memories and emotional experiences, and this further emphasizes the complex network of regions that are involved in recalling music specifically tied to personal life experiences (Janata, 2009).

Additional studies highlight the important role of the temporal lobes in music recognition. Satoh et al. (2006) used PET scans to study changes in regional cerebral blood flow (rCBF) that occur when listening to music known to participants and found that the bilateral anterior portions of bilateral temporal lobes, superior temporal regions, and parahippocampal gyri (located at the medial temporal lobe) were activated, reinforcing the

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importance of these temporal lobe structures in music recognition (Blaizot et al., 2004; Satoh et al., 2006). Similarly, Groussard et al. (2010) used high-resolution PET H_2O scans on 11 young subjects listening to familiar music and found that musical memory activated the superior temporal area and inferior and middle frontal areas in the left hemisphere and the inferior frontal area in the right hemisphere, confirming the involvement of a distributed network for music recognition (Groussard et al., 2010).

The left inferior frontal gyrus (IFG) is engaged differently in studies by Watanabe et al. (2018) and Groussard et al. (2010). Watanabe et al.'s fMRI study using fMRI scans using newly composed music to isolate the main brain regions responsible for activation found that left IFG activity was related to retrieval effort instead of storing musical memories, while Groussard et al.'s PET study using familiar music showed that left IFG activity, as well as activity in middle frontal regions, was associated to musical memory. This discrepancy is likely due to the differences in objectives and methods of the study (with Watanabe et al.'s goals in using newly composed music and Groussard et al.'s goals in using familiar music) as well as differences in the neuroimaging technique used. However, consistent activation of the superior temporal area and right hippocampus overall shows their importance in recognizing and processing familiar music (Groussard et al., 2010; Janata, 2009; Satoh et al., 2006; Watanabe et al., 2008). Together, these findings highlight the coordinated activity of various brain regions, namely the right hippocampus, temporal lobe areas, such as superior temporal regions and bilateral anterior portions of bilateral temporal lobes, and the dorsal medial prefrontal cortex (MPFC) which is located in the frontal (not temporal) lobe, in supporting musical memory, with the right hippocampus playing an important role in particular in the recall of music.

Musical Memory & Alzheimer's Disease

When linking musical memory with Alzheimer's disease, a striking pattern emerges: regions essential for processing music and are involved in musical memory appear to remain relatively intact despite widespread brain degeneration. Jacobsen (2015) used ultra-high field 7 T fMRI scans to perform imaging studies on 32 normal adults to compare brain responses to unknown, recently known, and long-known music. The study found that regions such as the caudal anterior cingulate cortex (cACC) and the ventral pre-supplementary motor area (ventral pre-SMA) are crucial for encoding long-term musical memory. While earlier studies emphasized the role of the right side of the brain and temporal lobes in music retrieval and recognition, the cACC and ventral pre-SMA are part of the medial frontal cortex (which is in the same region as the dorsal medial prefrontal cortex (MPFC) mentioned above in Janata's 2009 fMRI study) are these regions are crucial for encoding and organizing the musical information itself. These areas of the brain help combine the order and emotions of music. This combined information then interacts with memory areas like the right hippocampus and temporal lobes, helping to create long-term musical memories. When these regions were examined in 20 Alzheimer's patients, they showed very little cortical atrophy and minimal disruption of glucose metabolism, even though the regions had a similar amount of harmful amyloid-beta build-up as the other parts of the brain. This suggests that these musical memory networks remain intact until the later stages of Alzheimer's (Jacobsen, 2015). Even though studies above on Alzheimer's progression in the brain show that the hippocampus is one of the brain regions that deteriorates first, with the left-side atrophy being more prominent (Benzinger et al., 2013; Du et al., 2004; Li et al., 2010; Planche et al., 2022; Pusparani et al., 2025), the strength of the right hippocampus in musical memory networks may explain the strength of musical memory in Alzheimer's patients despite overall hippocampus decline.

Additionally, Peck et al. (2016) conveyed that music exposure can enhance memory and emotional function in Alzheimer's patients by stimulating resilient brain networks. The default mode network (DMN), as discussed previously in Fjell et al.'s 2014 findings, is highlighted as one of the biggest contributors in memory processes. Peck et al. (2016) explains that the DMN's connectivity may be improved by music exposure, which, as a result, will help maintain overall memory function in Alzheimer's patients despite degeneration. Even as Alzheimer's leads to severe damage in many areas, these research findings show that neural pathways supporting musical memory, specifically regions like the caudal anterior cingulate cortex and ventral pre-SMA, which are connected to the DMN, appear to be spared. This offers a promising glimpse into music-based interventions to slow cognitive decline.

Recent Findings on the Resilience of Musical Memory Networks

Recent studies have provided further evidence that musical memory networks are exceptionally resilient. King et al. (2019) conducted an fMRI study with Alzheimer's patients over the course of three weeks and found that listening to personalized, preferred music increased functional connectivity in the supplementary motor area (SMA) and other related networks. This enhanced connectivity, especially with preferred music, suggests that music can increase functional connectivity, especially in a short time period, improving synchronization in brain networks (King et al., 2019). Furthermore, Böttcher et al. (2022) compared older adults with different histories of musical activity, such as adults who previously played an instrument and adults who are non-musicians and revealed that lifelong musical engagement is associated with better cognitive functioning. Although differences in gray matter volume in brain regions were not always significant, the correlation between brain structure and cognitive ability was stronger in musically active individuals (Böttcher et al., 2022). This indicates that musical participation over a long period might improve the brain's capacity to withstand neurological changes, even the ones in Alzheimer's. All in all, music not only engages multiple memory systems in the brain but also protects and reinforces them, offering an accessible and non-invasive option for therapeutic interventions in Alzheimer's disease.

MUSIC THERAPY

This preservation of musical memory regions supports the idea that music-based therapies may help reduce cognitive decline. Music therapy is a low-cost and non-invasive intervention that can directly calm the body's stress response through the autonomic nervous system (Kemper & Danhauer, 2005). Music therapy includes active activities like playing instruments, singing, clapping, or dancing, as well as passive activities like simply listening to music (Matziorinis & Koelsch, 2022). Patients of all ages report less anxiety, better mood, and even reduced pain when music is part of their treatment (Kemper & Danhauer, 2005). In Alzheimer's disease specifically, patients are still able to learn new songs, encode new verbal information, and respond emotionally to music, and this phenomenon has driven the development of targeted music therapy programs. These programs have been shown to boost mood, lower depression and anxiety scores, enhance autobiographical recall, improve verbal fluency, and produce measurable gains in cognition (Matziorinis & Koelsch, 2022). Because Alzheimer's often begins long before symptoms appear, early music interventions could offer an effective way to delay or slow neurodegeneration in individuals at risk for Alzheimer's disease (Matziorinis & Koelsch, 2022).

Music's Ability to Delay Cognitive Degeneration

The following subsections will look at the behavioral studies showing how music interventions slow cognitive decline and then the neuroimaging evidence that reveals what is happening in the brain.

Behavioral Evidence Behavior outcomes from music therapy offer the clearest evidence for its role in supporting cognitive function in Alzheimer's disease. Svansdottir and Snaedal (2006) conducted a case-control study investigating the effects of music therapy on behavioral and psychological symptoms of dementia (BPSD) in patients with moderate to severe Alzheimer's disease. Over six weeks, 38 patients participated in group music therapy sessions which included listening to familiar songs, group singing, and playing instruments. As measured by the Behavior Pathology in Alzheimer's Disease Rating Scale (BEHAVE-AD), results showed significant reductions in aggressiveness and anxiety (Svansdottir & Snaedal, 2006). This shows that music therapy can be an effective short-term way to reduce agitation and discomfort in people with more advanced stages of Alzheimer's disease. Randomized studies conducted by Chu et al. (2013) and Lyu et al. (2018) further support the therapeutic potential of music therapy in Alzheimer's. Chu et al. found that biweekly group music therapy sessions over a period of six weeks greatly reduced depressive symptoms and improved cognitive function, especially short-term recall, in 104 elderly patients with mild to moderate dementia (Chu et al., 2013). Lyu et al. (2018) extended these findings to a larger study with 298 patients experiencing varying stages of Alzheimer's. Participants were randomly assigned to a singing group, a lyric reading group, or a no-intervention control group. While both active groups (singing and lyric reading) showed improvements, the singing group showed significant changes in verbal fluency and memory among patients. Overall, there were improvements in cognitive scores and BPSD. Lyu et al.'s study also highlighted the importance of music familiarity and patient preference, suggesting that personalized music in music therapy sessions may elicit stronger emotional and behavioral responses than general group music interventions (Lyu et al., 2018). These studies all show that both standardized and individualized music therapy can help reduce symptoms like anxiety and depression, improve aspects of thinking and memory, and even lessen certain behavioral problems.

Neuroimaging Evidence To see what is actually happening inside of the brain during music therapy, researchers have turned to EEG, fMRI, and diffusion tensor imaging (fMRI-DTI) to see how music activates the brain circuits that Alzheimer's often damages. They consistently found effects in the superior temporal gyrus, thalamus, entorhinal cortex, precuneus, and medial prefrontal cortex, which are regions critical for memory, autobiographical thinking, and the default mode network (DMN). Xiao et al. (2023) conducted a controlled fMRI-DTI study and showed that music therapy stimulates both the central and peripheral nervous systems in patients diagnosed with minimal consciousness state (MCS), an impairment in awareness. Patients exposed to familiar music demonstrated significant improvements in autonomic nervous system (ANS) activity and showed structural brain changes, such as fiber bundle reconstruction in areas like the corpus callosum, brainstem, thalamus, and superior temporal gyrus (Xiao et al., 2023). Raglio et al. (2015) conducted a similar study but with healthy adults. Their fMRI research on Active Music Therapy (AMT) showed that when participants listened to their own musical improvisations, key brain areas lit up, including the superior and middle temporal gyri (linked to auditory and memory processing), the precuneus (involved in self-referential thought), and the prefrontal cortex (Raglio et al., 2015). These regions are also involved in autobiographical memory and personal meaning, indicating that musical experience, whether through self-created songs or personally meaningful ones, engages brain networks responsible for identity and emotional connection. This is especially relevant to research in Alzheimer's disease, where these memory and emotion-related circuits remain accessible longer than others. This resilience makes music a great tool for therapy; and not just for Alzheimer's, but also for other types of dementia and cognitive problems too. These similar effects demonstrate that music could help a wide range of people.

Broader Clinical Applications of Music Therapy in Neurodegenerative Diseases

In other neurologic conditions, music therapy has shown it can tap into memories and abilities that patients can not normally reach on their own. Tomaino (2002) explains that even when brain injuries or diseases block someone's ability to remember a song or movement, the underlying motor templates and song associations remain intact. By using familiar melodies and rhythms, therapists help patients reconnect with those lost functions, whether it's recalling a tune or re-learning how to move their bodies (Tomaino, 2002).

Comparing the anatomy of Alzheimer's disease to that of Parkinson's disease, another prevalent neurodegenerative disease, Burton et al. (2004) find that people with Parkinson's disease dementia show less atrophy in the temporal lobe, especially in the parahippocampal gyrus and hippocampus (Burton et al., 2004). From the studies mentioned above, the parahippocampal gyrus is especially important in musical memory and recognition (Satoh et al., 2006). On the other hand, the hippocampus is one of the first regions of the brain to deteriorate in Alzheimer's (Benzinger et al., 2013; Du et al., 2004; Li et al., 2010; Planche et al., 2022), with the right hippocampus having stronger resilience than the left in Alzheimer's progression as well as in musical memory (Jacobsen, 2015; Pusparani et al., 2025; Watanabe et al., 2008). The decreased atrophy in these regions in patients with Parkinson's disease make music therapy an even more promising route. With the knowledge about the mechanisms of Alzheimer's disease and its connection to musical memory in this review, music therapy is a treatment that can not only help Alzheimer's patients, but it can be adapted to help people with a wide range of neurodegenerative and neurological challenges by reopening memory pathways, aiding diagnosis, and creating environments that encourage engagement and rehabilitation.

DISCUSSION AND FUTURE DIRECTIONS

This paper is focused strictly on how music therapy can be an accessible intervention for patients with Alzheimer's disease, as musical memory networks are among the last to be impacted by the progression of the disorder. However, some gaps exist and many questions still remain. For example, the studies above use various interventions in music therapy practices. Some studies have patients just listening to music, while other studies actively involve singing or playing instruments. When each study does something slightly different, it is difficult to compare the results. Additionally, the stronger the familiarity of a song, the stronger the emotional and behavioral response, suggesting that the personalization of music has a crucial role in music therapy, as highlighted by Lyu et al. (2018) and Vanstone et al. (2012). Future research should focus on developing methods for personalizing music interventions and could incorporate factors such as genre preferences and cultural background to not only see the effects of preferred music vs. nonpreferred music in therapy but to see how personalized music impacts neural activation over a longer time. Another factor that could have a lasting impact on music therapy's effectiveness is the difference between individuals with lifelong musical experience and musical training and individuals with minimal musical training, (Baird & Samson, 2009; Vanstone & Cuddy, 2009; Vanstone et al., 2012). Analyzing how these differences influence the effectiveness of music therapy could help tailor therapy sessions to suit different people's needs; for example, a person with no musical background may need different approaches than a person who was a former musician.

The length of time of these studies could also be a limitation, since most of them last for around six weeks, such as the six-week studies by Svansdottir & Snaedal (2006) and Chu et al. (2013). Although they often show immediate improvements in mood, behavior, and cognition, it is not clear whether these benefits last months or years or if regular music therapy sessions are needed. Extending the period in between sessions in future works could show if music therapy can truly slow the progression of neurodegeneration, instead of only providing patients a short-term remedy. In this line of thought, future studies could also investigate how often sessions should occur, whether it be daily, weekly, or monthly, how long each session is, and if starting music therapy at different ages or at different disease stages (early, middle, or late) could result in stronger benefits of the treatment. Starting treatment in the early stages of Alzheimer's could positively affect people with family history and other risk factors, mentioned previously by Reiman and Jagust (2012), as earlier music interventions could especially delay progression. Combining music therapy with other accessible treatments, such as physical movement or simple cognitive training exercises, could be another area for future study, as it may be a small, yet significant, task that could enhance music therapy's effectiveness.

Even though this paper focuses on Alzheimer's disease, music therapy's accessibility to improve mood, memory recall, and cognitive function in this specific type of dementia make it a promising strategy for improving the conditions of patients with other dementias and could be useful to test in future studies. For example, one could explore whether the same musical memory networks remain resilient in vascular dementia, Lewy body dementia, or frontotemporal dementia, and in general, how music can impact the trajectories of neurodegenerative disorders such as Parkinson's disease. By addressing these gaps and conducting these future studies, researchers can move beyond the short-term improvements and start exploring whether and exactly how music therapy can affect the progression of cognitive decline.

CONCLUSION

Overall, the findings in this paper show the resilience of brain regions associated with musical memory. Neuroimaging evidence, such as fMRI and EEG scans, shows that when Alzheimer's patients listen to familiar music, regions such as the superior temporal regions (which help recognize and process familiar sounds), the medial prefrontal cortex (which links music to emotion and personal memories), and the caudal anterior cingulate cortex and ventral pre-supplementary motor area (which organize and encode musical information) stay functional even when other brain areas have already begun to deteriorate. These regions still light up and show functional connectivity which demonstrates that music can engage neural networks that remain intact. Understanding its endurance can help researchers gain more knowledge about Alzheimer's, other types of dementia, and in general, neurodegenerative diseases. These findings are especially important in the field of clinical neuroscience today since music therapy can improve mood, memory, and speaking abilities as well as reduce depression and anxiety in patients. Even though the studies discussed in this paper focus on short-term results, there may be greater improvements with more-frequent music therapy sessions over a longer period. All in all, music therapy is an accessible and low-cost treatment for Alzheimer's, and understanding the mechanisms of how music can positively affect brain function, especially now knowing that the regions responsible for musical memory remain intact are the last to deteriorate in the progression of Alzheimer's, can help lead to fewer severe cases and improve the quality of life for patients affected by Alzheimer's disease and neurodegeneration.

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