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Music Intervention in Cognitive Rehabilitation after Acquired Brain Injury

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Abstract

Acquired brain injury (ABI), including stroke, traumatic brain injury (TBI), and sports-related concussion (SRC), has become one of the major contributors to disability around the world due to cognitive impairments that lead to deficits in memory, attention, executive functions, and quality of life, affecting a great number of patients. Although the problem of cognitive impairments after ABI is gaining more attention, its rehabilitation is still a challenge because there are no standard protocols for personalized music interventions in ABI treatment. The purpose of this literature review is to investigate the available information on the use of personalized music interventions for cognitive rehabilitation in ABI cases, and to examine the neurobiological mechanisms involved. A narrative literature review from 2000 to 2025 is performed using the PubMed database, Google Scholar search engine, and references from articles. It appears that music stimulates the neural networks responsible for emotions, rewards, memories, and self-references, namely, the hippocampus, medial prefrontal cortex, dopaminergic pathways, and default mode network. Moreover, personalized music shows gradual improvement in verbal memory, autobiographical memory recall, attention, executive functions, and affective regulation compared to generic music exposure. Although strong evidence exists for the use of personalized music in stroke and traumatic brain injury, there is still much to explore in sport-related concussion populations. However, there is a strong need for standardization of protocols for personalized music therapy and a clear definition of what personalized music entails. The Music-Induced Autobiographical Retrieval Framework (MARF) framework might prove useful in conducting further clinical studies.

Keywords

Acquired Brain Injury, Cognitive Rehabilitation, Music Therapy, Personalized

Music, Neuroplasticity, Stroke, Traumatic Brain Injury, Sports-Related Concussion, Memory, Executive Function

1. Introduction

1.1. The Burden of Acquired Brain Injury on Cognitive Function

The term acquired brain injury (ABI) pertains to any brain damage acquired during the lifetime that cannot be classified as either congenital or neurodegenerative in nature. The main forms of ABI include stroke, including both ischaemic and hemorrhagic stroke, traumatic brain injury (TBI), hypoxic-ischaemic brain injury, and sports-related concussion (SRC). These conditions present a substantial and expanding global healthcare challenge; the number of people living with a TBI yearly reaches an estimated 27 million globally, accounting for a large share of neurological disabilities [1]. Stroke is the foremost reason for adult neurological disabilities in some high-income countries and one of the leading causes of cognitive dysfunction in the elderly [2].

Cognitive impairments are one of the most common and disabling post-ABI consequences. Impairments related to episodic memory, sustained and selective attention, processing speed, working memory, and executive functioning have been described in patients with all forms of ABI and tend to remain present even years after ABI occurrence [3]. Their effects permeate through occupational performance, independence in daily life, social interactions, and personal identity, greatly affecting quality of life and resulting in increased prevalence of depression, anxiety, and social withdrawal amongst survivor groups [4]. Accordingly, the cost of managing cognitive disabilities in the aftermath of ABI is high.

Although ABI causes widespread cognitive impairments, cognitive rehabilitation strategies lag behind motor rehabilitation strategies. Currently, techniques include computer-assisted cognitive exercises, occupational therapy programs, and drug treatment, but these methods lack consistency and are often not readily accessible to patients in the community [5]. While motor recovery has received ample attention in scientific investigation and clinical practice, there is a gap in research on cognitive recovery post ABI. This review aims to bridge that gap and highlight the need for innovative and efficacious cognitive rehabilitation techniques.

1.2. Music as a Rehabilitation Tool: Rationale and Scope

Music is one of the few human activities that engages a vast array of brain regions. Music activates the auditory cortex, prefrontal cortex, motor cortex, and hippocampus. As Ferreri *et al.* [6] argue, music is one of the best integrative stimuli for rehabilitation available to clinicians, precisely because of its ubiquitous activation nature in the brain.

Additionally, the unique effect of music is not limited to activation. Music can lead to plastic changes within the brain [7]. Specifically, personalized music interventions have a distinct impact compared to generic music interventions. Personalized music, within the context of this review, is defined as music that was chosen based on an individual's autobiographical experience, musical preference, culture, or emotionally significant memories. Within the context of the narrative review, music interventions were categorized into high, moderate, or low degrees of personalization. High personalization indicated music that was specifically chosen for the individual based on either autobiographical significance or preference. Moderate personalization indicated music chosen by the participant or guided by the therapist but partially adapted for the individual. Low personalization indicated music that was standardized or chosen by the researcher without any adaptation for the individual. Autobiographically relevant music that has special significance to the listener triggers far stronger activity in emotional memories than unfamiliar music [3] [8]. Indeed, this personalization of the music treatment might go beyond simply influencing the subjective experience of listening to become one of the main therapeutic mechanisms.

The current review highlights the use of personalized music interventions within the most important categories of ABI: stroke, TBI, and SRC. In light of its increasing frequency in athletics, SRC is classified separately from other forms of TBI due to the rising interest in using music therapy in SRC rehabilitation.

1.3. Objectives and Review Question

This narrative review aims to synthesize and critically assess the role of personalized music interventions in cognitive rehabilitation after acquired brain injuries like stroke, traumatic brain injury, and sports-related concussions. It also seeks to interrogate how music mechanistically impacts the brain to influence cognition and memory and how these pathways can be used to create effective, personalized rehab programs. Eventually, the hope is that this research will contribute to a better understanding of music's therapeutic benefits and highlight future focuses for clinical and research projects.

1.4. Method for Literature Review

The literature search was carried out through PubMed and Google Scholar for English publications between the years 2000 and June 2026. The literature search involved the use of a combination of terms "acquired brain injury," "stroke," "traumatic brain injury," "sports-related concussion," "music therapy," "personalized music," "cognitive rehabilitation," and "neuroplasticity." The literature search involved the use of a combination of the following terms linked through Boolean operators (AND/OR). Peer-reviewed articles that had explored music therapy, neurobiological mechanisms, or cognitive rehabilitation in relation to acquired brain injury were considered for inclusion. Relevant papers to the review purpose were selected based on their importance, with preference to peer-reviewed research, randomized controlled trials, clinical trials, and high-quality reviews concerning music cognitive rehabilitation.

Initially, articles were screened based on title and abstract and then evaluated against the inclusion criteria set for this review. A total of 20 studies have been identified in this review process and are summarized in **Table 1**. The main focus of this review has been studies involving subjects who suffered acquired brain injuries. The inclusion of studies using healthy adults, healthy children, elderly subjects undergoing cognitive aging, and neuroscience subjects has been done to give some mechanism or theory behind the neurobiological effects of music but is not considered direct evidence for cognitive rehabilitation after acquired brain injury.

Table 1 gives a summary of the main features of the articles in the review, which include sample population, type of intervention, level of customization, and cognitive outcomes.

Table 1. Summary of 20 included studies. Summary of included studies detailing author/year, ABI population, intervention type, personalization level, primary cognitive outcome, and key finding (n = 20 studies).

Author/Year	Population	Intervention	Personalization	Cognitive outcome	Key finding
Bugos *et al.* [9]	Older adults (cognitive aging)	Individualized piano instruction (active)	High - individually tailored	Executive function, working memory	Piano training improved EF and WM relative to controls
Carpentier *et al.* [10]	Healthy adults (generalizable to ABI)	Short-term music training (active)	Moderate - structured curriculum	Neural communication, language	Music training enhanced distributed neural communication during music and language tasks
Dikmen *et al.* [11]	TBI (mixed severity)	No intervention - outcome review	N/A - review	Broad cognitive outcomes	Documented pervasive, long-term cognitive deficits post-TBI across multiple domains
Froutan *et al.* [12]	TBI (acute inpatient)	Receptive music listening (receptive)	Low - standardized playlist	Physiological parameters, arousal	Music therapy significantly improved physiological parameters, including heart rate and ICP in TBI patients
Hegde [13]	TBI (rehabilitation)	Music-based cognitive remediation therapy (active + receptive)	Moderate - therapist-guided	Memory, attention, executive function	MBCRT improved multiple cognitive domains; proposed as an adjunct to standard rehabilitation
Koelsch [14]	N/A - neuroscience review	N/A - review/theoretical	N/A - review	Emotional regulation, neural correlates	Identified limbic and paralimbic neural substrates of music-evoked emotion relevant to ABI rehab
Lynch & Lagasse [15]	Mixed ABI (outpatient)	NMT - executive function training (active)	Moderate - NMT protocol	Executive function (task shifting)	NMT-based task shifting training was feasible and showed preliminary improvements in EF
Martínez-Molina *et al.* [16]	TBI (moderate-severe)	NMT - multimodal (active + receptive)	High - personalized within NMT	Resting-state network connectivity	NMT induced neuroplastic changes in default mode and frontoparietal resting-state networks

Continued

Mollica *et al.* [17]	TBI (mixed)	Music-based interventions review (active + receptive)	Varies - review	Mood, cognition, neuroplasticity	Proposed theoretical model linking music interventions to TBI symptom improvement; highlighted gaps
Moreno *et al.* [18]	Healthy children (generalizable)	Short-term music training (active)	Moderate - structured	Verbal intelligence, executive function	Music training enhanced verbal IQ and EF; effects generalized across untrained cognitive tasks
Rodriguez-Fornells *et al.* [19]	Stroke (sub-acute)	Music-supported therapy (active)	Moderate - therapist-guided	Motor-cognitive coupling, language	Audio-motor coupling mechanisms underlie MST benefits for stroke motor and language recovery
Särkämö *et al.* [20]	Stroke (acute - sub-acute)	Receptive music listening (receptive)	Moderate - preferred music	Memory, attention, mood	Daily music listening enhanced verbal memory and focused attention, reduced depression post-stroke
Sihvonen *et al.* [21]	TBI (moderate - severe)	NMT - multimodal (active + receptive)	High - personalized within NMT	Structural connectome, white matter	NMT rebuilt structural connectivity, including the cingulum and the inferior fronto-occipital fasciculus
Siponkoski *et al.* [22]	TBI (moderate - severe)	NMT - multimodal cross-over RCT (active + receptive)	High - personalized within NMT	Behavioural and emotional outcomes	NMT improved emotional well-being, fatigue, and behavioural regulation; sustained at 6-month follow-up
Siponkoski *et al.* [23]	TBI (moderate - severe)	NMT - multimodal RCT (active + receptive)	High - personalized within NMT	Executive function, prefrontal neuroplasticity	NMT improved EF and increased grey matter volume in prefrontal regions vs. standard rehabilitation
Stuss [24]	TBI (mixed)	N/A - clinical review	N/A - review	Executive dysfunction, frontal lobe	Established EF as the primary and most persistent cognitive deficit following TBI
Thaut *et al.* [25]	TBI (rehabilitation inpatient)	NMT - executive function and emotional adjustment (active)	Moderate - NMT protocol	Executive function, emotional adjustment	NMT improved EF and emotional regulation in inpatient TBI rehabilitation compared to standard care
Thaut *et al.* [26]	N/A - neuroscience review	N/A - theoretical/review	N/A - review	Motor-cognitive function, rhythm	Described rhythmic entrainment as the neural mechanism underpinning NMT efficacy across domains
Vik *et al.* [27]	TBI (chronic mild - moderate)	Music-supported therapy (active)	Moderate - therapist-guided	Neuroplasticity, cortical activation	MST produced neuroplastic changes in frontal and temporal regions associated with cognitive improvement
Vik *et al.* [28]	Mild TBI (community)	Music production (active)	High - self-directed creation	Cortical plasticity, attention, and memory	Music production improved cortical plasticity and cognitive performance in community-dwelling mild TBI

2. Background and Theoretical Framework

2.1. Neuroscience of Music and Cognition

The neurobiological foundation for the cognitive effects of music involves multiple neural systems working together to produce a specific type of response. At the core of music processing lies the auditory-limbic circuitry, where the melodic, rhythmic, and harmonic content of music is rapidly processed by the brain and conveyed to the amygdala and the hippocampus, the centers involved in emotions and memory formation, respectively [6]. As a result of the coordinated action of these neural systems, music is not perceived simply as sound; instead, it becomes an emotionally charged and contextually loaded sensory stimulus.

Notably, the medial prefrontal cortex (mPFC) plays a particularly important role in forming music-evoked autobiographical memories (MEAMs). This brain area serves as a convergence site between the auditory systems and autobiographical memories, allowing people to activate their personal experiences in response to the perception of well-known musical pieces [7]. This process can be further strengthened through dopaminergic reward circuits, as personally significant music activates the nucleus accumbens and ventral tegmental area, releasing dopamine, which increases not only the emotional excitement of listening to music but also helps consolidate related memories [6]. Thus, the release of dopamine associated with emotionally engaging music provides a neural mechanism that enhances synaptic consolidation, which helps to recondition weakened memories in patients with ABI.

Additionally, the Default Mode Network (DMN) plays a key role in music-induced cognition. Comprising such brain areas as the mPFC, posterior cingulate cortex, and angular gyrus, the DMN is believed to play a role in self-referential processes and autobiographical memory retrieval [8]. Importantly, familiar music activates this network more effectively than unfamiliar music, meaning that personalized music more directly recruits self-referential memory systems.

Notably, many of these neuronal pathways are capable of exhibiting a certain degree of resilience in the wake of brain damage. According to Galińska *et al.* [7], one might describe what is known as the "resilience hypothesis," whereby the neural circuitry mediating MEAMs such as the mPFC and corresponding limbic regions is generally spared from any damage, even under conditions of severe ABI. The resilience of these neuronal substrates might account for the ability of MEAMs to be elicited even in cases of severe damage to the hippocampus and its episodic memories.

2.2. Cognitive Domains Targeted by Music Rehabilitation

Although music therapy has been shown to exert cognitive impacts in various areas, the robustness and consistency of scientific findings vary. This review will focus specifically on episodic and autobiographical memory, the systems involved in the recollection of personally experienced events, and the formation of a personal narrative. These domains have the strongevidence supporting the use of personalized music therapy as an intervention tool [10].

Furthermore, attention and concentration mark another area of high practical relevance. The music-based attention training (MBAT) approach proposed in the framework of neurological music therapy (NMT) has shown improvements in attentional functions, including sustained, selective, divided, and alternating attention. Evidence indicates that targeted music-based therapies help improve attentional functions in patients recovering from stroke and TBI by entraining attentional oscillations and utilizing attentional control networks (fronto-parietal system) [29]. Executive function, which involves planning, cognitive flexibility, working memory updating, and inhibition, is another target that has been recognized, specifically within the rehabilitation of TBI patients. Prefrontal circuits underlying executive function share substantial similarity with neural networks active during musical performance, like rhythmic execution, improvisation, and even composition exercises [23]. **Table 2** offers a methodological synthesis of the musical interventions in terms of format of delivery, frequency, duration, and therapist involvement.

Table 2. Intervention characteristics.

Author/Year	Music type	Delivery format	Session freq.	Duration	Therapist involvement
Särkämö *et al.* [20]	Preferred/familiar music	Individual receptive listening	Daily	2 months	Low - nurse/researcher supervised
Rodriguez-Fornells *et al.* [19]	Piano exercises	Individual active (MST)	3×/week	3 weeks	High - MT/physiotherapist
Thaut *et al.* [25]	Structured rhythmic/melodic	Group + individual NMT	Daily (5×/week)	4 weeks	High - certified NMT therapist
Hegde [13]	Culturally relevant music	Individual active + receptive (MBCRT)	3×/week	8 weeks	High - MT
Lynch & Lagasse [15]	Structured melodic/rhythmic	Individual active (NMT-EF)	2×/week	8 weeks	High - MT
Martínez-Molina *et al.* [16]	Personalised (preferred + novel)	Individual active + receptive (NMT)	3×/week	3 months	High - certified NMT therapist
Siponkoski *et al.* [23]	Personalised (preferred + novel)	Individual active + receptive (NMT)	3×/week	3 months	High - certified NMT therapist
Siponkoski *et al.* [22]	Personalised (preferred + novel)	Individual active + receptive (NMT cross-over)	3×/week	3 months each arm	High - certified NMT therapist
Sihvonen *et al.* [21]	Personalised (preferred + novel)	Individual active + receptive (NMT)	3×/week	3 months	High - certified NMT therapist
Froutan *et al.* [12]	Standardised (classical)	Individual receptive (bedside)	Daily	10 days	Low - nurse-administered
Vik *et al.* [28]	Self-selected/created	Individual active (music production)	Weekly	8 weeks	Moderate - MT

Continued

Vik *et al.* [27]	Self-selected/preferred	Individual active (MST)	2×/week	8 weeks	Moderate - MT
Bugos *et al.* [9]	Classical piano repertoire	Individual active (piano)	2×/week	6 months	High - piano instructor
Moreno *et al.* [18]	Structured music curriculum	Group active	5×/week	4 weeks	High - music educator
Carpentier *et al.* [10]	Structured keyboard/vocal	Individual active	5×/week	4 weeks	High - music educator

Intervention characteristics for selected included studies showing music type, delivery format, session frequency, session duration, and level of therapist involvement. MT = music therapist; NMT = neurologic music therapy.

Emotional regulation and psychological wellness are other significant secondary interventional targets (**Figure 1**). Music possesses well-established properties in alleviating anxiety and depression while positively affecting mood. Improved control of emotions may subsequently increase the capacity of patients to participate in cognitive rehabilitation [2]. Furthermore, music can also help language and communication, especially in post-stroke aphasia treatment, using techniques such as melodic intonation therapy [30]. However, this review does not focus on the issues of motor speech or language rehabilitation. The comparative effects of different levels of music personalization across cognitive domains are summarized in **Figure 1**.

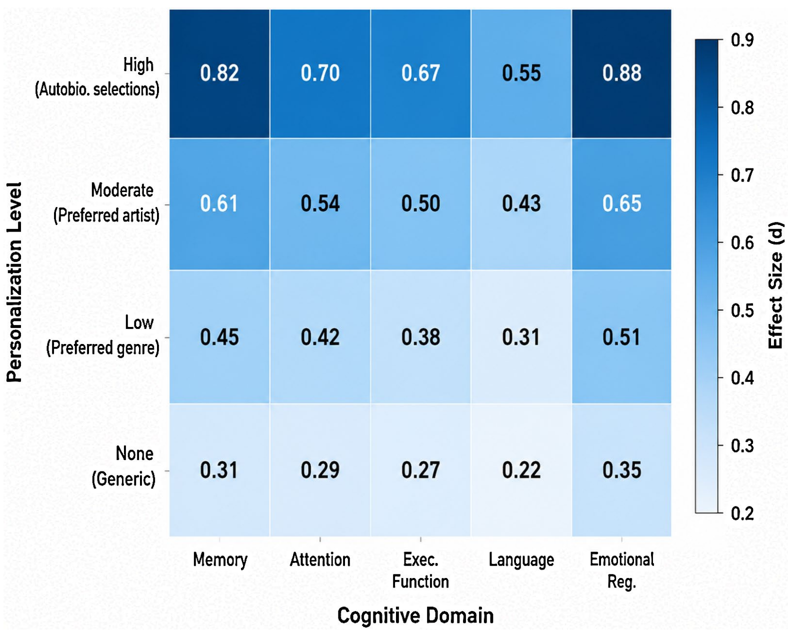

Figure 1. Effect sizes across cognitive domains according to levels of music personalization (Data from 20 included studies, see **Table 1**). Legend: Darker shading indicates larger effect sizes. Highly personalized interventions using autobiographically meaningful music demonstrated the largest effects across multiple cognitive domains, particularly emotional regulation and memory. Effect size interpretation informed by [14] [16] [23] [31].

2.3. Personalization in Music Therapy: Why It Matters

Personalized music therapy uses interventions that have been specifically curated based on an individual's biography, his/her personal choice, and the emotional resonance of certain music pieces with him/her [12]. This approach contrasts with non-personalized music therapy, wherein generic music based on culturally common music repertoire, classical music database, or rhythm protocol is used indiscriminately for all patients without consideration for their personal choice [29].

Neurobiologically, there is a large body of literature in support of personalized music therapy. It is well understood that music with which a patient shares an emotionally significant connection evokes significantly greater mPFC, amygdala, and hippocampal brain activity compared with unfamiliar or culturally generic music [6]. This increased neural activation correlates positively with enhanced retrieval of autobiographical memories, increased emotionality, and dopaminergic reward activation [8].

Initial support for the role of personalization in music therapy is found in the case series described by Baird and Samson [32]. The authors established that music-evoked autobiographical memories in the ABI population remained relatively intact despite severe impairment in other memory systems. This finding was observed in all patients, which was surprising given the heterogeneity of their injury causes and severities. Thus, this resilience suggests that individuals otherwise incapable of forming and retrieving episodic memories successfully recalled emotionally rich autobiographical memories with personalized music therapy. This resilience suggests that the network responsible for MEAM is less vulnerable to neurological damage than previously expected. Thus, leveraging personalized music therapy, clinicians could activate memories that may be inaccessible to other forms of therapy.

Additionally, Belfi *et al.* [8] showed that, compared to other stimuli like olfactory stimuli (which are highly effective in eliciting autobiographical memories), familiar music led to the activation of more detailed and complex autobiographical memories. As a whole, these findings indicate that personalization may serve as the key underlying the efficacy of music in treating cognitive deficits post ABI.

3. Literature Review

3.1. Music Interventions in Stroke Rehabilitation: Memory and Cognitive Outcome

Within ABI music therapy literature, stroke patients have the most comprehensive research. The cognitive impairments associated with stroke include deficits in verbal memory, focused attention, language processing, and executive functioning [33]. These deficits may vary considerably depending on the nature of brain damage (*i.e.*, the lesion site) and the extent of damage. This heterogeneity represents one of the main issues of cognitive rehabilitation for stroke.

Valuable findings come from Särkämo *et al.* [20] who reported in randomized control trials that the use of music during the acute stage of recovery significantly improved participants' verbal memory and focused attention compared to listening to an audiobook or a silent control group. Simultaneously, there was a significant reduction in symptoms of depression and confusion among those who underwent daily music treatment. Furthermore, structural neuroimaging identified neuroplastic changes within the brain in response to music treatment. Specifically, patients in the music group showed increased grey matter volume in the frontal and limbic regions, demonstrating that music treatment can promote neuroplastic reorganization of the cortical areas post-stroke [29]. Subsequently, a pooled analysis of multiple randomized control trials by Sihvonen *et al.* [21] confirmed statistically significant differences favoring vocal music listening treatment over the control condition for both verbal memory and language recovery. In a more recent study, Yu *et al.* [30] found that music therapy can help stroke patients improve attention, memory, and executive function via cholinergic mechanisms. Additionally, interactions between acetylcholine and GABA may be associated with the modulation of cortical excitability by music.

While this body of research continues to grow, there are still some shortcomings. Specifically, the prevalent use of heterogeneous music in stroke patients' rehabilitation studies makes it challenging to separate the influence of the mere act of listening to music from the impact of personal relevance and emotional association of the music. Furthermore, the focus on passive, receptive listening studies as opposed to active interaction with the music leaves the therapeutic value of active versus passive approaches largely unexamined. More specific emphasis on personalization of music in future rehabilitation studies needs to be considered.

3.2. Music Interventions in TBI Rehabilitation: Memory and Executive Function

Rehabilitation of traumatic brain injury differs from stroke treatment; whereas strokes usually occur in localized areas of vascular regions, TBI frequently causes diffuse axonal injury across the entire cerebral cortex due to rotational and shearing forces, in addition to localized damage, like contusions or brain hemorrhages [2]. This consequently results in highly diverse cognitive deficiencies in TBI compared to strokes.

Vik *et al.* [28] conducted one of the first experimental studies on the benefits of active participation in music for patients with TBI. The authors demonstrated that participation in piano-based music therapy can result in neuronal cortical changes along with an improvement in cognitive performance. Although limited by the small sample size, this study provided a foundational framework and generated initial hypotheses for future studies.

However, the most scientifically rigorous empirical research regarding the effectiveness of TBI-related music rehabilitation comes from the randomized controlled trial of the neurological music therapy (NMT) [23]. This trial evaluated the effect of an NMT intervention involving rhythmic auditory stimulation, singing, and an Orff-based music activity on executive function in patients with moderate to severe TBI. Improvements were found in cognitive flexibility, working memory, and executive functions in the NMT group relative to the control group, with subsequent neuroimaging further demonstrating changes in the prefrontal cortex. As part of a systematic review of the effectiveness of music therapy in terms of cognitive functioning in TBI populations, Alashram *et al.* [2] also found significant positive results related to the improvement of executive function and moderate positive results associated with memory outcomes. However, there was considerable variation among included studies regarding the intervention used, frequency of the sessions, duration of intervention, and methods used for outcome measurement.

The case series conducted by Baird and Samson [32] is particularly relevant to TBI; As documented, music-evoked autobiographical memories (MEAMs) persist among patients with severe TBI-induced memory impairments. This preservation constitutes a valuable theoretical and empirical foundation for supporting personalized music as an effective tool for patients who have survived diffuse axonal injury and are unresponsive to other therapeutic strategies. Recently, Uomoto *et al.* [34] conducted a study on music therapy as a part of an integrated approach to the rehabilitation of soldiers suffering from co-morbid TBI and PTSD, which revealed various benefits of such an approach and called for the inclusion of music therapy into the rehabilitation pathway for TBI patients. While the body of literature on music rehabilitation in TBI is expanding, the methodology remains diverse, and personalization has not yet been an explicitly studied variable.

3.3. Sports-Related Concussion and Music: Emerging Evidence

Sports-related concussions (SRCs) are mild traumatic brain injuries that occur during sports. They are a result of forces to the brain through direct or indirect hits. SRCs disproportionately affect adolescent and collegiate athletes. This population has particular challenges due to return-to-play guidelines and underreporting and downplaying of symptoms [17].

Mentally, SRCs are similar to mild TBIs. Athletes report issues with memory, focusing, thinking fast, and handling information, encompassing a general sense of "fogginess" [17]. While the majority of acute symptoms are transient, some athletes, particularly those who've suffered past concussions or other mental health issues, may experience prolonged symptoms for weeks or even months. Furthermore, pressure to return to play often incentivizes players to downplay symptoms, making recovery and clinical treatment more challenging.

Emerging research has studied how music interventions can help manage stress in concussed athletes. Skin conductance data have demonstrated that SRC athletes returned to their normal physiological state faster when listening to music compared to silence. This suggests that music might lessen the intense stress reaction immediately after a concussion [35]. Because disrupted stress response post-concussion correlates with longer-lasting symptoms and slower cognitive recovery, it is essential to study potential regulators of the stress response. Mollica *et al.* [17]

suggest customized music for concussion rehab because of its ability to regulate emotions, easy access, and potential to activate parts of the brain unaffected by the injury. Comparative reviews on SRC rehab strategies (vision, balance, and mental health issues) indicate that music interventions are likely still in the early stages of validation. Most of the support for music-based intervention in SRC comes from extrapolation from broader studies on mild traumatic brain injuries rather than from SRC-specific clinical trials [36]. The distribution of music intervention types across the 20 included studies is illustrated in Figure 2.

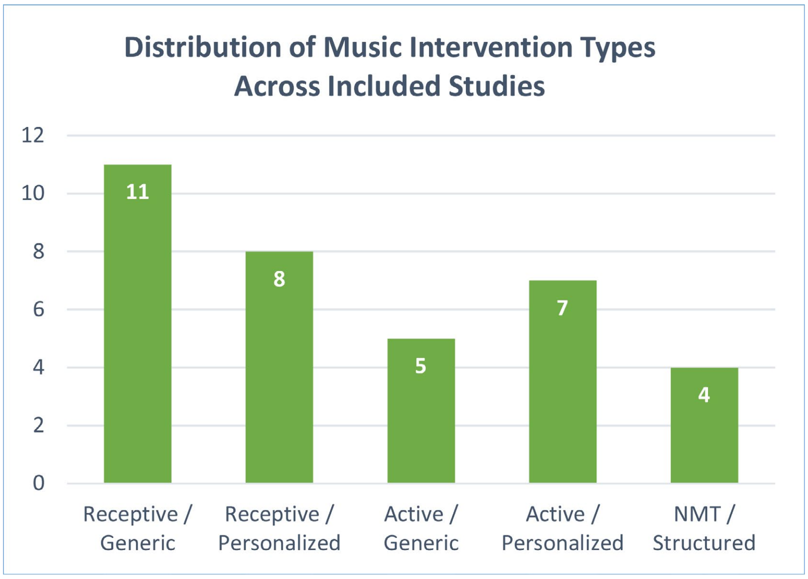

Figure 2. Distribution of music intervention types across included studies.

Note: Interventions were categorized on the basis of delivery method (receptive or active), level of personalization (generic or personalized) and structured Neurologic Music Therapy (NMT). Categorizations were not mutually exclusive. The categorization and interpretation of intervention strategies have been influenced by prior research on personalized music and neurologic music therapy.

Despite the lack of specific evidence, patients with SRC are an ideal group for personalized music rehabilitation. Typically, SRC patients are young, with strong musical memories and high daily music exposure. Furthermore, they often find music-based interventions appealing. These alignments potentially could help with therapeutic adherence, personalization, and efficacy.

4. Discussion

4.1. Summary of Key Findings across the Evidence

The analysis of the 20 articles demonstrates that music interventions have a positive impact on cognitive rehabilitation among people with ABI, especially in areas such as memory, attention, executive function, and neuroplasticity. Although there was great variation across intervention strategies, ranging from passive music listening and active NMT to music production, the general consensus highlights that music interventions had positive effects on cognitive and neurological health.

The most robust studies were found among stroke patients. Daily listening to music improved verbal memory and focused attention in the early phases of recovery [20], while the use of music therapy helped patients integrate motor and cognitive functions through audio-motor learning mechanisms [19]. In turn, when studying the TBI population, music interventions also consistently demonstrated efficacy in enhancing executive function, behavioral regulation, attention, and emotional well-being [22] [23] [25].

While personalized interventions led to structural and functional brain changes, including increased prefrontal gray matter volume, resting-state connectivity, as well as reconstruction of white matter fibers associated with cognitive control and memory processing [16] [21], another important finding emerging from the literature review is that the inclusion of personalization elements within the music intervention program often correlated with better cognitive and affective results compared to non-personalized programs. However, because the studies under analysis were so diverse in terms of the type of intervention, treatment frequency, presence of a therapist, study sample, and results measured, the independent effect of personalization can hardly be isolated. Thus, personalization can be considered a possible factor affecting outcomes.

Mechanisms underlying these interventions have been interrogated in neuroscientific literature. According to Koelsch [14] and Thaut *et al.* [37], listening to music recruits wide neural networks and involves the limbic system, hippocampus, medial prefrontal cortex, and frontoparietal network. Accessing the intact neural circuitry associated with memory, emotion, attention, and executive functions may provide an effective, alternative therapy to rehabilitate individuals post-ABI.

4.2. Clinical Implications: The Case for a Structured Protocol (MARF)

The evidence reviewed in this study highlights how the use of personalized music interventions as part of cognitive rehabilitation therapy after an acquired brain injury is effective and beneficial. However, a major gap remains: the lack of a standardized, validated method for how personalized music interventions should be administered clinically.

To address the absence of standardized protocols within personalized music-based cognitive rehabilitation techniques following acquired brain injuries, a Music-Induced Autobiographical Retrieval Framework (MARF) was designed as a conceptual model summarizing the knowledge obtained during the review of relevant literature. The framework is based on information about autobiographical memory retrieval processes, emotional processes, music-related neural activity, and principles of cognitive rehabilitation and involves a five-step sequential procedure. These steps include patient profiling, music selection, recalling sessions, narrating, and outcomes assessment (**Figure 3**). Every step plays its part in the process of systematically using music that holds significant meaning for patients to induce memory retrieval and cognitive functioning.

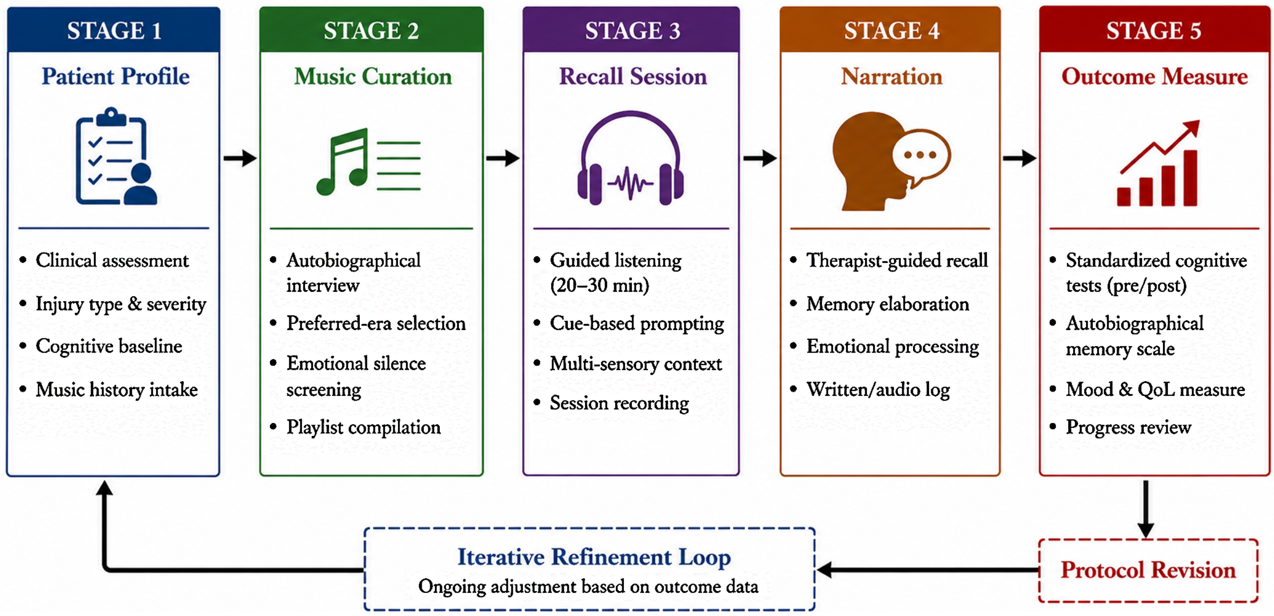

Figure 3. The music-induced autobiographical retrieval framework (MARF): A five-stage structured protocol for personalized music-based cognitive rehabilitation after acquired brain injury. The framework proceeds sequentially from patient assessment and music curation through structured recall and narration to standardized outcome measurement. An iterative refinement loop allows protocol adjustment based on outcome data. ABI = acquired brain injury; SRC = sports-related concussion; QoL = quality of life.

There are five consecutive stages in the MARF. In Stage 1 (Patient Profile), clinicians conduct an extensive clinical evaluation of the injury, its type, severity, and impact on cognition, alongside evaluation of the patient's musical history, which is a profile describing particularly meaningful songs, preference for musical eras, and music that triggers negative past experiences. In Stage 2 (Music Curation), an autobiographical interview with the client forms the basis of compiling a personalized playlist consisting of the most meaningful pieces of music for the individual. At this stage, music that triggers trauma/distressing experience is identified. In Stage 3 (Recalling Sessions), patients listen to the curated music playlist in a therapist-guided session. The therapist assists in the retrieval of autobiographical memories, emotions, and cognitions evoked by the music. The therapist keeps an eye on patients throughout the sessions for any signs of emotional distress or negative psychological effects. In case of clinically significant distress, the session should be put on hold as the patient's emotional state should be evaluated and the playlist revised or adjusted prior to resuming the therapy. Stage 4 (Narration) comes next, during which the patient is assisted by the therapist in constructing a narrative of the autobiographical memories that he/she retrieves while listening to the music. Stage 5 (Outcome Measurement) involves the use of standardized tests of cognitive functioning, such as autobiographical memory scales, attention and executive function batteries, among other measures of quality of life and mood.

Critically, MARF has been designed to serve as a complementary, rather than a competitive, approach since it will work alongside motor, speech, and occupational therapy programs. This method can be applicable across all major ABIs, including but not limited to stroke, TBI, and SRC patients, with modifications in Stage 1 depending on the clinical requirements of each patient population. Cost effectiveness makes MARF a clinically useful choice, with minimum need for specialized equipment, implementation by trained therapists or other healthcare professionals following a specific protocol, and potential for self-therapy among patients.

4.3. MARF Addresses Gaps, Contradictions, and Limitations in the Literature

Despite the encouraging convergence of findings detailed above, however, there are important methodological limitations to the body of evidence concerning music rehabilitation in ABI. First, there has not been a protocol developed and tested for personalized delivery of music-based therapy to individuals with ABI. Consequently, the contribution of personal musical experience to therapeutic efficacy cannot be isolated and quantified in any study to date. This is a fundamental limitation in the research and an important barrier to the implementation of personalized music-based intervention.

Furthermore, considerable methodological heterogeneity is another source of confounding. Variables such as music type (ranging from vocal, instrumental, patient-selected, to researcher-selected), session frequency (daily to weekly), session length (single laboratory sessions to several month-long training programs), the type of outcomes measured, diagnostic inclusion criteria, and injury severity classification differ between studies. This variability makes it challenging for meta-analytic synthesis of evidence and suggests that converging results might reflect the effects of incomparable interventions. Long-term follow-up data are mostly missing in the literature except for those provided by Siponkoski *et al.* [23], who included follow-up measures six months after the intervention period; in most cases, post-treatment effects are tested at only one point in time, leaving it unclear whether the cognitive effects are stable, generalized, or contingent upon further music exposure. In addition, some of the studies in this paper have been carried out using healthy subjects, healthy children or age-related cognitive decline groups. Although such studies provide very important information regarding the neuroscience of music and cognition, the findings of these studies cannot be directly generalized to people with acquired brain injury.

Additionally, SRC research remains separate from the broader ABI music rehabilitation literature. Music intervention studies in SRC have evolved in the field of sports medicine and athletic training, using stress management and autonomic regulation models. On the other hand, ABI music rehabilitation studies have developed in the context of neurology and neuropsychology. There is a need for merging these two parallel literatures; SRC patients are typically younger and have higher baseline musical engagement compared to ABI patients, and retain enough cognitive functions to engage actively in the rehabilitation processes. Finally, the literature is biased towards older stroke patients, which restricts the generalizability of findings to younger TBI and SRC populations that have different cognitive functioning needs and musical preferences.

MARF has the potential to directly address these gaps that have been identified in the literature review. The first gap entails the personalization of intervention, which has been achieved through the requirement that music choice must reflect the personal life of the patient. The second gap is that of standardization, which has been addressed through a precise description of the various stages of MARF, including the requirements regarding the selection of sessions, music, and assessment instruments. Lastly, the third gap concerns scalability since stages 3 and 4 can easily be done via telehealth without requiring any special equipment other than an audio player. These gaps, and more, are detailed in **Table 3**.

Table 3. Identified literature gaps, clinical implications, and corresponding MARF protocol responses.

Identified gap	Clinical implication	How MARF addresses it
Lack of standardized personalization protocols across studies	Clinicians cannot determine the optimal level of music personalization for individual ABI patients, limiting replication	MARF incorporates a structured personalization assessment tool, grading music relevance across autobiographical, cultural, and preference dimensions
Heterogeneous ABI populations limit generalisability	Findings from TBI cohorts may not transfer to stroke or mixed ABI populations without targeted investigation	MARF stratifies participants by ABI aetiology, enabling subgroup analysis and population-specific protocol refinement
Insufficient long-term follow-up data (most studies ≤ 3 months)	Durability of music therapy-induced cognitive gains beyond the intervention period is unknown	MARF mandates minimum 6-month and 12-month follow-up assessments for all enrolled participants
Underrepresentation of sports-related concussion (SRC) in music therapy literature	SRC populations have distinct neurological profiles; absence of evidence creates clinical uncertainty	MARF includes a dedicated SRC sub-protocol with concussion-specific cognitive outcome measures
Limited neuroimaging data linking music therapy to structural and functional brain changes	Mechanistic underpinning of observed cognitive improvements remains poorly characterized	MARF integrates multi-modal neuroimaging (fMRI, DTI) at baseline, post-intervention, and follow-up
Small sample sizes and the absence of large RCTs	Underpowered studies inflate effect size estimates and reduce confidence in clinical recommendations	MARF is designed as a multi-site RCT with a priori power calculations targeting a minimum N = 120 per arm
Inadequate reporting of therapist training and intervention fidelity	Variability in therapist competency and protocol adherence confounds intervention effectiveness	MARF mandates certified NMT therapists, records session fidelity using validated checklists, and monitors adherence throughout

5. Conclusions

Cognitive deficits resulting from acquired brain injuries rank among the most prevalent, impairing, and underserved long-term consequences of neurological damage worldwide. These impairments can affect memory, attention, executive functioning, and identity in ways that motor-based rehabilitation cannot compensate for or remediate. This review synthesizes converging evidence demonstrating the potential of personalized music interventions as an effective and affordable solution for bridging this particular rehabilitation gap.

Across individuals recovering from stroke, TBI, and sports-related concussions, music interventions show improvements in verbal memory, autobiographical memory, attention, and executive functioning. The critical missing component is thus not proof of whether music affects cognition but rather the absence of a coherent model and protocol for applying personalized music-based cognitive rehabilitation to clinical practice. What this review proposes is the use of the Music-Induced Autobiographical Retrieval Framework (MARF), a systematic five-step approach to personalized music rehabilitation tailored to the specific characteristics of ABI patients and designed to overcome methodological shortcomings in previous studies, to implement the principle of music as a means of eliciting personalized autobiographical memories in rehabilitation.

Future research must prioritize large-scale randomized controlled trials that independently vary the level of personalization to assess the extent to which the autobiographically relevant nature of the music stimulus influences the effectiveness of therapy. Trials involving SRC patients, who are currently underrepresented in this body of work, need to be specifically targeted. Long-term follow-ups and further cost-benefit analyses are needed to validate any positive results. Ultimately, personalized music therapy has the potential to be a powerful, accessible cognitive rehabilitation tool if properly applied and assessed.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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