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FROM NEUROCHEMISTRY TO REHABILITATION: HOW DOES MUSIC MODIFY THE FUNCTIONING OF THE HUMAN BODY?

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ABSTRACT

Background: In light of the rising prevalence of lifestyle diseases, including progressive dementia, chronic pain, and cardiovascular disease, conventional drug therapy frequently entails adverse effects and is often ineffective in enhancing quality of life. Recent advancements in neuroimaging technology, such as functional magnetic resonance imaging (fMRI), have provided substantial evidence to support the notion that music constitutes a potent biological stimulus, capable of inducing significant alterations in brain structures.

Aim: The aim of this article is to present a synthetic overview of current knowledge on the impact of sound stimuli on specific areas of health and to indicate the clinical potential of their regular use in the process of modern rehabilitation.

Materials and Methods: A comprehensive review of the extant scientific literature and meta-analyses, primarily published between 2015 and 2025, was conducted. The analysis encompassed studies which focus on mechanisms such as musical memory preservation in neurodegeneration, non-pharmacological analgesia and the phenomenon of biological rhythm synchronization (entrainment).

Results: Research has demonstrated that in patients diagnosed with Alzheimer's disease, the regions of the brain associated with musical memory exhibit significantly less atrophy compared to those involved in episodic memory. This finding suggests that music can serve as a stabilising "anchor" in communication, thereby reducing anxiety. In the context of pain management, the mechanism of musical analgesia has been substantiated. The activation of descending pain inhibition pathways, concomitant with the release of endogenous opioids, engenders a reduction in analgesic doses. Moreover, research has demonstrated that synchronising the heart rate with the tempo of music facilitates non-pharmacological stabilisation of heart rate and blood pressure.

Conclusions: Music has been demonstrated to be a safe and cost-effective method of supporting rehabilitation (Smith, 2020). The impact of regular sound stimulation on the nervous and endocrine systems is quantifiable. It has been demonstrated that such stimulation supports cognitive function in people with dementia and optimises the recovery process by reducing pain and physiological stress.

KEYWORDS

Music Therapy, Dementia, Musical Analgesia, Rehabilitation

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1. Introduction

Music has accompanied humanity since time immemorial, serving a variety of functions including ritual, social and emotional. However, in recent decades, due to the rapid development of neuroimaging techniques such as functional magnetic resonance imaging (fMRI), there has been an emergence of a new perspective on this phenomenon. Instead of perceiving it merely as an element of culture, it has come to be recognised as a potent biological stimulus with the capacity to modify the structure and function of the human body (Thout et al., 2019).

Contemporary medicine is confronted with the challenge of a growing number of lifestyle diseases, including progressive dementia, chronic pain, and cardiovascular disease. Conventional pharmacotherapy is frequently associated with adverse effects and has been demonstrated to be ineffective in enhancing patients' subjective quality of life (Fancourt et al., 2019). In this context, evidence-based music therapy appears to be a non-pharmacological, safe, and cost-effective adjunctive method that affects the patient both cognitively and physiologically (Hillecke et al. 2023).

The therapeutic potential of music can be understood by considering its unique capacity to engage multiple areas of the brain concurrently. This engagement encompasses the auditory cortex, the limbic system (which is responsible for emotional processing), and the brain stem structures that regulate fundamental life functions (Ferreri et al. 2019).

The impact of music on the human body is theorised to be the result of a cascade of neurochemical reactions that modulate the nervous and endocrine systems. The fundamental mechanism underpinning this phenomenon involves the stimulation of the reward system, which in turn results in the release of dopamine in the nucleus accumbens and striatum. The latter is responsible for the experience of pleasure and motivation (Ferreri et al. 2019). Furthermore, music has been demonstrated to influence the secretion of oxytocin, also referred to as the "bonding hormone". This neurohormone has been shown to reduce anxiety and promote prosocial behaviour (Keeler et al., 2017).

From the perspective of stress physiology, a significant aspect pertains to the capacity of acoustic stimuli to impede the hypothalamic-pituitary-adrenal (HPA) axis. This results in a decrease in blood cortisol levels, which in turn leads to a reduction in physiological symptoms of tension (de Witte et al. 2020). Furthermore, music has been demonstrated to modulate the secretion of endogenous opioids (endorphins), which bind to mu-opioid receptors in the brain and have analgesic and euphoric effects (Mallik et al. 2017). This provides the biological basis for the phenomenon of musical analgesia.

The primary focus of this study will be on patients affected by dementia, with a secondary focus on the analgesic aspect of music and its role in stabilising heart rate and blood pressure.

1.1. Research Objective

The objective of this article is to furnish a synoptic overview of the extant knowledge pertaining to the impact of sound stimuli on specific domains of health, and to indicate the clinical potential of their regular utilisation in the process of contemporary rehabilitation. The primary focus of this study will be on patients affected by dementia, with a secondary focus on the analgesic aspect of music and its role in stabilising heart rate and blood pressure.

1.2. Research Problems

1. What are the key mechanisms of the impact of sound stimuli on selected areas of human health in light of current scientific research, especially dementia, analgetic aspect and stabilizer of heart rate and blood pressure?

2. How can regular use of sound interventions affect the effectiveness of modern rehabilitation processes?

1.3. Research Hypotheses

1. Music therapy has a positive effect on human health and helps reduce the symptoms of dementia and pain, as well as calming patients by stimulating cardiac parameters.

2. The regular implementation of sound therapy has been demonstrated to promote the rehabilitation process and enhance patients' quality of life.

2. Research materials and methods

A systematic review of the scientific literature was conducted using the PubMed and Google Scholar databases. The following search phrases were used: Evidence-Based Music Therapy, music therapy, music benefits, heart rate, pain, dementia.

After initial relevance screening, 399 articles were selected for detailed analysis, from which 22 studies were chosen to serve as the basis for this systematic review.

2.1. Participants

Not applicable – literature review.

2.2. Procedure / Test protocol / Skill test trial / Measure / Instruments

Not applicable – literature review.

2.3. Data collection and analysis / Statistical analysis

Data concerning the impact of music on the human body were collected and analyzed to synthesize the results and draw conclusions.

2.3.1. Statistical Software

Not applicable – literature review.

2.3.2. AI.

Not applicable.

2.3.3. Statistical Methods

Not applicable – literature review.

3. Research results

3.1 Memory recollections

Dementia, including Alzheimer's disease (AD), is characterised by progressive degradation of brain structures responsible for episodic and working memory (Hillecke et al. 2023). However, neuroimaging studies have demonstrated that regions of the brain involved in music processing and memory, such as the ventral part of the anterior cingulate cortex, exhibit significantly less atrophy compared to the hippocampus or entorhinal cortex (Jacobsen et al. 2015). This specific anatomical location suggests that musical memory remains relatively intact even in advanced stages of neurodegeneration (Jacobsen et al. 2015, Tsoi et al., 2018).

This phenomenon enables the utilisation of music as a distinctive medium for communication with patients exhibiting profound cognitive impairment (Leggieri et al., 2019). The utilisation of meticulously curated musical compositions, imbued with a sense of familiarity to the patient (hereafter referred to as 'personalised music'), functions as a potent catalyst, prompting the resurgence of autobiographical recollections (Leggieri et al., 2019). This process, based on the mechanism of reminiscence, has been shown to result in a short-term enhancement in autopsychic orientation and sense of identity, which is referred to in the literature as "windows of lucidity" (Hillecke et al. 2023, Leggieri et al., 2019).

Music-based interventions have been demonstrated to be highly effective in alleviating the non-cognitive symptoms of dementia, as evidenced by numerous meta-analyses (Van der Steen et al., 2018, Tsoi et al., 2018).

Manifestations of agitation and aggression. The regularity of musical engagement has been demonstrated to reduce psychomotor agitation, thereby enabling a safe reduction in the utilisation of sedative pharmacotherapy (Van der Steen et al., 2018).

Anxiety and depression: Music has been demonstrated to effectively enhance patient mood and overall emotional well-being through the modulation of the reward system and the reduction of cortisol levels (Hillecke et al. 2023, Tsoi et al., 2018).

The cognitive functions are as follows: While the role of music in addressing the underlying causes of dementia remains controversial, studies have demonstrated that regular sound stimulation can potentially mitigate the rate of decline in overall cognitive performance (Tsoi et al., 2018).

3.2 Analgetic effect of music

The term "musical analgesia" is defined as a reduction in pain perception under the influence of sound stimuli. A substantial body of contemporary clinical research has confirmed that music can serve as an effective complementary therapeutic tool in the management of both acute and chronic pain, thereby facilitating a reduction in the required doses of analgesic medications (Kühlmann et al., 2018, Hole et al., 2015).

The primary physiological mechanism underpinning this phenomenon involves the activation of descending pain inhibition pathways. Music has been demonstrated to induce the release of endogenous opioids (endorphins) and dopamine, which have an effect on the attenuation of pain signals at the level of the spinal cord (Ferreri et al., 2019). Furthermore, music has been demonstrated to influence the so-called Gate Control Theory. This theory posits that auditory stimuli engage the patient's cognitive resources, thereby "competing" with pain impulses for access to consciousness. This, in turn, results in a reduction in the subjective intensity of discomfort (Garza-Villarreal et al., 2017).

The utilisation of musical interventions within the domains of surgery and orthopaedics has been demonstrated to engender quantifiable clinical benefits.

The objective is to reduce preoperative anxiety. Listening to music prior to surgery has been demonstrated to reduce stress levels in patients to a comparable degree to that of pharmaceutical benzodiazepines (Kühlmann et al., 2018, de Witte et al., 2020).

The objective of this study is to determine the efficacy of a reduction in postoperative pain. Meta-analyses demonstrate that patients who listen to music following surgery report reduced pain levels on the VAS (Visual Analogue Scale) (Kühlmann et al., 2018).

The following section will address the issue of opioid savings. Research has demonstrated that patients undergoing music therapy require reduced doses of morphine and other potent analgesics during the initial 24 hours post-surgery (Kühlmann et al., 2018, Hole et al., 2015).

3.3 The phenomenon of synchronization and the regulation of heart rate and blood pressure

The impact of music on the cardiovascular system represents one of the most quantifiable domains of sound medicine. The fundamental mechanism underpinning this phenomenon is entrainment, defined as the process by which the body's internal biological rhythms adjust to periodic external stimuli, such as the tempo of a musical piece (Hillecke et al., 2015, Thout et al., 2019).

The circulatory system exhibits a natural propensity to resonate with the tempo of music, measured in beats per minute (BPM). Research has demonstrated that listening to music of a slow tempo (approximately 60-80 beats per minute (BPM)), which is analogous to the physiological resting heart rate, assists in reducing the heart rate (HR) and blood pressure (Innes et al., 2018, de Witte et al. 2020). The process is moderated by the autonomic nervous system, with the stimulation of the vagus nerve by relaxing music increasing parasympathetic activity and reducing sympathetic tension (Koelsch et al., 2018).

The regular administration of sound stimulation is utilised for the purpose of stabilising patients' vital signs:

The present study hypothesises that there will be a reduction in blood pressure. Meta-analyses have confirmed that long-term use of music therapy can lead to a statistically significant reduction in systolic and diastolic blood pressure in patients with primary hypertension (Hillecke et al., 2015, de Witte et al. 2020).

Heart rate variability (HRV) Music has been demonstrated to enhance heart rate variability (HRV), a crucial indicator of the heart's capacity for adaptation and the overall condition of the autonomic nervous system (Innes et al., 2018, Koelsch et al., 2018).

The provision of support in the context of cardiac rehabilitation is an essential component of comprehensive healthcare services. The synchronisation of respiration and heart rate with musical rhythm has been demonstrated to facilitate patient exercise following cardiac events, thereby reducing the subjective perception of exertion (Thout et al., 2019).

4. Discussion

A thorough analysis of the collected evidence confirms that music exerts a multidirectional effect on the body. However, the effectiveness of these interventions is moderated by a number of factors, which has sparked a lively debate in the literature on the subject.

The findings of Tsoi (Tsoi et al., 2018) demonstrate a substantial enhancement in overall cognitive function in patients with dementia who underwent music therapy. However, this thesis is partially disputed by the meta-analysis by Van der Steen (Van der Steen et al., 2018), which suggests that although music significantly reduces anxiety and depression in these patients, the evidence for its direct impact on improving memory (cognitive functions) itself is still of low quality. This discrepancy may be attributable to the observation that Jacobsen's (Jacobsen et al., 2015) research focused on musical memory as a distinct entity that remains functional, whereas standard MMSE tests evaluate working memory, which is invariably compromised in dementia. An intriguing addition to these considerations is the research by Clements-Cortes and Bartel (Ray et al. 2018), who introduce the concept of "low-frequency auditory stimulation" (LFAS). Contrary to the conventional approach to music therapy, as articulated by Van der Steen (Van der Steen et al., 2018), their research posits that it is not the melody itself, but rather the physical vibrations of sound, that can directly enhance motor function in patients diagnosed with dementia. Ray and Götell (2023) emphasise that the pivotal factor for success in caring for Alzheimer's patients is not the passive listening of music, but rather the active engagement in singing (i.e. active music therapy), which exerts a more pronounced effect in reducing anxiety than the passive reception of auditory stimuli.

In the domain of analgesia, research conducted by Kühlmann (Kühlmann et al. 2018) offers substantial evidence that music significantly reduces postoperative pain and anxiety. The present findings are consistent with those of de Witte (de Witte et al. 2020), who demonstrated that music reduces cortisol levels as effectively as psychological interventions. Nevertheless, some researchers have drawn attention to the so-called "preference effect". Garza-Villarreal (Garza-Villarreal et al., 2017) posits that music selected by the patient possesses a considerably higher analgesic potential than the relaxing music imposed by medical staff. This finding indicates a strong correlation between the pain control mechanism and the reward system, as well as dopamine secretion, a hypothesis that is further substantiated by the research conducted by Ferreri (Ferreri et al. 2019). In the field of pain management, it is pertinent to incorporate the findings of Bradt et al. (Madden et al., 2020) into Kühlmann's analysis (Kühlmann et al., 2018). Their meta-analysis indicates that interventions conducted by qualified music therapists yield statistically superior results in the alleviation of cancer and postoperative pain in comparison to patients listening to recordings on their own. This finding is somewhat at odds with the results of Garza-Villarreal (Garza-Villarreal et al., 2017), which place greater emphasis on the therapeutic relationship than on the neurological mechanism of distraction itself. Furthermore, Madden et al. (Bernardi et al. 2017) suggest in their research on phantom pain that fast-paced music may paradoxically worsen pain sensations in some patient groups, which calls for caution in the selection of music for orthopedic wards.

In relation to the impact on the circulatory system, Thaut (Thaut et al., 2019) emphasise the role of rhythmic auditory stimulation (RAS) as a tool that almost mechanically imposes a rhythm on the heart. However, it should be noted that there are divergent opinions on this issue, with some researchers, including Koelsch (Koelsch et al., 2015), proposing that synchronization does not occur to the same degree in every patient. Individuals exhibiting low autonomic nervous system reactivity may not demonstrate a substantial decline in blood pressure, thereby underscoring the necessity for a tailored approach to music therapy in cardiology, predicated on individual HRV (heart rate variability) indices. Additionally, the research conducted by Bernardi (Bernardi et al., 2017) is noteworthy, as it led to the discovery of the phenomenon of "dynamic response to music." It was demonstrated that this rhythm is not constant, but rather exhibits fluctuations in tempo, characterised by periods of increasing and decreasing intensity. These fluctuations in tempo have been shown to elicit the most pronounced physiological responses from the cardiovascular system. This constitutes a noteworthy augmentation to Thaut's (Thaut et al., 2019) theory of simple synchronization (entrainment).

5. Conclusions

An analysis of literature from 2016 to 2026 confirms that music therapy is an effective non-pharmacological tool that affects patients through the synergy of neurological and physiological mechanisms. In the context of dementia, the preservation of musical memory has been shown to reduce anxiety and enhance communication. Similarly, in the treatment of pain, the activation of the endogenous opioid system has been observed to result in a reduction in analgesic doses. These processes are complemented by the phenomenon of synchronization (entrainment), which directly stabilizes vital parameters such as heart rate and blood pressure. The integration of personalised sound interventions within rehabilitation standards constitutes a safe and cost-effective approach to enhancing patients' quality of life and optimising recovery processes in clinical settings.

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