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# MUSIC AND MEDICINE: MUSIC THERAPY IN APHASIA REHABILITATION

*MÚSICA E MEDICINA: MUSICOTERAPIA NA REABILITAÇÃO DE AFASIA*

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# MUSIC AND MEDICINE: MUSIC THERAPY IN APHASIA REHABILITATION

*MÚSICA E MEDICINA: MUSICOTERAPIA NA REABILITAÇÃO DE AFASIA*

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“Music expresses that which cannot be said in words and on which it is impossible to be silent.”

- Victor Hugo

**ABSTRACT**

Stroke is a major public health concern both worldwide and in Portugal where it is the first cause of death. Aphasia is one of the major poststroke disabilities, affecting language comprehension and expression. Stroke unit care is the only established way to improve outcomes and there is a constant need for poststroke interventions such as reperfusion therapy, drugs, non-invasive brain stimulation and conventional behavioural approaches like speech and language therapy.

Nowadays, alternatives as music therapy (MT) are gaining popularity due to an increased interest in other non-pharmacological approaches and a more personalised medicine. Implementing MT for aphasic patients is challenging, namely in Portugal where recognition of music therapists is currently in progress. Thereby, this review is necessary to address this current issue.

Music and language are linked in the brain and share some learning processes, cerebral connections and processing methods. MT may aid language acquisition and recovery when interventions are goal-directed by a trained professional. Melodic intonation therapy is the main technique for developing verbal fluency and prosody.

The main goal is to provide theoretical support for MT implementation as an add-on therapy to speech and language therapy in poststroke aphasic patients in Portugal. The review will evaluate the impact of MT in the rehabilitation of poststroke aphasic patients and explore the role of music in medicine by presenting its therapeutic effects and clinical applications based on scientific evidence. It also seeks to discuss the role of professionals trained in health and music in clinical contexts, summarizing the main limitations and future perspectives.

There are many limitations in MT studies, namely guidelines absence, poor quality evidence, unclear mechanisms, short-term intervention periods and low adherence. The development of effective therapies and clinical protocols requires more and better research. Targeted assessment, interdisciplinary collaboration, and treatment planning are needed. A randomised controlled trial using MT for non-fluent aphasia rehabilitation in Portugal is proposed.

***Keywords***: aphasia, stroke, music therapy, rehabilitation, language speech therapy

**RESUMO**

O Acidente Vascular Cerebral (AVC) é um dos grandes problemas de saúde pública, tanto a nível mundial como em Portugal onde é a principal causa de morte. A afasia é uma das principais incapacidades pós-AVC, afetando a compreensão e expressão da linguagem. As unidades de AVC são a única maneira reconhecida de melhorar os resultados, havendo necessidade constante de intervenções pós-AVC tais como terapia de reperfusão, fármacos, estimulação cerebral não invasiva e abordagens comportamentais convencionais como terapia da fala.

Atualmente, alternativas como a musicoterapia (MT) estão tendo destaque devido ao maior interesse por outras abordagens não farmacológicas e por uma medicina mais personalizada. A implementação de MT em doentes afásicos é desafiante, especialmente em Portugal onde o reconhecimento dos musicoterapeutas está em curso. Assim, esta revisão é necessária para abordar este tema atual.

Música e linguagem estão relacionadas no cérebro e partilham alguns processos de aprendizagem, conexões cerebrais e métodos de processamento. A MT pode ajudar na aquisição e recuperação da linguagem quando as intervenções são direcionadas a um objetivo por um profissional treinado. Terapia de entoação melódica é a principal técnica para desenvolver a fluência verbal e a prosódia.

O principal objetivo é dar suporte teórico à implementação da MT como terapia complementar à terapia da fala em doentes afásicos pós-AVC em Portugal. A revisão avaliará o impacto da MT na reabilitação de pacientes afásicos pós-AVC e explorará o papel da música na medicina, apresentando os seus efeitos terapêuticos e aplicações clínicas com base na evidência científica. Procura, ainda, discutir o papel dos profissionais formados em saúde e música em contextos clínicos, sintetizando as principais limitações e perspetivas futuras.

Existem muitas limitações nos estudos de MT, sobretudo ausência de diretrizes, evidência de baixa qualidade, mecanismos pouco claros, curtos períodos de intervenção e baixa adesão. O desenvolvimento de terapias eficazes e protocolos clínicos requer mais e melhores estudos. É necessária cooperação interdisciplinar, avaliação dirigida e planeamento adequado do tratamento. Propõe-se um ensaio controlado randomizado usando MT para reabilitação de afasia não fluente em Portugal.

***Palavras-chave***: afasia, acidente vascular cerebral, musicoterapia, reabilitação, terapia da fala

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| | |
|---|---|
| **AAT** | Aachen Aphasia Test |
| **AQ** | Aphasia Quotient |
| **ART** | Aphasia Rapid Test |
| **ASHA-FACS** | American Speech-Language-Hearing Association Functional Assessment of Communication Skills for Adults |
| **AVC** | *Acidente Vascular Cerebral* |
| **BAAL** | *Bateria de Avaliação de Afasia de Lisboa* |
| **BDAE** | Boston Diagnostic Aphasia Examination |
| **BDNF** | Brain-Derived Neurotrophic Factor |
| **BL** | Bedside De *Lenguaje* |
| **CILT** | Constraint-Induced Language Therapy |
| **DALYs** | Disability-Adjusted Life-Years Lost |
| **GHQ** | The General Health Questionnaire |
| **LH** | Left Hemisphere |
| **MIT** | Melodic Intonation Therapy |
| **MT** | Music Therapy |
| **NMT** | Neurological Music Therapy |
| **P-AAT** | Portuguese Aachen Aphasia Test |
| **PALPA-P** | *Provas de Avaliação da Linguagem e da Afasia em Português* |
| **RH** | Right Hemisphere |
| **SAQOL** | Stroke and Aphasia Quality of Life Scale |
| **SLT** | Speech and Language Therapy |
| **TST** | The Scenario Test |
| **WAB** | Western Aphasia Battery |
| **WAB-R** | Western Aphasia Battery – Revised |

## 1. INTRODUCTION

Stroke is a major public health concern worldwide and particularly in Portugal where it is the first cause of death. Aphasia is one of the major poststroke disabilities. The present work will focus solely on poststroke aphasia and in particular in Broca's aphasia and exclude other aetiologies such as neurodegenerative disorders (e.g., primary progressive aphasia). (1–5)

Traditional rehabilitation approaches for poststroke aphasia include speech and language therapy (SLT). However, other non-pharmacological therapies including music therapy (MT) are becoming increasingly popular as the 21st century has seen a growing interest in a more drug-free and personalised medicine. (1) Although music therapists are not yet recognized in Portugal, there is a process underway for their recognition. However, the implementation of MT for aphasic patients in Portugal faces several challenges, such as the lack of therapeutic guidelines and heterogeneity in existing studies, difficulty finding and recruiting music therapists, among others. (6–8)

The review will evaluate the impact of MT in the rehabilitation of poststroke aphasic patients and explore the role of music in medicine by presenting its therapeutic effects and clinical applications based on scientific evidence. The present work also seeks to discuss the role of professionals trained in health and music in clinical contexts and summarize the main limitations and future perspectives.

This literature review ends with a research project proposal entitled "Music Therapy in Poststroke Non-fluent Aphasia Rehabilitation in Portuguese Patients" that outlines the steps required to apply MT in clinical settings in Portugal. The proposal's primary goal is to overcome the initial challenge of implementing MT as a Broca's aphasia rehabilitation approach for Portuguese patients.

## 2. METHODS

PubMed, Cochrane Database of Systematic Reviews, Journal of Music Therapy, Nordic Journal of Music Therapy and Google Scholar were searched for papers published using the Medical Subject Headings “stroke”, “aphasia” and “rehabilitation” combined with “music”, “music therapy” or “melodic intonation therapy”. Additional references were gathered from reference lists and relevant articles. Languages included: English, Spanish, European and Brazilian Portuguese.

The resulting articles were imported and analysed in MAXQDA Analytics Pro 2020 by coding relevant segments with the headings and sub-headings previously defined to structure the main body of the present literature review.

## 3. STROKE

Stroke is a prevalent cerebrovascular disease. The Global Burden of Disease 2019 stroke burden estimates placed stroke as the second leading cause of death and adult disability worldwide and in the Europe Union. However, in Portugal it is the first. Over the past 20 years, the lifetime risk of stroke has grown by 50% to one in four adults. Hence, it is the third leading cause of death and disability combined as measured by disability-adjusted life-years lost (DALYs). The growing number of older people in Europe is a contributing factor to this with a projected 35% increase between 2017 and 2050 and Portugal follows the same pattern. (2,4,9–11)

Projections indicate that until 2047, Portugal is expected to have more stroke survivors, fewer deaths and DALYs lost. This is due to Portugal’s estimated greatest reductions in stroke incidence (−1.57%) and prevalence (−1.3%), which could be attributed to improvements in healthcare: reductions in stroke risk factors[1], better clinical diagnosis and case detection. (4)

### a) POSTSTROKE DISABILITY

Stroke is a leading cause of global disability, resulting in various impairments affecting daily activities such as motor (e.g., poor balance) and cognitive impairments (e.g., memory and attention deficits) as well as depression and anxiety. Depending on stroke aetiology and location, disability severity and type can vary. (1,9–13)

Over one-third of stroke survivors get aphasia that severely hinders communication and worsens neurological functioning by inhibiting linguistic expression and comprehension. Improvements in stroke therapy and life expectancy are leading to increased language impairment in adults. As the population ages, the incidence of aphasia following stroke is also increasing, affecting 43 to 60 out of 100,000 individuals in Europe and in the United States of America. (4,10,14)

[1] Portugal stroke risk factors prevalence: high blood pressure (29%), high cholesterol (55,9%), smoking (22,6%), raised glucose (9,2%) and atrial fibrillation in > 40-year-old adults (2,5%). (3)

### b) SPONTANEOUS RECOVERY

Since lesion onset, stroke recovery has three phases: acute (< 1 week), subacute (< 6 months), and chronic (> 6 months). Aphasia spontaneous recovery is greatest in the first 3 months. For instance, Broca's aphasia patients recover 70% of their full potential within that time frame, but two thirds still have language difficulties 18 months later in the chronic phase, even after extensive SLT. Furthermore, some individuals decline and deteriorate due to vascular dementia or lack of SLT. (1,16,17)

### c) REHABILITATION

Stroke rehabilitation involves a functional approach to specific activities, frequent and intense practice and early initiation. It improves neurological function at various stroke phases, depending on brain plasticity. According to Kleim and Jones' ten principles of neuroplasticity[2], research has shown that brain plasticity can persist beyond the first year after a stroke. Hence, therapy can still be beneficial for individuals with chronic aphasia. (10,11,18)

After acute pharmacological management strategies, only stroke unit care is proved to improve stroke outcomes as it reduced death and institutional living at 3 months after stroke onset and improved long-term survival in all patients' subgroups (i.e., age, sex, stroke subtypes and level of consciousness). Stroke units provide better medical and nursing treatment, task-oriented training and a stimulating, motivating atmosphere for patients. Thus, to promote adequate rehabilitation, it is necessary to maximise therapeutic impact, reduce treatment cost and lessen family and social illness burden. (10,19)

The United Nations Convention on the Rights of Persons with Disabilities recognises the right to rehabilitation. However, a report on Stroke in Europe from 2017 revealed that its access varies greatly across Europe. (10)

[2] These principles include: use it or lose it, use it and improve it, specificity, repetition, intensity, time, salience, age, transference and interference. (18)

## 4. APHASIA

Aphasia is caused by brain damage (i.e., stroke, head injury, brain tumour and progressive neurological conditions) to language-related regions (i.e., semantic knowledge, phonological, morphological and syntactic). Aphasia is commonly caused by ischemic and haemorrhagic strokes, with the latter accounting for 87% of all strokes. Poststroke aphasia is caused by damage to cortical and subcortical structural networks in the dominant language hemisphere, often the left hemisphere (LH). Thus, language production and comprehension (i.e., listening, speaking, reading and writing) are affected. (9,21,22)

Aphasia ranges from modest word retrieval issues to full language incapacity. Some patients recover fast and have no (or just minor) language impairments within a few weeks after stroke while others remain severely non-fluent and unable to create language. (22–24)

### a) CLASSIFICATION

The symptoms of aphasia are traditionally categorised into two classes: fluent (e.g., Wernicke's) and non-fluent (e.g., Broca's). However, note that the wide diversity among patients demands more detailed subdivision (Table 1). (18,21,24)

The Boston School of Aphasia classifies Broca's motor aphasia as non-fluent just like motor transcortical, mixed transcortical and global. 12% of aphasics have Broca's aphasia, mainly caused by a lesion in the left inferior frontal gyrus but recent studies show that injury to the subcortical area (e.g., basal ganglia)[3] and to the pre- and postcentral gyrus cause comparable symptoms. (21,25,26)

Therefore, patients have difficulties with grammatical sentences (agrammatism), word-retrieval (anomia) and apraxia of speech (i.e., a motor-speech disorder that impacts speech movement planning and programming). They use short four-word sentences without postpositions or function words. (25,27) Agrammatism and apraxia of speech distinguish Broca's from other aphasias, yet anomia is the primary symptom of all aphasic syndromes. (21,25)

[3] Left putaminal haemorrhage, branch atheromatous disease-induced basal ganglia infarction, and diaschisis with hemodynamic repercussions can cause non-fluent aphasia by disrupting subcortical-to-cortical blood flow. (21)

**Table 1.** Boston Neoclassical System for Aphasia Classification [adapted from (1)]

| Fluency | Simple Verbal Comprehension | Repetition | Naming | Classification and Lesion Site |
|---|---|---|---|---|
| Non-fluent | ✗ | ✗ | ✗ | **Global**<br>Posterior inferior frontal lobe and posterior superior temporal lobe |
| | | ✓ | ✗ | **Mixed Transcortical**<br>Sensory and motor transcortical regions |
| | ✓ | ✗ | ✗ | **Broca's**<br>Posterior inferior frontal lobe |
| | | ✓ | ✗ | **Transcortical Motor**<br>Frontal lobe watershed between MCA and ACA territories |
| Fluent | ✗ | ✗ | ✗ | **Wernicke's**<br>Posterior superior temporal lobe |
| | | ✓ | ✗ | **Transcortical Sensory**<br>Temporoparietal watershed between MCA and PCA territories |
| | ✓ | ✗ | ✗ | **Conduction**<br>Arcuate fasciculus |
| | | ✓ | ✗ | **Anomic**<br>Numerous possible lesion sites |

**Abbreviations: ACA** = Anterior Cerebral Artery; ✗ = Impaired; **MCA** = Middle Cerebral Artery; **PCA** = Posterior Cerebral Artery; ✓ = Preserved.

### b) ASSESSMENT

A comprehensive aphasia assessment is crucial to determine its impact on a patient's life. This includes taking a complete case history and evaluating various language abilities, as well as diagnosing any non-linguistic cognitive problems that could affect treatment. In Portugal, the available assessment tools for aphasia are limited. *Bateria de Avaliação de Afasia de Lisboa* (BAAL), Portuguese Aachen Aphasia Test (P-AAT), and *Provas de Avaliação da Linguagem e da Afasia em Português* (PALPA-P) are commonly used. However, many of the recently developed assessment tools in Portugal are still being studied for their psychometric properties. (1,8)

The most important scales for aphasia screening, comprehensive language impairment evaluation, functional communication improvement, quality of life and emotional well-being assessment will then be briefly discussed. Lastly, some considerations for applying assessment tools in aphasia research studies will be presented.

## APHASIA SCREENING

**ART | Aphasia Rapid Test:** It is a quick and simple 26-point scale used to assess the severity of aphasia in acute stroke patients. It consists of six subtests evaluating comprehension, repetition, naming and speech fluency. The ART can be administered in less than three minutes and is an independent predictor of long-term outcome on the first day of testing. The higher the score, the worse the performance. It is validated for the Portuguese population. (28)

**BL | Bedside De *Lenguaje*:** It evaluates spontaneous speech, understanding, repetition, writing and reading. Healthcare professionals can screen and diagnose aphasia in 10 minutes to refer patients to early therapy. Due to significant illiteracy rates, the Portuguese version contains two cut-off criteria for literate and illiterate individuals and it has 82% sensitivity and 90% specificity. (29)

## COMPREHENSIVE LANGUAGE REHABILITATION BATTERIES

**WAB | Western Aphasia Battery:** It was initially designed to assess aphasia related to stroke but later standardised for Alzheimer's and Frontotemporal Dementia. It evaluates spoken language, reading, writing, praxis and visuospatial skills to group individuals into syndromes or identify specific deficiencies. It is a reliable and valid clinical test that assesses aphasia severity and classification and has been translated into over 33 languages. The summary score is the Aphasia Quotient (AQ). The revised version (WAB-R) includes a quick bedside test for severely affected patients. (1,30)

**BAAL | *Bateria de Avaliação de Afasia de Lisboa:*** BAAL is the main instrument currently available in Portugal to diagnose aphasia and classify the type and severity of the disorder using the AQ similarly to the WAB test. However, it has limitations for cross-linguistic comparisons and P-AAT should be used instead. (29,31)

**P-AAT | Portuguese Aachen Aphasia Test:** It is used for diagnosing and evaluating speech therapy efficacy in individuals with aphasia. It includes six subtests that evaluate spontaneous language, repetition, auditory comprehension and naming. It provides numerical scores for language performance, compares individual performance with reference to normative data of standard syndromes and evaluates spontaneous language production. Cultural adaptations may be necessary if the test is to be used outside of European Portuguese-speaking populations. P-AAT is useful for carrying cross-linguistic and multicentre studies. (20,31)

**PALPA-P | *Provas de Avaliação da Linguagem e da Afasia em Português*:** These tests aim to identify language processing problems in people with acquired lesions. The PALPA-P is the Portuguese adaptation, consisting of 60 psycholinguistic tasks assessing language abilities. However, the battery has limitations such as not covering areas like sentence production, grammatical complexity, conversation and discourse analysis. The assessment of reading and writing in the PALPA-P battery is insufficient, and further validation of stimuli is recommended for more accurate evaluation of illiterate individuals. (32)

## FUNCTIONAL COMMUNICATION

**ASHA-FACS | American Speech-Language-Hearing Association Functional Assessment of Communication Skills for Adults:** This tool evaluates functional communication (i.e., communicating feelings and needs in daily life scenarios) beyond isolated language abilities and has 43 components covering different areas of communication (e.g., social communication, basic needs communication, reading, writing, numerical concept and daily planning). It can be used to obtain an average for each domain and a global average of the subject's communicative independence. The ASHA-FACS has been translated and validated in Portugal. (33)

**TST | The Scenario Test:** For measuring communication changes in moderate to severe aphasia patients, TST is valid, reliable, and sensitive. Its validity comes from using common events and allowing patient-interlocutor verbal and non-verbal exchange. TST's interactive nature may cause administration unpredictability. Cognitive capacity affects all communication tests. (1,34)

## QUALITY OF LIFE AND EMOTIONAL WELL-BEING

Individuals with aphasia can experience reduced quality of life due to difficulties in functional communication, limitations in activities and changes in social relationships. To address this, it is important to assess their quality of life through the Stroke and Aphasia Quality of Life Scale (SAQOL) and emotional well-being with the General Health Questionnaire (GHQ). Both scales have Portuguese versions. (1,8,35)

## APHASIA RESEARCH STUDIES

The Research Outcome Measurement in Aphasia consensus statement provides recommendations for a core outcome set (i.e., minimal outcomes that should be collected and reported) to be used in aphasia treatment studies. It includes five essential outcome constructs, which are language, communication, patient-reported satisfaction with treatment and impact of treatment, emotional well-being and quality of life. Thus, the core outcome set in aphasia research should include: Language (WAB-R), Communication (TST), Emotional well-being (GHQ) and Quality of Life (SAQOL). (34,35)

### c) REHABILITATION

Aphasia rehabilitation has been more effective throughout the years and it may include pharmacological (e.g., catecholaminergic, cholinergic, nootropic and serotonergic drugs) and reperfusion therapies (e.g., intravenous thrombolysis), non-invasive brain stimulation (e.g., transcranial magnetic stimulation) and behavioural approaches (e.g., SLT and MT). (1,11)

A Cochrane meta-analysis showed that conventional SLT during at least 100 hours can enhance language function. However, extensive treatment times and a dearth of qualified professionals may delay patients' language recovery. (17)

Aphasia patients, regardless of lesion size, activate right hemisphere (RH) areas during speech/language functional magnetic resonance imaging tasks. Aphasia recovery has two main paths: undamaged brain structures in the RH are recruited to restore function (RH path) or the brain networks that produce language in the LH may recover (LH path). (36–38)

Pitch changes may help process rhythmic patterns and reactivate rhythm- and language-related areas in the LH through transcallosal pathways, following the classical Hebbian axiom "neurons that fire together wire together." (27) Activities like music and singing that stimulate homologous RH areas may enable language improvements beyond spontaneous recovery in patients with severe LH injuries in language-relevant regions. (13,37,38)

Constraint-induced language therapy (CILT) and melodic intonation therapy (MIT) are the most studied stroke-related aphasia behavioural treatments. Comparative clinical trials have not shown that one therapy is better than another. Thus, the type and severity of aphasia and the therapist's experience and confidence determine which strategy to use. (1,20)

## SPEECH AND LANGUAGE THERAPY

SLT is the primary behavioural treatment for aphasia and is recommended worldwide for stroke rehabilitation. A Cochrane meta-analysis found that SLT improves functional communication, reading, writing and expressive language better than no therapy. It has several methods but there is little evidence of a clear winner and it is uncertain how long these advantages last. (19,24)

SLT is heterogeneous and aphasia research includes multiple outcome metrics, making results difficult to interpret. Individual patient characteristics (e.g., motivation and mental health status), family support, and clinician skill/experience can also affect SLT results. Hence, due to its limitations and single-training mode of most approaches, patients find it hard to follow or results are slow. Additionally, limited insurance coverage for formal SLT sessions can make it hard for people to get the assistance they need. Virtual rehabilitation may partially solve this problem. (12,20)

Due to the COVID-19 pandemic, SLT telemedicine has increased. This method helps geographically or physically isolated patients and it has been found to both assist patients and train communication partners. Patients can complete SLT tasks at home with computer programmes (e.g., Sentence-Shaper, Lingraphica and Touchspeak), self-delivered tablet or computer rehabilitation (e.g., Sentactics) as well as making social connections and practising with their therapists through EVA-Park which is a multi-user virtual world. Therefore, the pandemic provided new diagnostic and therapeutic tools for future use. (1)

## 5. LANGUAGE AND MUSIC BRAIN PROCESSING

Music and language are hierarchical, rule-based and learned implicitly. Different brain systems are involved in music and language processing, as suggested by double dissociations (i.e., amusia[4] and aphasia). (39,40) The LH is responsible for both language (i.e., syntax, grammar and vocabulary) and music comprehension (i.e., melody and harmony). The RH processes language intonation and prosody and music rhythm, timbre and emotional context. Singing, which stimulates both hemispheres, can help aphasics express themselves. (24,26)

Pitch, rhythm and timbre are shared by music and language, suggesting similar cerebral connections and processing methods. Music training may help language acquisition and recovery. Singing and imagining playing an instrument engage Broca's brain region and share a sensorimotor network with speaking. As a result, language and music appear to be brain-linked (Figure 1). (11,41,42)

### a) LANGUAGE PROCESSING

Nowadays, there are two accepted models to explain how language is processed in the brain: the classical model (i.e., Broca-Wernicke-Lichtheim-Geschwind) and the dual stream model. (38,43) The fast components of speech (e.g., formant and consonant-vowel transitions) require quick processing and are localized in one hemisphere due to interhemispheric transfer delays. These tasks are preferred to be processed in the LH. In contrast, slower components of speech (e.g., syllables and prosody) are processed in both hemispheres. (41)

According to the classical model, word sounds are transferred from the primary auditory cortex in the temporal lobe to Wernicke's area for meaning extraction and then they are conveyed to Broca's area via the arcuate fasciculus for morpheme formation and subsequent speech production in the motor cortex. This paradigm emphasises the LH Broca's and Wernicke's language processing centres. (38,43)

In contrast, the dual stream model stresses language processing's dorsal and ventral streams. It was developed since Broca's and Wernicke's regions are not uniformly defined and there are more fibre pathways involved beyond the arcuate fasciculus. The dorsal stream connects speech sounds to articulatory movements for speech production and is left dominant while the

[4] Amusia is a condition that affects musical ability, including comprehension and expression. It primarily manifests as a difficulty in processing pitch but can also affect musical memory and recognition. Those with amusia may experience an inability to produce or understand music or musical sounds. (49)

ventral stream interprets words and integrates semantic information and is bilaterally distributed. The dual stream model includes the left inferior frontal gyrus, superior temporal gyrus, angular gyrus, middle temporal gyrus and RH brain areas as well as many fascicles (e.g., uncinate and inferior longitudinal fascicles). (38,43)

Despite research with poststroke aphasic patients supporting the dual stream model's anatomical basis, this review will employ the classical model for simplicity, clarity, and consistency with the MIT studies included. (38)

### b) MUSIC PROCESSING

The perception of music involves various regions of the brain, including the frontal, parietal and temporal lobes, cerebellum and limbic system. The cortico-subcortical structures involved in rhythm processing include the prefrontal cortex, cingulate gyrus, insula, supplementary motor cortex, temporal cortex, thalamus, cerebellum and inferior parietal cortex. (21,37)

The frontal lobe is responsible for attention, planning, motor preparation and unique human skills like imitation and empathy, which are essential for musical and emotional development. (37) The prefrontal cortex is responsible for attention, decision making and planning, as well as higher-level cognitive processes such as language comprehension, working memory and the creation of non-reflexive responses to external stimuli. The medial prefrontal cortex stores memories, links familiar music with emotion and controls self-referential processes (e.g., hearing your own music as you play). The motor cortex (i.e., primary, pre-motor and supplementary) is responsible for controlling the body's motor output and both hemispheres are connected to coordinate bilateral movements. (44)

The parietal lobe and temporo-occipital areas process multimodal inputs from auditory, visual and somatosensory sources that will be then integrated by the angular gyrus. The cerebellum plays a role in the modulation of emotion and the processing of musical structure and temporal organization. It helps with timing, synchrony and tracking the beat in music. It is involved in sensing the emotional aspects of music such as the difference between major and minor chords. (37,44,45)

The limbic system[5] is crucial for music's emotional perception, memory formation and an individual's motivation to participate in musical activities. The amygdala is activated through unpleasant or dissonant music. The basal ganglia[6] are involved in various functions (e.g., motor control, learning, emotional control, motivation and beat perception). The nucleus accumbens reacts to emotional music and releases dopamine as part of the pleasure and reward system leading to increased motivation which improves attention and learning. This enhances therapeutic outcomes beyond language skills. The nucleus accumbens, the ventral tegmental area and the hypothalamus interact to regulate emotional responses to music. (21,37,44–46)

Musical performance requires working memory supported by frontal lobe networks for obtaining, retaining and altering information and long-term memory supported by the hippocampus and other medial temporal lobe structures for storing information. (39,45)

## MUSICIANS AND NON-MUSICIANS

Music has a significant impact on the brain, activating various networks and auditory centres. The inferior frontal gyrus region plays a significant role in multimodal reception and sensorimotor integration as it is activated by hearing, seeing or doing certain acts, particularly musical ones. Skilled musicians have been found to have more grey matter in the inferior frontal gyrus than non-musicians. Additionally, professional instrumentalists have been shown to have higher grey matter density in cortical sensory-motor, auditory, left dorsolateral prefrontal cortex and cerebellum areas than non-musicians and amateurs. Absolute pitch is connected with a bigger leftward planum temporale asymmetry. The middle temporal gyrus, which determines absolute pitch with early music exposure, is associated to this region. At last, skilled musicians have larger hand areas in the motor cortex than non-musicians. (37,39,47)

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[5] The limbic system has cortical (i.e., orbitofrontal cortex, hippocampus, insula, cingulate gyrus and parahippocampal gyrus) and subcortical (i.e., amygdala, olfactory bulb, hypothalamus, thalamus and septal nuclei) components.

[6] The basal ganglia are the striatum (caudate and putamen), globus pallidus, substantia nigra and subthalamic nucleus.

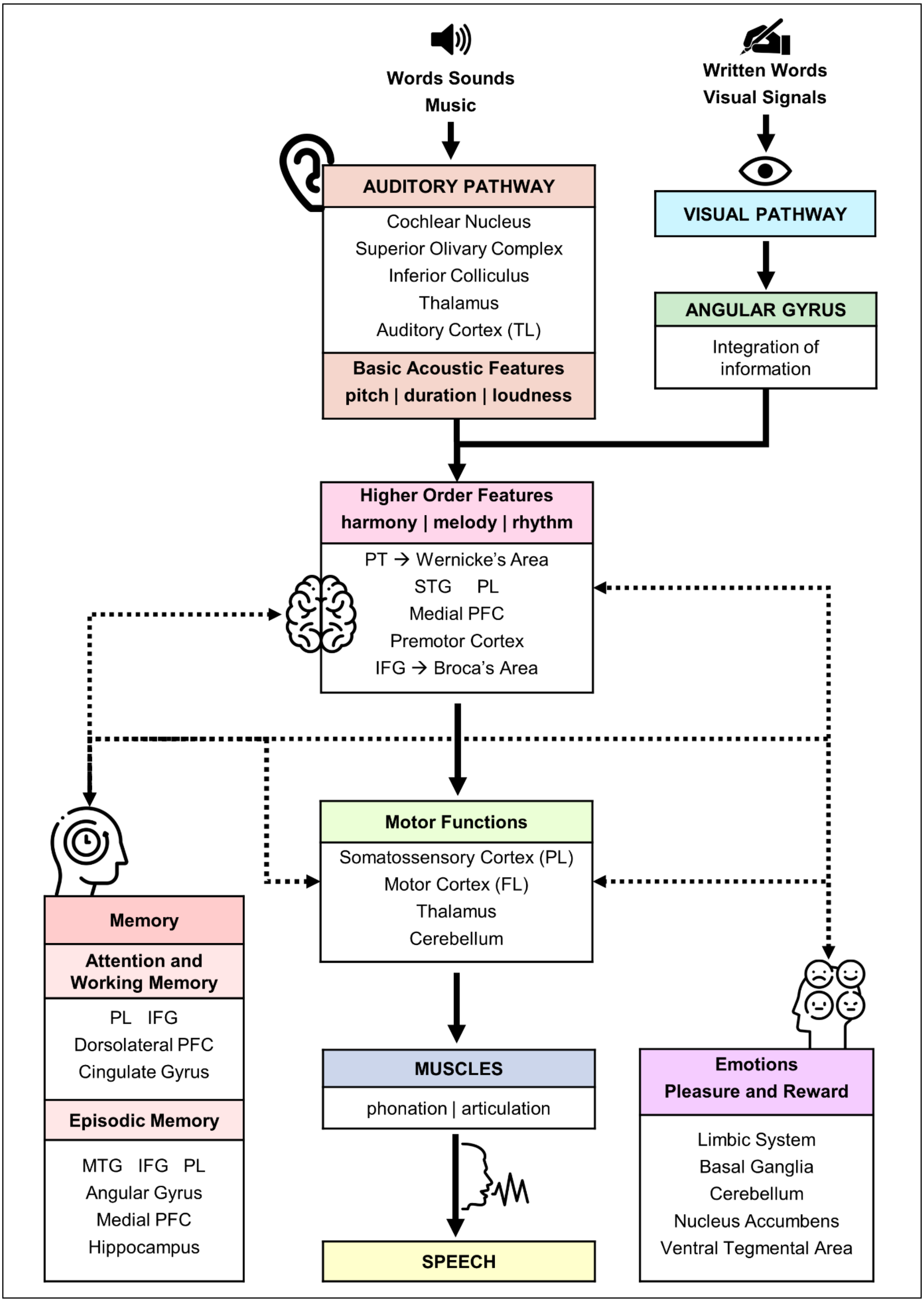


**Figure 1.** Language and Music Brain Processing [adapted from (13)]

**Abbreviations: FL** = Frontal Lobe; **IFG** = Inferior Frontal Gyrus; **MTG** = Middle Temporal Gyrus; **PFC** = Prefrontal Cortex; **PL** = Parietal lobe; **PT** = Planum Temporale; **STG** = Superior Temporal Gyrus; **TL** = Temporal Lobe.

## 6. MUSIC THERAPY[7]

MT is a hybrid intervention because it combines art (music) and science (therapy), allowing a holistic approach. (48) Two methodologies can be distinguished: 1) active MT when patients actively sing, play instruments and move to music and 2) passive MT when patients listen to familiar songs passively. Active MT uses rhythmic music, while passive MT uses personal preference. (11,13)

MT interventions differ from passive music listening or recreational music activities when these elements are present: 1) goal-directed music interventions by a trained professional, or 2) acute brain injury specific music experiences. (15) There are various models of MT, including but not limited to Benenzon Music Therapy, Guided Imagery and Music, Behavioural Music Therapy, Nordoff-Robbins Music Therapy and Neurological Music Therapy (NMT). (49)

MT often includes melodic intonation therapy (MIT), singing and playing instruments. (17,24) It is also worth mentioning that MT can be done in the absence of musical instruments as people can naturally make music. Each person has a tuned voice that can be employed freely. Hence, it has a broad use nowadays as it can aid patients with educational, social, linguistic, emotional, behavioural and physiological issues not only in clinical settings but also in educational and social ones. Moreover, it is possible to adapt the treatment to target different ages and abilities. Therefore, it contributes to the development of a more personalised medicine. (7,13,48)

### a) AREAS OF CLINICAL INTERVENTION

MT is used mostly in rehabilitation settings (e.g., neuropsychological and psychiatric disorders, chronic pain, oncology and palliative care). (6,44,49) For poststroke patients, MT has been found to improve cognition, mood, language, dysphagia, and promote recovery of motor function. (11,17,48) MT is a non-invasive and non-pharmacological approach, making it an attractive option for researchers studying its effects in rehabilitation settings. (15,17,49)

In Portugal, MT focuses on special education and rehabilitation. Lately, Portuguese music therapists have worked in public hospitals, residential facilities for disabled and elderly people, public schools, day-care centres and special education settings. (6,7)

[7] See Appendix I for more information on music therapy, including its historical background and the problem of the profession's lack of recognition.

### b) THE ROLE OF THE MUSIC THERAPY PROFESSIONAL

MT requires specific training and qualifications beyond those of SLT. A certified music therapist should have a diverse range of musical experiences and cultural backgrounds and must also play at least one musical instrument, preferably harmonic (e.g., piano or guitar) and have voice skills. They may also use small percussion and wind instruments and they should be familiar with information and communication technologies (e.g., audio recording). (6,24,44) A certified music therapist is considered more effective than other specialists. (12,15,26)

The MT therapeutic plan includes assessing the patient's condition, identifying their symptoms and dysfunctions, setting goals and choosing the appropriate intervention approach (e.g., musical improvisation, songwriting and singing). The sessions can be conducted either solo or in groups and the chosen approach depends on the patient's sickness severity, age, gender and culture. Moreover, the patient and family are involved in the therapeutic plan and have the choice to decline treatment. (7,11,48)

### c) NEUROLOGICAL MUSIC THERAPY

NMT is a system of treatment procedures based on the neuroscience model of music perception and production to rehabilitate cognitive, sensory and motor disorders associated with nervous system diseases. The 20 strategies of NMT are classified based on the diagnostic treatment aim and the mechanisms in music perception and production that can be used to reach the treatment goal (Appendix II). (44,50)

NMT interventions aim to improve verbal processing efficiency, stimulate brain areas corresponding to injured areas and restructure tissues. Rehabilitation interventions may involve music listening, playing, singing and improvisation, among other activities, tailored to match the patient's injury severity and linguistic mode. While limited research exists, NMT has potential to enhance rehabilitation and improve quality of life for neurological disorder patients. (14,15) Although NMT is an experimental procedure with evolving treatment guidelines, attempts are being made to standardise and computerise some techniques while still adapting the treatment to each patient's needs. (26,46,47)

## 7. MELODIC INTONATION THERAPY

MIT is one of the NMT techniques aiming to develop verbal fluency and prosody. MIT candidates are selected using the following criteria: 1) strong auditory comprehension, 2) self-correction ability, 3) limited verbal output, 4) reasonable attention span and 5) emotional stability. Hence, MIT rehabilitates people with Broca's aphasia mostly. (20,21,51)

MIT originally has three levels of progressive difficulty and uses high-frequency word and phrase stimuli, including familiar names and patient communication terms. Each level has 20 high-probability words (e.g., "Water") or social phrases (e.g., "I love you") with visual signals. Each item has calm, consistent intonation, high and low pitches and natural linguistic accents and rhythms. MIT uses left-hand tapping, humming (i.e., closed-mouth melodies and harmonies), intoned speech and *Sprechgesang* (i.e., dramatic vocalization between speech and song) as facilitation approaches (Table 2). (23,52,53)

Levels 1 and 2 use polysyllabic words and brief high-frequency phrases, accompanied by musical tempo through hand-tapping for each syllable worked. Level 2 introduces 5-second delays between stimulus and response. Level 3 uses more complex and lengthier sentences. At the end of each session, the patient receives a percentage score based on the number of items completed. The patient can advance to the next level after five consecutive sessions with scores above 90%. Go back if needed. (24,36,52) MIT requires high-frequency therapy sessions, ideally daily. To ensure this, family or caretakers are usually trained as music therapists' assistants. (40,50,53)

### - Brain Plasticity

Brain imaging has demonstrated that music can change brain morphology, fine nerve tissue architecture and functional brain network connections. Brain plasticity allows the brain to respond to stress, events and brain damage by reorganising intact regions. These changes can occur over varying periods of time, ranging from seconds to weeks and involve the expansion of neurons, alteration of synaptic density and even the creation of extra support structures such as capillaries and glial cells. Neuroimaging supports the hypothesis that language-capable RH and LH perilesional activation enhance functional and structural brain development at MIT. Brain plasticity of homologous areas occurs when a neighbouring area adjusts for a localised contralateral brain lesion. (36,50,51)

Regarding genetics, Brain-Derived Neurotrophic Factor (BDNF) modulates activity-dependent synaptic brain plasticity in human motor cortex. BDNF val66met, a common polymorphism that lowers BDNF secretion, affects activity-related cortical brain plasticity in response to motor training in healthy people and is associated with higher inaccuracy and poorer short-term motor learning retention. (40)

**Table 2.** Melodic Intonation Therapy Programme [adapted from (50,53,54)]

| | |
|---|---|
| **Intoned** | **LEVEL 1** |
| | **1.1 \| Humming:** Therapist introduces target phrase by displaying a visual cue, humming it once at 1 syllable/second, then singing it again while tapping patient's left hand. |
| | **1.2 \| Unison:** Therapist taps patient's left hand once per syllable as they sing target phrase. |
| | **1.3 \| Unison with fading:** Therapist and patient begin to sing and tap target phrase together, but halfway through, therapist fades out and patient finishes singing with hand-tapping without verbal or oral/facial cueing. |
| | **1.4 \| Repetition:** Therapist says and taps target phrase as patient listens. With only left-hand tapping, patient repeats target phrase. |
| | **1.5 \| Answer to a question:** Patient repeats target phrase (1.4) when therapist asks, "What did you say?". Hand-tapping only. |
| | **LEVEL 2** |
| | **2.1 \| Listening:** Therapist taps the patient's left hand once per syllable while saying target phrase twice (1 syllable/second). |
| | **2.2 \| Unison with fading:** Similar to 1.3. |
| | **2.3 \| Delayed repetition:** Therapist says and taps target phrase as patient listens. Patient repeats target phrase with solely left-hand tapping after a 5-second delay. Verbal help is forbidden. |
| | **2.4 \| Answer to a question:** 1.5 with a 5-second delay between therapist question and patient answer and no help. |
| | **LEVEL 3** |
| | **3.1 \| Delayed repetition:** Similar to 2.3. |
| **SPG** | **3.2 \| *Sprechgesang*:** Therapist says and taps target phrase twice while patient listens. |
| | **3.3 \| *Sprechgesang* with fading:** After hand-tapping target phrase together, therapist fades out and patient finishes it alone. |
| **NSP** | **3.4 \| Delayed Repetition:** 2.3 in NSP and without hand-tapping. |
| | **3.5 \| Answer to a question:** 2.4 in NSP and without any help. |
| **Target Phrases Examples:**<br>• **Level 1 \| 2-3 syllables**: "Hi", "Thank you" and "Goodbye";<br>• **Level 2 \| 4-5 syllables**: "I love you", "I am thirsty/hungry" and "I have to relax";<br>• **Level 3 \| 6-10 syllables**: "I am going to train today" and "It is 10 a.m.". | |

**Abbreviations: NSP** = Normal Speech; **SPG** = *Sprechgesang.*

- **Hand Taping**

MIT incorporates repetitive tapping on the patient's left hand to activate the RH sensory network that controls hand, orofacial and articulatory movements. Left-hand tapping helps sound-motor mapping, syllable creation and promotes sentence formation. Hand-tapping improved phrase repetition more than intonation alone. (12,37,50)

MIT has two main hypotheses to explain hand-tapping effects: left-hand tapping activates a right sensorimotor integration network that links hand and articulatory movements and synchronised singing activates an "auditory–vocal interface" to improve articulatory motor function by facilitating auditory-motor mapping and engaging a sensorimotor network controlling both hands and articulatory movements. However, neither hypothesis has been completely investigated and proven. The role of rhythmic hand movements in synchrony with articulatory movements benefits speech production and speech-motor relearning after a stroke. (41,42)

- **Memory**

MIT can aid memory processes, including encoding, storage and decoding of musical experiences, as well as the analysis of musical syntax and meaning. This can improve the patient's episodic-semantic verbal memory and prospective memory recognition functions, making it useful in the rehabilitation of memory as well. (36)

### a) EXPECTATIONS

The use of MIT involves prompting patients to produce words, sentences, or short phrases using melody patterns, which can lead to the expansion of the target utterance by facilitating speech as a song with integrated melodies. (26,29) Additionally, singing isolates phonemes so they can be heard clearly, and sustained vowel sounds allow time to "think ahead" about the next sound and self-correct. MIT repeats musical phrases at various lengths and with a 5-second delay, which requires working memory essential to retaining information activated (heard or read) and simultaneously process it. (63,65)

MIT aims to improve propositional speech (i.e., the language most people use to convey their thoughts). Therefore, the programme wants patients to be able to speak both trained and untrained phrases. (25,33,63)

Functional communication should be the main goal for poststroke aphasia patients to promote their social reintegration. After completing the MIT programme, patients should be able to communicate using appropriate terms in any context, even if they speak telegraphically. "Telegraphic" phrases include only essential words (e.g., verbs, nouns, adjectives and adverbs) and do not include functional words (e.g., articles, prepositions and connectives), which do not contribute to the meaning but make the sentence grammatically correct. (9,15,16)

### b) PRECAUTIONS AND THE MUSIC THERAPY AND HARM MODEL

MIT can have negative effects if not used properly, such as maladaptive neuroplasticity and altered sensory perceptions. The Music Therapy and Harm Model lists six health hazards in MIT sessions: 1) the music, 2) the therapist, 3) the therapeutic use of music, 4) the therapeutic relationship, 5) patient-music interactions and 6) ecological factors. These sources are always present and linked, and the patient's demands, diagnoses, personal history, and cultural connections must be recognised. The music therapist must handle reports of adverse events. (55)

MIT for aphasia involves careful progression of linguistic materials in length and difficulty with gradual therapist withdrawal. Error correction should be limited to just one "retrial" or "back-up" trial with the item dropped if it remains uncorrected to avoid reinforcing errors, which could cause maladaptive neuroplasticity and affect communication. Repetitive behaviours in musicians can create altered sensory perceptions, motor incoordination and chronic suffering, which may also occur in MIT patients. However, further research is needed. (50,55)

Controlled latencies should be used between stimulus presentation and patient response to avoid reflexive habitual answers and a good variety of meaningful material should be provided to prevent practice effects. Verbal feedback should be kept restrained to avoid stress and disruption for patients. A smile or nod for a correct response works better. (50)

### c) RESULTS

A recent systematic review of MIT studies with non-fluent aphasia patients since 1970 found that most researchers used language assessment tools for outcome evaluation (26 of 39 studies) and just a few used imaging assessments (13 of 39 studies). The Boston Diagnostic Aphasia Examination (BDAE), AQ from the WAB-R in several languages and the Aachen Aphasia Test (AAT) are among the standard language assessment scales used in quantitative studies. The imaging assessment techniques were magnetic resonance imaging, functional magnetic resonance imaging and diffusion tensor imaging. Moreover, comparative case studies, self-controlled investigations and small sample experiments were most common. (24)

- **Language Assessment Tools**

According to research, the MIT group performed better than the SLT group in understanding, retelling, response time, memory time, and retelling phrase length, indicating that MIT improves both trained and untrained speech. (22–24) Other studies found that MIT enhances functional communication and repetition tasks, as demonstrated by the Communicative Activity Log, with effects lasting up to three months after therapy. (20,24,51) MIT significantly improved phrase length after one hour, and a 6-week crossover study on three aphasia patients showed significant improvement in syllable clarity. (27) MIT also improved repetition, listening comprehension, spontaneous speech, and response items, but did not affect agrammatism. Thus, MIT may affect apraxia of speech. (24,53)

The studies suggest that MIT improves functional communication, repetition and naming but not comprehension. Early MIT for stroke patients improves cognitive function and sensory-perceptual brain plasticity. (11,17,56) MIT improved BDAE outcomes, articulation and sentence creation. Linguistic skill transfer to untrained environments was also supported by a recent study comparing MIT to control therapy. (37) The MIT intervention helped patients to be more spontaneous and motivated in normal conversations and it helped to improve lexical access and memory rehabilitation. Thus, it improved all ASHA-FACS domains[8], confirming adult patients' functional communication. (11,23,36) Also, combining selected non-MIT approaches can further improve communication ability. If the goal is to increase functional communication, aphasics shouldn't rely solely on MIT. (57)

[8] This examination covers all verbal and non-verbal communication, efficiency, and communicative independence as suitable responses to daily demands. (36)

- **Imaging Assessment Tools**

Neuroimaging studies demonstrate brain remodelling through increased fibre quantity and volume after MIT therapy. (37) BrainNet Viewer[9] was used to locate the brain regions of interest from functional magnetic resonance imaging research supporting MIT. These regions were the precentral gyrus, precentral sulcus, postcentral gyrus, middle frontal gyrus, superior temporal gyrus, superior temporal sulcus, middle temporal gyrus, inferior temporal sulcus, lingual gyrus and angular gyrus. All MIT patients showed more activation in the RH than the LH. (24)

MIT has been found to increase the number of fibres in the arcuate fasciculus, reactivate language motor zones like Broca's area in the LH and reduce aberrant activation in the RH. High-intensity MIT has also been shown to remodel the right arcuate fasciculus, indicating that the contralateral homolog tract can be malleable. Brain scans from patients who undergo MIT demonstrate changes in brain neural networks important for emotional processing and memory recovery after stroke. However, some studies suggest that LH-lesioned aphasics who develop language expression skills after MIT may have diminished abilities recovered following additional RH injuries. (11,16,41)

## d) RELEVANT VARIABLES AND OUTCOMES

Studies suggest that treatment intensity and time post-onset of stroke are the most significant factors affecting outcomes in MIT. Patients who received MIT earlier after stroke and with higher intensity showed better improvement in language skills and generalisation to functional communication. Note that MIT's effect size may decrease by 43% when using unvalidated outcomes for untrained items compared to validated tests. The frequency of MIT interventions also impacts magnetic resonance imaging results. Additionally, lesion location and corticospinal tract and cortical-subcortical connections can affect outcomes as well. (22–24,40,57)

The choice of music and the familiarity of the lyrics also appear to be important factors. Patients tend to do better with premorbid familiar tunes because when the lyrics were unfamiliar or learned after the brain injury, motivation and articulation precision decreased. (13,22,56) Melody had no greater effect on language production in non-fluent aphasia than rhythm. Adding musical pitch, however, helped to generalise rhythm to connected speech. (22,27)

[9] With this tool, researchers can visualise topological structural and functional brain networks from diverse imaging modalities. (24)

## 8. PRESENT LIMITATIONS AND FUTURE PERSPECTIVES

### - Lack Of Standardisation

Due to the complexity of music stimuli and other elements like choice of music, form of delivery or combination with other intervention strategies, music-based therapies are hard to define fully and clearly. (58) The original MIT protocol has been interpreted in various ways by different therapists. Some use two pitches separated by a perfect fourth or fifth, while others use an original melody for each phrase with 7-8 pitches in a specific key. Some even play the piano, sing familiar songs or quickly “play” 4-5 notes up and down the patient's arm while singing. (54)

There is an urgent need for MT practise to have its own treatment guidelines for aphasia based on empirical evidence and backed by experimental research employing electrophysiological and brain-imaging techniques. Appendix III provides a checklist of seven criteria that researchers might use when developing their own MT research and to assess reports of music-based therapies. (56,58) Future studies and meta-analyses would benefit from control groups with standardised and empirically validated forms of intervention, number of weekly sessions and hours of daily training. (57)

### - Lack Of Follow-Up Assessment

The long-term effects of MT on stroke-induced aphasia are unknown as studies often do not assess them. Some studies suggest that MT's beneficial effects may continue for up to six months. Future meta-analyses should examine MT's long-term efficacy. (17,22,54) The immediate impacts of MT on speech accuracy should be distinguished from its long-term effects on language recovery. Studies should examine how formulaic verbal content improves propositional speech. (16,23,53)

### - Heterogeneity Hinders Comparisons

Most current studies results cannot be generalised and compared between each other due to sample heterogeneity (i.e., uneven age, educational and musical background), small sample sizes, single-centre data, various experimental designs, different aphasia characteristics (i.e., time after stroke, type and severity), therapy plans (i.e., treatment course, intensity, procedure and combined rehabilitation) and outcome measurements (i.e., different tasks and assessment scales). (11,17,57)

The Cochrane meta-analysis comprised 74 randomised controlled trials with a median sample size of 30 patients and at least 20 intervention strategies. The variability of techniques hinders direct comparison between them because some variations in the protocol may engage different brain areas, which may change both the therapy goal and rationale. As a consequence, the supporting data is weak which prevents the endorsement of a specific therapy. (42,51,53)

Therefore, future large-scale clinical trials are needed to prove MT's efficacy and better methodological studies are required to select a control group, forms of aphasia, and particular assessments to focus therapeutic indications and protocols. (11,26,51,57)

- **Low Quality Biased Evidence**

Despite MT widespread use, the evidence is poor. Most studies do not compare therapy success in treated and untreated groups statistically. (23) Because the therapeutic approaches required MT, blinding patients and therapists was not possible, and most trials lost scores regarding research quality due to lack of allocation concealment and blindness to subjects and therapists. (17) Also, there has been little research linking clinical and experimental data on human musical and language responses. (56) As a consequence, most of the studies are highly biased, so the evidence is low quality especially when it is applied in early poststroke phase when spontaneous recovery and therapeutic effects are intertwined. (15,22,57)

- **Lack of Professional Recognition**

One of the limitations is the lack of professionals. To overcome this, international cooperation and exchange programmes are required to train more therapists globally. Additionally, the lack of professional recognition of MT in many countries is a hindrance to the employment of music therapists. This, in turn, limits the development of scientific research in this field and the application of MT techniques in clinical settings. (6,11,14)

- **Unclear Mechanisms**

The mechanisms behind the efficacy of music-based interventions in aphasia rehabilitation are unclear and require further investigation. The relationship between anatomy and function, individual differences, genetic and epigenetic causes and the role of motivation and emotion need to be explored. (11,39,53)

The compensating role of the RH is insufficient to explain why music interventions work effectively on some but not most patients and the nature of MIT-induced brain plasticity, the role of the mirror neuron system and the interaction between music and language cognitive processes need to be better understood. (11,42)

Research is needed to understand the interaction between neuronal plasticity and delayed pathophysiological mechanisms in stroke recovery, adopting methods from other fields (e.g., stem cell research and gene therapy). The methodology for evaluating functional recovery in experimental stroke models needs improvement. Clinical and experimental research must collaborate to help doctors treat patients by better understanding language and music processing. (10,56)

- **Solo and/or Group Interventions**

Some studies found out that individual aphasic patients benefited from MIT as individual assessments on functional tasks showed changes in some participants while its group effect was small and temporary with few or no benefits in speech and language skills. This suggests that specific regions, volumes of injury and degrees of aphasia may present specific needs that are often not addressed in group therapies. (23,26) MIT may promote neuroplastic reorganisation in the context of individual and language type differences as well as time since stroke may affect language-related brain activation lateralization. Thus, individual factors may conceal MIT's brain correlates. MIT's wide improvement range raises the question of which patients are best suited. (11,23,53)

- **MIT Definition Not Consensual**

MT is defined differently across the globe and there is no agreement on the definition of MIT, which has sometimes been limited to the intoned-speech facilitation technique rather than the full programme. Therefore, MIT programmes differ widely. (53,59) The questions of 1) how well it works, in terms of its effect size and comparison to other treatment options, 2) when it works, including for which patient groups and treatment protocols, and 3) why it works are still up for debate. Several research groups are striving to find solutions using carefully structured studies and randomised controlled trials. (42)

- **Pre- And Post-Therapy Evaluation Deficit**

Pre- and post-therapy acquisition was not used in all investigations. Many research groups only published post-treatment results and pre-treatment data was missing. Additionally, pre- and post-treatment brain activity patterns and neuroimaging during speech production are not recorded in most investigations and use different language tasks and/or stimuli. Thus, the outcomes cannot be attributed to the therapy effect. (16,53,57)

- **Undocumented Lesion Characteristics**

To accurately assess the efficacy of MIT therapy, it is crucial to document the lesion characteristics, including its location and size, as these can affect brain reconfiguration after a stroke. Some studies have lacked this essential information, which impacts their validity. The hierarchical model of brain compensatory techniques after a stroke suggests that the RH can only assist with language recovery if the LH language areas are disrupted. In addition, routine scans at admission can sometimes indicate no structural damage, leading to MIT therapy beginning without reliable lesion information. (22,23,53)

- **Stress-timed languages versus Syllable-timed languages**[10]

The effectiveness of intoned-speech facilitation in MIT may depend on the rhythm of the patient's native language. Syllable-timed languages may benefit from additional stresses to aid with syllable and word segmentation while stress-timed languages may benefit from emphasising their natural rhythm for a more natural prosody. (53,60)

It is important to adapt MIT for different languages since not all languages share the same prosodic properties (i.e., tone, rhythm, order of stressed and unstressed syllables) and not only translate it literally. Tone matters more than other prosodic elements. (16,25,52)

- **Short Intervention Period and Low Adherence**

The use of MIT for aphasia requires a long treatment cycle and patient compliance. (11) The intervention period reported in studies is typically short (about four weeks) so that further studies should have a longer treatment phase. (14,16) Not all aphasic patients can endure long-term language therapy and high-intensity therapy studies have more dropouts than low-intensity studies according to the last Cochrane review. (19,23) Future studies should evaluate altering training session frequency and length. (37)

[10] Recent rhythmic analysis models such as "The Control/Compensation Index" can group languages as syllable-timed languages (e.g., European Portuguese, French and Italian) with constant syllabic duration or stress-timed languages (e.g., English and German) with regular intervals between the accents. Furthermore, languages can be categorized according to the compressibility of unstressed syllables, with those allowing compression referred to as "compensation languages" (e.g., English) and those not allowing it referred to as "check languages" (e.g., Italian). (25)

## 9. RESEARCH PROJECT PROPOSAL

**TITLE:** Music Therapy in Poststroke Non-fluent Aphasia Rehabilitation in Portuguese Patients

### 1. INTRODUCTION

This study evaluates if adding music therapy (MT) to speech and language therapy (SLT) helps Portuguese aphasic patients with Broca's aphasia, a poststroke impairment. The 6-month multicentre randomised controlled trial with two groups will be followed by a 6-month follow-up. The aphasia quotient (AQ) from *Bateria de Avaliação de Lisboa* (BAAL) will be the primary endpoint. The secondary outcomes will be neurological damage, language, communication, quality of life, emotional well-being, physiological stress reactions and pain.

The study will employ constraint-induced language therapy (CILT) in 90-minute group sessions twice a week. A certified music therapist will lead three weekly 60-minute individual sessions of melodic intonation therapy (MIT). Statistical analysis and ethical standards like the Helsinki Declaration and Good Clinical Practice will be followed. The study's potential to improve poststroke aphasia rehabilitation and quality of life, as well as its contribution to Portugal's scarce evidence of MT rehabilitation in literature, makes it significant.

### 2. BACKGROUND

Stroke survivors often have aphasia. Poststroke aphasia impacts communication and quality of life. MT may enhance language function in poststroke aphasia. MT for Portuguese poststroke aphasia patients is understudied.

### 3. AIMS

This study aims to provide evidence for the effectiveness of MT in poststroke aphasia rehabilitation in Portuguese patients. Ultimately, this study may contribute to the development of more effective and personalised rehabilitation programs for poststroke aphasia patients in Portugal.

**Research Question**: *How does the inclusion of MT as an adjuvant of treatment impact rehabilitation outcomes in patients with poststroke aphasia (subacute and/or chronic phase) undergoing rehabilitation with SLT?*

## 4. OBJECTIVES

- To investigate the effectiveness of SLT combined with MT as an adjuvant treatment for poststroke aphasia rehabilitation.
- To compare the rehabilitation outcomes of patients with poststroke aphasia who receive SLT only with those who receive SLT combined with MT.
- To examine the long-term effects of SLT combined with MT on poststroke aphasia rehabilitation outcomes.
- To promote the use of a non-pharmacological intervention technique in the rehabilitation of poststroke aphasia
- To contribute to the recognition of MT as a complementary technique to SLT

## 5. HYPOTHESIS

### 5A. PRIMARY HYPOTHESIS

The addition of MT to SLT in patients with poststroke aphasia will result in a greater improvement in the AQ from BAAL compared to SLT alone.

- **H0**: There is no significant difference in the mean AQ score between the SLT group and the SLT+MT group.
- **H1**: The mean AQ score of the SLT+MT group is significantly different from the mean AQ score of the SLT group.

Independent samples t-test will be used to compare the AQ scores of the two groups at baseline (T0), at 6 months (T1) and at 12 months (T2).

### 5B. SECONDARY HYPOTHESES

The SLT+MT group compared to the SLT group at 6- and 12-month follow-up will have:

- greater improvements in neurological damage, language and communication skills.
- higher levels of quality of life and emotional well-being.
- reduced physiological stress responses and lower levels of pain.

**6. DESIGN:** Randomised controlled trial in add-on to clinical practice with group SLT and group SLT+MT. Intervention period of 6 months with a 6-month follow-up period.

**7. SETTING/LOCATION:** Multicentred study in Portuguese hospitals with stroke care rehabilitation units.

**8. POPULATION:** Portuguese poststroke Broca's aphasic adults.

## 9. ELIGIBILITY CRITERIA

**9A. INCLUSION CRITERIA:** Adults (≥ 18 years old), fluent in Portuguese, right-handed, Broca's aphasia diagnosis, unilateral LH single stroke in the subacute or chronic phase (post-stroke time > 1 week), absence of hemispatial inattention, without significant attention deficit with ability to follow orders and collaborate, without psychiatric pathology and tonal audiometry with hearing loss < 40 decibels.

**9B. EXCLUSION CRITERIA:** Patients under 18 years of age, non-fluent in Portuguese, left-handed or ambidextrous, other diagnoses of aphasias (global, transcortical, Wernicke, …), aphasias of aetiology other than stroke or with previous stroke history, acute phase (poststroke time < 1 week), unable to collaborate, psychiatric illness, substance dependence within 12 months prior to their stroke and tonal audiometry with hearing loss > 40 decibels.

## 10. OUTCOMES

**10A. PRIMARY OUTCOME**: AQ from BAAL.

**10B. SECONDARY OUTCOMES:** Neurological damage**;** language**;** communication**;** quality of life**;** emotional well-being**;** physiological stress responses and pain.

## 11. PROCEDURES

**11A. RECRUITMENT OF PARTICIPANTS**

**Contact potential participants**: The first step is to contact potential participants who meet the inclusion criteria through collaboration with stroke care rehabilitation units.

**Screening:** Once the potential participants are identified, they will be screened for eligibility criteria such as age, stroke diagnosis, and absence of other speech and cognitive disorders.

- **Medical records**: aphasia classification and aetiology; psychiatric illness and substance dependence.
- **Bedside de *Lenguaje***: aphasia screening.
- **Mini-Mental State Examination:** screen cognitive deficits that could affect the participant's ability to collaborate and complete the interventions.
- **Tonal audiometry**: exclude significant hearing loss (> 40 decibels) that could interfere with the MT and SLT exercises.

**Informed Consent:** Before enrolling, participants should be informed about the study, its methods, outcomes and concerns. Participants or their representatives must sign the informed consent form and audio/video recording should be authorised.

**Baseline assessment (T0):** After the participant consents to participate in the study, they should undergo baseline assessments to collect demographic information, assess language and cognitive abilities, and establish the baseline measures of the outcome variables. For further details, see “11D. Measurement tools used”.

**11B. RANDOMISATION:** Participants should be randomly assigned to group A (SLT) or group B (SLT+MT) after baseline assessment. An impartial researcher who is not involved in participant recruiting or intervention period will keep a computer-generated list of random numbers for randomisation. Investigators should only see the list following baseline assessments. To balance the groups, participants should be assigned 1:1 by stroke severity, age, and gender.

## 11C. INTERVENTION METHODOLOGY AND STUDY OUTLINE

**SLT:** CILT in 90-minute group sessions twice a week for 6 months (Table 3) led by a certified speech and language therapist in accordance with the Portuguese Decree-Law no. 261/93, of July 24. CILT comprises a card game with illustrations from relevant topics in aphasia practice performed by 2-3 patients and a therapist and they should collect matching pairs of cards. Each turn, one patient asks another if they have a card and they answer. Although therapists can give as many cues as needed, patients are limited to verbal responses and alternative communication is prohibited (e.g., gesturing). Initially, relevant utterances are accepted but as patients progress full sentences are required.

**MT:** MIT in 60-minute individual sessions three times a week for 6 months (Table 3) led by a certified music therapist from *Associação Portuguesa de Musicoterapia*. Each patient will have its natural pitch determined in order to establish the melodic range of the MIT exercises. Then, the therapist must create a set of MIT exercises with Portuguese target phrases according to the case example below (Figure 2) and apply the MIT technique following the programme previously described (Table 2). After five consecutive sessions with scores above 90%, the patient progresses to the next level. If the patient cannot complete the following level's exercises, level down. No musical instruments, speakers or headphones are required.

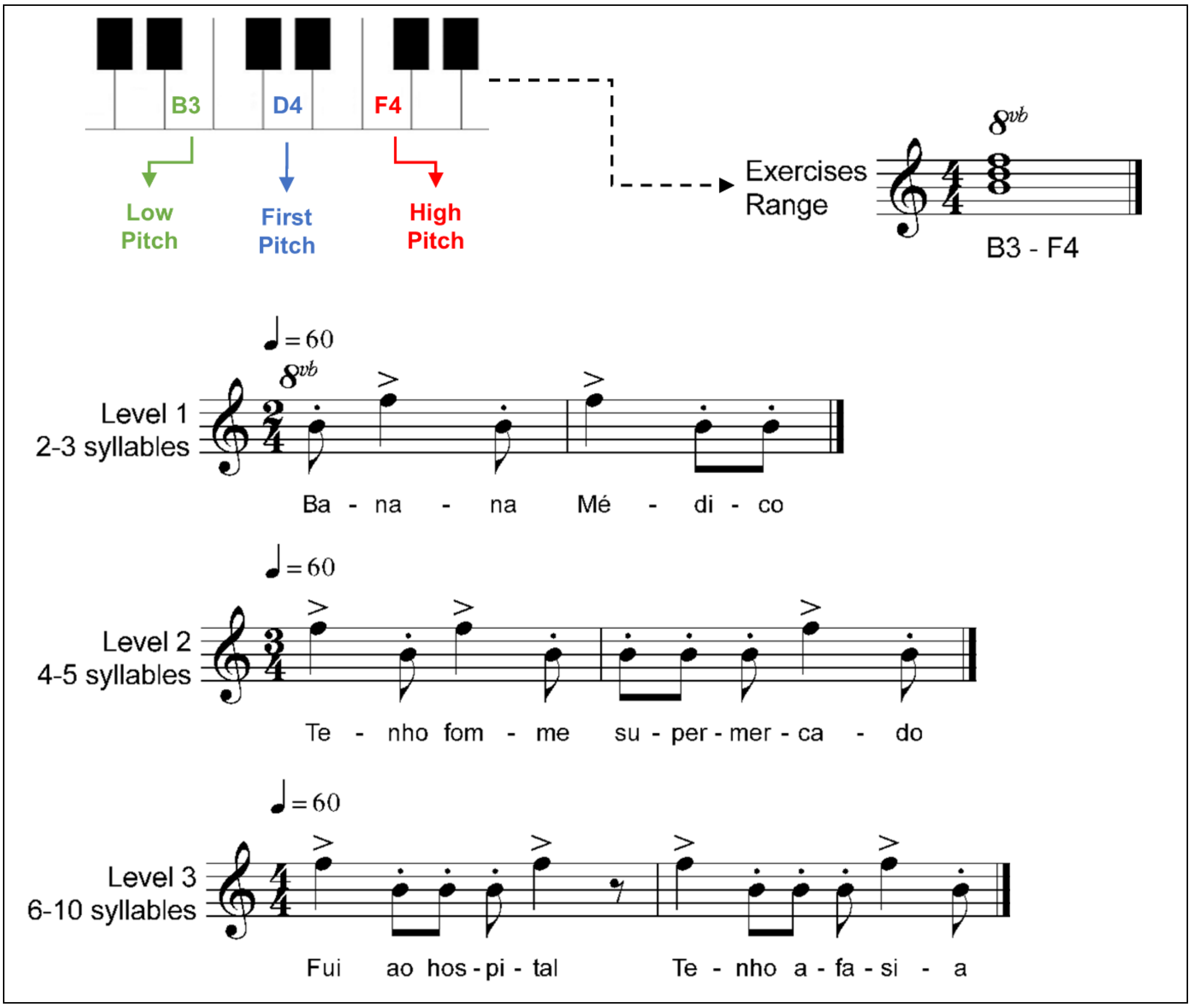


**Figure 2.** Melodic Intonation Therapy - Case Example

European Portuguese is a stress-timed language. Hence, it benefits from emphasising its natural rhythm for a more natural prosody. Target phrases should have their stressed syllables identified previously according to Portuguese phonology. Then, the following should be done: 1) patient's natural speaking range (**first pitch**); 2) minor third above first pitch (**high pitch**); 3) minor third below first pitch (**low pitch**); 4) higher voice intensity, high pitch and quarter notes (*stressed syllables*); 5) lower voice intensity, low pitch and eighth notes (*unstressed syllables*), and 6) develop a set of exercises with target phrases within relevant topics for each level.

## RELEVANT TOPICS TO INCLUDE IN APHASIA PRACTICE

**Actions** (e.g., verbs)

**Clothes** (e.g., accessories)

**Communication** (e.g., newspaper)

**Descriptive terms** (e.g., colours)

**Entertainment** (e.g., sports)

**Events** (e.g., Easter)

**Feelings and emotions** (e.g., tired)

**Food and drink** (e.g., meals of the day)

**Health** (e.g., body parts)

**House** (e.g., housework)

**Money** (e.g., forms of payment)

**Nature** (e.g., animals)

**Numbers** (e.g., ordinals)

**People** (e.g., names and greetings)

**Personal care** (e.g., cosmetics)

**Personal items** (e.g., jewellery)

**Places** (e.g., public buildings)

**Shopping** (e.g., types of shop)

**Stationery** (e.g., pencil)

**Technology** (e.g., hardware)

**Time** (e.g., days of the week)

**Travel** (e.g., vehicles)

**Weather** (e.g., temperature)

**Work and education** (e.g., jobs)

## EXAMPLES OF PORTUGUESE TARGET PHRASES

**LEVEL 1 | 2-3 syllables:** *água, ajuda, alface, almoço, azul, banana, banho, barriga, bom dia, braço, cabeça, café, camisa, caneta, cão, carne, carro, casaco, ceia, chapéu, comer, dinheiro, dormir, escrever, falar, febre, fruta, gato, hospital, lanche, laranja, legumes, leite, levantar, Maria, médico, meias, peito, peixe, perna, tomate, verde, vermelho, …*

**LEVEL 2 | 4-5 syllables:** *amizade, boa tarde/noite, companhia, família, iogurte, não gosto disso, não sei cantar/tocar/(…), preciso de (…), quero comer (…), sou o João/(…), supermercado, televisão, tempestade, tenho sede/fome/sono/frio/calor/(…), …*

**LEVEL 3 | 6-10 syllables:** *ali estou melhor, dói-me a cabeça/barriga/(…), está muito quente/calor/cozido/(…), fui ao hospital/supermercado/(…), tenho afasia, gosto muito de aprender/ler/escrever/(…), não consigo falar/comer/dormir/(…), preciso de ajuda, sinto-me cansado/triste/(…), …*

**Note:** stressed sylables are underlined.

**Table 3.** Interventions' Schedule

| Group | Monday | Tuesday | Wednesday | Thursday | Friday |
|---|---|---|---|---|---|
| **A** | - | SLT | - | SLT | - |
| **B** | MT | SLT | MT | SLT | MT |

**Abbreviations: MT** = Music Therapy; **SLT** = Speech and Language Therapy.

**Post-Intervention assessment (T1):** After the participants finish the intervention period, they should undergo post-intervention assessments. For further details, see "11D. Measurement tools used".

**Follow-up assessment (T2):** A follow-up assessment should be conducted with the participants during a medical appointment at 6 months after completion of the intervention period (12 months from the baseline assessment). For further details, see "11D. Measurement tools used".

## 11D. MEASUREMENT TOOLS USED

**Neurological damage:**

- Brain Computed Tomography scan and Magnetic Resonance Imaging assessment: document lesion site and characterize it.
- Modified Rankin Scale: evaluates patients' impairment and recovery over time.
- National Institutes of Health Stroke Scale: assess stroke related impairments.

**Language: AQ** from **BAAL** and Portuguese Aachen Aphasia Test **(P-AAT).**

**Communication:** American Speech-Language-Hearing Association Functional Assessment of Communication Skills for Adults **(ASHA-FACS).**

**Quality of Life:** Stroke and Aphasia Quality of Life Scale **(SAQOL).**

**Emotional well-being**: General Health Questionnaire **(GHQ).**

**Physiological stress responses and pain**: salivary cortisol measurement, blood pressure, heart and respiratory rates and visual analogue pain scale.

All outcomes will be measured at baseline (T0), 6 months (T1), and 12 months (T2).

## 11E. SAFETY CONSIDERATIONS/PATIENT SAFETY

**Physical and Emotional Safety:** Precautions should be taken to avoid falls and other injuries. Aphasia can cause emotional distress so that patients should be regularly evaluated. Researchers should consult a psychologist or psychiatrist to assure participants' safety.

**Adverse Events Reporting and Emergency Procedures**: Report and manage adverse events according to the Common Terminology Criteria for Adverse Events. Emergency medical staff must be available.

**Data Security**: Limit data access to study participants to ensure data security and confidentiality. Employ password-protected files and encrypted data transmission. Avoid participant identification by using anonymised or de-identified data. Maintain data integrity by backing up data regularly.

## 12. STATISTICAL CONSIDERATIONS AND DATA ANALYSIS

### 12A. SAMPLE SIZE AND STATISTICAL POWER

Given that the minimum detectable change in AQ is 5 points, and assuming a conservative effect size of 0.5, a sample size of 32 participants per group (total of 64 participants) would provide a statistical power of 80% at a significance level of 0.05. However, to account for potential dropouts or loss to follow-up, a higher sample size may be necessary.

### 12B. STATISTICAL METHODS

The data will be analysed using the Statistical Package for the Social Sciences version 26.0.

- **Descriptive statistics (e.g., mean, standard deviation and frequency):** describe the characteristics of the study sample at T0.
- **Baseline differences**: independent t-tests or chi-square tests to determine if there are any significant differences between the two groups at T0.
- **Within-group changes over time**: paired t-tests to assess changes in outcomes within each group from T0 to T1 and from T0 to T2.
- **Between-group differences**: independent t-tests to compare the primary and secondary outcomes between the two groups at T1 and at T2.
- **Mixed-effects models:** analyse the differences in the primary and secondary outcomes between the two groups over time, while adjusting for covariates if necessary.
- **Subgroup analyses**: examine if there are any differences in outcomes between subgroups based on demographic or clinical characteristics.

## 13. ETHICAL CONSIDERATIONS

This study will be conducted in accordance with the principles of the Declaration of Helsinki, Good Clinical Practice and *Associação Portuguesa de Musicoterapia* Ethical Code. It will then obtain ethical approval from the relevant healthcare institutions. Informed and voluntary consent will be obtained from all participants or from their legal representative or family members.

## 14. OUTCOMES AND SIGNIFICANCE

The study will reveal whether MT improves rehabilitation outcomes in poststroke aphasia patients. The BAAL AQ will measure language function alterations. Secondary outcomes include stroke disability, communication, quality of life, emotional well-being, physiological stress reactions and pain.

The study could improve poststroke aphasia rehabilitation and quality of life. If MT works as an adjuvant to SLT, it could be used to help poststroke aphasia patients recover. The study will also add to the literature on MT in rehabilitation specially in Portugal where it is scarce.

## 10. CONCLUSIONS

MT has the potential to complement conventional medicine and ongoing treatments. Music-based interventions, including MIT, have been developed and have demonstrated positive results for individuals with language impairments. However, MIT is not effective for all individuals, and individualised assessment and treatment planning is necessary. Understanding the cognitive mechanisms and neural correlates underlying MT can lead to the development of more effective interventions for poststroke aphasia patients. In order to have officially approved MT clinical guidelines, further development of MT research based on sufficient funding and interdisciplinary collaboration is necessary.

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## APPENDIX I: MUSIC THERAPY

### a) HISTORICAL BACKGROUND

The relationship between singing and language impairment has been observed in case studies and research for hundreds of years which led to investigations into singing ability in non-fluent aphasia. In the 19th century, music lost its therapeutic power due to industrialisation and a biotechnological worldview, but the therapeutic efficacy of music therapy (MT) was rediscovered in the mid-20th century (Figure 3). After World War II, music was used to treat American veterans with post-traumatic stress disorder, leading to the establishment of the first MT course (Michigan State University, 1944). The American Association for Music Therapy was founded in the United States of America in 1950 to promote the use of music in medicine and to train qualified professionals. Music therapists with medical, therapeutic and music understanding emerged in the mid-20th century, and MT is now being used worldwide for rehabilitation and healthcare. (42,48,61) In the early 1970s, neurologic researchers Albert, Sparks, and Helm[11] developed melodic intonation therapy (MIT). (36) The World Federation of Music Therapy was established in 1985 to promote awareness of MT around the world. (6) Since then, several different languages, including French (25), Spanish (52), Persian (60), Italian (25), Greek (16) and Brazilian Portuguese (36), have their own versions of the original MIT. (23) This suggests that MIT therapy is effective across populations. Therefore, there have been progressively more research looking into MIT's efficacy. Publications rose from 28 in 2000 to 111 in 2019. (11,12,42,62)

#### EUROPE AND PORTUGAL

MT training programmes were launched in Europe in the 1960s, with the first programmes established in the United Kingdom (1958), Austria (1959), Germany (1960) and The Netherlands (1965). Currently, around sixty MT training programmes exist in Europe although some countries still do not have established them (e.g., Luxembourg and Cyprus). Portugal's Education through Art research group gave MT scientific value in the 1970s. In 1989, the Regional Division of Special Education of Madeira and the University of Montpellier held the first training course for music therapists in Funchal led by Jacqueline Verdeau-Paillés, which other Portuguese universities have since followed. (48,63) In January 1996, *Associação Portuguesa de Musicoterapia* (APMT) was founded. This non-profit organisation promotes MT in Portugal. (6)

[11] They reported the case of a 67-year-old patient, aphasic for 18 months, who had undergone SLT for three months, with no effect, thus initiating MIT. After just two days of starting MIT, the patient began to produce a few words. Two weeks later he had the vocabulary of 100 words and six weeks later he could carry on simple conversations. (36)

The Master's Degree in Music Therapy at *Universidade Lusíada de Lisboa* is the only degree in Portugal currently active that meets APMT accreditation requirements to become a certified music therapist. Note that a degree does not make someone a certified music therapist. (6,7) The requirements for APMT certification include: 1) university-based training programme (minimum 2 academic years) including an internship (minimum 80 hours/5 months duration); 2) clinical supervision (minimum 40 hours individual sessions or 60 hours group sessions); 3) clinical experience (200 hours of direct contact/minimum 1 year); 4) personal development, self-experience or psychotherapy (80 hours/minimum 2 years); 5) supplementary courses or academic training (music, psychology, health and social sciences). (6,64)

Researchers from several countries have collaborated to expand music therapy knowledge, giving future practitioners with the most specialised studies and MT peer-reviewed journals. However, Portugal lacks a peer-reviewed MT journal and academic publications. *Cadernos de Musicoterapia,* the only Portuguese publication, is a compilation of articles issued by the APMT in 1997 during the European Pre-Conference. (6,62)

### b) NON-RECOGNITION OF THE MUSIC THERAPY PROFESSIONAL

Professional recognition of MT is important as it provides credibility and protection for both therapists and patients. Patients benefit as it ensures services are provided by qualified and competent individuals who can ensure their safety and confidentiality. Plus, due to the absence of regulation, MT cannot be covered by health insurance. (63)

The professionalisation of MT in Europe has often undergone five stages: 1) pioneering, 2) professionalisation of MT services, 3) formalisation of education and research, 4) development of university-level training and research, and 5) full professional recognition of MT as a profession, including its recommendation in national clinical guidelines. Portugal has yet to reach this final stage. (63,65)

MT can be regulated independently or in conjunction with other arts therapies (i.e., music, art and theatre). Individual recognition (e.g., Austria 2008) provides more autonomy, while collective recognition (e.g., United Kingdom 1999 and Latvia 2009) offers more resources and supports common interests. Although legal recognition has its benefits, it also has drawbacks, such as limiting the ability of music therapists from countries without legal recognition to practice in nations with recognition. The process of recognition within Europe is challenging. (63,66)

## THE PORTUGUESE CASE SCENARIO

MT in Portugal has limited institutional job prospects. However, MT demand is rising in special education and gerontology and many interventions are provided unqualified technicians. To address this issue, the APMT developed a document in 2010 outlining certification requirements and procedures to initiate the official recognition of MT. Since 2016, the APMT has begun the process of certification and launched an online petition entitled "Recognition of the Music Therapy Professional in Portugal" which garnered 4,373 signatures. It was submitted to the *Assembleia da República* on February 26, 2020[12], and was considered valid and formally accepted as Petition 62/XIV/1ª for debate on May 14, 2020. (6,7,67)

On January 13, 2023, it was discussed in a plenary meeting and most parliamentary groups acknowledged the need to regulate the profession. During the plenary session, it was noted that music therapists are not included in the *Classificação Portuguesa das Profissões (CPP/2010)*, but are classified under the International Standard Classification of Occupations 2008 (ISCO-08) as art therapists (2269 Health Professionals Not Elsewhere Classified). In fact, there is a legislative issue in Portugal due to a law regulating professions[13], which requires a prior proportionality study by the relevant government sector and an opinion from the *Direção-Geral do Emprego e das Relações de Trabalho (DGERT)* before the *Assembleia da República* can legislate on professional regulation. This poses a significant constraint on its legislative power. (67–69)

[12] *Diário Assembleia da República II série B n.º 39, 2020.05.16, da 1.ª Sessão Legislativa da XIV Legislatura (p. 20-22).*
[13] *Lei n.º 2/2021, de 21 de janeiro.*

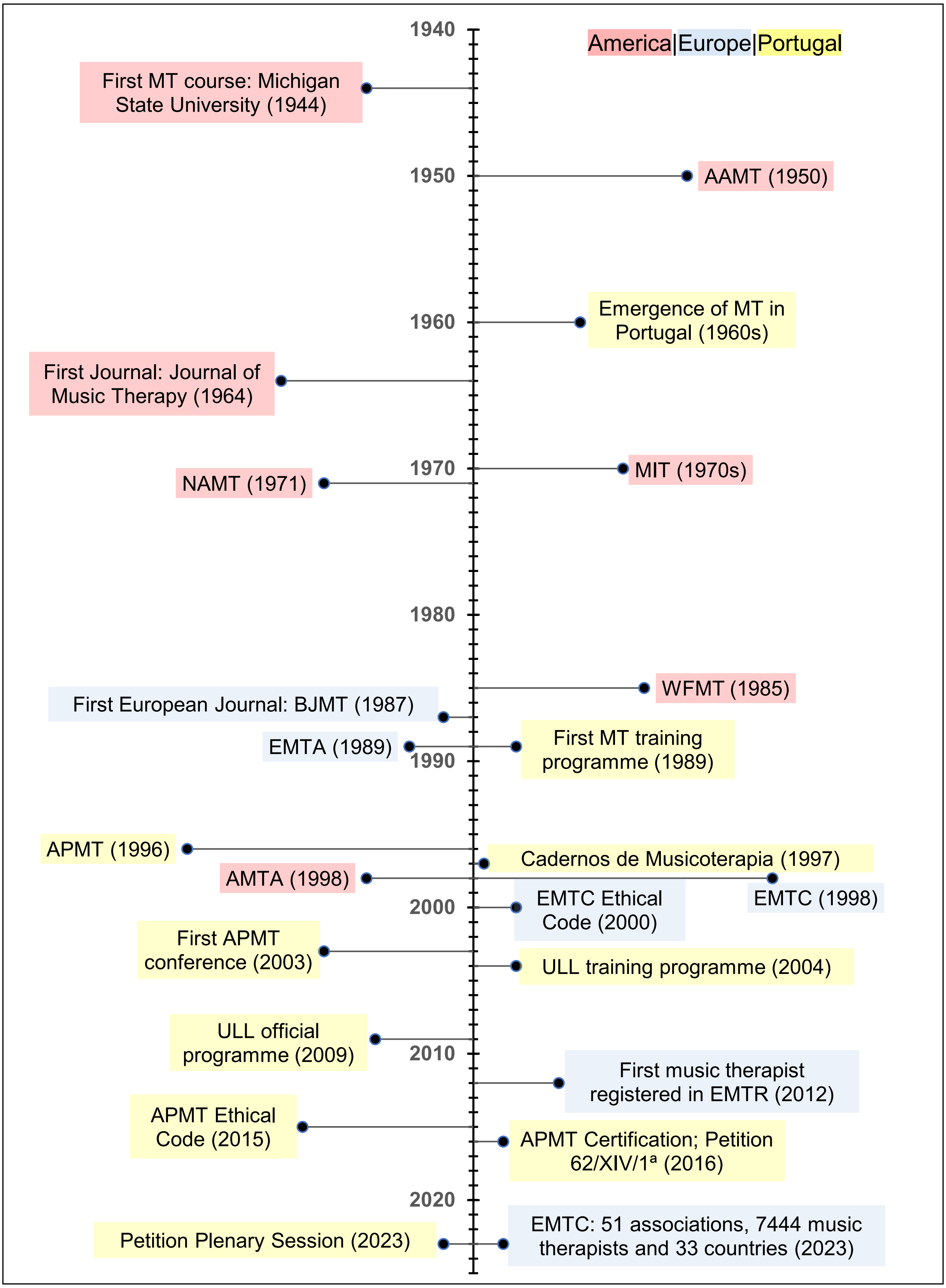


**Figure 3.** Music Therapy Historical Timeline Overview (6,59,63,65)

**Abbreviations: AAMT** = American Association for Music Therapy; **AMTA** = American Music Therapy Association; **APMT** = *Associação Portuguesa de Musicoterapia;* **BJMT** = British Journal of Music Therapy; **EMTA** = European Music Therapy Association; **EMTC** = European Music Therapy Confederation; **EMTR** = European Music Therapy Register; **MT** = Music Therapy; **NAMT** = National Association for Music Therapy; **ULL** = *Universidade Lusíada de Lisboa.*

## APPENDIX II: NEUROLOGICAL MUSIC THERAPY

**Table 4.** Overview of Neurological Music Therapy Techniques [adapted from (50)]

| | | |
|---|---|---|
| - | **TDM** | **Goals:** RSMM* clinical extension.<br>**Methods:** Step-by-step strategy to turning non-musical therapeutic experiences into music-based interventions for goal-oriented musical applications.<br>**Indications:** Before every music therapy-based approach. |
| **Sensorimotor Rehabilitation** | **RAS** | **Goals:** Biorhythmic movement rehabilitation (e.g., gait).<br>**Methods:** Uses auditory rhythm's motor system effects as a rhythmic stimulus for movement and training aid to improve gait patterns.<br>**Indications:** Gait deficits (e.g., PD, CVA, TBI, MS, CP and orthopaedic patients). |
| | **PSE** | **Goals:** Functional movement patterns and sequences.<br>**Methods:** Rhythmic, melodic, harmonic and dynamic-acoustical music to offer temporal, spatial and force signals for non-rhythmic movements (e.g., hand movements).<br>**Indications:** Neurological and orthopaedic disorders with impact on functional motor skills (e.g., upper/lower limb). |
| | **TIMP** | **Goals:** Promote functional movement patterns.<br>**Methods:** Playing musical instruments in different locations to develop functional motions. Focus on strength, endurance, functional hand movements, finger dexterity and limb coordination.<br>**Indications:** Motor impairment (e.g., paresis, tremor and rigidity). |
| **Speech and Language Rehabilitation** | **MIT** | **Goals:** Spontaneous and voluntary communication.<br>**Methods:** A three-level program that combines sung and chanted melodies.<br>**Indications:** Broca's aphasia. |
| | **MUSTIM** | **Goals:** Non-propositional speech and functional speech responses.<br>**Methods:** Let the patient finish sentences with songs, rhymes and chants.<br>**Indications:** Non-fluent aphasia with cognition impairments; patients unable to follow MIT complexity or that have progressed with MIT and need to enhance their functional language use beyond MIT phrases. |
| | **RSC** | **Goals:** Promote motor planning, muscle coordination and pace.<br>**Methods:** Metric and patterned rhythmic cueing to manage speech initiation and rate.<br>**Indications:** Apraxia, dysarthria (e.g., PD) and fluency disorders. |
| | **OMREX** | **Goals:** Enhance articulatory control, respiratory strength and speech apparatus function.<br>**Methods:** Sound vocalisation and wind instrument playing to work on strength and coordination in making speech sounds.<br>**Indications:** Speech disturbances (e.g., TBI or CVA, muscular dystrophy, Down syndrome, …). |

| | | |
|---|---|---|
| | VIT | **Goals:** Maintain, develop and restore voice control (i.e., inflection, pitch, breath control, vocal timbre and volume).<br>**Methods:** Vocal exercises similar to choir warm-up and practice.<br>**Indications:** Voice quality abnormalities (e.g., hypernasality, restricted pitch range or breathy vocal quality). |
| | TS | **Goals:** Improve respiratory function. Promote language initiation, development and articulation.<br>**Methods:** Singing activities.<br>**Indications:** All ages and diagnoses. Follow-up exercise of OMREX, RSC and VIT. |
| | DSLM | **Goals:** Target speech production, language development or both.<br>**Methods:** Use of developmentally appropriate musical resources through singing, chanting, playing instruments, and mixing music, speech, and movement.<br>**Indications:** Children with speech and language delays (e.g., CP and Down syndrome), teenagers and adults with extremely delayed language skills. |
| | SYCOM | **Goals:** Train communication behaviour, language pragmatics, appropriate speech gestures, emotional communication.<br>**Methods:** Structured instrumental or vocal improvisation in a nonverbal language system.<br>**Indications:** Complete loss of language (e.g., stroke or TBI) or an absence of development of functional expressive language (e.g., CP). |
| Cognitive Rehabilitation | MSOT | **Goals:** Stimulate arousal and recovery of wake states.<br>**Methods:** Live or recorded music stimuli to train basic attention maintenance. It involves sensory stimulation, arousal, direction, vigilance and attention.<br>**Indications:** Disorders of consciousness (i.e., coma, vegetative state, stages of post-trauma recovery), dementia, TBI, birth defects, learning disorders, ASD, … |
| | APT | **Goals:** Improve auditory perception and sensory integration.<br>**Methods:** Musical exercises to discriminate and identify different components of sound which integrate visual, tactile and kinaesthetic senses.<br>**Indications:** Developmental disorders, hearing loss, disorders that affect auditory perception (e.g., Down syndrome, ASD, TBI and CVA). |
| | MNT | **Goals:** Focus attention to neglected visual field.<br>**Methods:** 1) Musical instrument performance exercises structured in time, tempo, rhythm, and space and 2) receptive music to enhance hemisphere brain activation during visual neglect or inattention training.<br>**Indications:** Hemispatial neglect (e.g., CVA or TBI). |
| | MEFT | **Goals:** Increase executive functions (e.g., organisation, problem solving, decision making, reasoning and comprehension).<br>**Methods:** Improvisation and composition exercises.<br>**Indications:** ADD, TBI, CVA, behavioural disorders, MS, PD, … |

| | | |
|---|---|---|
| | **MMT** | **Goals:** Improve memory through mnemonics (memory aids).<br>**Methods:** Musical stimuli (i.e., rhythms, melodies and chants) as mnemonic strategies.<br>**Indications:** TBI, CVA, brain tumours, MS, PD, dementia, … |
| | **MEM** | **Goals:** Retrain echoic memory**.<br>**Methods:** Involves the immediate recall of musical sounds from singing, instrumental playing or recorded music.<br>**Indications:** Auditory memory loss (e.g., TBI), dementia, cochlear implant users, children with developmental language difficulties, ASD and schizophrenia. |
| | **AMMT** | **Goals:** Memory, learning and recall improvement.<br>**Methods:** Music mood induction approaches enhance memory by 1) producing a mood-congruent state to promote memory recall; 2) engaging associative mood and memory networks; and 3) instilling a favourable mood at both encoding and recall.<br>**Indications:** Amnestic disorders (e.g., dementia, TBI, CVA, tumours and MS). |
| **-** | **MPC** | **Goals:** Enhance psychosocial functioning.<br>**Methods:** Any music-based strategy can be used.<br>**Indications:** ASD; TBI or CVA; other neurological problems (e.g., PD); dementia and depression (i.e., secondary to TBI, CVA or psychiatric diagnosis). |

*RSSM is a scientific theory model based on neuroscience and behavioural science studies.
**Echoic memory lasts 2-4 seconds and stores auditory information until a future sound gives it meaning.

**Abbreviations: ADD** = Attention Deficit Disorder; **AMMT** = Associative Mood and Memory Training; **APT** = Auditory Perception Training; **ASD** = Autism Spectrum Disorders; **CP** = Cerebral Palsy; **CVA** = Cerebral Vascular Accident; **DSLM** = Developmental Speech and Language Training Through Music; **MIT** = Melodic Intonation Therapy; **MPC** = Music in Psychosocial Training and Counselling; **MEM** = Musical Echoic Memory Training; **MEFT** = Musical Executive Function Training; **MMT** = Musical Mnemonics Training; **MNT** = Musical Neglect Training; **MS** = Multiple Sclerosis; **MSOT** = Musical Sensory Orientation Training; **MUSTIM** = Musical Speech Stimulation; **OMREX** = Oral Motor and Respiratory Exercises; **PD** = Parkinson's Disease; **PSE** = Patterned Sensory Enhancement; **RSMM** = Rational Scientific Mediating Model; **RAS** = Rhythmic Auditory Stimulation; **RSC** = Rhythmic Speech Cueing; **SYCOM** = Symbolic Communication Training Through Music; **TBI** = Traumatic Brain Injury; **TS** = Therapeutic Singing; **TIMP** = Therapeutical Instrumental Music Performance; **TDM** = Transformational Design Model; **VIT** = Vocal Intonation Therapy.

## APPENDIX III: REPORTING MUSIC-BASED INTERVENTIONS GUIDELINES

**Table 5.** Checklist For Reporting Music-based Interventions (58)

| **Music-based intervention reporting criteria** |
|---|
| **A: Intervention theory**<br>Provide a rationale for the music selected; specify how qualities and delivery of the music are expected to impact targeted outcomes. |
| **B: Intervention content**<br>Provide precise details of the music intervention an, when applicable, descriptions of procedures for tailoring interventions to individual participants. |
| **B.1: Person selecting the music**<br>Specify who selected the music: (1) pre-selected by investigator; (2) participant selected from limited set; (3) participant selected from own collection; or (4) tailored based on patient assessment. |
| **B.2: Music**<br>When using published music, provide reference for sheet music or sound recording.<br>When using improvised or original music, describe the music's overall structure (i.e., form, elements, instruments, etc. ). |
| **B.3: Music delivery method (live or recorded)**<br>When using live music, specify who delivered the music and the size of the performance group (e.g., interventionist only, interventionist and participant).<br>When using recorded music, specify placement of playback equipment and the use of headphones vs. speakers. Specify who determined/controlled volume (e.g., interventionist; participant.<br>Specify decibel level of music delivered and/or use of volume controls to limit decibels. |
| **B.4: Intervention materials**<br>Specify music and/or non-music materials. |
| **B.5: Intervention strategies**<br>Describe music-based intervention strategies under investigation (examples: music listening, songwriting, improvisation, lyric analysis, rhythmic auditory stimulation, etc.). |
| **C: Intervention delivery schedule**<br>Report number of sessions, session duration, and session frequency including practice sessions. |
| **D: Interventionist**<br>Specify interventionist qualifications and credentials.<br>Specify how many interventionists deliver study conditions. |
| **E: Treatment fidelity**<br>Describe strategies used to ensure that treatment and/or control conditions were delivered as intended (e.g., interventionist training, manualized protocols, and intervention monitoring). |
| **F: Setting**<br>Describe where the intervention was delivered: include location, privacy level, and ambient sound. |
| **G: Unit of delivery**<br>Specify whether interventions were delivered to individuals or groups of individuals, including the size of the group. |

*Note: This checklist may be reprinted and used without permission as a tool to help ensure transparent reporting of music-based interventions.* (58)