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REVIEW

Musicality is Preserved in Neurodegeneration

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Certain musical abilities can endure even as language, memory, and behavior decline in dementia, yet the neural basis of this resilience remains poorly understood. We draw on behavioral and neuroimaging evidence to explain why musicality is selectively preserved or impacted across Alzheimer's disease (AD) and the frontotemporal dementias (FTDs). Adopting a network-based perspective, we describe how musicality arises from interactions across large-scale brain systems that support perception, emotion, and memory. Evidence from case studies and neuroimaging work suggests that music engages lower-level auditory processing and higher-order networks across the brain, which may help explain the heterogeneous effects of neurodegeneration on musicality. Preserved and impaired musical abilities may reflect the selective vulnerability of distinct intrinsic connectivity networks. In early AD, relatively preserved salience and reward circuitry may sustain emotional responses to familiar music and facilitate autobiographical recall even as episodic memory declines. Degeneration of anterior temporal and salience network regions in the FTDs may disrupt the emotional and conceptual interpretation of music while leaving lower-level auditory systems relatively intact. Significant gaps remain in understanding how different components of musicality are affected in specific neurodegenerative diseases. Greater methodological standardization, larger cohorts, longitudinal study designs, and multimodal approaches will be critical for identifying how musicality is preserved or impacted across dementia syndromes. Addressing these questions may advance theoretical models of music perception in the human brain and guide the development of targeted music-based interventions that enhance emotion, memory, and quality of life for people living with dementia.

INTRODUCTION

The preservation of musicality across neurodegenerative diseases remains poorly understood, as most evidence for it is derived from a limited number of behavioral and neuroimaging studies [1-5]. There is a need for mechanistic research that provides a syndrome-specific characterization of which musical abilities are preserved

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Abbreviations: AD, Alzheimer's disease; ADRD, Alzheimer's disease and related dementias; DMN, default mode network; PPA, primary progressive aphasia; PCA, posterior cortical atrophy; FTD, frontotemporal dementia; MRI, magnetic resonance imaging; fMRI, functional MRI; svPPA, semantic variant PPA; nfvPPA, non-fluent variant PPA.

Keywords: music cognition, Alzheimer's disease (AD), frontotemporal dementia (FTD), primary progressive aphasia (PPA), atypical Alzheimer's disease, salience network, default mode network (DMN), auditory-motor coupling, emotional processing, autobiographical memory, neurodegeneration

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and which are impaired. Individuals with Alzheimer's disease (AD) have been reported to have impairments in episodic and semantic memory while retaining the capacity to sing familiar melodies, recognize well-known songs, or engage in musical performance [5,6].

This dissociation is frequently observed in clinical settings and has been highlighted in public cases such as that of the well-known musician Tony Bennett, who continued to perform professionally following his AD diagnosis. Although he exhibited difficulty recalling the names of other performers with whom he had worked for much of his career, he remained able to perform complex musical repertoires with high accuracy [7]. His wife reported:"[He was] a physically fit 89-year-old who performed timeless ballads perfectly […] Occasionally, a song will remind him of a story from earlier in his life [7]."

Such cases underscore music's potential to elicit autobiographical recollections in dementia, sometimes more effectively than non-musical cues [8], with effects that vary by disease stage, cue type, and outcome definition. In the case of Tony Bennett, lifelong professional music training may have contributed to the preservation of his musical abilities. However, prior research suggests that select musical abilities can also be preserved in individuals with dementia without extensive musical training [2-5]. Why is musical memory selectively resilient relative to other domains of memory and cognitive functions?

The public health burden of dementia is growing: approximately 7.2 million Americans over the age of 65 are currently living with dementia, a number projected to rise to 13.8 million by 2060 [9]. As the societal and economic costs of dementia escalate, there is increased interest in interventions that are effective, scalable, and accessible, especially those that can be implemented at minimal cost and maximal enjoyment for both patients and their caregivers.

Music, a universal human behavior with deep cultural and evolutionary roots [10], may be a promising candidate for supporting emotional well-being and quality of life in individuals with AD and related dementias (ADRD) [4,11-15]. And in some cases, music may even improve cognitive abilities such as autobiographical memory retrieval, though results have been inconsistent across studies [15,16]. Here, we synthesize behavioral and neuroimaging evidence to clarify which components of music processing are relatively preserved and which are selectively vulnerable across amnestic AD, primary progressive aphasia syndromes, and other frontotemporal dementias (FTDs). We then identify critical gaps that must be addressed to support the development of a robust and mechanistically grounded framework for music perception in neurodegenerative disease.

MAPPING MUSIC IN THE BRAIN

Music engages multiple cognitive and affective systems, including those related to memory, emotion, and self-identity [17-19].

Personalized music, in particular, elicits heightened activity in self-referential and affective neural hubs and enhances functional connectivity across these systems in older adults [20,21]. Here, personalized music refers to songs that are self-selected and personally meaningful to each participant, usually identified during a structured interview component of the study. Familiar music denotes researcher-selected pieces that are widely recognized but not necessarily personally significant. Even when not personally selected, familiar music can serve as a cue for autobiographical memories. These memories vary in vividness and emotional salience and are more frequently associated with life events when rated as strongly autobiographical [17].

Notably, music-evoked autobiographical memory remains relatively preserved even in moderate to late stages of AD, in contrast to spoken language and other semantic domains [4,8,22]. The default mode network (DMN), which is critical for autobiographical memory and self-referential processing, is one of the earliest affected functional networks in AD, showing reduced functional connectivity before clinical symptoms appear [23,24].

In contrast, other systems recruited during music listening show a different trajectory in AD. The salience network, which supports detection and prioritization of emotionally meaningful stimuli [25], exhibits dynamic changes in functional connectivity as the disease progresses [24]. By comparison, auditory-motor networks involved in rhythm, pitch, and beat perception [26-28] are relatively preserved [5] or undergo functional reorganization [29-32]. Such patterns may reflect compensatory mechanisms that help maintain musical abilities even as other cognitive domains deteriorate.

Although numerous studies have investigated the clinical and behavioral benefits of music-based interventions in dementia [16,33-36], a smaller body of work has begun to characterize the neural substrates of musical memory and music engagement in AD [1,5,27,37]. These studies demonstrate that aspects of musical processing can be supported by relatively preserved neural circuitry. However, the literature often focuses on single syndromes or specific musical domains and has yet to establish a comprehensive account of how distinct dementia syndromes differ in the preservation or vulnerability of musical functions.

In the sections that follow, we synthesize behavioral and neuroimaging evidence to characterize how music engages distributed neural systems involved during music-evoked memory and emotion across AD, FTD, and related dementias. We distinguish between musical semantic and procedural memory, which involve the recognition of familiar melodies and performance of overlearned musical material, and music-evoked autobiographical memory, in which music serves as a cue for self-referential recall of past experiences. Music-evoked emotion captures the affective and reward responses that contribute to the salience of these experiences.

These processes are deeply interconnected as music often acts as both an emotional cue and a mnemonic trigger [38-40]. We highlight how these systems reorganize, or fail to reorganize, during neurodegeneration, and we discuss emerging theoretical frameworks that may explain music's preserved function despite widespread cognitive decline.

HEALTHY INDIVIDUALS

Music engages a distributed network of systems that support autobiographical memory, emotional processing, and auditory-motor integration [41-46]. Rather than being localized to a single network, music perception and enjoyment emerge from dynamic coordination across the default mode [47], salience [48], auditory [49], motor [50], and reward networks [51].

SELF-REFERENTIAL AND AUTOBIOGRAPHICAL SYSTEMS

During music listening, core DMN regions, including the medial prefrontal cortex [17,20], posterior cingulate cortex [17,20], angular gyrus [20], temporoparietal junction, and medial temporal lobe, are engaged when listening to music that involves autobiographical salience or self-relevance [52]. These regions are associated with music-evoked nostalgia and autobiographical memory retrieval, especially for familiar or self-selected music. Older adults show stronger activation of these DMN regions during nostalgic music-listening compared with younger adults, suggesting that aging may amplify the recruitment of self-referential and affective systems [20]. Indeed, music and autobiographical memory are linked, as evidenced by behavioral studies [53-60].

EMOTION AND SALIENCE APPRAISAL SYSTEMS

Emotionally engaging music activates the salience network, which helps detect and prioritize emotionally relevant stimuli while mediating switches between internally and externally directed attention [25]. Core regions, such as the insula, amygdala, and orbitofrontal cortex, integrate sensory input with affective value [61-63]. The salience network interacts closely with the mesolimbic reward circuit, including the nucleus accumbens and ventral striatum, which mediate pleasure, reward anticipation, and dopaminergic signaling [19,64,65]. Together, these systems form a salience-reward axis that is particularly activated by emotionally moving, self-relevant, or novel/unexpected music [18,51,66].

AUDITORY-MOTOR COUPLING SYSTEMS

Music also engages a network of auditory and sensorimotor systems that parse rhythm, pitch, and melody [26-28,67]. The superior temporal gyrus supports primary auditory perception [68-70], while the inferior frontal gyrus and supplementary motor area contribute to rhythmic and syntactic processing [1,28,71]. The basal ganglia supports rhythm perception and motor planning [5,20,72], while the cerebellum fine-tunes timing and coordination during music engagement [71-73]. These subcortical regions give rise to auditory-motor coupling, enabling predictive timing, and entrainment that bridge perception and movement.

REWARD AND INTEGRATIVE PROCESSING

Reward-related activity is especially robust during pleasurable music listening, particularly when the music is familiar or self-selected [64,65]. The nucleus accumbens plays a central role in reward anticipation and hedonic valuation and is consistently engaged under these conditions [19]. It is functionally connected with the auditory cortices, amygdala, and prefrontal regions involved in emotional evaluation and memory integration, including the orbitofrontal cortex, anterior cingulate cortex, and medial prefrontal cortex [19,27,65].

In addition to the mesolimbic system, positive affective responses to music engage the cortico-thalamo-striatal circuit, including the dorsal and ventral striatum, motor regions, and limbic areas [27,74]. Collectively, these findings demonstrate that music reward processing is not confined to subcortical pleasure centers but extends across a broader network that links affect, movement, and memory.

Taken together, the functional neuroimaging literature reveals that music perception arises from coordinated interactions among large-scale brain networks. Integrative hubs, particularly within the medial prefrontal and orbitofrontal cortices, along with the temporoparietal and superior temporal cortices, are anatomically positioned to integrate communication between systems supporting autobiographical recall, emotional salience and reward, and sensorimotor processes. This integration may explain why familiar music can evoke powerful emotional responses, vivid autobiographical memories, and motor engagement, often simultaneously.

MUSICALITY IN DEMENTIA

AD

AD is the most common cause of dementia and the number of individuals living with the disease is rapidly rising [9]. The pathological hallmarks of AD include the extracellular deposition of beta-amyloid and intraneuronal inclusions of tau protein, and it is typically characterized by symptoms of progressive amnesia [75].

In some cases of ADRD, specific components of music perception and memory may be relatively preserved. Cohort studies demonstrate selective dissociations across musical subdomains that vary by disease stage and dementia syndrome. For example, in AD and posterior cortical atrophy, musical semantic memory may remain intact despite impairment in musical episodic memory relative to healthy individuals [1]. In a separate cohort of individuals with moderate to severe AD, substantial heterogeneity was observed at the individual level, with some participants performing similarly to healthy controls, others showing partial sparing, and some demonstrating near complete loss of musical memory [76]. However, the mechanisms underlying these variable patterns remain understudied.

In previous work, we have discussed the potential for musical symptoms, such as musical alexia (difficulty reading music) and agraphia (difficulty writing music), to serve as early indicators of neurodegeneration, as illustrated in the case study of a professional orchestral musician [77]. Other research suggests that certain deficits in music perception, such as impaired global pitch processing, may help differentiate AD from other dementia syndromes, but further investigation is warranted in larger cohorts [2].

In AD, episodic memory for newly encountered musical material becomes impaired [1]. This impairment is consistent with core hubs of the posterior midline DMN that undergo degeneration early in AD, particularly within the posterior cingulate cortex [78] and precuneus [79]. In contrast, musical semantic memory (eg, recognizing familiar tunes) and procedural memory (eg, playing a learned instrument), are relatively preserved well into the course of the disease [3,80-82]. The preservation of these abilities has been linked to regions that are structurally and functionally spared, including the medial prefrontal cortex and supplementary motor area [5,37].

In healthy individuals, the salience and default mode networks flexibly reconfigure as attention shifts between internal and external focus. In AD, however, this dynamic balance progressively deteriorates: the DMN shows abnormal activation during sensory tasks, indicative of inefficient network switching [83]. Familiar music listening activates anterior DMN hubs, including the medial prefrontal cortex, while driving functional coupling with salience and motor circuitry, particularly the supplementary motor area, anterior cingulate, insula, and temporal lobes [5,37,84]. By contrast, posterior DMN hubs such as the posterior cingulate cortex are canonical early sites of dysfunction in AD [78].

Emerging neuroimaging work has begun to examine whether music-based interventions influence functional connectivity. In a cohort of 17 individuals with AD who completed a 3-week personalized music listening program, resting-state functional MRI (fMRI) was acquired immediately before and after self-selected music listening within a single session. At the group level, a modest increase in mean global functional connectivity was observed following the listening task. However, the durability of these effects remains unclear, as imaging was conducted only once at the conclusion of the intervention period [37]. Similar studies report increased connectivity after a 6-month music-based intervention within frontal (superior frontal and precentral gyrus) and temporal (inferior and superior temporal gyri) regions [85]. In a pilot study of 14 individuals with early-stage cognitive decline, 3 weeks of daily autobiographically salient music listening was associated with reduced activity in the bilateral basal ganglia and right inferior frontal gyrus, as well as declines in fronto-temporal connectivity. Participants also showed a significant improvement in the memory subdomain of the Montreal Cognitive Assessment [86].

Music listening, particularly familiar or emotionally salient pieces, evokes autobiographical memories by activating the DMN. Autobiographical memory recall significantly improved for individuals with AD when listening to Vivaldi's Four Seasons (which was presumably familiar to participants) compared to silence or background noise [60,87,88] and personalized music, as defined earlier, produced even greater benefits [89]. Emotionally evocative music, especially sad pieces, have been shown to further amplify autobiographical recall, suggesting that the associated emotion, rather than music *per se*, triggers these memories [90].

At a perceptual level, patients with AD show impaired processing of melodic contour (ie, overall directional pitch patterns in a melody, relative to its musical context) but relatively preserved local pitch, temporal pattern, and tune recognition abilities [2], although a small number of studies have systematically examined music perception ability in people with dementia. Similarly, AD participants exhibit normal emotional reward responses to the ending of melodies despite subtle deficits in the processing of harmonic information [91]. Other studies have found that individuals with AD are less accurate in labeling a melody as finished or unfinished, potentially reflecting altered processing of musical expectation and resolution [92].

Altogether, these findings suggest that AD may disrupt predictive and integrative aspects of music perception, while emotional reward systems remain relatively spared. By engaging residual DMN function, these preserved reward systems may support autobiographical recall in individuals with AD.

ATYPICAL AD

Logopenic Variant Primary Progressive Aphasia

Primary progressive aphasia (PPA) has several variants that we will discuss here. The first, logopenic variant PPA, is characterized by word retrieval and sentence repetition deficits associated with atrophy of the left temporo-parietal junction [93] and underlying AD pathology [94]. Basic aspects of auditory and music perception appear relatively preserved in logopenic variant PPA. Participants generally perform similarly to healthy controls on measures of pitch, rhythm, and timbre discrimination, suggesting that low-level auditory processing remains intact [95].

More complex forms of auditory processing in logopenic variant PPA reveal a mixed picture. In the same study, performance on a local pitch-sequence detection task was significantly correlated with a composite score spanning single-word, pseudoword, and sentence repetition, suggesting a link between auditory sequencing and phonological working memory capacity [95]. Although participants did not, on average, differ from controls, the observed correlation is consistent with overlapping neural substrates within left temporo-parietal regions that support both verbal repetition and auditory sequencing [95]. Other work has demonstrated group-level deficits in logopenic variant PPA for global pitch processing, a higher-order integrative function that requires tracking pitch relationships over time to perceive melodic contour [2]. Together, these findings suggest that logopenic variant PPA primarily affects higher levels of auditory integration, where music and language converge through shared temporal sequencing and phonological working memory mechanisms.

Beyond music processing, logopenic variant PPA patients also show difficulty identifying the emotional tone of auditory stimuli when cues are degraded, suggesting broader impairments in auditory integration under challenging listening conditions [96,97]. The overlap between regions that normally decode and integrate continuous sound streams and those affected by atrophy in logopenic variant PPA, particularly in the posterior superior temporal gyrus, inferior parietal lobule, and fronto-parietal auditory-motor circuits, likely underlies these deficits [93,96]. Nevertheless, direct neuroimaging of patients while engaging with music tasks has not been undertaken, leaving open questions about how degeneration of these systems impacts the perception of music structure, emotional prosody, and predictive timing in this population.

Posterior Cortical Atrophy

Posterior cortical atrophy (PCA) is the visuospatial variant of AD [98] and is associated with atrophy in parietal-occipital regions of the brain [99]. Patients with PCA show deficits in interpreting complex, dynamic visual environments that require object parsing [100]. This impairment extends into auditory scene analysis, suggesting parallel breakdowns in segregating and integrating auditory and visual information [101], rather than a specific deficit in auditory processing.

Case studies have provided insight into how PCA affects musical abilities. One musician with right-predominant PCA exhibited spatial agraphia, visuopraxic deficits, and difficulty performing music, despite intact rhythm repetition [102]. Another musician developed alexia for music prior to words, highlighting that the ventral visual system contributes to reading both music and language [103]. On formal testing, PCA participants show impaired musical episodic memory, but intact musical semantic memory, along with abnormal activation of the posterior cingulate during repeated melodies [1].

In contrast, a professional musician with absolute pitch (ie, the relatively rare ability to name the pitch level of a musical note without consulting a reference tone) who developed PCA retained pitch and rhythm working memory despite verbal working memory loss [104]. Although this case illustrates a dissociation between musical and verbal working memory in the context of PCA degeneration, its generalizability may be limited by the individual's high level of musical expertise. Research on PCA and auditory processing remains limited, and broader cohort-level studies are needed to determine whether similar patterns extend to less musically trained individuals.

FTD

While AD provides a model for the memory-related aspects of music's resilience in the brain, studies of musicality in FTD reveal how disruptions in socio-emotional and language networks alter music processing. FTD encompasses a spectrum of neurodegenerative disorders that primarily affect behavioral or linguistic functions, typically due to atrophy of the frontal, insular, and anterior temporal lobes of the brain, and are pathologically distinct from AD [105,106].

Behavioral Variant FTD

People with behavioral variant FTD exhibit progressive behavioral changes, inappropriate social conduct, and executive dysfunction [107]. Neurodegeneration in behavioral variant FTD selectively targets the salience network [25], particularly the anterior cingulate, frontoinsular cortex, striatal, and frontopolar regions that support socio-emotional processing [108]. Given the proposed role of the salience network in affective and reward responses to music [20,43,48], behavioral variant FTD provides a useful model for examining how disruption of this network may be associated with alterations in music perception. Changes in musical reward, including musicophilia, characterized by an increased craving for music, and musical anhedonia, a reduced interest or pleasure in music [109], have been described across FTD phenotypes [110-112]. The majority of behavioral variant FTD participants in one study reported altered music appreciation, with musicophilia being the most common [113]. These behavioral phenotypes may be representative of dysfunction within the salience network, which typically supports both emotional and social cognition. In a follow-up study, behavioral variant FTD participants showed significant impairments in music emotion discrimination, melody, tempo, and accent recognition, which paralleled deficits in facial emotion recognition and theory of mind [114].

Voxel-based morphometry showed atrophy in the anterior temporal, insular, and orbitofrontal regions, core salience network hubs that mediate social and affective meaning [115] and are among the earliest affected in behavioral variant FTD [116-118]. These same regions show both regional atrophy [108,119,120] and disrupted intrinsic connectivity [121-123], supporting the notion that salience network degeneration may underpin the impaired emotional salience appraisal and disrupted predictive processing observed during music listening in this population.

Despite this disruption of affective circuitry, basic auditory perception appears relatively preserved. During an fMRI paradigm assessing emotional processing, behavioral variant FTD participants retained normal activation to simple acoustic analysis but abnormal responses to musical emotion. Specifically, group-by-condition interactions were observed in the dorsal brainstem regions in the vicinity of the locus coeruleus and raphe nuclei, as well as in limbic, paralimbic, and prefrontal cortices. This interaction reflected a crossover pattern in which emotional variation enhanced activity in healthy controls but reduced activity in individuals with behavioral variant FTD [124]. These findings suggest that while sensory encoding remains intact, higher-order emotional appraisal and arousal are dysregulated in behavioral variant FTD.

During a task that measured sensitivity to expectation and surprise in music, participants showed reduced accuracy in detecting both structural (ie, syntactic) and meaning-related (ie, semantic) deviations, along with diminished behavioral and physiological responses to unexpected musical events [125]. Consistent with this, other work shows that behavioral variant FTD is associated with reduced accuracy in classifying melodies as finished or unfinished and exhibit both impaired decoding of harmonic structure and abnormal emotional responses to the way a melody ends [91,92]. Together, these findings provide evidence that behavioral variant FTD influences how musical expectations are generated and emotionally evaluated, linking disrupted predictive processing with blunted affective responses seen in this population.

Semantic Variant PPA (svPPA)

Semantic variant PPA (svPPA) is characterized by fluent speech with anomia and profound semantic loss. The syndrome is typically left-dominant and characterized by atrophy of the anterior temporal lobe [106]. Although patients with the disorder lose the meaning of words, they nonetheless maintain intact grammar and prosody [106]. Semantic memory is thought to not only support emotional processing [126] but also music perception [127], making this population of particular interest for the study of auditory processing.

Converging neuroimaging evidence indicates that many musical functions overlap with regions that subserve language processing, particularly the superior temporal gyri and inferior frontal cortex, which support auditory, syntactic, and prosodic processing [128-130]. These regions are functionally integrated with the anterior temporal lobe via long-range white matter tracts [131-133]. Ventral connections, including the uncinate fasciculus, support semantic integration, whereas the dorsal arcuate fasciculus contributes to phonological and sensorimotor mapping processes [134,135]. Degeneration of the anterior temporal hub in svPPA likely disrupts the integration of structural and emotional components of music, impairing its semantic associations while leaving perceptual processing relatively intact.

Some studies report that individuals with svPPA preserve their ability to identify familiar melodies [82,136] and in some cases can continue singing a familiar melody if cued [137]. However, despite recognizing a tune as familiar, they often show difficulty in accessing its semantic or affective associations – for example, linking a piece to its emotional valence, cultural context, or functional category. This pattern reflects a decoupling between perceptual familiarity ("knowing a melody") and conceptual understanding ("knowing its meaning") [136]. Across multiple studies, participants show deficits in recognizing basic emotions from music [82,136,138]. Interestingly, happiness and anger/fear were generally better recognized than sadness for participants during a behavioral music listening task [136].

Whereas individuals with svPPA show difficulty identifying musical emotion, as discussed earlier, individuals with AD often exhibit strong emotional and autobiographical responses to familiar or sad music [90]. This may be indicative of a dissociation between emotional recognition and emotion-evoked memory retrieval, or differences in emotional salience processing between these two groups. Compared to healthy controls, svPPA participants perform worse on linking musical excerpts to semantic categories (eg, lullabies, funerals, or celebrations) [136] and show difficulty in identifying musical instruments based on their sounds alone [82]. Atrophy in svPPA typically begins in the left anterior temporal pole, disrupting the semantic representations that support language and conceptual knowledge [139,140]. As the disease progresses to the right anterior temporal pole, regions critical for processing social and emotional meaning become increasingly affected, leading to deficits in linking music with affective significance [138,141]. Longitudinal imaging work indicates that atrophy may later extend into the orbitofrontal cortex, amygdala, and insula [142], which are key nodes of the salience network that mediate emotional appraisal and interoceptive awareness [143].

The right temporal pole appears particularly important for processing familiar tunes and faces [138,144]. In a case report of a musician with absolute pitch and left temporal damage, absolute pitch and tone notation were preserved despite impaired verbal short-term memory [145]. In a separate study of two individuals with svPPA, recognition of musical excerpts was preserved, whereas semantic association to music was impaired. Only the participant with bilateral anterior temporal lobe atrophy exhibited deficits in recognizing musical emotion; the participant with predominantly left-sided atrophy did not [146]. This progression suggests that the right temporal and salience network degeneration jointly undermine the emotional resonance of music, even as lower-level perceptual and syntactic aspects remain intact.

In addition to deficits in musical semantic and emotion processing, svPPA is associated with abnormalities in musical reward and the processing of musical structure. Although participants can decode melodies as tonally resolved or unresolved, they exhibit an abnormal reward response to the end of musical sequences [91] and rate unfinished melodies as less unpleasant than healthy controls do [92]: the musical "rules" remain intact, but emotional and predictive reward systems supporting musical pleasure are disrupted, likely due to degeneration of anterior temporal and, at later stages, orbitofrontal regions that support evaluation and integration of semantic and emotional information.

Although formal network analyses are lacking, these findings are consistent with disrupted interactions between temporal-semantic and salience systems, which together support the mapping of conceptual knowledge onto affective and motivational value. Once right temporal and salience-related regions are affected, these disruptions likely erode the emotional resonance and reward value that music holds for individuals with svPPA.

Non-Fluent Variant PPA (nfvPPA)

Individuals with non-fluent variant PPA (nfvPPA) (also known as primary nonfluent aphasia) struggle with agrammatism and slow, labored speech production [93], associated with atrophy of the left posterior (and inferior) frontal lobe and insular cortex [147]. Their language symptoms are the result of broader dysfunction in auditory-motor integration [2].

Participants with nfvPPA performed significantly worse on a pure-tone audiometry test compared to AD and displayed asymmetric hearing loss, reflecting reduced peripheral auditory sensitivity in this group [148]. Higher-order auditory processing tasks reveal additional deficits. During behavioral music tasks, participants showed reduced ability to detect altered notes in familiar musical excerpts in addition to lower accuracy in detecting basic sound changes (ie, shifts in pitch, loudness, or timbre) compared to healthy controls [125]. In a pitch pattern decoding task, they performed worse in detecting both overall changes in melodic contour and smaller pitch changes between adjacent tones [2], though consensus is mixed. Another study reveals that participants have more difficulty with processing pitch changes across a tone sequence than between pairs of tones [95]. Individuals with nfvPPA also exhibit a similar pattern of local and global deficits in the realm of temporal pattern and identifying whether a familiar tune is present [2]. Furthermore, this group exhibited significant impairment in processing rhythm of tone sequences compared to other groups [95]. This impaired perception of musical melodies parallels deficits in speech prosody.

NfvPPA participants also have a significantly higher false-alarm rate compared to healthy controls, over-interpreting normal variations within melodies as errors [125]. This suggests that their auditory system makes overly rigid predictions about upcoming sounds and is consistent with a generalized deficit in detecting unexpected deviations within a musical sequence.

Together, research across these dementia syndromes illustrates that music and memory are not localized to a single "music center" but instead emerge from the dynamic interaction of distributed neural systems. Each clinical phenotype highlights a different facet of this organization: AD emphasizes the role of the default mode network in autobiographical and predictive aspects of musical memory; behavioral variant FTD and svPPA reveal how salience and semantic networks anchor music's emotional and conceptual meaning; while nfvPPA illuminates the auditory-motor circuits essential for rhythm, prosody, and syntactic structure. Figure 1 illustrates the

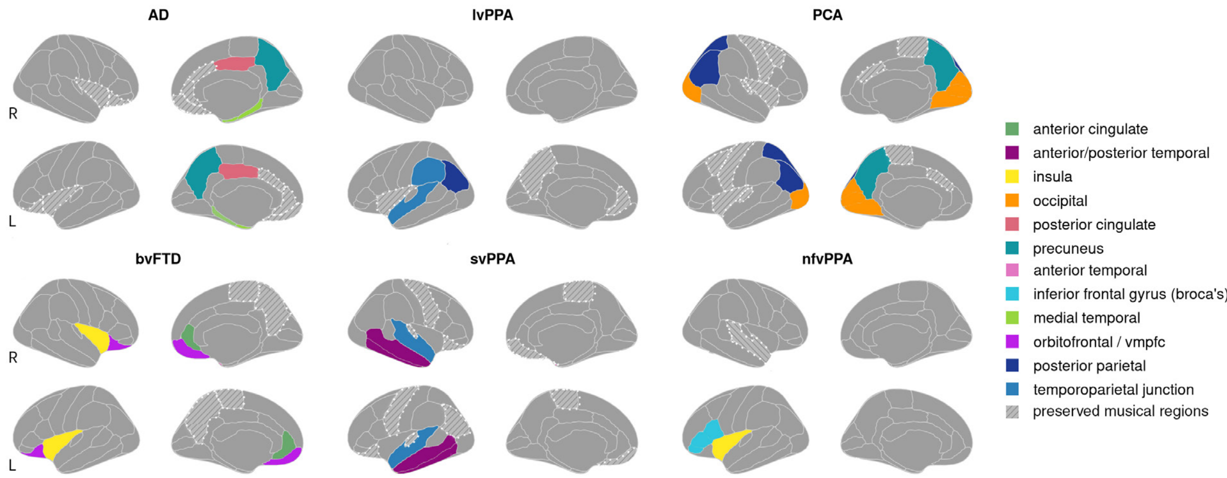

Figure 1. **Syndrome-specific patterns of cortical vulnerability disrupt memory, emotion, or predictive processing while sparing integrative hubs implicated in musical cognition**. Lateral and medial brain visualizations show regions of predominant cortical atrophy across six dementia syndromes: Alzheimer's disease (AD), logopenic variant primary progressive aphasia (lvPPA), posterior cortical atrophy (PCA), behavioral variant frontotemporal dementia (bvFTD), semantic variant PPA (svPPA), and non-fluent variant PPA (nfvPPA). Distinct colors indicate major cortical regions affected in each syndrome: anterior cingulate (green), anterior/posterior temporal lobe (purple), insula (yellow), occipital (orange), posterior cingulate (red), precuneus (teal), anterior temporal (magenta), inferior frontal gyrus/ Broca's area (light blue), medial temporal (lime green), orbitofrontal/ventromedial prefrontal cortex (violet), posterior parietal (dark blue), and temporoparietal junction (blue). Hatched regions with white outlines denote preserved musical regions, which show relative structural and functional resilience across syndromes and overlap with auditory, salience, and reward networks. Together, these maps highlight syndrome-specific patterns of cortical vulnerability that selectively disrupt memory, emotion, or predictive processing while sparing integrative hubs supporting music cognition.

characteristic patterns of cortical vulnerability across these syndromes alongside regions implicated in music processing, while Table 1 summarizes the preserved and impaired aspects of musical function described across dementia syndromes.

Viewed collectively, this work shows that music draws upon canonical brain networks for memory, emotion, and communication, whose differential vulnerability in neurodegeneration offers a unique window into how the brain orchestrates musical experience.

FUTURE DIRECTIONS

Interest is growing in the study of musicality in neurodegenerative syndromes [77,85,113,114,136,149]. Several knowledge gaps remain, however. First, there is relatively little standardization across studies both in the musical stimuli and auditory perception batteries used. Researchers frequently select musical excerpts based on their age or presumed familiarity, while auditory-perception batteries assess many different aspects of musicality, ranging from autobiographical memories to peripheral auditory processing. The lack of standardization leads both to significant methodological heterogeneity and limitations in the generalizability of conclusions across music studies. In order to understand a complex phenomenon like music perception, it needs to be studied systematically, including low-level auditory perception through high-level musical semantics.

Second, most existing work relies on small cohorts, typically of amnestic AD participants, while musicality in other dementia syndromes remain comparatively understudied. Case reports and small-cohort studies suggest that different syndromes may have heterogeneous effects on music reading, performance, and memory [2,77,91,92,102,104,113,114]. Larger and more diverse cohorts, including those that are multi-site, may help determine whether and how differences in musicality are associated with specific dementia syndromes. Clarifying how patterns of preserved and impaired musical functions map onto different neurodegenerative diseases could also inform the development of music-based interventions tailored to the strengths of patients with each type of dementia.

Third, longitudinal studies will be essential in mapping how music perception shifts across stages of disease progression. Including participants across the spectrum from mild cognitive impairment to advanced disease would clarify how musical abilities change over time in each dementia syndrome. Similarly, longitudinal intervention studies may capture the long-term efficacy of music interventions on brain and behavioral outcomes.

Table 1. Preserved and Impaired Musical Functions Across Dementia Syndromes

Dementia syndrome	Preserved musical functions	Impaired musical functions
AD	Familiar tune recognition Procedural musical skills Emotional engagement with music	Episodic memory for new music Global pitch and melodic contour processing Predictive closure
lvPPA	Pitch, rhythm, and timbre discrimination Low-level auditory perception	Auditory sequencing and global pitch integration Emotional prosody recognition
PCA	Musical semantic memory Rhythm repetition Pitch and rhythm working memory	Musical reading and visuospatial coordination Musical episodic memory Auditory-visual integration
bvFTD	Basic auditory perception Sensory encoding	Emotion discrimination, melody and tempo recognition Predictive and reward processing Emotional blunting or hyperreactivity (musicophilia/anhedonia)
svPPA	Recognition of familiar melodies Singing when cued Musical structure decoding (syntax, rhythm)	Emotion recognition Instrument/semantic categorization
nfvPPA	Residual local auditory detection	Rhythm and timing processing Pitch contour and interval discrimination Prosody and auditory deviance detection

Rather than relying on a single post-intervention scan, studies could, for instance, incorporate pre- and post-intervention imaging, as well as follow-up assessments to determine whether the observed changes in brain activity persist over time.

Finally, much of the existing literature emphasizes higher-order aspects of music perception such as emotional salience or assess the impact of music on autobiographical recall. Comparatively fewer studies have systematically characterized basic auditory-perceptual abilities such as pitch, rhythm, or timbre perception, across dementia syndromes. A clearer characterization of lower-order auditory abilities will better encapsulate the full spectrum of preserved or impaired musicality in dementia and guide interventions that translate into meaningful improvements in patients' daily lives.

Moving forward, advances in methodological standardization, larger and more diverse cohorts, longitudinal designs, and investigations that assess multiple domains of musicality will be critical for developing empirically grounded frameworks that determine how different components of musicality are preserved or disrupted across neurodegenerative syndromes. Multimodal approaches that combine behavioral paradigms with neuroimaging may help clarify how autobiographical, salience, auditory-motor, and reward systems interact during music listening. This work could inform future music interventions that leverage preserved neural systems to support emotional and cognitive health in individuals living with different types of dementia.

CONCLUSION

We highlight both the therapeutic potential of music and its value as a natural model for understanding the brain's reliance on distributed neural networks to support complex cognitive and affective functions.

Music perception and enjoyment emerge from the dynamic integration of multiple large-scale systems, encompassing perceptual, emotional, mnemonic, and executive processes. Studying music perception and cognition in the context of neurodegeneration sheds light on the organization and resilience of the human brain. The relative resilience of musical abilities is better understood when musicality is modeled not as a single "musical network," but as a hierarchically organized process supported by multiple large-scale intrinsic connectivity systems spanning auditory, motor, limbic, and default mode regions.

While some aspects of music perception may be impaired in each syndrome, musicality as a gestalt often remains relatively resilient because it relies on widely distributed brain systems, including lower-level perceptual systems and higher-order associative networks that synergistically support prediction, emotion, and memory; this view is consistent with the idea that music perception is a core component of audition in humans [150]. Neurodegenerative syndromes selectively affect distinct large-scale brain networks [108]. As such, syndrome-specific patterns of preserved and impaired auditory-perception abilities may offer a window into how the brain coordinates specialized yet interacting circuits that support musicality.

Recent research has begun to reveal how selective patterns of degeneration and network dysfunction in specific dementia phenotypes affect different aspects of musical processing. In AD, relatively preserved salience and reward systems might sustain emotional responsiveness to familiar music and facilitate autobiographical recall, even as the default mode network and episodic memory decline, contributing to deficits in musical episodic memory and predictive and integrative processing. In svPPA, anterior temporal degeneration disrupts processing of the emotional and conceptual meaning of music while sparing lower-level auditory processing, whereas salience network dysfunction in behavioral variant FTD may underlie altered emotional responses to music, including musicophilia or musical anhedonia.

From a wider perspective, mapping musical abilities onto canonical intrinsic connectivity networks in the context of neurodegeneration offers a framework for advancing a circuit-based model of music perception in the human brain. Such an approach may help to optimize future therapeutic applications of music, moving beyond generalized approaches toward a more nuanced characterization of how different dementia syndromes produce distinct profiles of preserved and impaired musical functions. Ultimately, a systematic understanding of syndrome-specific patterns of musical processing will advance theoretical models in the cognitive science of music while enabling the development of individualized, mechanism-informed music-based therapies tailored to each patient's residual neural architecture.

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