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Music in Health and Diseases

Edited by Amit Agrawal, Roshan Sutar and Anvesh Jallapally

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Meet the editors

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Preface

Music has the power to improve mental health as a form of art that is easily accessible and has instantaneous effects on one's mind. Music is a form of sound energy that has great potential to heal both the body and mind. Studies show that music therapy is particularly effective in patients with cognitive deficits. In India, music therapy is a blend of symphonic compatibility between the seven notes (i.e., swara) and seven primary chakras in the human body. Ragas, which are central features of classical Indian music, have an innate quality of affecting the emotions of the listener and hence overall wellbeing. Music therapy is a unique option for rehabilitating patients with cognitive deficits as well as maintaining wellbeing in healthy individuals. This book focuses on various aspects of music and its role in enhancing health and recovering from a disease. Chapters explore music as a healing method across civilizations and measure the effect of music on human physiology and functions.

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Chapter 1

Introductory Chapter: Introducing Biobehavioral Perspective of Music

Roshan Sutar, Ashish Pakhre, Anuradha Kushwah and Amit Agrawal

1. Introducing biobehavioral perspective of music

Listening to music is an important part of a pleasant human experience. It allows the ventilation of pent-up emotions in a socially acceptable manner. Music does affect large aspects of human emotions and impacts biobehavioral processes such as arousal, concentration, sleep, and social bonding. There is evidence reporting on the effect of music activating complex neural networks critical for cognitive and emotional processing. Therapeutic effects of listening or playing music have been a focus of research in recent years especially focusing on the regulation of mood under strained physical and psychological conditions. It is important to realize from a cognitive neuroscience perspective how the musical tones are linked to synchronous activation of certain emotional states with the genre of music that is being played. It is also crucial to understand the neural correlates involved in the transformation of musical experience into generating certain emotional or mood states. How music-based therapeutic model function is being explored and has been attempted under various clinical circumstances? Therefore, it is pertinent to comprehend the psychological aspects governing emotional responses to music in human beings.

2. Music types and significance from a biobehavioral standpoint

Literature supports the evidence for the induction of certain emotional states with music. The various psychological frameworks that are involved in listening to music are cognitive appraisal, episodic memory, musical expectation, emotional contagion, visual imagery, and rhythmic entrainment. The induction of pleasure experience is widely studied and dopaminergic activity reinforcement is considered as a postulated target for a music-induced rewarding experience. It is significant to understand that why some combinations of sounds become pleasant to humans but not to animals? A possible reason being the mesolimbic system interacts with other regions of the brain but structural and functional connectivity varies across the species due to the complexities of the brain. The concept of reward in human existence can take various forms, such as enjoying the process of attending music concerts, reading fiction, visiting museums, photography, and esthetic activities such as planting flowers, decorating wardrobes. Esthetic rewards are often abstract and involve significant cognitive components that could be appreciated by well-developed neuronal connections in humans. The rewarding nature of esthetic stimuli varies across cultures and between individuals within the same cultures, depending on previous experiences with a particular nature of stimuli. A musical lexicon is a storage system for musical information, which stores whatever an individual has been exposed in their life. This system is considered to help an individual to categorize the type of music they are listening to and subsequently determine its reward value for that individual. It is observed that listening to classical and self-selected music can result in a reduction in anxiety, anger, and sympathetic nervous system arousal and lead to increased relaxation but not so when heavy metal music or such genres are played. Similarly, music with a slower tempo is associated with sadness and lower levels of evoked arousal. This is also associated with increased mind-wandering during sad music suggesting differential levels of enjoyment during sad and happy music [1]. Stimulation of the parasympathetic nervous system and positive emotional experience occurs when classical and relaxing self-selected music is perceived by an individual. There is strong support for self-selection of musical choice, which induces enhancement of mood states, greater joy, reduced anxiety, and sadness. Individuals with high levels of emotional distress and trait can benefit from musical upliftment of emotional state. It is to be noted that the impact of the type of music on subjective and physiological parameters may vary and may not be consistent. Therefore, it is crucial to consider individual variation for music-associated mood upliftment. However, most commonly observed responses include the experience of jazz music to enhance mood state with increasing age. A variety of musical pieces or genres may be required to see the influence on physiological and emotional responses and to determine the best suitable fit for any therapeutic purpose.

3. Differential effects of music on neuronal circuits during listening, singing, and playing

Music is considered a language of communication among musicians because it exhibit characteristic features such as melody, timbre, rhythm, and expression. Music composition essentially involves a complex interplay of mathematics, geometry, and language that gives the amalgamation of existential and materialistic interwoven structure and texture to it [2]. Passive listening to the music of a certain type involves passive engagement of the auditory apparatus and resting-state network of the brain. Perception of self and passive participation of audio-visual sensory apparatus is best understood through activation of the default mode network of the brain [3]. Surprisingly, the processing of the music among non-musicians can be effectively handled by our neuronal networks of the brain to produce feelings of joy, tears, and love! This endorses the hypothesis that the interplay of music and emotions is a part of collective unconsciousness accessible to each individual that can be tapped without learning the theories of music. Further active participation in listening can help to express emotions openly, which is automatically executed by different areas of the brain. The best example is the semi-automatic participation of the motor cortex in activating different areas of the body such as hands, legs, fingers, and trunk to simulate the generalized dance-like movement of the body. What happens during singing then? Singing is an active sensory-motor process that orchestrates the multisensory involvement through direct and active neuronal participation in addition to inputs from audio-visual sensory apparatus. We all have a song that we deeply connect to and appreciate; therefore, even the analysis of lyrics provides an opportunity for an individual to identify the song that may correlate with their experience. On the other hand, playing a musical instrument additionally adds up the active processing of the motor cortex through activation of the prefrontal area of the brain. The fine motor aspects of finger movements and bilateral hand-eye-ear coordination set a platform that establishes sensory-motor harmony with the internal state of consciousness and vibes of music. Songwriting gives freedom to articulate in a positive and remunerating way that can help to mirror own contemplations and encounters with the help of instruments and beats. This cycle can be self-approving and can help in building self-esteem and immersing oneself within. The imprints generated from this harmony help to build a neuronal primer for functional neuroplasticity of the brain [4]. This affects emotion processing through decoding by the same reward system of the brain used for hunger, thirst, and sex. The difference lies probably in the ceiling effect of the basic rewards in contrast to music-associated rewards. Our neuronal networks are adapted to have a specific threshold of inhibitory signaling to garner the internal homeostasis of the physical body. This is applicable for satiety and orgasm; the processes help to keep the inhibitory check on the basic reward system. For music, the sheer nature of the combination of predictability and expansive creativity, there is no ceiling effect observed by the brain and even the old pieces of music can be perceived as completely new through alteration in varieties of neuropsychological parameters such as attention, memory, motor control, imagery, spatial processing, and abstract thinking. Though contemporary music is blended with a semantic word, mere listening to instrumental tunes or ragas brings about the identity of music as a universal and existential construct [1]. This is probably the biggest reason why psychophysiological processes are inherently involved beyond the geographic, ethnic, linguistic, religious, and cultural context to give rise to the feeling of connectedness with the language of music. The language of the music can engage the different areas of the brain simultaneously with neurohormonal changes to produce its effect through tears, goosebumps, bringing changes in skin conductivity, and heart rate variability. The extra edge of the impact of musical processes on the human mind opens up the possibility of infinite potential and carries the ability to transcend to ecstasy as described by spiritual texts.

4. Neuronal reward mechanisms and the process of subjective "high" with music

It is seen that the reward produced by the components of music is mediated through areas of the brain involving ventral tegmentum, nucleus accumbens, insula, and hippocampus through neurohormones involving dopamine, oxytocin, vasopressin, and opioids [5, 6]. Additionally, immune mediators such as interleukins and cytokines are also activated in carrying out the perceived response to music. Oxytocin as well as vasopressin have a strong effect on the development of empathy and social bonding. Thus, a group singing activity has the potential to hypnotize millions of individuals that work through a sense of cohesiveness produced by the differential effect of components of music [7]. Besides oxytocin being the hormone of love, it generates affection by regularizing the emotional disharmony in our mind [8]. This happens to be the reason why components of music are generally appreciated for motivation, peacefulness, and tranquility by many of us. Many people perceive music as energetic, powerful, and inspired when presented with the contextual semantic context. In a way, music has the quality to amplify and transcend our emotional state to a higher level [1]. The reason for portraying the symbol of gods and goddesses with a variety of music organs is a testimony of our ancient understanding of music. Music brings the union of unconscious memory with conscious emotions and this technique is being researched in neuroscience. The recollection of events associated with happy memories and their powerful coding can be traced in the form of the personal toolkit in patients with recurrent depressive disorder, post-traumatic stress disorder, and Alzheimer's dementia [9].

Different types of music can resonate with the functional networks in the brain, which indirectly help in inducing alteration in the perception of emotions and thoughts. Regular listening or playing of a certain type of music delivers potential neuroplastic effects on the structural synapses and exerts functional changes that could be utilized as a facilitatory approach in certain mental health conditions [10]. The fundamental basics of which lies in the synchronization or matching between the frequency of structured sound waves and neuro-hemodynamic oscillations needs to be addressed in future research.

The impatience and impulsivity of the mind can be effectively replaced by music by changing the attentional processes of the brain. Music can be used to direct the mindset. Because of its rhythmic and repetitive aspects, music engages the neocortex of our brain, which calms us and reduces impulsivity. In addition, since music utilizes the same reward pathways of the brain used by the substances of addictions, can music be proposed as a form of healthiest addiction in such clients remains the area of future research [11].

5. Music therapy as a primer for disorders of mental health

There is emerging evidence to support the use of music therapy in the treatment of disorders of mental health. Literature shows different models of music therapy that have been developed. In a systematic review of music therapy in an adult acute psychiatric care setting, delivery of music therapy and its effect on acute stages of mental illnesses were assessed [12]. It is important to note that the delivery of music therapy faces a challenge when disorders of mental health are concerned and chronic mental health conditions could be better suited than acute states. These challenges could be the type of music, type of setting, diverse needs of the patients, and ethical fitness. Due to the severity of symptoms, engagement and attendance become difficult for music therapy. It is challenging to establish the role of isolated music therapy in depressive disorders as studies have limitations in terms of methodological approaches and heterogeneity across the models [9]. But some randomized trials have shown that the combined approach of music therapy and standard care has been effective in ameliorating depressive symptoms, anxiety, and quality of life. Findings from a recent review on the role of music therapy in depression versus treatment, as usual, indicated that music therapy does provide short-term beneficial effects in reducing depressive symptoms. Treatment as usual combined with music therapy has done better in improving depressive mood states compared to treatment as usual approach in addition to the reduction of anxiety levels and enhancement of overall functioning in depressed patients. In a review comparing music therapy with standard of care, placebo, or no treatment, moderate to low quality of evidence for music therapy as add-on treatment was established in improving negative and general symptoms, social functioning, and quality of life of patients with schizophrenia. It is important to note that outcome effects have shown variation due to the number of sessions given and the quality of music therapy delivered. It is considered that musical experience and improvement in relationship development may help in communication and expression in patients with autism spectrum disorder, a study that compared music therapy or music therapy add-on to the standard of care with placebo or no treatment. Short-term and medium-term effects on music therapy delivered in children diagnosed with autism were assessed from 10 studies indicated that music therapy may assist children in improving social interaction, communication, understanding social–communication reciprocity. Music therapy also enhanced non-verbal communication skills in these patients. It is suggested that music therapy positively contributes to enhancing social adaption skills in patients with autism and improve the quality of child–parent relationships. But important to understand the fact that music therapy services require specialized academic and clinical training, which may halt the wider reach. More research in this area can improve our understanding regarding overcoming the challenges in research designs and improve the effect size of the outcome in mental health disorders.

6. Music therapy for mental healing and conclusion

Much old is the relationship between music and the mind. Ancient Greek Philosopher, Plato (428–347 BC), cited "Music gives a soul to the universe, wings to the mind, flight to the imagination and life to everything." Plato thought that music played in various modes would excite various feelings. This is applicable even today, where an influence of music is utilized to build up a remedial relationship, sustain an individual's development, and aid in self-realization. The relief from day-to-day stress could be achieved through self-selected music by non-professionals to the development of deeper connection with the self by professionals, the cycle is a vicious process. In this process, music is consciously being used for the enhancement of living, being, and becoming. Music acts as a medium for processing emotions, trauma, and grief but music can also be utilized as a regulating or calming agent for anxiety-like states. In a nutshell, music therapy is the use of music as a therapeutic tool for the restoration, maintenance, and improvement of psychological and physiological health through achievements across physical, social, and spiritual dimensions.

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Chapter 2

Music Therapy in Medicine of Islamic Civilisation

Roziah Sidik, Azmul Fahimi Kamaruzaman and Mohd Jailani Abdullah

Abstract

Ibn Sina's (Avicenna) denotes that one of the most effective methods in medical treatment is listening to music, which clearly illustrates the position of music therapy in medical treatment. This chapter discusses four matters: (i) the concept of music therapy as medical treatment, (ii) the function of music therapy as a method of complementary treatment aimed more towards calming and relieving pain, but not as a total cure for the patient, (iii) the hospitals that applied music therapy as treatment, and (iv) the process of applying music therapy in the medical tradition of the Islamic civilisation. Music here includes instrumental music, the sound of singing, *adhan* (call to prayer), Quranic recitation, as well as sounds of nature, such as of birds singing and of water from a fountain pool. Among the hospitals that applied such therapy was Bimarastan Fez in Morroco, Bimarastan al-Mansuri at Cairo, Egypt, Bimarastan al-Arghuni at Allepo, Syria, Bimarastan Nur al-Din at Damascus City, and Suleymaniye Sifahanesi.

Keywords: music therapy, medicine, Islamic civilisation

1. Introduction

Using music as a therapy has been discussed and practised in various civilisations of the world. The act was thought to begin earlier than Islamic civilisation. A study by Mohd Jailani [1] showed that music therapy was applied in the ancient civilisations of Egypt, China, Greece, and Roman. The ancient Egyptians were described by al-Farabi [2] as pioneers in the field of music based on a picture depicting David treating Saul with *al-ma'azif* (a stringed musical instrument) for a melancholia caused by the disturbance of evil spirits (or deities). The influence of evil spirits gradually eroded the good spirit from Saul's body, and David applied music therapy to Saul until his health was restored. This picture was found on the wall of a tomb in Thebes (ancient Egyptian city east of the Nile River) [3]. The first ancient Egyptian physician who used music therapy in treatment was I-em hotep, a competent physician who lived around 3500 B. C, in the era of the third Dynasty of Ancient Egypt. I-em hotep also established a medical institution that applied music therapy as a line of treatment [4].

The history of ancient Chinese civilisation indicates that the Chinese had already recognised the benefits of music therapy since 4000 years ago [5]. The Chinese Emperor (Emperor Chung) himself was convinced that well-composed music could evoke the feelings of tolerance, compassion, pleasure, and courage, thus indicating that music could affect human emotions. Confucius, a well-known Chinese philosopher, also stated that music can improve eyesight, sharpen hearing, and improve blood circulation [6]. He considered the art of music as a symbol of civilization [7, 8].

The Greek civilisation similarly believed that music therapy could play an important role in dealing with physical, mental, and spiritual health problems. Koc et al. [6] reported that the Greek poet Homer (who lived in the 9th Century BC) mentioned the ability of music therapy to stop bleeding. Music therapy was therefore said to be suitable for patients who underwent surgery. Pythagoras (who died in the year 495 BC) also recommended that music therapy be applied to a hot-tempered person and to those who suffer from disappointment. Pythagoras also believed that music therapy is very effective in treating diseases caused by hormonal disorders in the body [5]. According to Penelope & Burnett [9], Pythagoras had practically applied music therapy on an intoxicated young man from Taormina (located in Sicily) to restore his sanity and calm him down.

Music therapy was also applied as a line of treatment in the Roman civilisation [6]. The Roman society used it to assuage grief, overcome hysteria, alleviate pain from poisonous insect bites, treat microbial diseases, and treat dumb patients. Examples of music-based treatment in the Roman civilisation were their applications for individuals who suffered psychological disorders and for deaf people (using a trumpet). The therapy was also used in treating severe mental disorders, such as anxiety or restlessness. The Roman society believed that music therapy could alleviate pain, strengthen their spirit, and increase perseverance when they were unwell [10].

2. Concept of music therapy as medical treatment

We refer to several organisations to obtain a more precise definition of music therapy. The American Music Therapy Association (AMTA) defines music therapy as a clinical and evidence-based use of music interventions to accomplish individualised goals within a therapeutic relationship by a credentialed professional who has completed an approved music therapy program [11]. Another organisation, the World Music Federation Therapy (WMFT), refers to music therapy as the professional use of music and its elements as an intervention in medical, educational, and everyday environments with individuals, groups, families, or communities who seek to optimise their quality of life and improve their physical, social, communicative, emotional, intellectual, and spiritual health and well-being. Research, practice, education, and clinical training in music therapy are based on professional standards according to social, cultural, and political contexts [12]. Music therapy is also defined as a therapy based on engagement in musical activities, namely the use of music as a therapeutic element to reduce anxiety, improve cognitive functioning, promote physical rehabilitation, and enhance interpersonal communication [13].

In the context of the Islamic civilisation, we use the definition of music therapy expressed by al-Faruqi [14]: the art and science of combining sounds or voice tones or instrumental sounds to form various expressions that satisfy emotions, aesthetics and structure of the basis for belief system held. This definition sums up the three main characteristics that form the basis of music: (i) sound, tone of voice, and instrument; (ii) capability of satisfying emotions and aesthetics, and (iii) fulfilling a particular purpose in a belief system. This definition is found to be relevant to the concept of music therapy in the Islamic medieval era as follows:

i. Sound, tone of voice, or instrument

The method of music therapy is not limited to using only instrumental music and singing but also includes *adhan* (call to prayer), recitation of the Quran, and the sound of water as a medium of therapy, particularly with the elements in the sounds, such as tone, rhythm, and melody.

ii. Capability of satisfying emotions and aesthetics

Treatment with music therapy functions to give tranquillity, alleviate pain, and reduce symptoms. The therapy is one of the methods applied with main treatment (medication or surgery) besides using other complementary treatments such as aromatherapy, bath therapy, storytelling, dance, and theatre presentation.

iii. Fulfilling particular purpose in a belief system

Music therapy in the Islamic medieval era encompasses using music in *al-sama'* rituals by sufi dervishes at sufi activity centres, known as *khaniqah, ribat,* and *zawiyah*. The disciples of a sufi fraternity (*tariqa*), guided by their Sufi Sheikh or Master, used *al-sama'* as physical and mental therapy for the ennui (boredom and weariness) of the vagaries of life, and even as the remedy for the soul's longing to meet with the Divine. Hence, *al-sama'* is an essential ritual for sufis as it is considered a *wasilah* (means to get closer) to Allah SWT through the sense of hearing. It is also said to be the *wasilah* to gain peace of mind and purify the soul that has sinned. The reality of *al-sama'* is said to occur when a sufi experiences *al-wajd* (spiritual ecstasy in witnessing the grandeur of the Divine secret) and feels himself *fana'* (self-annihilation or extinction while still physically alive) from worldly affairs.

We can summarise here that music therapy is a treatment for increasing a person's health level emotionally, physically, and spiritually. It is not restricted to using particular musical instruments but includes the *adhan* (call to prayer), recitation of al-Quran, and sounds of nature (such as flowing water and singing of birds). However, music therapy is more of a complementary treatment applied adjunctly with main treatments, such as the use of medication or surgery.

3. Function of music therapy as a complementary treatment

As a medical treatment, music therapy has its functions. Among the functions, according to Ibn Sina and Ikhwan al-Safa, are (i) to entertain, soothe, relieve, or reduce pain; (ii) to strengthen body immunity (antibodies) to diseases; (iii) to help in healing, and (iv) to distract attention from pain and calm down, in order to facilitate the recovery process [15–17]. Clearly, the goal is more towards calming down and relieving pain, not to heal totally. On this basis, music therapy plays the role of complementary treatment. Another function of music therapy is to reduce stress as well as soothe and relieve symptoms. Cassileth and Deng [18] explained that a complementary treatment refers to the treatment administered adjunctly with the mainstream treatment. Music therapy is in the domain of body and mind intervention; it is categorised by the National Centre for Complementary and Alternative Medicine (NCCAM) (the Health Care Centre under the National Institute of Health of America) as a complementary treatment—similar to other treatments such as hypnosis, massage, and acupuncture [19]. The World Health Organisation (WHO) [20] refers to music therapy as a broad set of health care practices that are not part of that country's traditional medicine and are not fully integrated into the dominant health care system. However, if complementary treatment was to be integrated with conventional treatment, it would certainly improve its effectiveness and help to alleviate severe symptoms [21]. Complementary treatment is included in the category of mind and body therapeutic approach to assuage anxiety, emotional disorders, and chronic pain as well as increase the quality of life.

Hence, we can conclude that music therapy is a complementary treatment. In support of this, the treatment procedure is presented for some types of mental disorders for which music therapy was one of the treatments recommended to alleviate and distract attention from the pain, as stated in some authoritative medical works such as *al-Kamil fi Sina'at al-Tibbiyyah* by al-Majusi, *Maqalah fi al-Malikhuliya* by Ibn 'Imran and *al-Qanun fi al-Tibb* by Ibn Sina. Based on *al-Kamil fi Sina'at al-Tibbiyyah*, al-Majusi explained the treatment using music therapy for hypochondriac melancholia (*al-maraqiya*) and lovesickness (*al-'ishq)*. According to al-Majusi [22], a melancholia patient was also treated with music therapy besides treatment using evacuation (*istifragh*); pricking the calf and arm veins; and giving a bath, massage, oral medication, and nutritious diet. The patient was taken for a walk in the garden while listening to melodious strains of music. For the lovesick (*al-'ishq)* patient, music therapy was used adjunctly with bath treatment, horse riding, and massage. Music therapy was usually applied by playing the oud instrument.

Based on *Maqalah fi al-Malikhuliya*, Ibn 'Imran [23] suggested music therapy for treating melancholia besides nutritious diet, evacuation, mother's milk, warm water mixed with chamomile flowers, poppy peel, hibiscus seeds, violet leaves, liqourice and cloves, immersion therapy, bath therapy, and massage. In *al-Qanun fi al-Tibb*, Ibn Sina [24] explains that music therapy is for mental disorders, including insomnia, melancholia, and lovesickness. For insomnia, the treatment was to use music therapy through gentle and melodious singing with rhythms like *al-hazaj* and *al-thaqil*, besides other treatments, such as eating cold foods, bath therapy, smearing oil on the head, forehead and both sides of the area between the eye and jaw, rubbing milk on the head, dropping oil into the nose and ears, opium, and recreation. For treating melancholia, Ibn Sina recommended listening to music and singing, besides ventilation, selected foods, bath therapy, massage with poultice, medication, evacuation, cupping, wrapping, and distracting patient with something pleasurable and soothing, such as bringing someone he/she likes. For lovesickness, Ibn Sina recommended treatment by listening to singing or music, besides evacuation, nutritious diet, bath therapy, and counselling.

The treatment methods recommended by al-Majusi, Ibn 'Imran, and Ibn Sina for melancholia, insomnia, and lovesickness clearly illustrate that music therapy was not the main (conventional) treatment. Music therapy was more of an adjunct treatment to complement the main treatment methods suggested, with the role of overcoming symptoms so that the patient is distracted, calmed down, and entertained.

4. Hospitals that applied music therapy

Many Islamic civilisation medieval hospitals applied music therapy as a treatment. The hospitals were Bimarastan Fez (Sidi Frej) in Morocco, Bimarastan al-Mansuri in Cairo, Bimarastan al-Arghuni in Aleppo, Syria, Bimarastan Nur al-Din in Damascus, Kayseri Gevher Nesibeh Darussifas, Divrigi Ulu Mosque and Darussifas, Amasya Darussifas, Fatih Darussifas in Istanbul, Edirne Sultan Bayezid

II Darussifas, Suleymaniye Sifahanesi, and the hospital established by Ayse Hafsa Sultan.

Bimarastan Fez (Sidi Frej) in Morroco was built in the year 1286 AD by Sultan Yusuf ibn Ya'qub (Banu Marin). Here, patients suffering from depression were treated with music therapy, herbs, and spices [25]. This hospital was also a shelter for insane patients [26]. The writer's personal experience in a visit to the hospital site in Morocco in the year 2019 witnessed that it became a bazaar selling souvenirs to tourists. Interestingly, written on the notice board at the location was a statement that this hospital later became the prototype for building a psychiatric hospital in Valencia, Spain, in the year 1410 AD (**Figures 1** and **2**).

Bimarastan al-Mansuri in Cairo, Egypt (Mamluk era) was the hospital built in the year 1284 AD by Malik al-Mansur Sayf al-Din Qalawun. It was the most famous and prestigious in the history of Islamic medieval era hospitals and was acclaimed by many scholars. Al-Balawi [27] described the hospital as a marvellous large palace with the most perfect building structure. al-Qalqashandi [28] and Ibn al-'Umari [29] were very impressed with the hospital architecture and described the facility as highly reputable beyond compare. Ibn Batutah [30], who managed to visit this hospital on vacation in Egypt, also commented on its indescribable beauty. Hunke [31] denoted this hospital to be the biggest and richest health institute ever built on this planet. This hospital was operated fully using endowment *(waqf)* funds from the following sources (**Table 1**).

As recorded by Ibn Iyas [33], the endowment (*waqf)* documents required the hospital to comply with two stipulations. The first precondition was that an ensemble of musicians would play musical instruments, such as oud, every evening to

Figure 1.
Photo showing the original site of the hospital have been turned into bazaar selling souvenirs.

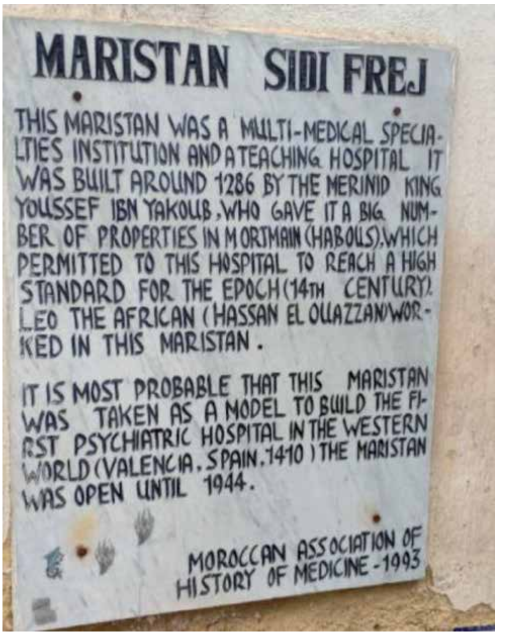

Figure 2.
Picture displaying information that the hospital was a prototype for building a psychiatric hospital in Valencia, Spain.

No.	Types of premises	Location
1	Qaysariyyah al-Subanah	Fustat
2	Funduq al-Malik al-Sacid (hotel)	Fustat
3	Hammam al-Sabat	Cairo
4	Qaysariyyah al-Mahalli	Cairo
5	Qaysariyyah al-Diyafah	Cairo
6	Qaysariyyah al-Fadil	Cairo
7	Suq al-Katbiyyin	Cairo
8	Suq al-Qufaysat	Cairo

Source: ʻIsa Bek [32] and Mohd Jailani [1].

Table 1.
A list of premises that channel endowment funds to Bimarastan al-Mansuri.

strengthen the spirit of patients. The musicians were paid a fixed monthly income. The second stipulation was that Qurra' were required to recite the holy verses of al-Qur'an in *al-Qubbah* (domed hall). They were also paid monthly with four *aradib* (600 kilogrammes) of wheat and birds such as pigeons.

As a hospital that applied music therapy as a treatment, it was designed with a suitable structure and landscape to support the implementation of music therapy. According to Dols [34], its landscape featured a pool, a water fountain, and a garden that had a therapeutic effect on patients. The sound of flowing water could be heard in every space in the hospital [35, 36]. The sound of *adhan* that reverberated from the nearby mosque minaret also became therapy for insomnia patients. This hospital also used the services of a specific ensemble of musicians to make a concert presentation so that the patients were always cheerful and restful [37]. These musicians were paid from a special provision for their daily performance [38]. After having served for seven centuries, the hospital is now called Mustashfa Qalawun for treating eyes or ophthalmology.

Bimarastan al-Arghuni in Allepo, Syria, was another hospital that applied music therapy. The building was originally a palace which was later modified to become a hospital by the Allepo governor Arghun al-Saghir al-Kamili (Mamluk Emir) in the year 1344 AD. The building continued to function as a hospital until the 16th Century AD. Music therapy applied in this hospital was not restricted to using instruments and singing, but also included the strains of Qur'an recitation every morning and evening. Interestingly, the hospital provided a stage specifically for the music ensemble to entertain patients, especially mental patients, so they would be calmer and always cheerful. The salaries for musicians were paid from a special allocation from the hospital expenditure [39].

Hospital al-Arghuni was also listed as a hospital that applied music therapy. In the same way, music therapy was applied to mental patients using instrumental music and the sound of water. Instrumental music used in therapy was played in a big *iwan* (vaulted hall with an arched opening to the courtyard) at the southern side of the hospital. There, musicians presented musical concerts with singing to entertain mental patients. For therapy using the sound of water, this hospital utilised the sound of flowing water from a fountain in a small pool in the middle of the hospital garden. The mental patients were also treated with the fragrance of flowers of potted plants placed in every corner of the pool and the entire hospital garden. In addition, the aroma of basil also had a therapeutic effect as an anti-depressant, as it helped to calm the mind. The mental patients were also entertained by dance and theatre presentations, storytelling, and the strains of Qur'an recitation [39].

Bimarastan Nur al-Din in Damascus had the design and landscape which supported applying music therapy for mental patients [40]. The hospital design and beautiful landscape featured a water fountain in a pool and garden, which had a therapeutic effect on mental patients. Even the sound of *adhan* reverberating from the mosque minaret nearby became therapeutic for insomnia patients [34]. However, this building no longer functions as a hospital as it was converted into a museum for the history of Arabic medical science [25].

Next, Kayseri Gevher Nesibeh Darussifas was also listed in the list of hospitals that applied music therapy [41]. Usually, this therapy was applied to mental patients whereby the hospital's own musicians performed three times daily in the middle section of the hospital, which extended directly to the patients' rooms through the balconies. The hospital musicians played several types of musical instruments such as flute, violin, tanboor, and dulcimer [42]. However, the hospital no longer functions as it was converted into a museum of the history of medicine of the Kayseri Gevher Nesibeh's Faculty of Medicine.

Divrigi Ulu Mosque and Darussifas was a hospital built by Turan Malik in the year 1228 AD. In this hospital, music therapy was intensively applied together with herbal treatment [41]. The application of music therapy was facilitated by the hospital building structure, which featured facilities conducive for a health institution. The amenities included a pool and a water fountain system, which made natural music. Currently, the hospital building is a gazetted UNESCO World Heritage Site [43].

Amasya Darussifas was a hospital built in the year 1308 AD. In this hospital, music therapy was applied to mental patients through a combination of instrumental music and the sound of water [5].

Fatih Darussifas Istanbul was built in the year 1470 AD and was the first hospital built in the Ottoman era. It had 70 rooms and 80 domes. Music therapy was applied to treat mental patients and this continued until the year 1824 AD [44].

Edirne Sultan Bayezid II Darussifas also offered music therapy specifically for mental patients [45]. This treatment used not only instrumental music but also the burbling sound of water flowing from the pool fountain in the middle of the facility [40]. Music therapy applied in this hospital was considered the peak in the history of medieval music therapy for its systematic implementation, namely through musical concerts three times daily by the hospital's ensemble of musicians. The ensemble comprised ten musicians, three of whom were singers, and the rest were musicians who played various types of instruments. This hospital was also equipped with a stage for a musical concert. The instruments frequently used the reed-flute, dulcimer, harp, kemence (similar to a small violin), pan flute or pan-pipe, and oud. With these instruments, various melodic modes (*maqam)* were played, such as *neva/nawa, rast, dugah/dukah, segah/sikah, cargah/jaharkah, suzinak, zankulah,* and *busalik* [42]. The combination of the sounds produced by the musical instruments and flowing water added to the therapeutic effect not only to the patients but also to the visitors.

Suleymaniye Sifahanesi was a hospital built by the famous architect, Mimar Sinan, in the year 1550 AD, as commissioned by Sultan Suleyman. In contrast to other hospitals, Suleymaniye Sifahanesi provided music therapy through a specific unit, namely the Neurology Unit. Music therapy as a treatment was availed until mid-19th Century AD [45], using the services of about 30 staff [46].

Another hospital that applied music therapy was established by Ayse Hafsa Sultan, the mother of Sultan Suleyman and wife to Sultan Selim 1. The facility was established in Manisa in the year 1522 AD. Despite its relatively small size, it provided music therapy as a treatment to mental patients until the 19th Century AD. As for now, the hospital building is currently a museum [45].

The existence of these hospitals showed that music therapy was widely applied in the Islamic medieval centuries, specifically in the Seljuq and Ottoman eras. The application involved not only instrumental music but singing, the recitation of al-Qur'an, and the sound of water. The use of instrumental music was supported by the use of a domed hall or stage for presentation. For enhanced therapeutic effect, some of the hospitals were equipped with an acoustic system; a dome was built to reflect sound off its concave walls, which focused it in the centre, thus amplifying the sound. This acoustic system helped in disseminating the sound of music to reach all corners of the hospital. The hospital landscape with its fountain pool in the garden was conducive for therapy using the natural sound of flowing water; such created a tranquil ambiance not only for the patients but for the hospital staff and visitors as well. Those treated with music therapy were frequently mental patients as well as individuals with psychological disorders, such as depression, insomnia, and melancholia. The function of this treatment was to entertain, calm down the patients, and relieve pain. However, music therapy was no longer available in these Islamic medieval hospitals by the 19th Century AD.

5. Process of applying music therapy in Islamic civilisation medicine

We use the example of music therapy applied in Bimarastan al-Mansuri in Cairo. This hospital was selected based on four considerations. First, the important document relating to the hospital's affairs, specifically the endowment (*waqf*) document, is extant and kept in good condition for reference. Second, this hospital has a long lifespan of almost six centuries, from the end of the 13th Century until the beginning of the 19th Century AD. According to Ibn al-'Umari [29], the hospital building itself still stands until now. However, its status as a general hospital was changed to an ophthalmology hospital by the 20th Century AD. Third, this hospital is based on two unique principles: welfare (free treatment) and equality. Thus, its treatment services were available regardless of rank and position. Leaders, military, social elite, or common people - all were entitled to equal treatment. Fourth, this hospital provides formal and intensive music therapy treatment as stipulated in the *waqf* document.

We refer to records from sources such as *Wasf Misr-Madinah al-Qahirah: al-Khutut al-'Arabiyyah 'ala 'Awamir al-Qahirah* [44], *Shams al-'Arab Tasti' 'ala al-Gharb* [31], *A History of Egypt Vol. 6 The Middle Ages* [47], *Cairo Fifty Years Ago* [48], *L'Arabe, Les Monuments Du Kaire* [49] and *al-Rehlah ila Misr wa al-Sudan wa al-Habsyah* [50] to identify the application of music therapy at Bimarastan al-Mansuri. Based on these sources, we deduced four matters.

The first matter is that Bimarastan al-Mansuri used two out of three main characteristics that form the basis of music therapy: (i) sound, tone of voice or instrument; and (ii) satisfying emotions and aesthetics. The second matter is that the hospital structure was designed to suit such treatment. The interior was spacious, measuring 150 feet in length and width. In the center of the building was a large pool with a fountain from which water is shot up as high as a combined height of two male adults. Next to the pool was the prayer hall (*musalla*). Some nearly healed patients in the process of rehabilitation usually rested by the pool while enjoying the sound of water from the fountain wall and being served by hospital staff. Chronic mental patients were placed in spacious rooms equipped with a pool and wall fountain to enable enjoying the engrossing sound of flowing water. This hospital also had a psychiatric unit that warded mental patients. They were treated with full concern through the burbling sound of fountain water in the porch area of the hospital.

The third matter is that musicians and *Qurra'* formed part of the hospital staff, apart from physicians and nurses. Musicians were given the responsibility to soothe and entertain the patients with singing and the melodious strains of musical instruments, at once distracting their attention from the pain they endured. This hospital even provided payment to musicians who came daily to entertain patients, including those who were going through rehabilitation sessions, with singing and music. *Qurra'* were also paid to recite al-Qur'an at neighbouring mosques to create spiritual peace. This hospital paid fixed salaries to 50 *Qurra'*. The fourth matter is that music therapy was given as a complementary treatment. Thus, it was applied adjunctly with other treatment, including listening to stories told by professional storytellers, watching dance presentations and comedy sketches, and using medication.

Bimarastan al-Mansuri had a specific process relating to music therapy. The usual procedure for a patient before admission to a ward was to undergo a preliminary examination by an assistant or trainee physician at a polyclinic in the southern part of the hospital. If further treatment was required, the patient would be advised to be warded so that his/her level of condition could be monitored constantly. The main procedure required registration before admission to a ward. In this process, the registration record must first be verified by the chief physician and only then, can a patient be placed in a ward based on gender as wards for men and women were separate with attending male and female nurses, respectively. Nurses always gave their best service throughout the patient's stay in the ward; they administered medication, gave food and drink, managed the bedding, and bathed and clothed the patients.

In the context of treating with music therapy, a musical band or ensemble was assigned the task of entertaining patients every evening by playing the oud. Insomnia (primary or secondary) patients and rehabilitation patients were frequently treated with instrumental music. Although treated in a special room provided by the hospital for the music therapy, other patients could hear the music in their respective wards. Thus, music therapy was indirectly applied to all patients, mental or physical, through nature's music (sound of water), and human vocals (chanting of *adhan* and recitation of the holy verses of al-Qur'an).

6. Conclusion

Even though music therapy of the Islamic civilisation medieval era had ended by the 19th century AD, it is still relevant to the approach of modern medicine. This is due to the awareness of its most encouraging effectiveness as complementary medicine. Data from the World Health Organisation (WHO) [20] showed that the use of complementary medicine among populations is strongly acknowledged in many regions, including the African Region (87%), the Region of the Americas (80%), and the Eastern Mediterranean Region (90%). Based on the categorisation of medical subfields by the National Center for Complementary and Alternative Medicine (NCCAM), music therapy is placed under the subfield of mind and body interventions in the art therapy grouping. Mind and body interventions refer to the techniques of enhancing the level of mental ability so that it can influence the body functions and overcome symptoms. Besides music therapy, meditation and prayer (supplication) are also included under this subfield.

Positive development in the use of complementary treatments in hospitals will certainly ensure the continuity of using music therapy as the complementary treatment in today's hospitals. The basic matters that need to be developed first are the training of music therapists and selection of music genre-appropriate to a country's moral values, customs, and socioculture. To gain expert advisory services, strategic cooperation needs to be forged with music therapy organisations such as the American Music Therapy Association (AMTA), World Federation of Music Therapy (WFMT), and Traditional Turkish Music and Movement Therapy (TUMATA). These organisations have vast experience in music therapy, particularly in training programmes and facilities.

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Chapter 3

Classic and Traditional Music Role in Cognitive Function and Critically Ill Patients

Anak Agung Ayu Putri Laksmidewi
and Valentina Tjandra Dewi

Abstract

Music has been known since the ancestral era, and undoubtedly it has become an integral part of human life. Music has been widely studied, and its purpose encompassed not only as art and recreational but also as therapeutic agents. Listening to music enhances modulation in the mesolimbic pathway and affecting accumbens nucleus (NAc), ventral tegmental area (VTA), hypothalamus, and insula. Evidence support that music could enhance neuroplasticity and stimulate cognitive function. Laksmidewi et al. have already investigated that listening to western classical music and instrumental Balinese flute music therapy improved cognitive function in the elderly. Cognitive improvement by listening to music has been linked to the relationship between the orbitofrontal cortex and the dopaminergic mesocorticolimbic circuit. Besides, musical intervention in severely ill patients showed its advantages in alleviating anxiety and distress symptoms. Patients with mechanical ventilation are prone to high anxiety and stress levels triggered by many factors such as endotracheal tube placement, critical care environment, frequent suctioning, and fear. Non-pharmacological intervention with music therapy is expected to help patients manage their anxiety and distract patients from stressful environments to assist their ventilator weaning effort.

Keywords: classic, cognitive, critical ill, music, role, traditional

1. Introduction

Cognitive function can be improved with pharmacological and non-pharmacological measures. The non-pharmacological methods generally more familiar and safe methods to apply, especially in the elderly population. Non-pharmacological methods for improving cognitive function include physical, emotional, mental, artistic, and musical exercises. Music is a universal human culture and is received by listeners differently depending on one's culture, history, location, and tastes [1]. Various musical activities can be listening to music, singing, playing musical instruments, and composing songs [2].

Munro and Mount first introduced music therapy in 1978. Music therapy is used in the health sector to overcome deficiencies in the physical, emotional, cognitive, and social aspects of someone who has a particular disorder or disease. However, the effects of music therapy cannot be generalized to all mental processes, and not all types of music can be used as music therapy [3].

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Music contains various elements, including rhythm and melody, that will reach different parts of the brain. Music mainly affects the right hemisphere and the limbic system related to emotion and language and the function of the left brain hemisphere. The auditory cortex accepts musical waves as complex input because it contains pitch, tempo, and harmony components. Those components distinguish it from auditory information when listening to a voice or conversation on the phone [4].

Listening to music activates brain areas related to memory, cognitive function, and emotions [5]. Music can help maintain cognitive function by decreasing brain dysfunction and activating memory-related regions, especially in the elderly with critical illness [6]. Besides their role in cognitive function, music might reduce anxiety and stress level. Music has been studied in intensive care units (ICU) for critically ill patients using mechanical ventilation. Emotional stress and psychological factors influence weaning failure from a ventilator. Many studies show the usefulness of music therapy in the ICU to reduce stress and anxiety in patients [7].

Classical music has long been studied and is known to have a Mozart or Vivaldi effect which results in increased concentration and cognitive function [8]. Some classic song titles used in research are Four Seasons, Spring, and White Noise by Antonio Lucio Vivaldi, Fur Elise by Beethoven, Sonata (K.488) by Mozart [8]. The positive effects of western classical music cannot be generalized to all cognitive processes. However, there have not been many studies regarding the role of traditional music on cognitive function and biological markers related to memory and brain plasticity. Certain community groups have long known traditional music close to their daily culture. Therefore traditional music can be a potential choice of music therapy for society. In this chapter, we will discuss the role of classical and traditional music on cognitive and psychological functions, especially in critical patients in the ICU. In addition, the results of the author's studies will also be presented concerning this topic.

2. Music therapy

Music therapy is defined by American Music Therapy (AMTA, 2005) as a clinical and evidence-based musical intervention used to achieve specific goals. The selection of music type for therapy needs to consider the listener's preferences, comfort, personality, and education level. These things will affect persons' psychological and physiological responses to the type of music they listen to. Music therapy can be done by listening to music through a headset with a volume of 70–90 dB, which is a volume that is generally comfortable for the listener [1].

Joseph and Ulrich in 2007 explain the frequency of sound measured in Hertz (Hz) [9]. The hertz is the number of beats per second at which the wave vibrates. The human ear has a limit on listening to sounds with a frequency of 20–20,000 Hz. These acoustic waves can be captured by the human ear and then carried to the auditory cortex. AMTA 2008 states that music frequencies above 40 Hz can affect cognitive function. The 40 Hz frequency is the basic frequency in the thalamus so that the same frequency will trigger a cognitive effect on music therapy [9].

The tempo or rhythm also plays a critical role in brain stimulation [10]. Music with a slow beat will affect the whole body by decreasing the pulse and breathing rate. That condition happens because the human body tries to adjust to the music's rhythm or tempo being heard. Wigram also explained characteristics of music therapy are pleasant music for listeners, with a soft and harmonious tempo of 60–80 beats per minute and usually non-lyrical [11]. The volume in music therapy is a comfortable volume for the listener. Based on previous studies, music volume

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provides a therapeutic effect of at least 40 dB to 60 dB. The duration recommendation for music therapy is 20–60 minutes at least two times a week which can be done at bedtime [12].

Pharmacological and non-pharmacological steps can improve cognitive function. Non-pharmacological measures are a more general and safe method to apply, especially to the elderly population. Non-pharmacological methods for improving cognitive function include physical, emotional, mental, artistic and musical exercises. Musical activities include listening to music, singing, playing musical instruments and composing songs. This series of activities is expected to stimulate various cognitive functions and increase brain plasticity in the elderly to compensate for the decline in cognitive function with aging [2].

Music therapy is a non-pharmacological modality that can manage anxiety and stress and is a therapeutic modality provided by board-certified music therapists. In contrast to music therapy by specially trained and board-certified music therapists, a music listening intervention is a self-administered intervention that requires minimal assistance from a music therapist. This type allows the patient to use music whenever needed, even when there is no music therapist. Previous studies have shown that at least 30 minutes of listening to music can induce relaxation and reduce anxiety in the ICU in mechanically ventilated patients. However, not all previous studies used a method where participants could choose and arrange the music they used. Allowing patients to choose the desired music ensures that the patient avoids the discomfort of listening to music that is unfamiliar or that they do not like [13, 14].

2.1 Classical music

Kamus Besar Bahasa Indonesia (KBBI) in 2008 defines classical music as music whose compositions are born from European culture and are classified according to certain periods. Listening to classical music can have a positive effect called the "Mozart effect" or "Vivaldi effect". Some of the classic songs that have been used in research on the relationship between music and cognitive function are Spring, Four Seasons and White Noise by Antonio Lucio Vivaldi, Fur Elise by Beethoven, Sonata (K.448) by WA. Mozart. Several studies showed an increase in mean memory function (recall memory) and visuospatial in 36 subjects who listened to Mozart Sonata K 448 music for 10 minutes [8, 15].

2.2 Traditional music

Traditional music is music that has developed over a long period in certain social communities. Traditional music develops in various regions and countries and is passed down from generation to generation. In general, traditional music uses local languages, styles and traditions. The concept of traditional music was created from the general habits of society and has undergone many developments. One of the famous traditional music in Indonesia is gamelan music. There are several types of gamelan in Indonesia, including those from Java, Bali and Lombok. One of the instruments in Balinese gamelan is Balinese flute music. The flute is a wind instrument made of bamboo [16]. Until now, Balinese flute playing is increasing in number. This music is very popular among Balinese people, which is used in religious ceremonies and everyday life and is combined with modern musical instruments. One of the Balinese flute players is a Balinese artist named Mr. Agus Teja Sentosa, S.Sn, known as Gus Teja. He is a composer and player of Balinese flute instruments and several types of flutes from other countries. Songs that have been known across Japan, Korea, America, Malaysia are "Hero" and "Morning

Happiness" [17]. The frequency of both songs is 440 Hz, and the tempo is between 70 and 90 beats/minute. Those songs are soft and slow. It is widely known and used in various public facilities.

3. The physiologic effect of music

The choice of music needs to consider aspects of personal preference. However, music with a slow rhythm without lyrics with a tempo of 60–80 beats per minute shows its effectiveness in reducing anxiety [18]. Furthermore, a relatively slow music rhythm is considered necessary because of its ability to synchronize with the listener's heart rate and breathing rate [19].

Pleasant, relaxing music triggers the brain's pleasure and reward centers during functional MRI (fMRI) and PET imaging [20]. Relaxing music is proven to effectively release endorphins and enkephalins and simultaneously decreases catecholamines associated with stress in listeners [19]. In contrast, sad music indicates activation of parts of the brain (amygdala, hippocampus etc) that are often associated with negative conditions or anxiety. Researchers suspect that different musical genres can activate nine affective states: joy, sadness, nostalgia, peacefulness, power, wonder, tenderness, transcendence, and tension [20]. The emotions that are generated depend on the specific type of music being played.

Listening to music shows activation of areas in the brain related to memory, cognitive function, and emotions [5]. Thus, music can help maintain cognitive function by decreasing brain dysfunction and increasing activation of memory-related areas, especially in the elderly who are critically ill [6].

4. Music and anxiety

4.1 Biomarkers of anxiety

Two previous studies used biological markers to evaluate anxiety. Beaulieu-Boire et al. examined the effects of music on sedative drug consumption, vital signs and markers of inflammation and hormonal stress. Markers studied were IL-6, prolactin, C-reactive protein, ACTH, and cortisol. A post-hoc analysis was also carried out for leptin and MET-enkephalin. The study group consisted of patients who used mechanical ventilation and listened to classical music for two hours in the morning and night. The music therapy study group showed significant cortisol reduction ($p = 0.02$) after intervention compared to controls. There was also a decrease in prolactin ($p = 0.038$) in the therapy group but not in the placebo. Music therapy does not affect leptin and MET-enkephalin levels. The markers of inflammation (CRP and IL-6) decreased with time but not significantly [19].

Another study by Chlan et that examined a 24-hour collection of urinary cortisol samples showed no significant reduction in cortisol levels in the music therapy group. Subjects in the study were acutely ventilated, conscious, able to understand commands and be able to hear. However, the pattern of cortisol levels showed extreme rates over time, while the control group's cortisol levels tended to increase throughout the trial [21].

4.2 Physiologic measures of anxiety

Physiological measures of anxiety from most studies include examining heart rate (HR), respiratory rate (RR), systolic blood pressure (SBP), and diastolic blood pressure (DBP). Korhan et al. in 2011 studied 60 ICU patients with mechanical ventilation who were hemodynamically stable and able to hear with a minimum GCS of 9. The study group listened to classical music through headphones, and sedation was stopped 30 minutes before data collection. Researchers found a significant decrease in SBP, DBP and RR in the treatment group, but there was no significant difference between SaO2 and HR compared to the control group [22].

Beaulieu-Boire et al. in 2013 also studied whether music could affect the amount of sedative drugs needed by patients in the ICU. It was found that music did not affect the amount of sedative medicines required, but this study showed a decrease in narcotics consumption by subjects after the music intervention ($p = 0.06$) [19]. A study by Chlan et al. 2013 also showed subjects in the music therapy group required less frequency and intensity of sedative medication than controls and reported decreased anxiety levels after music intervention [21].

An experimental (quasi) study by Sung et al. 2010 in Taiwan on 29 elderly with dementia showed that the anxiety level of the elderly who received music therapy with Taiwanese music was lower than the elderly who did not receive music therapy. In the study, the length of listening to music varied with 30–50 minute intervals per session for at least 2–3 times a week. Music therapy duration 1–6 weeks [23].

4.3 Music therapy in mechanically-ventilated patients

Patients who are mechanically ventilated in intensive care units are particularly prone to high stress and anxiety levels. In addition to critical illnesses suffered by patients, the treatment environment is full of constant alarm sounds, various equipment and invasive measures. Thus, it will increase the patient's stress susceptibility. Sedative drugs are commonly used in mechanically ventilated patients to reduce pain and anxiety. However, it can cause many side effects. These emotional and psychological factors also influence weaning failure from a ventilator. Many studies show the usefulness of music therapy in the ICU to reduce stress and anxiety in patients. It is also related to patients' attempt to wean from the ventilator successfully [7].

Things that can contribute to the increase in stress and anxiety levels of patients in the ICU are constant alarm sounds and machines, frequent examination and repositioning, bright lighting, and minimal patient communication [24]. Inserting an endotracheal tube into the patient will hinder the patient's ability to speak. The patient is unable to express complaints and communicate with other people. Patients also feel lonely due to minimal family assistance while in the ICU and unknown faces. Patients desperately need a more calming environment that can be obtained from a pharmacological and non-pharmacological perspective. Non-pharmacological methods can be applied to provide a more soothing care environment for the patient.

The prolonged use of a ventilator can have an impact on various complications. High levels of stress and anxiety can hinder the patient's ability to breathe independently and adequately [25]. Posttraumatic stress disorder is also found in some patients discharged from the ICU [24].

Music therapy has been used in various hospital settings, and most studies have shown a positive effect of reducing anxiety levels and increasing patient comfort [26]. Music is known to evoke a series of emotional and physiological reactions in listeners. In one subgroup of patients with dementia, music therapy improved the quality of interactions between patients and their caregivers [27]. A comparison study between regular patients groups and those receiving music therapy showed a significant reduction in anxiety levels in the experimental group [28].

Music therapy has also shown a reduction in pain perception seen in Randomized Controlled Trials (RCTs) of women at delivery. Pain assessment was performed hourly with Visual Analogue Scale (VAS) [29]. The decrease in pain level and anxiety is associated with the patient's rapid recovery period.

It is essential to control anxiety and panic in patients in the ICU because it is related to increased heart rate, blood pressure, respiratory rate and airway constriction. Panic feelings when patients had difficulty breathing will make the body instinctively fight the ventilator resulting in ventilator dyssynchrony and alveolar damage [24]. In addition, commonly used sedative agents often cause hypotension and respiratory depression, an increased risk of pressure ulcers, venous stasis, muscle atrophy and respiratory muscle weakness [25].

Evidence supports the use of music to calm the patient because of its ability to change the atmosphere. It will help patients rest and sleep better, which is very important in the recovery process [30]. The use of headphones to listen to music in the ICU also helps to distract patients from background noise that often disturbs patients [19].

5. Music and cognitive function

Music is the strongest auditory stimulation in the human brain. Listening to music triggers cognitive and emotional components with different neural substances. Even though listening to music may seem very simple, even humming in a familiar tone necessitates a complex auditory pattern-processing mechanism, attention, memory storage and recall, motor programming, sensory and motor integration [31].

Music will be processed in the right brain hemisphere since it is the center of creativity, spatial form, emotion, music, and color. The memory from the right brain is a long term memory. The inner ear processes sounds produced by musical instruments into neural impulses. This information travels through several pathways to the brainstem and mesencephalon, leading to the auditory cortex. Information from the auditory cortex then interacts with various areas of the brain, especially the frontal lobe, for memory information and its interpretation. The orbitofrontal area plays a role in emotional evaluation [32].

Listening to music is a powerful modulation activity in the mesolimbic pathway. It also affects accumbens nucleus, ventral tegmental area, hypothalamus, and insula [33]. Altenmuller also stated that music is a strong stimulus to the brain for adaptation and brain plasticity. The molecular and cellular mechanisms that explain the neuroplasticity induced by music are not well understood. The efficiency and size of the synapse can change within 10 minutes of listening to music. New synapse and dendrite growth occur within hours to days. Changes in synaptic density and other supporting structures such as capillaries and glial cells may take up to several weeks [33]. Music tempo will affect neurons in the brain stem. It activates several neurotransmitters, including norepinephrine, cholinergic, and dopaminergic in the brain stem. Activation in the brainstem also mediates sensory and motor functions via epinephrine, norepinephrine and serotonin. It is believed that music triggers the activation of a higher cortical function [1].

Music directly activates the neurovegetative system (hypothalamus, pituitary, suprarenal glands) to produce neurotransmitters. Listening to music affects neurotransmitters, especially dopamine. Most nerve cells are sensitive to neurotransmitters, especially those in the posterior frontal cortex called the mesolimbic system, which is responsible for emotions. Dopamine is recognized by almost all nerve cells. It plays roles in neurobiology, memory, learning and attention processes, essential in the brain plasticity process. The neurotransmitter serotonin also plays a vital role in brain plasticity. Serotonin increases significantly when a person listens to pleasant music [33].

Music can activate the stored memory. Brain imaging shows neural activity associated with listening to music extending from the auditory cortex to the bilateral frontal, temporal, parietal, and subarachnoid pathways [34]. Information processing starts from sensory memory, which captures all the information, then it is identified by the human sensory system. Information that has been stored in sensory memory will undergo encoding, retrieval of information and transformed into a meaningful mental form. The encoding results are then sent to short-term memory, which is limited in capacity so that only part of this sensory memory will be processed. Information on short-term memory depends on the attention given. With the effort to recall, this information will enter into long-term memory. Music will affect the encoding process. Positive emotions obtained when listening to music will encourage the improvement of cognitive functions [35].

Listening to pleasant music significantly increases cerebral blood flow (CBF) of the mesolimbic system, ventral striatum (nucleus accumbens and mesencephalon), as well as various other structures such as the thalamus, cerebellum, insula, anterior cingulated cortex (ACC) and orbitofrontal cortex (OFC). Increased brain vascularization will trigger brain plasticity that can improve cognitive function [1].

A study using functional MRI showed activation of NAc and VTA when listening to pleasant music. The relationship between NAc and VTA is known to regulate the autonomic system, emotional, and cognitive function. The insula becomes active because it is associated with NAc and plays a role in addictive behavior to something. Improvement of cognitive function with listening to music is due to the relationship between OFC and mesocorticolimbic dopaminergic circuits. Dopaminergic NT in neuronal pathways plays an important role in the brain's ability to process the heard music [1].

We summarize the impact of music therapy in cognitive function and critically ill patients in **Figure 1** below.

5.1 Author findings regarding music and cognitive function

The author and team conducted an experimental study in 2017 to determine the improvement in cognitive function and an increase in serum dopamine in the elderly after listening to Balinese flute music as the main instrument. Instrumental music was used in the study. It is the type of music that does not use vocals. Based on previous studies, instrumental, low-pitched music with a harmonious slow rhythm (60–80 beats per minute) is pleasing to the listener and can affect body physiology, slow down breathing rate and heart rate, and influence emotions via the limbic system [11].

The study by Laksmidewi et al. used music from the Balinese bamboo flute as its main instrument, which was composed with modern music and played by Balinese artist Agus Teja Sentosa, S.Sn. The song that was played entitled "Morning Happiness", with a tempo of 70–90 beats per minute and a frequency of 440 Hz. Classical music was also used in the study, namely Spring by Antonio Lucio Vivaldi. Listening to classical music can produce a positive effect called the Mozart effect or Vivaldi effect [36].

The study used an experimental pretest-posttest control group design. Subjects were 32 healthy geriatrics aged 60–74 years. Subjects were divided into 2 groups, namely the control and intervention groups. Subjects in the control group listened to western classical music entitled "Spring", while the intervention group listened to classical music "Spring" coupled with the Balinese instrumental "Morning

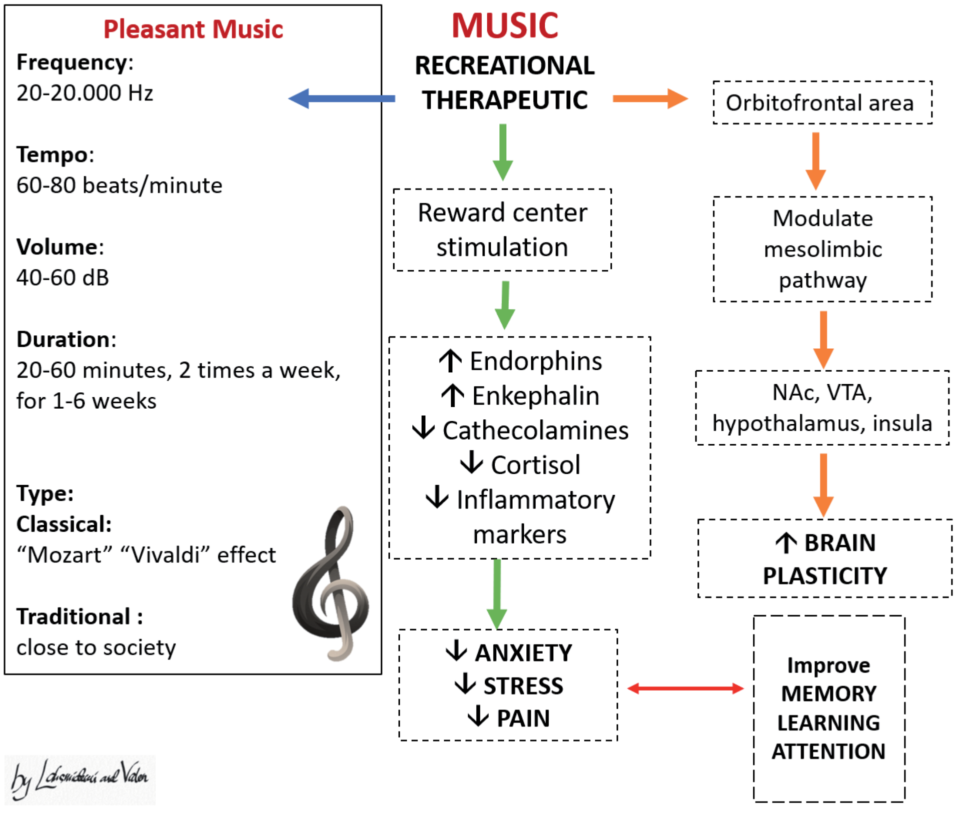

Figure 1.
Impact of music therapy in cognitive function and critically ill patients.

Happiness". Each song was played for 20 minutes every morning before the subjects carried out their daily activities. Cognitive function assessments with the Montreal Cognitive Assessment-Indonesian version (MoCA-Ina) were carried out before the intervention and 21 days after the intervention. Serum dopamine tests were also performed before the intervention and 21 days after the intervention.

The study results showed that the mean increase in cognitive function was higher in the intervention group (5.22; $p < 0.001$) than the control group (4.67; $p < 0.001$). The improvement in the MoCA-Ina score between the two study groups was not statistically significant with $p > 0.05$. The mean increase in dopamine levels in the control group (3.60) was greater than the intervention group (3.56). However, the mean increase was not statistically significant (0 = 0.085). This study concludes that there is a significant relationship between listening to Balinese flute instrumental music and improvement in cognitive function, especially in the memory domain in all subjects. However, the mean increase in cognitive function and serum dopamine levels did not reach statistical significance between the two study groups [36].

6. Conclusion

Music therapy has a significant role in cognitive function, brain plasticity, stress and anxiety management. Increased vascularization of various mesocorticolimbic structures and activation of dopaminergic neurotransmitters regulate the autonomic system, emotion and cognitive function. Besides classical music that was previously known to have a positive effect in the brain with the Mozart or Vivaldi effect, traditional music is also being studied. Traditional music grows and develops over a long period of time in society, this type of music has great potential in improving cognitive function, especially in the elderly. Further studies are needed to optimize the selection of appropriate music therapy for patients both in critical care settings and to improve cognitive function.

Conflict of interest

The authors declare no conflict of interest.

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Chapter 4

Music Therapy and Its Role in Pain Control

Avinash Thakare, Anvesh Jallapally, Amit Agrawal and Pooja Salkar

Abstract

Music has occupied our day-to-day life; as it is readily available, accessible and further technological advancement has made access to music a common norm. Music has been present since the very early part of human evolution and has helped in forming society and civilizations. It has served various purposes like social cohesion, emotional expressions, interpersonal communication as well as recreation. Due to its great bonding power; it is important in terms of social dynamics. Music therapy is convenient, inexpensive and user-controlled and seems to be influencing the physiological system positively if rightly used. Vast research is going on to find the right music that could be having a beneficial therapeutic effect. Music seems to affect the pain perception, modulation and also has the affective component to help positively in controlling the pain. This chapter is an attempt to evaluate the various pain modulating effects of music through a systematic music therapy intervention using the vast research work done in this field. This review is consistent to integrate the best scientific evidence for pain relief into practice, education, and research. Music being a non-pharmacologic, nontoxic intervention and is free from adverse effects and also is an inexpensive, low cost modality.

Keywords: music, human physiology, pain perception, pain control, music therapy, audio analgesia

1. Introduction

Music has marked its presence in every society past and present. It is considered omnipresent and is culturally universal. Each ethnic group, society may be a remote isolated one, has its music. Music is considered a universal way of communication and means of expression of feelings for mankind [1]. The existence of music can be ascertained from the existence of mankind as old as 2,00,000 years back. Evolutionary biologists consider music as a binding force between individual members of society and its existence was said to even predate the speech and language functions. It is said that music has great bonding power and has played role in creating society and civilization from each of the individual members. Music is been used as a form of leisure relaxation as it was used for recreational purposes. Historical evidences point out that music was used as therapy form Egyptian medical Papyri dating back to 1500 years, so as the Arab, Chinese, Indian and Greek literature mentioned the use of various notions of music as therapy. The ancient Egyptian civilization used musical songs for the healing of sick individuals. Likewise, music was considered as an art of medical healing by Hippocrates [2, 3]. The present chapter describes the pain-alleviating effect or analgesic effect of music using results put forward by the various research studies. The pain modulating effect of music is a prime one as the suffering causes the pain and brings about the agony at the level of mental as well as the physical state. The impact of music therapy on pain perception and its application as a form of treatment has been described in this section.

2. Physiology of pain perception

As per Sherrington, Pain is defined as "the psychical adjunct of an imperative protective reflex." Since there are definite receptors, nerve fibres, tracts and higher centers for pain perception, it is a part and parcel of a protective reflex mechanism. Similarly, from the definition of pain, it can be concluded that pain perception itself is a protective reflex against a harmful stimulus, and is an adjunct or added signal in consciousness accompanying this reflex [4]. Similarly, according to the International Association for the Study of Pain, pain is "an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage" [5]. Pain sensations are conveyed from the periphery towards the brain using specific neurons through spinal cord to thalamus and to cerebrum. At the level of the Cerebrum, pain perception and higher abilities like detection of pain form specific body part is done. Pain is a unique type of sensation in that it persists as long as tissue damage or painful stimulation is there. It is the non-adapting type of sensation. Functionally there are two types of pain as per the speed of pain impulses travelling through the peripheral sensory nerve fibres. The slow pain is carried by slowly conducting type C unmyelinated pain fibres which evoke the slow but dull type of pain. The fast pain sensations which are evoked within a fraction of seconds after applying painful stimulus and cause a sensation of sharp pain is carried by

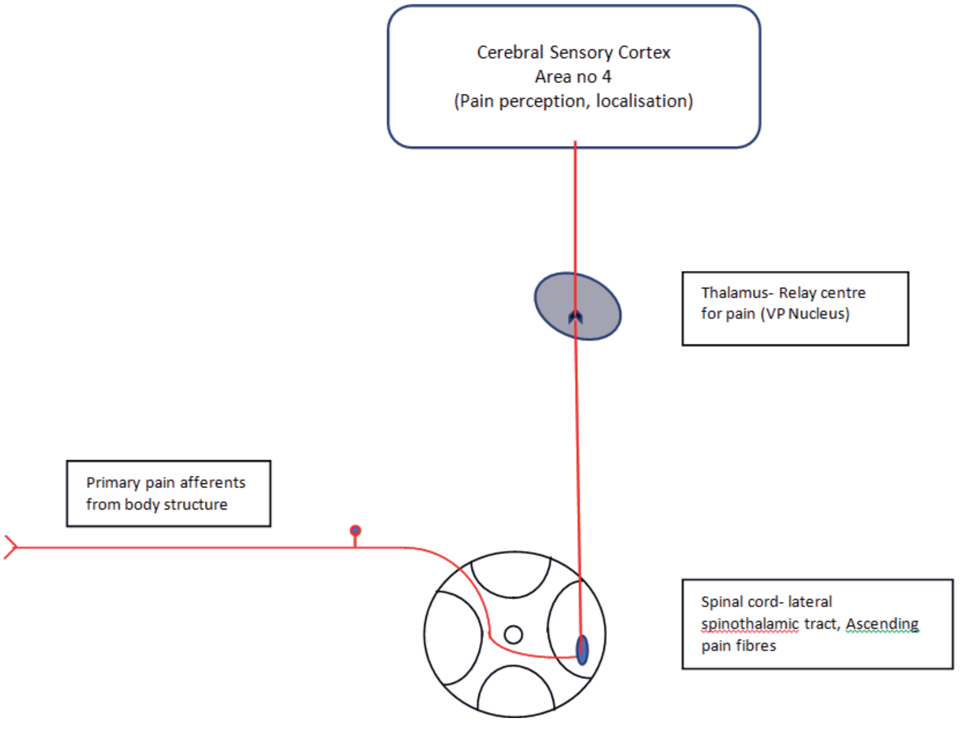

Figure 1.
Pain pathways from periphery to cerebral cortex.

Aδ (delta) myelinated nerve fibres. The pathways are somatotopically arranged in the contralateral half of spinal white matter in form of anterior and lateral spinothalamic tracts. The fibres ascend from these tracts to the VP (Ventro-posterior Nucleus) of the thalamus. The thalamus is the first relay center for pain. From where second-order neuron travel to Sensory cortex f cerebral hemisphere to final terminate in this area. The pain pathway is illustrated in **Figure 1**.

3. Analgesic effect of music

Listening to music can influence the pain sensation through the various proposed mechanism. There is a Descending Pain Modulating System (DPMS) in the body which can inhibit and modulate pain sensation arising from various body parts. The DPMS acts on the pain afferents (nociceptor fibres) and decreases the nerve impulse transmission through them leading to decreased pain perception. It has been suggested that the analgesic effect of music is aroused in the brain and acts through a top-down regulation through DPMS [6]. Further, it has been observed that self-chosen music has a higher analgesic effect than researcher-chosen music. Stress has also been a predisposing factor in chronic pain and amelioration of stress can influence the pain positively [7]. Hence for this analgesic effect, the term 'Audio analgesia' was proposed and used by Gardner and Licklider for effective pain management during dental procedures [8]. However, the underlying mechanism of Audio-analgesia remains to be elucidated as does the direct effect of music on pain amelioration and the indirect effect with the coping up of pain. One proposed mechanism could be due to improved control over pain that may be achieved via distraction from pain or via induced relaxation effected by the music [9–11]. Further, it has been studied that listening to music can reduce the intensity of pain and the requirement of opioid analgesics for post-operative pain [12]. Although, the positive effects associated with music listening on various physiological and psychological parameters have been demonstrated, the effect of music on pain perception was reported to be a small one. However, music listening is associated with a reduction in pain-related distress [13]. Further stimulation of the parasympathetic nervous is implicated in the analgesic effect of music [14]. Pain control through music Researchers have worked on the mechanistic explanation of the analgesic effect of music and the most important mechanism proposed for the same is through the gate control theory and pain neuromatrix theory. Music exerts its effect on pain modulation by affecting the cognitive and emotional processes associated with the music stimulus. The net result of music therapy yields as actual pain modulation as it is perceived at the levels of the Central nervous system (**Figure 2**).

There are two theoretical explanations for the analgesic effect of music on pain control, the first one is the ability to use music freely at any time while in pain that provides the subject "a feeling of control" and the ability to do something to counteract the negative experience [15]. Listening music is itself a distraction of attention from the pain and the painful stimulus [16]. Such distracting effect allows limited mental resources for pain perception [17]. Further, if the stimulus provokes emotional engagement, it acts as strongest distraction [18]. The attributes of music are involved in this emotional engagement as evidenced by the listening to the pleasantly valenced music that brings about the positive emotional induction which lies beneath this music's effect [19]. Indeed, the analgesic effect or pain-relieving effect largely resides on self-selected or participant selected music rather than the supposedly relaxing or calming music. The beneficial effect of music on pain modulation is due to the raised level of involvement with the music and this is related to past association and familiarity with music and cultural context as well [9].

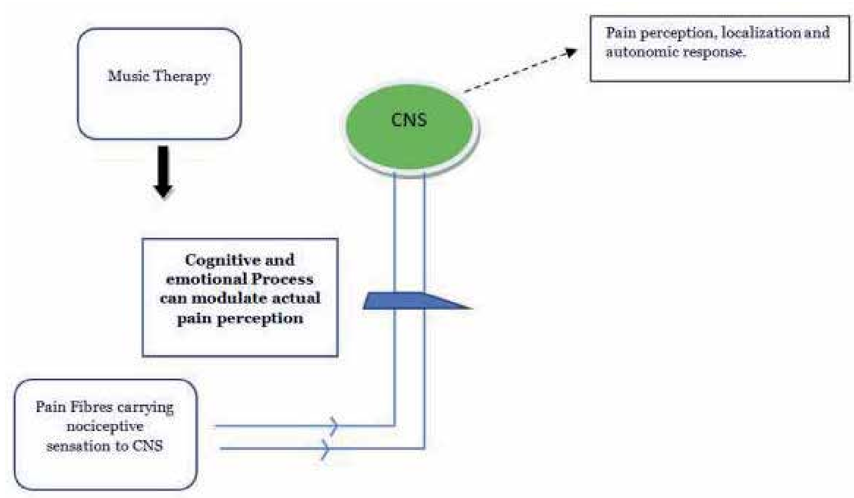

Figure 2.
Pain modulation pathway for music therapy.

Various experimental studies using music as a tool for pain relief have revealed that the self-selected music was associated with increased pain tolerance, increased perceived control over the pain, decreased anxiety, and decreased pain intensity as compared to white noise, arithmetic distraction, visual distraction and silence. The analgesic effect of music possibly lies in the emotional engagement of the listener which distracts the listener from the noxious stimuli. One of the commonest goals of music is to influence emotions and affect. Sloboda [20] there is marked agreement between different listeners about the emotions expressed by the music having different cultural backgrounds [21]. As per the Knox et al. [22] who studied the effect of participant chosen music on pain relief of experimentally induced pain. It was concluded that music content and structure have a role in the music choices made by participants and the efficacy of music listening for pain relief. The music chosen for pain relief by the participants chiefly expressed contentment and further it is stated the participant's emotional engagement with music and distraction from pain are dependent on the acoustic content and emotion expressed by that piece of music. A specific physiologic mechanism for pain relief using music has not been elucidated. However, decreased pain may be related to endogenous pain modulation and psychological outcomes including reduced anxiety, relaxation, improved mood, distraction [23]. Beck in his study on music therapy and pain relief of chronic cancer pain reported a twice greater decrease in pain with music than with sound in advanced cancer patients. The analgesic effect of music therapy was largely ascribed to distraction caused by music stimulus which has been supported by frame work theory. Music aroused emotions which have an impact on affect and cognitive function which accounts for improved mood, decreased anxiety, and increased control and distraction, all potentially reducing pain [24].

4. Music therapy as an intervention for pain relief

Music therapy is defined as a "controlled method for listening to music, making use of its physiological, psychological, and emotional impact on the individual during treatment for an illness or trauma" [25]. The principal factors that could decide the success of music therapy sessions are:

- The patient's taste and cultural background shall decide the choice of music.
- The instrumental music shall be administered for 20–30 minutes through earphones while wearing an eye mask, in a relaxed position.
- The session should be supervised and conducted by care staff, and particularly nurses.

Similarly Music therapy is defined as an effective and reliable source of treatment that helps the patient in the reduction of pain, anxiety, anguish without the need for medication [26]. The American Music Therapy Association defines music therapy as the prescribed use of music by a qualified person to effect positive changes in the psychologic, physical, cognitive, or social functioning of individuals with health or educational problems. Similarly, the British Association of Music Therapy has also defined music therapy as "an established psychological clinical intervention" that helps people "whose lives have been affected by injury, illness or disability through supporting their psychological, emotional, cognitive, physical, communicative and social needs." Music therapy based on self-selected or participant selected music could be improved with the use of instrumental music, preferably low tones with strings than to brass or percussion, and shall have a decibel intensity not greater than 60 db [27]. Similarly, the music selection is recommended to match the average heart rate of 60–80 bpm for promoting positive outcomes on pain and relaxations [28].

There has been a priority for research in the field of appropriate music that can have a positive impact on pain relief. Music listening can be a form of behaviour therapy and non-pharmacological intervention that can reconfigure the individual to anticipate, perceive and respond to pain. Such intervention can ensure adherence to drug therapy and make pain a manageable issue. Music as a modality can stimulate "Synesthesia"—a neurological phenomenon in which stimulation of one sensory or cognitive modality causes an automatic, involuntary experiences in a second sensory or cognitive pathway. A form of synaesthesia is seeing vivid colours upon hearing music. Like other positively valanced stimuli such as food, sex, money, psychoactive agents' music is akin to stimulate and activate the reward, reinforcement, motivation pathway in the human mesolimbic cortex [29–31]. Functional MRI studies have seen maximum Dopamine response with anticipation of, listening to participant selected pleasurable music in the respective brain structures [32].

It has been reported that listening to well-liked pleasant music enhances neuronal functional connectivity that can influence the valence and reward characteristics of multimodal sensory processing in patients suffering from chronic pain [33]. Pleasurable music can change neuronal pathways in patients suffering from pain. The diagrammatic representation for the putative mechanism of music therapy in pain relief through its actions of Gate control theory and neuromatrix theory is presented in **Figure 3**.

Individualised personal tailoring of self-selected music can be achieved by three ways as proposed by [34].

1. active personal curation (e.g., an individual searching for music and adding,
2. it to a personalised playlist),
3. professional curation (an authority in music curating content), and perhaps most appealing,
4. automated discovery.

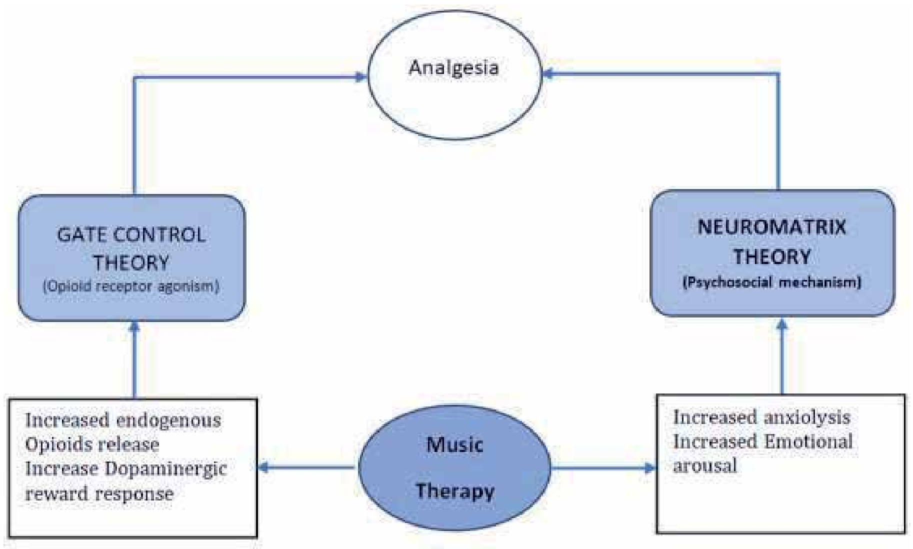

Figure 3.
Mechanism of music therapy in pain relief through the Gate control theory and neuromatrix theory.

Pain and anxiety are coexistent in critically ill patients. Pain can trigger anxiety due to fear and uncertainty as with other factors like associated treatment of the ailment and noxious stimuli. Persistent pain induces a widespread sympathetic response, sleeps disturbances and altered appetite pattern and increase the anxiety. Similarly, coexistent anxiety precipitates excessive pain leading to a positive feedback cycle. Music is a powerful distractor Music listening is a powerful distracting disengaging stimulus that occupies the discrete brain pathways with pleasurable stimulus instead of noxious or anxiety-provoking stimuli. It has been proposed 60–80 bpm simple music composition achieves relaxation [26]. A general rule of thumb has been proposed for relaxation and anxiety reduction purposes. The music listening shall be for minimum twice daily for at least 20–30 min in a comfortable environment and comfortable patient position. The patient should be encouraged to self-direct the duration and frequency of listening to the self-selected music. As music has a varied preference, there should be encouragement from family members as well as the patient to choose favourite selection for the music.

Further, the method of music delivery should be considered carefully and it is recommended to use headphones or earbuds for effective individual target. As music for one subject may be perceived as noise or noxious stimulus by others [35]. Guetin has reported from the finding of single-blind RCT that the music intervention can be an effective tool in managing chronic pain in medical conditions like lumbar pain, fibromyalgia, inflammatory disease, or neurological disease. The music intervention has a huge impact on pain reduction as well as associated anxiety as well as depression and also leads to a significant reduction in the requirement of analgesic medications [36].

However, as per Cepeda, music should not be considered a first-line treatment for pain relief as the magnitude of its benefits is small. How it is an important non-pharmacological adjunct for achieving effective pain control since listening to music for treatment of pain offers potential advantages of low cost, ease of provision, and safety [12]. The challenging task for Music therapist is designing clinical protocols that could be effective in helping people manage differing types of pain. Further music therapist is crucial in teaching people to fully listen to that music and also to appreciate its effect on themselves. They are also involved in teaching the patient to get engaged with the music so that pain perception is overcome by multiple sources on multiple levels. The various interventional techniques used by music therapy include singing, playing instruments, rhythmic-based activities, improvisation, composing/song writing, in addition to listening to music. Thus, this active music intervention has also been found to be useful in pain control [37]. As proposed earlier music affects the gate control theory of pain by acting on cognitive components. Likewise, by arousing emotions which in turn influences cognitive abilities and thus modulates the pain. Västfjäll et al. [38] music as a source of pleasure enables pain reduction and overall pain sensation [39]. Music can be considered as the relevant stimulus for releasing thoughts and feelings and has a positive influence on healing. Music intervention can be used to reduce post-operative pain and anxiety in patients undergoing biopsy procedures. Music listening can lead to the expression of nitric oxide, opiate, cytokine and hormone expression in listeners [33]. The engagement of these neurochemical systems, can drive the subject to a state of calmness and relaxation [32]. Similarly, because of its effect on emotions music, music can help achieve an anxiolytic state and effective pain control.

Modern-day medicine practice uses music therapy wildly in various physical, psychological, functional and educational settings to help improve the physiological and psychological status of patients. Park H has studied the effect of self-selected music on pain for home-dwelling persons with dementia. Pain levels were measured for the 30 min before listening to music, the 30 min while listening to the music, and the 30 min after listening to the music. The scores of Modified Pain Assessment in the Dementing Elderly (M-PADE) were used for assessing the pain levels with music intervention. There was no significant reduction in pain while listening to music, but pain levels were reduced after listening to the music compared with baseline. Based on the findings of the study, listening to music at least 30 minutes holds promise to assist in the control of pain [40]. Over many years there is the evolution of a wider range of pain management techniques that are based on the prime gate control and neuromatrix theory of pain [41, 42]. The strategies that can distract the subject' attention away from the sensory and emotional reactions brought out by noxious stimulation at the basic level is the most intuitive strategy and appealing one [43]. Using the effect of distraction Mitchell LA l studied the effect of three different distracting stimuli respectively music, arithmetic task and humour on experimental pain control. Preferred music listening was found to be resulted in a significantly longer tolerance of painful stimulation than a mental arithmetic task as does the ratings of perceived pain control using the music [11]. Dolores et al. studied the effectiveness of music therapy in chronic pain management in patients with fibromyalgia. The study findings concluded that listening to music at least once a day for ≥30 min for consecutive 4 weeks of music therapy can help to assist in pain control in people diagnosed with fibromyalgia. Further, it was proposed that Music therapy can be used as nursing as well as a self-management intervention to reduce pain and depression [44]. One form of pain which is associated with cancer is detrimental to the quality of life of the patient as it increases the patient anxiety. Krishnaswamy P evaluated the role of 20 minutes of music therapy in pain control in patients with cancer. The results of the study indicated that music therapy was found to lower the pain score (Numerical rating Scale) of a patient who had received standard palliative care for pain reduction. It was also more effective than the act of talking in reducing the pain score [45].

5. Conclusions

Owing to positive effects, music has on human pain perception and its capability to alter the pain sensation and pain perception along with associated anxiety, sense of loss of control. The modern medicine practice described music therapy as an evolving branch that is convenient, easy to administer, patient complaint, non-pharmacological, non-dependence producing strategy for pain modulation. The most seemingly positive effect of music on human pain relief also lies in its reward value and positive emotions associated with it. Similarly, by ameliorating associated stress, the uncertainty it is useful at the mind as well as somatic level. It can be concluded that Music Therapy and music therapist will be having a definitive role to play to achieve the mind-body harmony and optimum health in the management of chronic pain.

Conflict of interest

The author declares no conflict of interest.

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Chapter 5

The Effects of Music Therapy on Cortisol Levels as a Biomarker of Stress in Children

Idyatul Hasanah and Zikrul Haikal

Abstract

Stress is a physiological and psychological response to the perception of danger and threat. Stress can occur due to a physical injury, mechanical disturbance, chemical change, or emotional factor. Stress can occur at all ages, including children and adolescents. Various physical and psychological events can cause stress in children, for example suffering from an illness, injury/trauma, parental divorce, parental death, sexual abuse, natural disasters, war, etc. Various exposures to physical and psychological stress harmful to the body can cause it to carry out defense mechanisms against these threats, one of which is changes in the cortisol hormone. Cortisol hormone is used as a biochemical marker for acute and chronic stress. The increase in this hormone as an indicator of stress can be changed through psychosocial interventions, one of which is by the provision of music therapy. Music therapy can manage stress problems of people at various ages with minimal side effects and a small amount of money. It is also easy to apply and does not require any intellectual ability to interpret. There are no limitations for users to use music therapy.

Keywords: Music therapy, cortisol, stress

1. Introduction

Stress is a physiological and psychological response to the perception of danger and threat [1]. Stress can occur due to a physical injury, mechanical disturbance, chemical change, or emotional factor known as stress exposure. The body's response to these factors depends on the magnitude of the stress exposure, the duration of the event, and the patient's nutritional status [2]. Stress can occur at all ages, including children and adolescents. Various physical and psychological circumstances can cause stress in children, for example, the presence of an illness, injury/trauma, parental divorce, parental death, sexual abuse, natural disasters, war, and so on [3].

Exposure to stress can affect almost all aspects of life, i.e., physiological, psychological, cognitive, and social. Some of the symptoms of stress that appear physically include: increased vital signs, vascular vasodilation, increased sweat production, decreased immune system, complaints of headaches, abdominal pain, and increased neurohormonal responses (cortisol, epinephrine, vasopressin). Psychologically, the symptoms of stress include mood disorders, emotions, anxiety, eating disorders, sleep disorders, low self-esteem, ineffective coping, and irritability. In terms of the cognitive aspect, stress can appear in the form of impaired

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concentration and memory. Regarding a social aspect, the example of symptoms is impaired interpersonal function such as fear or suspicion, dislike of others, withdrawal, low self-esteem, low self-confidence, affecting relationships and interactions with others [1, 4, 5].

Various exposures to physical and psychological stress harmful to the body can cause it to take defensive actions to overcome the stress. One of the body's responses as a defense against stress is the constant release of stress hormones, including cortisol [1, 4].

Cortisol hormone is used as a biochemical marker for acute and chronic stress [6]. In addition to the increase in cortisol levels, the secretion of epinephrine and vasopressin will also increase due to exposure to stress, thus causing an increase in blood pressure and pulse [1].

Increased cortisol levels as an indicator of stress can be changed through psychosocial interventions. One of the psychosocial interventions often used to manage stress is music therapy [7]. It is an effective complementary approach to manage stress in children, which can achieve specific therapeutic results with minimal side effects in the clinical management of pediatric patients [8, 9]. For children and adolescents, listening to music in various health care contexts is considered feasible, easy to apply, and cost-effective [10].

The effectiveness of music therapy in reducing stress levels in children has been widely reported. It positively impacts reducing pain, heart rate, respiratory rate, and anxiety in children undergoing medical treatment. It can reduce the risk of increased Post Traumatic Distress Syndrome (PTSD) [11–14]. This chapter will review the effect of music therapy on salivary cortisol levels as a biomarker of stress in children.

2. Music therapy

2.1 Definition

Music therapy is a complementary approach by using music to help someone with various health conditions that can affect their physiology, psychology, and emotion [8, 9, 15, 16]. This therapy can manage stress problems of people of different ages with minimal side effects and a small amount of money. It is easy to apply and does not require the intellectual ability to interpret. There are no limitations for users to use music therapy.

Music therapy can generally be divided into two categories, i.e., active and passive. Active music therapy – in which patients play music, sing, or in some way – is encouraged to create or describe their experiences with music. While passive music therapy is a method in which the patient only listens to live or prerecorded music. In surgical and cancer patients, passive forms of therapy are recommended because this type of music therapy can be easily incorporated into clinical situations that involve minimal equipment and staff attention. The patient listens to relaxing music of their choice. It has a profound effect on stress and anxiety levels [17].

2.2 Benefits of music therapy

Music therapy can effectively help children adjust to a hospital environment. Children are usually not familiar with the hospital environment. Many new and scary things may happen in a child's life. Music therapy can be used to intervene for emotional state control, pain management, cognitive processing, and stress management [18, 19].

Music therapy positively affects physiological aspects (such as heart rate, blood pressure, oxygen saturation, and pain). It also positively affects the psychosocial behavior (such as anxiety) of hospitalized children [20]. This therapy reduces postoperative stress and pain in children by improving cardiovascular parameters and improving stress-induced hyperglycemia [21].

Music therapy is often combined with other techniques to improve anesthesia, analgesia, and relaxation. While live music sessions with a music therapist are considered most effective, this may not be possible in an environment or institution that does not have a trained professional therapist. Therefore, recorded music can be a choice.

2.3 Factors that can affect the effectiveness of music therapy in children

Characteristics of good music for pediatric patients are that the decibel level of musical stimulation should be 35–85 dB. Music stays in the soft to medium-volume range. The rhythm should also be regular, without sudden fluctuations in tempo. The use of headphones has several advantages, especially in critical care, including improving hearing at an acceptable decibel level, attention to ambient noise, and lower effect on other patients [8]. Several factors affecting the effectiveness of music therapy are as follows:

2.3.1 Environmental disturbance

Environmental disturbances can reduce the effectiveness of music therapy or even have a negative impact. Examples of such environmental disturbances are noise caused by people passing by, talking, crying, or shouting when music therapy is given.

Environmental noise can interfere with the effectiveness of music therapy even though earphones/headphones are being used [8]. This is probably brought about by the activeness of other senses (e.g., sight), which can still receive stimuli from the environment. The effect of uncontrollable noise levels during music therapy resulted in no positive impact of music therapy on neuroendocrine responses (cortisol levels) to stress [22].

2.3.2 Type of music and duration

Music therapy can provide direct benefits to patients regarding the physiological, psychological, and socio-emotional aspects [23]. An important factor that can increase the effectiveness of music therapy is the type of music that is based on the patient's choice (preferences), songs that are usually heard (familiarity), cultural context, and past experiences [8, 24]. In addition, letting the patient set the frequency, duration, and timing of the music intervention directly is the best approach in providing music therapy [25]. Giving music therapy more than 20 minutes can negatively impact children's stress levels, which can be seen from their cortisol levels [26].

2.3.3 Type of diagnosis and level of treatment

The type of diagnosis and level of treatment can influence the level of fatigue and stress in children and adolescents with cancer [27]. In pediatric cancer patients who experience fatigue, non-pharmacological therapy, including music therapy, is not very significant [28].

3. Cortisol as a biomarker of stress

Stress measurement through hormone examination in determining a person's emotional status is objective. This method is quite beneficial for pediatric patients who have not been able to express their feelings. It can identify stressful conditions in a person's body that are not visible to the naked eye. As previously explained, one of the hormonal responses to stress is an increase in cortisol as a self-defense effort. Elevated cortisol levels are a good indicator for someone experiencing acute stress or chronic stress [29]. Cortisol can be detected through a saliva test. Salivary cortisol examination is better, more effective, and more valid than blood examination to assess adrenocortical function [30, 31]. The advantages of using salivary cortisol are easy sampling, non-invasive, fast, and repeatable. It also does not require special equipment and can be performed outside the laboratory [32]. Over the past 20 years, salivary cortisol has become the most popular biomarker used in stress studies.

3.1 Cortisol physiology

Cortisol is the main glucocorticoid hormone produced by humans. Glucocorticoids increase blood glucose levels by counteracting insulin secretion and action to inhibit peripheral glucose uptake, promoting hepatic glucose synthesis (gluconeogenesis) and hepatic glycogen levels [33]. The main functions of cortisol are to control carbohydrate, protein, and fat metabolism, suppress inflammatory tissue processes in response to injury, suppress immune responses to foreign antigens, and increase the body's ability to withstand various harmful stimuli (stress) [34].

Cortisol secretion by the adrenal cortex is controlled by a negative feedback system involving the hypothalamus and anterior pituitary. Adrenocorticotropic Hormone (ACTH) from the anterior pituitary stimulates the adrenal cortex to secrete cortisol. The cells that produce ACTH, in turn, only work following orders from Corticotropin-Releasing Hormone (CRH) from the hypothalamus. The feedback control loop is complemented by the inhibitory effect of cortisol on CRH and ACTH secretion by the hypothalamus and anterior pituitary. The negative feedback system for cortisol maintains a relatively constant level of cortisol secretion. Two additional factors that influence plasma cortisol concentrations in the basic negative feedback control system are diurnal rhythm and stress, both of which react on the hypothalamus to vary the level of CRH secretion [1]. The control of cortisol secretion is shown in **Figure 1**.

3.2 Cortisol circadian rhythm

In the absence of stress exposure or under normal conditions, cortisol secretion exhibits a distinct circadian rhythm when concentrations are highest in the morning (circadian peak), progressively decline from late afternoon to early nocturnal periods (circadian trough), and show a sudden increase after the first few hours of sleep [36]. The circadian rhythm of cortisol can be seen in **Figure 2**.

Normal cortisol in children follows a pattern similar to the circadian pattern in adults, decreasing from 11.00 am to 4.00 pm [37]. The normal range of salivary cortisol levels is between 0.2–11.3 ng/ml. An increase or decrease in salivary cortisol levels is considered significant if there is a difference in 0.05 ng/ml [38].

3.3 Factors affecting cortisol secretion

The interpretation of elevated cortisol can consider several factors (shown in **Table 1**) that can influence it. Infectious factors such as viral infections are also

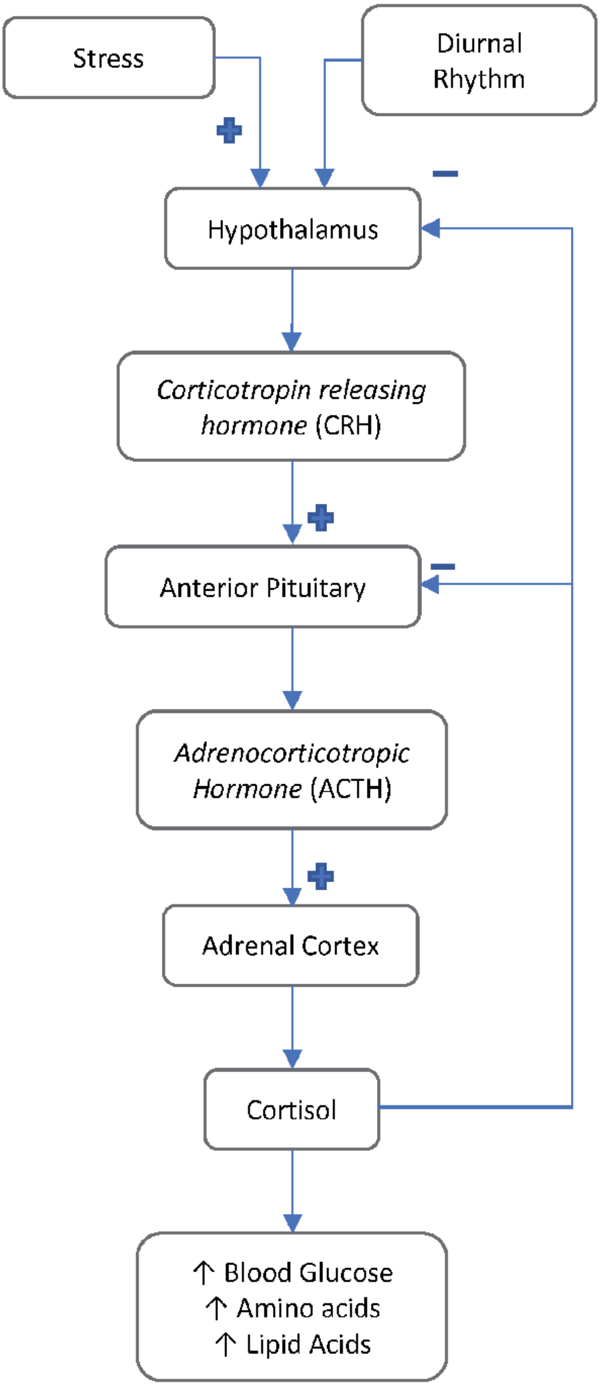

Figure 1.
Control of cortisol secretion [35]. Cortisol secretion is influenced by stress and diurnal rhythms. Increased cortisol in the blood will provide negative feedback on the hypothalamus and anterior pituitary to reduce cortisol secretion.

considered to affect increasing cortisol levels in the body [41]. Elevated cortisol occurs concomitantly with high C-Reactive Protein (CRP) and procalcitonin (PCT) in patients with fever without severe sepsis [42]. A person's symptoms and stress levels are closely related to physical suffering and psychological characteristics [43]. Thus, high cortisol levels are also associated with disability [26, 44].

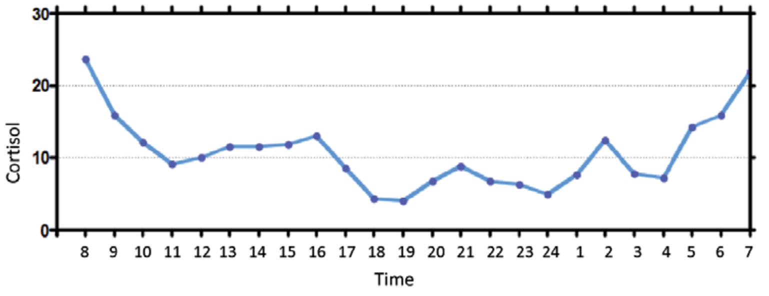

Figure 2.
Circadian rhythm of cortisol [36]. Concentrations are highest in the morning (circadian peak), decline steadily from late afternoon to early nocturnal periods (circadian trough), and show a sudden increase after the first few hours of sleep.

Factors affecting	Description
Individual factors including age, gender, and race	a. Cortisol levels increase with age, especially in the elderly. Besides, cortisol reactivity to stress differs depending on age. b. Gender does not affect basal cortisol, but there is a difference in experimental stress exposure. c. The research studied the influence of race on cortisol levels shows varying results. Further research is needed to determine for sure the effect of race on cortisol levels.
Somatic factors	a. Acute and chronic diseases, endocrine and autoimmune diseases. b. Use of drugs (glucocorticoids, anticonvulsants such as phenytoin and carbamazepine, and opioid drugs) c. Obesity
Lifestyle factor	a. Sleep patterns b. Food intake (especially lunch) c. High-protein foods d. Caffeine consumption (regular caffeine consumption increases the activation of the HPA axis, especially during the day) [40] e. Smoking f. Alcohol consumption g. Physical activity.
Psychosocial factors	Exposure to acute and chronic psychosocial stress

Table 1.
Factors affecting cortisol secretion [39].

Acute pain from mechanical, chemical, or thermal stimulation will release chemical mediators in the periphery that initiate the pain. Transient activation of peripheral nociceptive fibers sends pain signals through the dorsal horn of the spinal cord to the brain, where the pain signal is perceived. Stress from perceived pain can cause the release of stress hormones such as cortisol [45]. The slightest medical procedure can cause pain and distress in children [46]. Medical actions against the children's wishes, such as accidental removal of an IV needle and repeated needle sticking, can result in higher distress [26]. This can directly impact extreme physiological symptoms such as vasovagal responses, heart rate changes, stress hormones (cortisol and corticotrophin), and ECG [47, 48].

A sharp increase in cortisol secretion mediated by the central nervous system through increased activity of the CRH-ACTH-Cortisol system occurs in response to all kinds of stressful situations [1]. The magnitude of the increase in cortisol concentration is generally proportional to the intensity and extent of the stress stimulus. More significant increases in cortisol levels are elicited in response to severe stress. Music therapy is a complementary therapy that can be used to reduce the stress response. Still, for the previously mentioned conditions, music therapy does not positively impact the patient. Giving music therapy to individuals with extreme increases in cortisol levels may have minimal or no effect.

4. The effects of music therapy on cortisol levels

Children with health problems often require painful procedures to diagnose or treat their illness. Treatment of the disease may result in the child having to undergo a series of invasive procedures regularly. The most commonly performed invasive procedure is an intravenous puncture. This puncture can cause pain, resulting in stress, such as behavioral responses including crying, vomiting, verbal complaints, and physiological responses, including increased blood pressure, increased stress hormones, muscle tension, and sweating [49].

Physiological responses are controlled by the HPA axis and the sympathetic and parasympathetic components of the peripheral nervous system. The HPA axis interacts with stress-activating centers in the brainstem and hypothalamus and releases Corticotrophin Releasing Hormone (CRH), which is one of the main effects of the stress reaction. CRH stimulates the anterior pituitary to secrete ACTH, and increased ACTH secretion can stimulate the adrenal cortex to increase cortisol secretion [50]. Most studies support the cortisol response to both acute and chronic stress [51].

Cortisol is an objective biomarker associated with general psychological status. It can be used primarily to evaluate children's physiological reactions under stress exposure [52]. Stress is associated with increased production of the cortisol hormone, which is known to suppress the immune response [53].

Control of cortisol activity can be altered through psychosocial interventions [7]. Music therapy is a psychosocial intervention that is safe, easy, economical, and feasible to use and has the benefit of reducing cortisol levels as a stress biomarker in pediatric patients. Music is considered as an adjunct therapy in clinical situations causing pain or anxiety [54]. Several studies have shown the effectiveness of music therapy to reduce cortisol as a stress biomarker in pediatric patients. Furthermore, listening to music can reduce subjective stress levels, decrease salivary cortisol secretion, and increase salivary alpha-amylase activity, which is higher [26, 55]. In addition, music therapy has a positive effect in controlling salivary cortisol concentrations, systolic and diastolic pressure, heart rate, body temperature in anxious dental patients [56]. Listening to soft, relaxing music for an hour in the postoperative period has beneficial effects on the stress response, such as a much more significant reduction in cortisol levels [57].

The mechanisms underlying the effects of listening to music on stress levels are still being studied. There are three possible mechanisms. First, the regulation of activity in the mesolimbic dopaminergic system by music (primarily based on increased activity in the ventral tegmental area and nucleus accumbens with corresponding reactions to stress and pain). Second, the downregulation of amygdala central nuclear activity by music with a down-regulatory effect on fear and worry levels and activity of hypothalamic and brainstem nuclei involved in endocrine generation (HPA axis), and vegetative stress responses (such stress-related effects may also include modulation of beta-endorphin levels). The sound of music that has

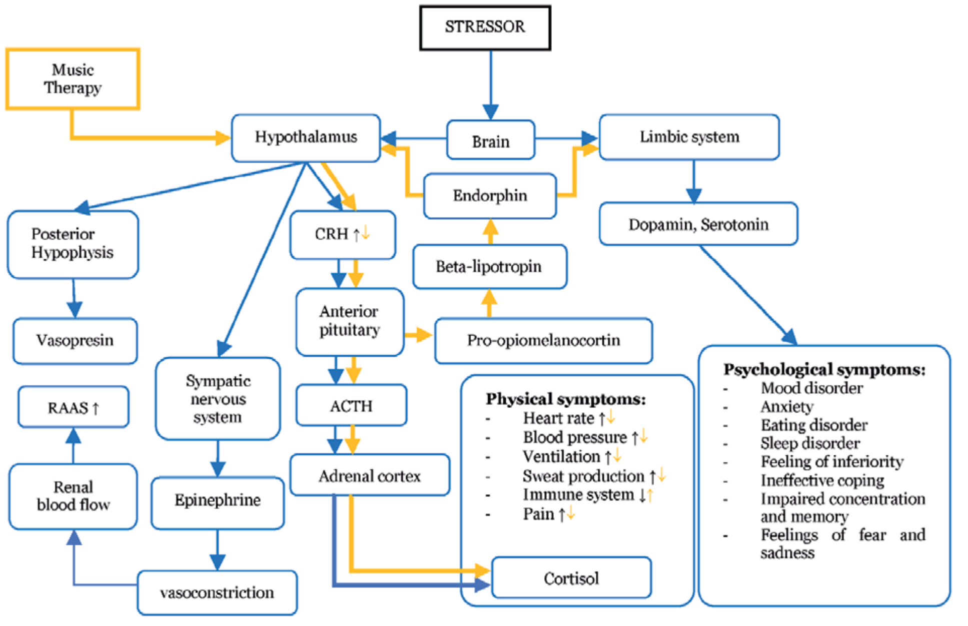

Figure 3.
Mechanism of music therapy in reducing cortisol and stress levels.

been received and perceived by the brain will stimulate the hypothalamus, which will then prompt the pituitary to produce endorphins. Endorphins are endogenous opiates (morphine) that function as the body's natural analgesics and protect/relieve the body from stressful conditions [1, 58]. Endorphins are mainly synthesized and stored in the anterior pituitary from the precursor protein proopiomelanocortin (POMC). POMC is a large protein broken down into smaller proteins such as beta-endorphin, alpha-melanocyte-stimulating hormone (MSH), adrenocorticotropin (ACTH), etc. The pituitary synthesizes POMC in response to signals from the hypothalamus (in the form of corticotropin-releasing hormone (CRH)). When POMC cleavage protein products accumulate in excess, a negative feedback loop suppresses CRH production in the hypothalamus, thereby decreasing the secretion of stress hormones, including cortisol [59]. Third, music affects the participants' cognitive resources (including attention) in the patients given the music intervention (**Figure 3**) [58, 60].

Music therapy is not adequate for specific conditions such as fever, the severity of infection, disability, children with cancer with relapse, repeated needle sticking, etc. A person in these conditions usually has extreme levels of cortisol. Music therapy is not effective, even has a negative impact if given when a person has excessive cortisol levels [26].

When a person has a fever, music therapy becomes ineffective in lowering cortisol levels. The cortisol hormone will directly increase when you have a fever. This happens because Cortisol Binding Globulin (CBG) is a thermocouple protein. It is a protein that is sensitive to temperature changes and will release cortisol in response to fever [61]. The cortisol hormone as a biomarker of stress will increase when children with fever are given music therapy [26].

5. Conclusions

Various physical and psychological events can be a cause of stress in children. This stressful condition can be identified through an increase in cortisol levels.

Increased cortisol level is considered the best indicator to determine a person's stress condition, both acute and chronic. The cortisol examination method can be carried out through saliva and blood. Cortisol examination through saliva is much better, more effective, and more valid than cortisol analysis through blood. Besides, this examination is more beneficial in children because it does not cause pain.

The increase in cortisol as an indicator of stress can be changed through psychosocial interventions, one of which is the provision of music therapy. Music therapy can manage stress problems in various ages with minimal side effects and a small budget. It is easy to use and does not require the intellectual ability to interpret. There are no limitations for users to use music therapy. However, several things must be considered before the therapy is given, for example, environmental conditions when the therapy is provided, adjustment of music type, the duration for pediatric patients (should be less than 20 minutes), and the severity of the disease experienced by the patient.

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Conflict of interest

The authors declare no conflict of interest.

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Chapter 6

Impulse Response Modeling of the Box Shaped Acoustic Guitar

Minakshi Pradeep Atre and Shaila Apte

Abstract

Music is the pulse of human lives and is an amazing tool to relieve and re-live. And when it comes to the signal processing, impulse is the pulse of the researchers. The work presented here is focused on impulse response modeling of noted produced by box shaped acoustic guitar. The impulse response is very fundamental behavior of any system. The music note is the convolution of the impulse response and the excitation signal of that guitar. The frequency of the generated music note follows the octave rule. The octave rule can be checked for impulse responses as well. If the excitation signal and impulse response are separated, then an impulse response of a single fret can be used to generate the impulse responses of other frets. Here the music notes are analyzed and synthesized on the basis of the plucking style and plucking expression of the guitar-player. If the impulse response of the musical instrument is known, the output music note can be synthesized in an unusual manner. Researchers have been able to estimate the impulse response by breaking the string of the guitar. Estimating the impulse response from the recorded music notes is possible using the methodology of cepstral domain window. By means of the Adaptive Cepstral Domain Window (ACDW) the author estimated the impulse response of guitar notes. The work has been further extended towards the classification of synthesized notes for plucking style and plucking expression using Neural Network and Machine Learning algorithms.

Keywords: impulse response, modeling, acoustic guitar, convolution, frets, octave rule, adaptive cepstral domain window

1. Introduction

The work starts with analysis of different ways of mathematical modeling of music instruments. The aim is to bridge the gap between the synthesized music note and the original note. Efforts have been taken to propose a model to preserve some of the oldest and 'on the verge of obsolete' music instruments. Past researchers developed various instruments' models. One of the models included attack, decay, sustain and release (ADSR) parameter-based model. **Figure 1** shows the ADSR graph. These parameters measure the time required for complete music note generation. The ADSR is also known as 'timbre' of the music note and is helpful for differentiating instrument families. Perception of the music note occurs with the timbre i.e. envelope and the fundamental frequency i.e. 'pitch' along with its harmonics. The fullness of the music notes is perceived by these harmonic frequencies. The Fast Fourier Transform (FFT) is the frequency domain representation of the

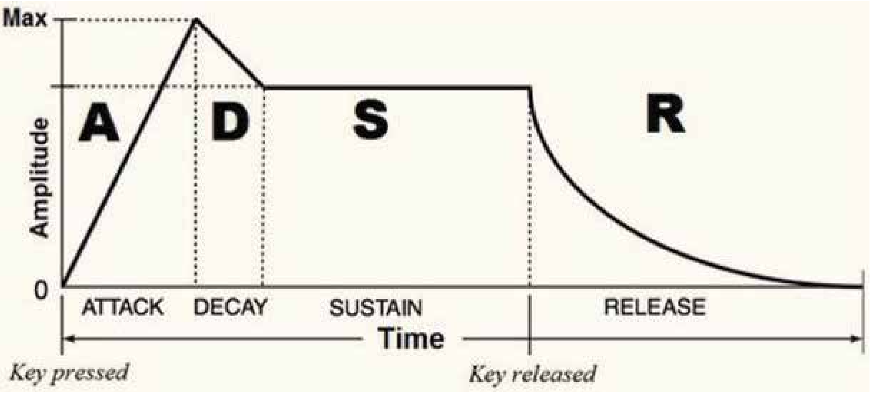

Figure 1.
ADSR parameters. Source: https://www.a-mc.biz/.

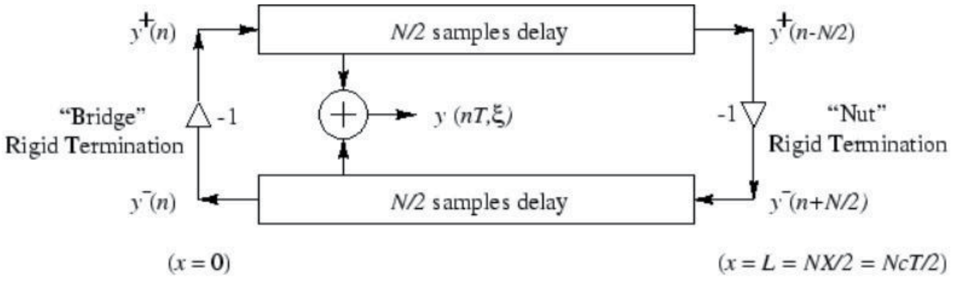

Figure 2.
DWG for acoustic guitar. Source: Ee.Columbia.Edu.

any signal (here, the music notes). In the early days of modeling, the pitch and timbre set the foundation for the current development in the instrument modeling. ADSR synthesis has limitations of producing the required number of harmonics mathematically to reach that richness or fullness of the original music note.

The other method, digital waveguide (DWG), is also used for modeling the musical instruments. **Figure 2** shows the schematic diagram of DWG technique. It is used to express the musical instruments in wave form guided between two fixed points. It puts forward the concept of music note as a wave traveling between two points. Bridge and Nut are the endpoints (rigid terminations) between which the music note wave is traveling. This DWG string modeling involves non-linear distortions and its post distortion gain needs to be adjusted to develop the model. DWG appears to be challenging due to more computational burden.

Then researchers also experimented with impulse response of the musical instrument. There has been competitive research to find the impulse response of musical instrument. Researchers have used hammer method for estimating the impulse response. The experimentation to find impulse response, also involved breaking the string of guitar as we discussed earlier. Well, keeping the limitations in mind, the research started with cepstral domain approach, well-known technique for speech processing.

Every instrument is unique and this uniqueness can be demonstrated with impulse response. It's as unique as the fingerprint of a person. The experiments involved breaking the string of the guitar to record the impulse response. Certainly, this made the author to think further to improve this uniqueness of the instrument,

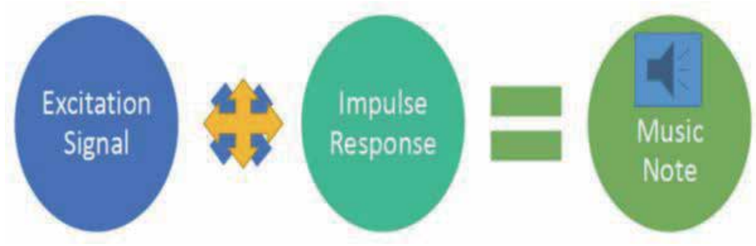

Figure 3.
Block diagram for music note generation using convolution.

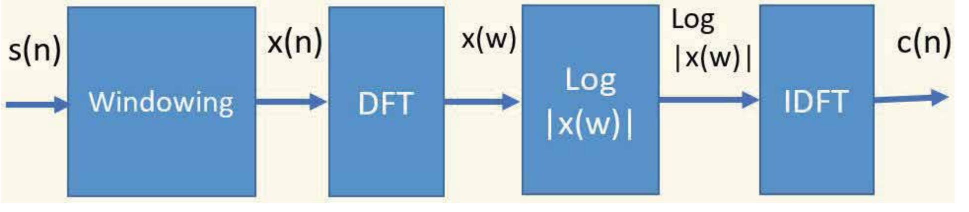

Figure 4.
Block schematic of cepstrum computation.

i.e. impulse response using cepstral domain representation. Being a guitar lover, the author chose the box shaped acoustic guitar music notes for the research work.

A simple convolution operation is involved in the generation of the music note. The excitation signal, x(t) is convolved with the impulse response of the instrument to generate the music note, y(t). **Figure 3** shows the block diagram for this signal processing operation. When the music note is recorded and x(t) is known, the impulse response can be estimated and recorded. This research demonstrated the extraction of the impulse response of the music note, based on adaptive cepstral domain window (ACDW) method. **Figure 4** shows the outline of the cepstral domain window approach. The impulse response based synthesis is carried out and the listening tests are conducted on the guitar players to measure the mean opinion score (MoS) of synthesized notes. Further, the machine learning algorithms are used to classify the synthesized notes for playing expression.

The outline of the chapter is as follows: the Section 2 will discuss the work by other researchers, Section 3 will discuss the methodology for the impulse response modeling while Section 4 will discuss the results in detail. The Section 5 will summarize the work and conclude the modeling work for acoustic guitar.

2. Literature review

This section reviews the modeling techniques of guitar as an instrument. The physical model of an acoustic guitar consists of three main parts: strings of guitar, the wooden sound box and the sound radiated by the soundboard. The review starts with the modeling techniques used for guitar strings, continues with the modeling techniques involving the sound box and finally the convolved signal i.e. radiated sound by the soundboard. It also covers the Neural Network (NN) and Deep Learning based classification techniques and verification of synthesized music instruments. The literature survey has been divided into: Physical or mathematical modeling and Impulse response methods.

The work by Gerald Schuller et al. in [1] has been used as reference for collection of acoustic guitar notes. They considered 5 plucking styles finger-style (FS), picked (PK), muted (MU), slap-thumb (ST), and slap-pluck (SP) and the 5 expression styles: normal (NO), vibrato (VI), bending (BE), harmonics (HA), and dead-note (DN) for feature extraction of plucking and expression styles of electric bass guitar. Anssi Klapuri et al. [2] have proposed a method for extracting the fingering configurations automatically from a recorded guitar performance. 330 different fingering configurations are considered, corresponding to different versions of the major, minor, major 7th, and minor 7th chords. Hidden Markov Model has been used.

Migneco et al. [3] proposed physical models for plucked string instruments that can produce high-quality tones using a computationally efficient implementation, but the estimation of model parameters through the analysis of audio remains challenging. Moreover, an accurate representation of the expressive aspects of a performance requires a separation of the performer's articulation (source) from the instrument's response (filter). This work explores a physically-inspired signal model for plucked guitar sounds. It facilitates the estimation of both string excitation and resonance parameters simultaneously. Julius O Smith [4] discussed the piano synthesis, focused on commuted synthesis. The instrument models can be treated as Linear Time Invariant systems and that's why the commutation is possible. Commuted synthesis promotes implementation of enormous resonators inexpensively, three orders of magnitude less computation for other string instruments. The sound board and enclosure (i.e. guitar body) are commuted. It needs stored recording of their impulse responses. Otherwise it demands higher order digital filters.

Further, the work by Meng Koon Lee et al. in [5] talks about the physical modeling based on the interaction of the strings of the guitar with other parts of the guitar body. The researchers experimented with the sound generated by guitar with respect to soundboard and its relationship with the guitar body. The soundboard plays an increasingly important role compared to the sound hole, back plate, and the bridge at high frequencies. Design of bracings and their placements on the soundboard increase its structural stiffness as well as redistributing its deflection to non-braced regions and affecting its loudness as well as its response at low and high frequencies. The work is focused to increase the sound level with bracing designs and their placements. The analysis is being carried out for the archtop guitar.

The paper [6], written by Keith D Martin explains the classification technique based on physical properties. It is focused on the classification using pattern recognition. A statistical pattern-recognition technique is applied to instrument tones within a taxonomic hierarchy. The salient acoustic features related to physical properties of source excitation and resonance structure are measured from output of auditory model for 1,023 isolated tones over the full pitch ranges of 15 orchestral instruments. The data set included examples from the string (bowed and plucked), woodwind (single, double, and air reed), and brass families. Eric J. Henry et al. [7] proposed a model that can yield representations for the chords that require minimal prior knowledge to interpret. The model has been developed to address both challenges by modeling the physical constraints of a guitar to produce human-readable representations of music audio, i.e. guitar tablature via a deep convolutional network.

Jakob Abeßer et al. [8] worked on a feature-based approach for the classification of different playing techniques in bass guitar recordings. The applied audio features are chosen to capture typical instrument sounds induced by 10 different playing techniques. This work introduced a set of low-level features that allowed modeling the peculiarities of 10 different bass-related plucking and expression styles by capturing typical timbre related characteristics. The work further in [9] models the plectrum which is used for playing guitar notes. Here Francois Germain et al. proposed a model of the plectrum, a guitar pick, for use in physically inspired sound synthesis. The model is drawn from the mechanics of beams. The profile of the plectrum is computed in real time based on its interaction with the string, which depends on the movement impressed by the player and the equilibrium of dynamical forces. A condition for the release of the string is derived, which allows driving the digital waveguide simulating the string to the proper state at release time. The algorithm proposed by Henri Penttinen et al. [10] estimates the plucking point of guitar tones obtained with an under-saddle pickup. This problem is approached in the time domain by applying autocorrelation estimation. Onset detection has been improved in this proposed work. It enables a new way to control audio effect parameters in real time by simply changing the plucking point. The plucking position changes the timbre of the string's tone, most notably the brightness. This effect is used as an expressive tool in music. By using the PPE (Plucking Point Estimation) algorithm to control an audio effect, change in the plucking position can affect the timbre even more dramatically than in the natural unprocessed case.

Gabriele Varieschi et al. [11] presented mathematical and physical models to be used in the analysis of the problem of intonation of musical instruments such as guitars, mandolins and similar instruments. The analysis is done by designing the fret's placement on the fingerboard according to mathematical rules assuming an ideal string. The intonation of a string note gets affected when other string's deformation and inharmonicity come into picture. To nullify the effects, the authors have designed some compensation procedures. V.E.Howle et al. [12] proposed a known tool of Eigenvalue to musical instruments. The work as its name "Eigenvalues and musical instruments" suggests is based on finding the eigenvalues of musical instruments. The instrument categories like strings, bars and drums fall under linear system's class. It is focused on plotting the eigenvalues for different types of musical instrument giving pictorial view of change in the eigenvalues with change in different parameters like stiffness, friction or sound radiations.

Antoine Chaigne et al. [13] considered the end conditions of piano strings and proposed that it can be approximated by the input admittance at the bridge. A method of validation of admittance measurements on simple structures is proposed in this paper. High resolution signal analysis performed on string's vibrations yields an estimate for the input admittance. This method is implemented on a simplified device composed of a piano string coupled to a thin steel beam.

A parametric modeling of string instruments is proposed by famous researchers, Matti Karjalainen et al. in [14]. Parametric modeling of musical instrument sounds again helps to re-synthesize the music sounds or morph them. This type of modeling can also be used to apply the parameters in physical and perceptual studies of acoustic instruments. It is typically based on pole-zero modeling technique applied to string instrument sounds. As proposed by Julius Smith the instruments are assumed to be linear time-invariant systems while using this parametric modeling. Our research work has been directed by the same principal as that of the work by Julius Smith.

The authors in work [15, 16] talk about sound separation. It is very important for developing the equalizers to balance the sounds of different musical instruments in music events. The method based on 'anisotropic smoothness' indicates that the harmonic instruments are smooth in the time domain whereas the percussive instruments are smooth in the frequency domain. The authors have worked on both the types of music notes. The spectrogram highlights this smoothness in time and the frequency domain and the method is implemented under some conditions. The work reduced the computational complexity for source separation as compared with the other methods as Monte-Carlo method and large-sized matrix multiplications. The results are discussed for the acoustic guitar and piano as the harmonic instruments and the drum as the percussive instruments. This paper again helped us to understand the spectrogram approach towards the source separation.

Further with reference to impulse response research, Nelson Lee et al. [17] proposed a method of decomposing a plucked string instrument into modular components. The model is based on parameter estimation of excitation signal, string vibration, body resonator and finally the radiated sound pressure. As the modeling progresses it becomes clear that for reaching close to body impulse responses, the order of the filter demands a hundred of poles and zeros. Inverse filtering is used to compensate for high orders of filters.

Friedrich Türckheim et al. [18] used the 'Novel Approach of Impulse Response measurement' as starting point for modeling approaches or to investigate the relationship between transfer functions and the instruments' quality. This is done usually for the experimental determination of transfer function as the complete and reliable physical models are still to be developed. The impulse responses here have been compared with the commonly used impact hammer method. The work proposed in above two references have limitations of filter orders and determination of exact transfer functions. So the author thought of different approach for the calculation of impulse response of the guitar body.

3. Methodology

Methodology adopted by the author is different than other researchers. So this section is the summary of the research work carried out for impulse response modeling of acoustic guitar. The sections 3.1 and 3.2 discuss the structure of acoustic guitar body and the collection of music notes for two different plucking styles and plucking expressions. Section 3.3 describes how the *Octave Rule* is used for the frequency calculation and verification of all music notes along the fretboard. Lastly, the Section 3.4 gives the details of the impulse response modeling.

3.1 Structure of acoustic guitar

Let us understand the structure of the box shaped acoustic guitar. It has a resonance cavity, shaped like a butterfly. The wings are short at nut side and are bigger at the saddle side. As shown in **Figure 5**, there are six strings on the acoustic guitar. The strings are tied between the saddle and the nut of guitar on the fingerboard. The fingerboard is also known as fretboard.

The fingerboard of guitar consists of 19 to 21 frets. The frets are the metal marks on the fretboard, arranged in logarithmic scale. They are shown with x1, x2, x3, ... x19 here. The acoustic guitar model, FAW 802 is chosen for the research work.

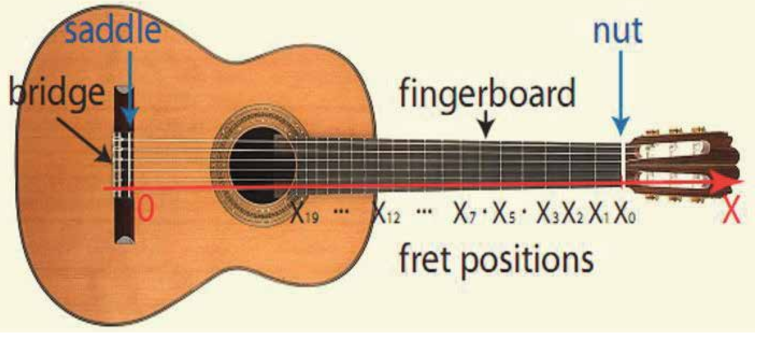

Figure 5.
Structure of the box shaped acoustic guitar. Source: Gabriele Umberto Varieschi.

The music notes were recorded in an acoustic studio. The acoustic guitar chosen for this research work has twenty-one frets and six strings. Music notes on twenty frets are considered for the analysis and synthesis purpose.

3.2 Collection of guitar notes and database generation

The music note is recorded for each fret of each string (except the 21st fret). The guitar notes are collected based on: plucking style and the plucking expression. The plucking style indicates the object used for plucking the string of the acoustic Guitar. The plucking expression indicates whether the note is played by a naïve (beginner) person or the expert person. The two players, one naïve and the other, expert, are recorded for two plucking styles. The **Figure 6** gives overview of the collection strategy of the Guitar notes.

When the string is plucked by finger, it will generate a music note and it is named as '*plucked note*' here. Similarly, if the string is plucked by plectrum (or pick), the generated music note will be named as '*picked note*'. The total number of notes generated are calculated as: the number of frets multiplied by the number of strings, i.e. (20* 6 =) 120 notes. These all are called as "fretted notes". If no fret is pressed, then the note played will be called as '*open string*' note. There will be a set of 120 fretted notes with 6 open string notes for single player for each style. The notes played by same player are recorded for another plucking style i.e. picked.

The **Figure 7** shows the frequency values for all strings and their frets. The frets are 1F to 20F. The first column gives the string numbers along with their names: string E, string B, string G, string D, string A, string E. The column, 'OPEN' gives the open string frequencies with 82 Hz as the lowest frequency value and 329 Hz as the highest open string frequency value. The frequency for fretted notes varies from 87 Hz for string 6 fret 1 to 1047 Hz for string 1 fret 20. This is the maximum frequency of the guitar note. All guitar notes are therefore recorded with 16 kHz

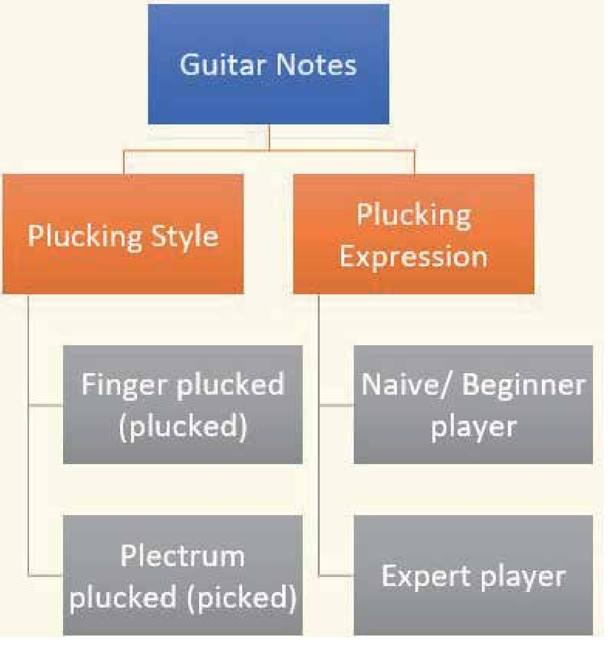

Figure 6.
Collection of acoustic guitar notes.

E — Note Name
329 — Frequency [Hz]

	OPEN	1F	2F	3F	4F	5F	6F	7F	8F	9F	10F	11F	12F	13F	14F	15F	16F	17F	18F	19F	20F
1st	E 329	F 349	F# 370	G 392	G# 415	A 440	A# 466	B 494	C 523	C# 554	D 587	D# 622	E 659	F 698	F# 740	G 784	G# 831	A 880	A# 932	B 988	C 1047
2nd	B 247	C 262	C# 277	D 294	D# 311	E 329	F 349	F# 370	G 392	G# 415	A 440	A# 466	B 494	C 523	C# 554	D 587	D# 622	E 659	F 698	F# 740	G 784
3rd	G 196	G# 208	A 220	A# 233	B 247	C 262	C# 277	D 294	D# 311	E 329	F 349	F# 370	G 392	G# 415	A 440	A# 466	B 494	C 523	C# 554	D 587	D# 622
4th	D 147	D# 156	E 165	F 175	F# 185	G 196	G# 208	A 220	A# 233	B 247	C 262	C# 277	D 294	D# 311	E 329	F 349	F# 370	G 392	G# 415	A 440	A# 466
5th	A 110	A# 117	B 123	C 131	C# 139	D 147	D# 156	E 165	F 175	F# 185	G 196	G# 208	A 220	A# 233	B 247	C 262	C# 277	D 294	D# 311	E 329	F 349
6th	E 82	F 87	F# 92	G 98	G# 104	A 110	A# 117	B 123	C 131	C# 139	D 147	D# 156	E 165	F 175	F# 185	G 196	G# 208	A 220	A# 233	B 247	C 262

Figure 7.
Standard frequency for guitar notes: Guitar frets and their notes versus frequency.

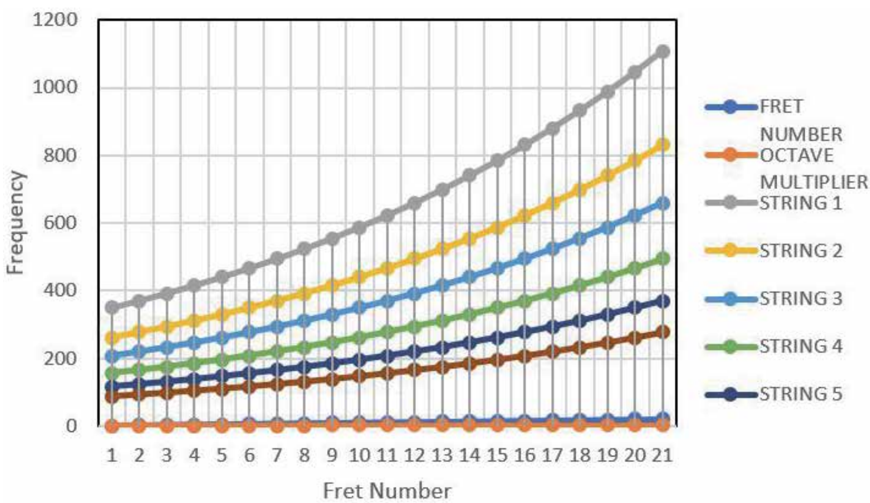

Figure 8.
Frequency generation for music notes on all frets and strings.

sampling frequency in '.wav' format. Software for sound analysis, named, 'Audacity' is used for noise removal of the guitar notes.

Figure 8 shows the scatter plot of the frequencies of all frets of all strings. The numbers 1 to 21 on the x-axis represent the fret numbers of the strings. The y-axis depicts the frequencies of guitar notes. This scatter plot helps to understand the mathematical relationship as well as the minimum and the maximum frequency values for these notes. The maximum frequency for the notes is 2 kHz so the sampling frequency of 16 kHz is selected for recording of the music notes in acoustic studio.

The string E with 329 Hz frequency is string 1, string B with 247 Hz frequency is string 2, string G with 196 Hz frequency is string 3, string D with 147 Hz frequency is string 4, string A with 110 Hz frequency is string 5 and the string E with 82 Hz frequency is string 6. The strings are mentioned by the numbers (like string 1, string 2 …) in further discussion of research work. Total 504 sound notes are recorded including two plucking styles and plucking expressions. Another set of 504 notes is recorded for string modeling. The dataset generated has been published on Mendeley Repository, Elsevier.

3.3 Pythagoras fractions OR rule of 18 (*octave rule*)

Pythagoras fractions or Pythagorean tuning system is developed to study frequency ratios of all intervals which are based on the ratio of 3:2. It is the rule, given by Eq. (1), which indicates the mathematical relationship of all the music notes and is used for checking the frequency of generated notes. Here the 'f_n' gives the frequency of the *n*th fret and 'f_0' is the frequency of open string. The ratio 1/12 is called an 'octave'. One can use this octave relationship for analysis and tuning of instruments. The frequency analysis of recorded notes is done on the basis of *octave rule*. The guitar used for this work is tuned each time before starting the recording of the notes. Once the instrument is tuned, the notes generated follow the octave pattern for frequency values. Here the open string frequencies of recorded notes are verified by autocorrelation formula and then verified by *Pythagoras Fractions.*

$$f_n = f_0 / \left(2^{\frac{n}{12}}\right) \qquad (1)$$

This will create a table for 20 frets of each string. **Table 1** shows the sample calculations of 6 frets for all the six strings from the open string frequencies. In this table, after knowing the open string frequency, all the other frequencies are calculated by using the second column which gives the octave multiplier factor. First column gives the fret number, '*n*'. The values in third to eighth columns are calculated in the way explained below.

Consider the sample values in cells which are highlighted in orange. The calculation for the frequency for string 1 fret 1 is done as:

e.g. 329 Hz * 1.059463 = 349.199 Hz

Thus the *octave rule* is used to verify the music note's frequency. The frequency graphs are plotted using FFT algorithms. After the verification of frequencies and observation of the spectrum of the music notes, it can be stated that picked music notes are closer (sharper) to ideal frequencies than the plucked music notes.

Open String frequencies →		329 Hz (Thinnest string)	247 Hz	196 Hz	147 Hz	110 Hz	82 Hz (Thickest String)
Fret Numbers from nut	Octave multiplier	String 1	String 2	String 3	String 4	String 5	String 6
fret 1	1.059463	349.199	261.5814	207.6548	155.5292	116.5409	87.29976
fret 2	1.122462	369.9635	277.1359	220.0026	164.7774	123.4708	92.49087
fret 3	1.189207	391.9627	293.6152	233.0846	174.5756	130.8128	97.99067
fret 4	1.259921	415.27	311.0745	246.9445	184.9564	138.5913	103.8175
fret 5	1.33484	439.9632	329.572	261.6286	195.9545	146.8324	109.9908
fret 6	1.414214	466.1248	349.1693	277.1859	207.6066	155.5635	116.5312

Table 1.
Frequency calculation for pick plucked guitar notes by octave method.

3.4 Impulse response modeling

The frequency analysis done in above sections helped to develop better understanding of the fullness of the music notes based on their number of harmonics. This is also helpful to get better understanding of the playing style and plucking expressions. The frequency analysis is now followed by the impulse response estimation. The next five subsections deal with the synthesis part of the research work and discusses the algorithmic approach towards the impulse response modeling.

3.4.1 Introduction

The cepstral domain approach is frequently used for speech signal processing but it is not so far used for music signal processing. This method is used for separation of vocal tract response and the excitation signal in speech signal processing. Based on the same principle, this modeling work is focused on separation of: 1) impulse response or body response from 2) excitation signal of the acoustic guitar notes.

The next section discusses the algorithm for Cepstral Domain Windowing (CDW) and its application for modeling of acoustic guitar notes using the same CDW method.

3.4.2 Cepstral domain window method

Let us focus on theoretical aspects of cepstral domain. **Figure 9** shows the block schematic of the cepstral domain method used for speech analysis. The input to the system is speech signal. The speech signal consists of excitation signal convolved with the impulse response of the vocal tract. On similar principle, the music note is given as input the system. It gives the representative picture of impulse response and the excitation signal, characteristically separated. The excitation signal is periodic in nature and the impulse response is the slowly varying function. The signal is passed through a smooth window function, a Hamming window function and the spectrum is plotted by calculating the FFT of the block. When the logarithm of the magnitude of FFT output is calculated, the periodic excitation signal is clearly seen as rapidly varying function and the vocal tract response appears as the slowly varying function. By using the cepstral domain window, isolation of excitation signal from body response is possible. Thus cepstral domain method can be used for modeling of music note of guitar.

3.4.3 Cepstral domain windowing method for acoustic guitar notes

The block schematic of cepstral domain windowing method for analysis of acoustic guitar music notes is given in **Figure 10**. The algorithm for CDW method

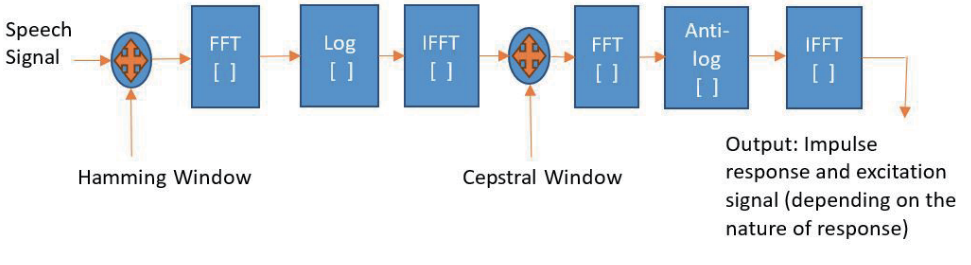

Figure 9.
Block schematic of the cepstral domain method.

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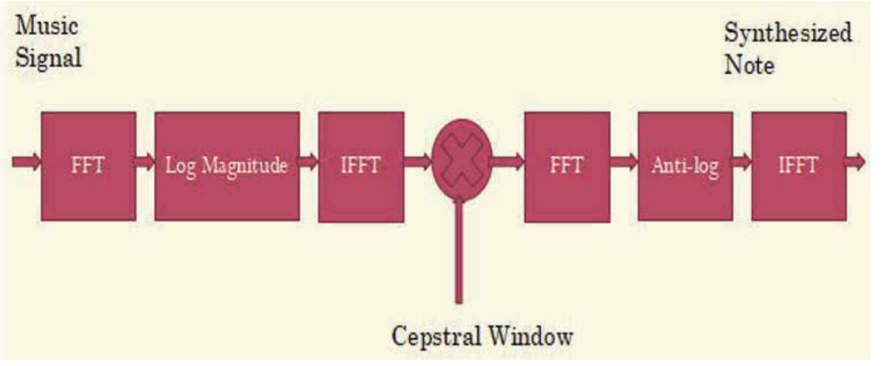

Figure 10.
Cepstral domain approach to synthesize the music note.

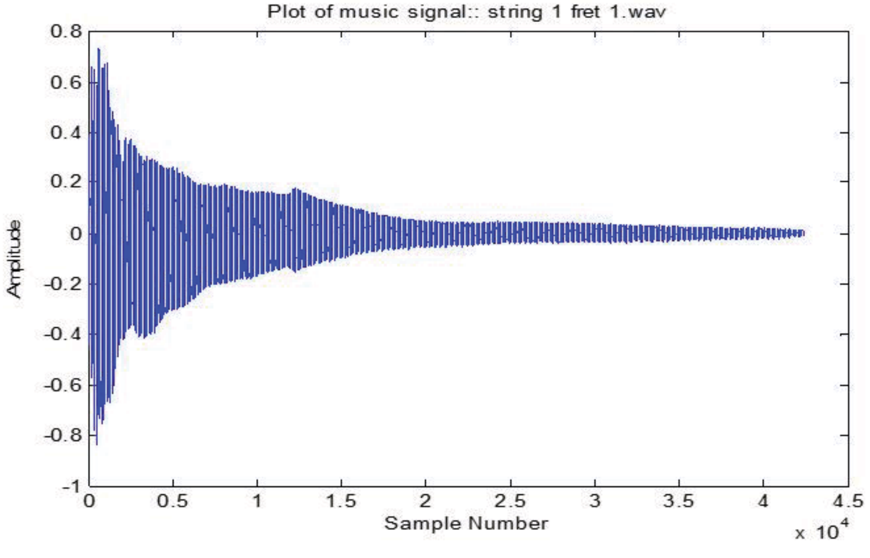

Figure 11.
Time domain representation of input music note, string 1 fret 1 finger plucked note.

discussed in Section 3.4.2 is used for calculation of body response or impulse response of the guitar box. The input to the system is the acoustic guitar note. The FFT block gives spectrum of the music signal and then the complex logarithm of magnitude of FFT output is taken. The periodic excitation is seen as a rapidly varying function and guitar body response appears as the envelope of the spectrum. The body response is a slowly varying function. After the IFFT of the signal is calculated it enters in the cepstral domain. The cepstral domain plot indicates a cluster near the origin that represents the body response and the periodic peaks after the cluster represent the periodic excitation generated due to plucking of the string by hand or by plectrum.

The string1 fret 2 note is taken as sample input to the different blocks in **Figure 10**. **Figure 11** shows the time domain representation of this acoustic guitar note used as input to the system for isolation of body response and the excitation signal for string 1 fret 2 with finger plucking style. The sampling rate for the recorded note is 16 kHz.

3.4.4 Synthesis of guitar note using isolated body response and the excitation signal

The body responses and the excitation signals are calculated for 252 guitar notes including the plucking style: finger and the plectrum plucked music notes. A note is then synthesized by convolving the estimated body response and the isolated excitation signal. The results are verified using the correlation coefficients and it is observed that the constant length window poses some limitations to give highly correlated synthesized guitar note. **Figure 12** shows the plots for the original guitar note and the synthesized guitar note. But the results are not satisfactory because of the low correlation coefficient values. **Table 2** presents the sample values of 6 frets of string 1 music notes.

The synthesis results are improved by changing the length of the window. This '*adaptiveness*' in the length of the window is named as the '*Adaptive Cepstral Domain*

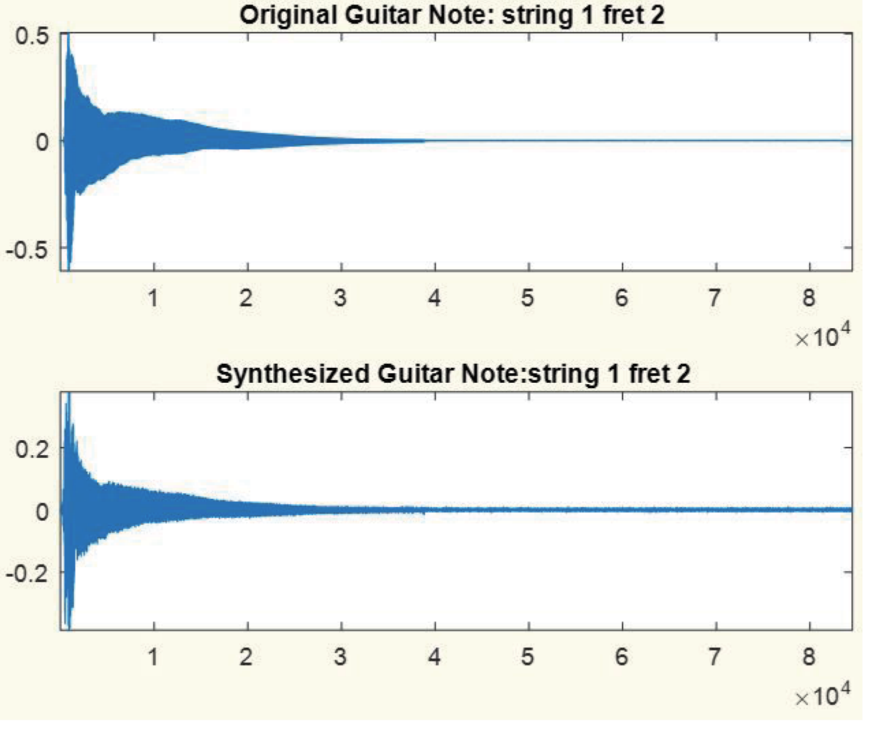

Figure 12.
Synthesized guitar note for string 1 fret 1 using CDW method.

String 1	Correlation coefficient	MoS Score based on (0–1) scale
Fret 1	0.8564	0.85
Fret 2	0.8229	0.85
Fret 3	0.8486	0.85
Fret 4	0.6842	0.8
Fret 5	0.8061	0.8
Fret 6	0.8340	0.8

Table 2.
Correlation coefficient calculations for the string 1 with all frets with fixed sized window.

Window (ACDW)'. The ACDW method gives the best estimation of the impulse response and isolates the excitation signal from the impulse response. Once it's isolated from the excitation signal, modeling of impulse response becomes the focus.

This section covers the discussion of the ACDW method along with the results of impulse response estimation and the synthesis of guitar notes. The length of the window in cepstral domain is changed in the range of 50 samples to 300 samples. The estimation of the best impulse response is done based on correlation coefficient. The correlation coefficient is the statistical parameter to indicate the degree of similarity. A lot of experimentation is done by varying the number of samples of the cepstral domain window. It is observed that the correlation coefficient drops when the number of samples in cepstral domain window are increased further. The range is finalized after studying the impulse response and the synthesis results.

Figure 13 plots the correlation coefficients versus the number of samples in the cepstral domain for the string 1 fret 1 finger plucked Guitar note. From the figure, it's clear that when number of samples in the chosen length of cepstral window is 70, ACDW synthesis gives highest correlation coefficient. The graph shows the decaying nature of the impulse response for the selected guitar note. So the improvement in the synthesis is achieved with the help of ACDW method. Once this is achieved, the extracted impulse responses are analyzed further to observe their relationship. The isolated impulse responses for all the frets of a single string are plotted and it's observed that these impulses are also following the important *Octave relationship* from one fret to the other.

This triggered the thought of using the impulse response of a single fret to generate the impulse responses for the other frets. The experimentation is carried out for string 1 with all its 20 frets for impulse generation. The generated impulses were convolved with the separated excitation signals to generate all the music notes along a single fret. This gives rise to generalized acoustic guitar model where a single impulse response can be stored and used to generate all other music notes of that guitar. **Figure 14** shows the time domain graph of the impulse responses showcasing their octave relationship. It demonstrates the *octave relationship* followed by the impulse responses and *a generalized model* based on impulse response is developed.

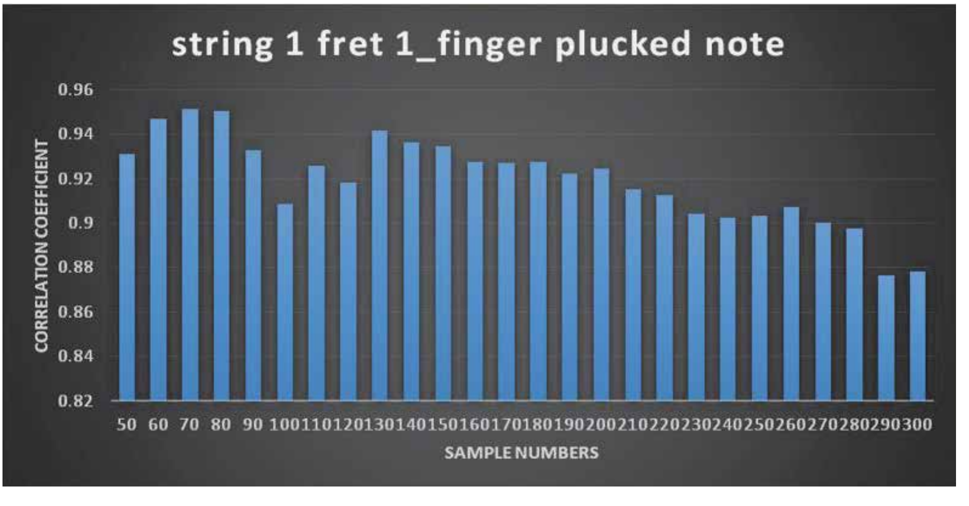

Figure 13.
Comparison of correlation coefficients for different number of samples for string 1 fret 1 finger plucked guitar note.

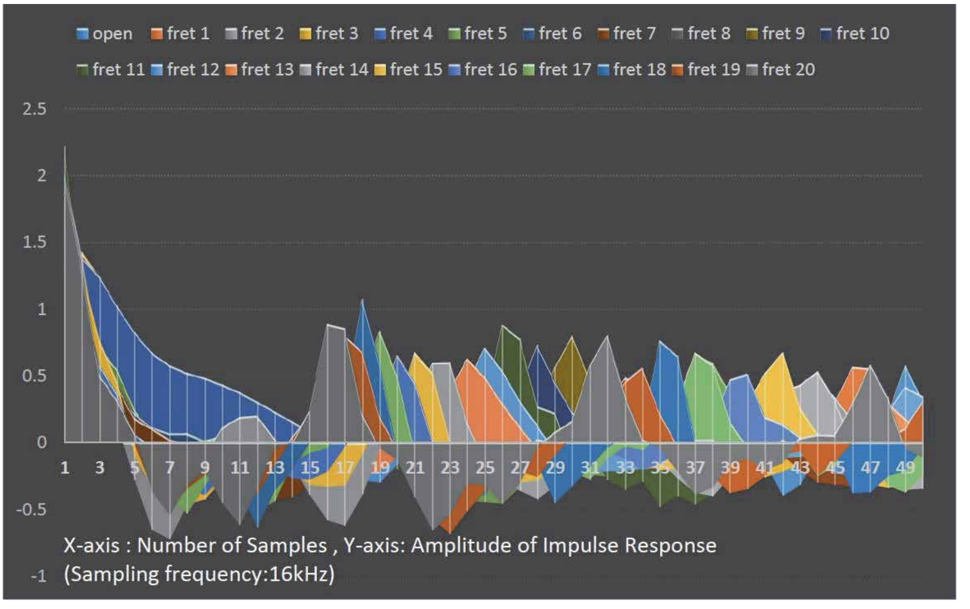

Figure 14.
Impulse responses of finger plucked guitar notes.

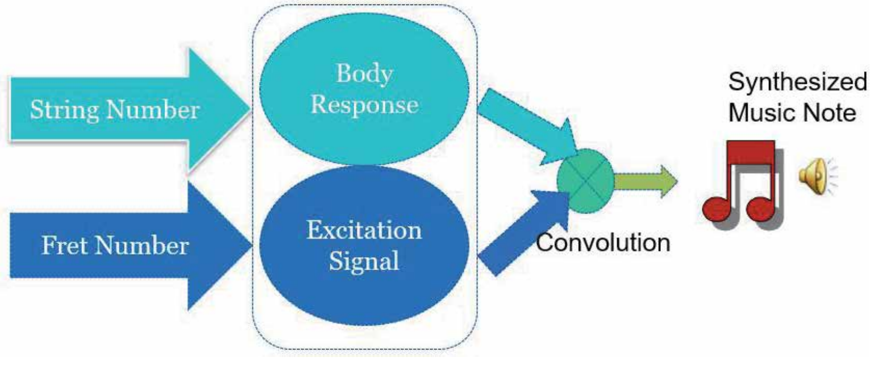

Figure 15.
Block schematic of the synthesized note using impulse response modeling.

In summary, **Figure 15** shows the model for the *'acoustic guitar notes synthesizer'*. The string number and the fret number should be passed to the model and then it will isolate the impulse or the body response from the excitation signal. The estimated impulse response can be convolved with the excitation signal to synthesize the acoustic guitar note.

4. Discussion of results

The synthesis results for the fixed sized windows is poor, given in **Table 2**, as verified with MoS (Mean Opinion Score), *the subjective tests*, taken from 10 guitar players. The MoS is carried out and also the correlation coefficient values are calculated. The results range from the value, 0.68 to 0.9 for the correlation coefficient. That's the reason, the length of the cepstral domain window is kept variable to achieve best correlation coefficient value. This improved the results and helped to

1	Finger pluck	Open string	Fret 1	Fret 2	Fret 3	Fret 4	Fret 5	Fret 6
2	Number of samples in the window	70	60	60	50	50	50	50
3	Correlation coefficient	0.9512	0.9596	0.9517	0.9489	0.8196	0.8856	0.9008
4	MOS score on the scale of(0–1)	0.95	0.95	0.95	0.9	0.8	0.8	0.9
5	Pick pluck	Open string	Fret 1	Fret 2	Fret 3	Fret 4	Fret 5	Fret 6
6	Number of samples in the window	50	190	100	170	300	60	60
7	Correlation coefficient	0.9498	0.9394	0.9452	0.9288	0.9238	0.9442	0.9476
8	MOS score on the scale of (0–1)	0.9	0.9	0.9	0.9	0.9	0.9	0.9

Table 3.
Correlation coefficients for ACDW samples: Results for plucked & picked sound notes.

achieve the best possible impulse response which is further used to develop the generalized guitar model. **Table 3** summarized the results of the *adaptive cepstral domain window method*. The column gives the plucking style and the parameters of the music note, such as, the number of samples in the window, correlation coefficients and MoS score on the scale of (0–1) for the synthesized music notes.

4.1 Synthesis results of the generated impulse response and excitation signal

The separated excitation signal and the estimated impulse response are convolved together to synthesize the acoustic Guitar note. The ACDW approach provides good scope for better synthesis. The synthesis has been carried out for the two playing styles, namely, finger plucked, and pick plucked notes. The highest correlation coefficient value is 0.98 for finger plucked guitar note. The MoS (Mean Opinion Score) is also best indication for the synthesized guitar note giving highest value as 0.95.

The NN and machine learning algorithms are used to classify the plucking style and plucking expression for the original recorded notes. Once the model is trained it is further deployed for cross-validation of the synthesized music notes based on the ACDW method. The results are discussed subsection 4.1.

The contribution of this impulse response modeling work is to isolate the body response and the excitation signal of acoustic guitar notes. An *innovative synthesizer for acoustic guitar notes* is implemented in this research work. The work has used innovative Adaptive Cepstral Domain Windowing (ACDW) method which is not used before for musical instrument modeling. The algorithm has used the cepstral domain approach. The other contribution of the present work is to develop the generalized model for Guitar Notes using impulse response of single fret. The reason why this is possible is '*the octave relationship*' of frequency of all the frets along a string. The other name for the music is '*harmony*' and the music notes generated by frets on strings follow this octave relationship to be in *harmony*. This research proved that '*not only in frequency domain but also in time domain the music notes live in harmony*'. This harmonic relationship in the time domain is used to generate the impulse response model using single fret. After plotting the graph of impulse response of all the frets for a string, fret 20 was chosen for modeling the impulse response for other frets.

To summarize the work, impulse response modeling is implemented with good accuracy. Further, the neural network (NN) is used for classification of naïve and expert player considering the expression in the note played. The classification is also done for plucking style i.e. finger plucking and plectrum plucking. The results of the two methods of synthesis i.e. ACDW and Generalized model are cross verified by NN model. The trained model of the classification is used for verification of the synthesized notes.

4.2 Discussion of the cross-validation results

The synthesis of the acoustic guitar notes is implemented using the ACDW method and a generalized model is developed using the body response of the single fret. The validation of the synthesized guitar notes is done by the subjective (listening) tests and the correlation coefficient values. NN model is used for the classification of guitar notes with respect to plucking style and plucking expression. Further this trained model is used for testing the synthesized guitar notes to identify plucking style and plucking expression. This is named as cross validation of the models.

Table 3 summarizes the validation of the synthesized guitar notes based on: 1) Mean opinion Score i.e. MOS as the subjective tests and 2) Correlation coefficients as the statistical parameter for finding the similarity between original and synthesized music notes using ACDW approach. The NN model is used for classification of the music notes based on: 1) plucking style and 2) plucking expressions.

Table 4 summarizes the cross-validation result for synthesized music notes, only of an expert player. The last two columns are highlighted to show the result of NN modeling to predict the class. The table values confirm the model validation as the classification results are greater than 80%. Only few sample results are shown in Table below.

Similarly, a cross-validation has been carried out for the plucking style where the acoustic guitar notes played by the Expert Player have been passed to the trained model and the plucking style is predicted. The results from the Impulse Response modeling method are considered for the identification of the plucking style. **Table 5** summarizes the results of the trained model for identification of plucking style of synthesized notes using NN classifiers. The cells highlighted with yellow indicate

Plucking Style	Music Note	(0–1)Scale for the synthesized note	Correlation coefficients	Existing Class	Predicted Class
Plucked Note	String1fret19	0.8	0.8477	Expert	Expert
	String1fret18	0.8	0.8144	Expert	Expert
	String1fret13	0.7	0.79	Expert	Expert
	String1fret12	0.7	0.71	Expert	Beginner
	String1fret2	0.8	0.8909	Expert	Expert
	String1fret1	0.8	0.8120	Expert	Expert
Picked Notes	String1fret19	0.85	0.8784	Expert	Expert
	String1fret18	0.85	0.86	Expert	Expert
	String1fret13	0.75	0.81	Expert	Expert
	String1fret12	0.75	0.79	Expert	Expert
	String1fret2	0.75	0.78	Expert	Beginner
	String1fret1	0.8	0.71	Expert	Expert

Table 4.
Cross-validation result for the expert's synthesized music notes.

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	Music Note	(0–1) Scale for the synthesized note	Correlation coefficients by Impulse Response Modeling	Original Style	Predicted Style
Expert	String1fret1	0.95	0.9283	Finger	Finger
	String1fret2	0.95	0.9441	Finger	Finger
	String1fret3	0.9	0.9324	Finger	Finger
	String1fret4	0.8	0.7897	Finger	Pick
	String1fret5	0.85	0.8856	Finger	Finger
	String1fret6	0.9	0.9008	Finger	Finger
Expert	String1fret1	0.95	0.9317	Pick	Pick
	String1fret2	0.95	0.9452	Pick	Pick
	String1fret3	0.9	0.9146	Pick	Finger
	String1fret4	0.9	0.9238	Pick	Pick
	String1fret5	0.9	0.9127	Pick	Pick
	String1fret6	0.95	0.9434	Pick	Pick

Table 5.
Cross-validation result for the plucking style of the expert player.

the wrong classification of the plucking style. The second column gives the names of the music notes while the 3rd and the 4th columns indicate the correlation coefficients for the subjective tests and the impulse response method.

5. Conclusion

The limitation of the impulse response method using the hammer method and string-breaking method are overcome with the help of cepstral domain window method. The challenges of isolation of impulse response from the excitation signal are overcome using ACDW approach and a model is developed using the body features. The main contribution of the present research work is: 1) Physical model for Guitar as an instrument using Adaptive Cepstral Domain Window (ACDW) approach, 2) Generalized Model for Impulse Response of Acoustic Guitar for All Frets using a Response of Single Fret, and 3) Classification of guitar notes based on plucking style and plucking expression. The validation of the synthesized notes is done by using subjective listening tests i.e. Mean Opinion Score (MOS) and the correlation coefficients. The classification of plucking style and plucking expression is done using NN modeling techniques. The trained model is used for testing the plucking expression of the synthesized model. This model can be used to certify if the player is becoming an expert. If the score for expert identification is greater than 95% then player can be certified as expert.

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Chapter 7

Multivariate Approach to Reading Comprehension and Sight-Reading

Michel A. Cara

Abstract

This chapter focuses on the study of the relationship between reading of music and verbal texts and it seeks to define an ecological music reading task that allows comparison of musical and verbal domains. Participants were preservice music students who performed different music reading tasks correlated with a verbal text comprehension test. A Principal Component Analysis (PCA), was performed, explaining 91,5% of the variance. The following two axes were defined: one related to reading compression and the other to music performance variables. The relationship between the selected variables in the factorial plane, particularly the strong association between sight-reading and literal comprehension, suggest that sight-reading is a relevant factor with regards to the study of musical and verbal domains.

Keywords: Sight-reading, music reading, reading comprehension, principal component analysis

1. Introduction

Much of the current research emphasizes the importance of studying music and verbal language together, in order to reach more definitive conclusions regarding brain function and learning [1, 2]. In fact, verbal text reading literature provides a fairly complete theoretical framework that can be applied to reading sheet music. Therefore, we attempt to contribute to the growth of multidisciplinary and inclusive initiatives to the understanding of the mechanisms of acquisition of musical language in adulthood for school or university education.

The objective of this chapter is then to explore the relationship that exists between music and verbal language through written supports (the score and verbal text). We have proposed to explore different tasks in the musical field (e.g., sight-reading) in order to look for correlates with verbal comprehension tasks and the underlying cognitive processes.

> *Whether music students, in addition to developing specific musical competences and showing good results in music reading, are equally effective in verbal comprehension?*
>
> *Is there an ecological task that provides support to the study of music and language?*
>
> *Could a system of language comprehension be extended to music reading?*

1.1 Music reading and sight-reading

Music reading is characterized by a vertical component (simultaneous reading of the notes) and it also implies an expressive timing (e.g. changes in the speed of execution), as part of the character of the composition. The sequential units are formed in music by series of chords, which correspond to groups of notes that sound simultaneously or consecutively [3, 4]. Music reading is associated with the ability to develop an auditory representation that can be activated when a musical excerpt is presented [5]. In fact, there are currently two types of hypotheses that underlie the main studies on intermodality. The first hypothesis corresponds to perceptual processes (cross-modal), and the second to conceptual processes (intermodal integration) [6]. Less expert musicians would mainly use their ability to recode information, as shown by Drai-Zerbib and Baccino [7], while experts would be able to elaborate an amodal representation based on their previous knowledge. This amodal representation is a part of an action monitoring systems while reading music [8].

The overall success of musical performance mostly depends on the musician's first contact with the score. This first encounter with the score is called sight-reading, and represents the ability to perform written music for the first time without previous practice. During sight-reading musicians must read with fluency and progressively (or even immediately) adjust their tempo as indicated by the composer. In addition to the speed of execution, it is important not to make reading errors. Sight-reading is considered a fundamental skill for western musicians [9] and it is a musical skill that can be developed with practice. In fact, Mishra [10] meta-analysis shows that sight-reading is tightly correlated to constructs, such as improvisational skills, ear-training ability, technical ability, and music knowledge. These specific practice-related skills are developed thanks to a strong action-perception association between the musical stimuli and the corresponding motor programming [8]. There is evidence that specific psychomotor movement speed skills can be a dominant predictor when music complexity highly increase [11].

1.2 Evidence for comparing music and language domains

Despite the fact that comparative studies of music and text reading have been increasing progressively in recent years, particularly thanks to the incorporation of new techniques, such as eye-tracking or brain imaging, making comparisons between musical and verbal processing it is still challenging [12–14].

Studies of cortical stimulation have shown the existence of common brain areas for reading texts and scores [15]. Through brain imaging studies other authors demonstrate the existence of specific areas for the processing of visuospatial information in reading of scores [16]. More recently Bouhali et al. [17], point out the influence of domain specific expertise (word or music reading) for the specialization of the ventral occipitotemporal cortex and an enlarged overlap of functional activations in musicians for language and music.

It has also been suggested that in simultaneous tasks music and language share common resources in terms of syntactic integration processes [1] or that, on the other hand, these respond to the thesis of a modular brain organization [18, 19]. Moreover, in terms of transfer the relationship between music and language could be explained as a result of a more developed temporal processing in those individuals who have a greater musical training [20].

As far as the information processing is concerned, the perceptual elements of music (discrete) and verbal language respond to certain hierarchical principles (syntax), which allow the combination of structural elements in sequences [21–25]. These basic musical or linguistic events (notes, phonemes) are combined into more complex units (chords, words) and then form sentences (musical, linguistic) [22]. From this perspective, Patel [1] proposes the syntactic integration resource hypothesis that postulates that music and language share a limited amount of resources that in turn activate syntactic representations separately. This implies that syntactic integration could be required when there is a concurrent process in the opposite domain [26]. It would be needed more cognitive resources to connect the various components of the sentence (Dependency Locality Theory) [27]. Consequently, in verbal text reading the subject-verb distances determine the resources involved and in the case of music reading, the tonal distances.

1.3 Comprehension in music and language

In verbal comprehension it is possible to distinguish the processes of decoding, literal comprehension, inferential comprehension and metacomprehension [28]. The inferences intended as an integrated conception constitute procedures that scaffold the architecture of what is understood and also constitute the representations of this new information not made explicit in the text itself [29]. According to Nadal et al. [30], language has certain elements that allow minimizing the cognitive costs associated with inferential computations. Indeed, part of these elements that guide the reading (discursive markers) contain "a set of syntactic-semantic instructions that determine both its position within a statement and the informative articulation of the elements under its scope at the sentence and textual level" ([31], p. 198). The same occurs with punctuation marks, since they delimit processing units, which minimizes the reader's effort in comprehension [32]. Finally, reading texts entails the simultaneous implementation of a series of activities where the objective would be the elaboration of a coherent mental representation of the meanings of the text [33].

The macrostructure theory [34, 35] proposes the existence of two levels of discourse representation: the microstructure and the macrostructure. The microstructure corresponds to the linear semantic structure of a text (threads: recognition of the words and the inferences or bridges necessary for the linking of the propositions, among others). The macrostructure, for its part, processes from the microstructure through a selective reduction of information (sub-processes: hierarchization of the ideas of the text, application of inferences based on previous knowledge. Macroprocessing activities allow the construction of the situation model (mental model constructed from the text). Unlike the microstructure, whose construction is relatively automatic, the construction of the macrostructure is rather conscious and aims at the establishment, codification and local coherence of the propositions. In synthesis, the levels of representation include the representation of the surface form of the text, afterwards a base text is generated (meaning of the sentences) and finally the situation model [36].

Following these evidences, Cara and Gómez [37] show that musicians can demonstrate similar abilities for the reading of verbal texts and scores (during silent reading of music and text). The authors analyze the information integration mechanisms in functional piano students by studying the duration of ocular fixations and the number of regressive ocular fixations. The authors demonstrate that there are different patterns of reading verbal texts and scores according to the inter- and intra-sentence levels in the processing of information and as regards the styles and types of text. Eye movements account for different strategies for processing verbal and musical information. Differences have been observed in the number, duration and type of trajectory of eye movements. All this indicates that, despite the similarity in the global understanding of music and texts, the underlying processes are different, which does not rule out the possibility that both domains share resources.

The present study aims to expand the results of the aforementioned study, this time, within the population of university students with at least 3 years of experience in the systematic practice of music reading. Previous studies show that university students have deficiencies in the selection and hierarchization of relevant information, and in capturing the author's communicative intentionality and in building the situation model [35] of the texts [38]. A preliminary analysis has been reported elsewhere [39].

With regard to music comprehension and considering the nexus between the comprehension processes and meaning, the bibliography consulted is mainly divided into two positions: the first considers that music only has a self-significance [40] and we could only have an approximation to musical comprehension from the musical form [41, 42]. The second position states that music and language respond to common cognitive abilities and therefore it would be possible to refer to musical comprehension [25]. However, this implies considering a broader view of meaning [25, 43, 44].

The literature on process of music comprehension from a written support describes the existence of different levels of processing: notational processing, syntactic processing, analytical-structural processing and referential processing [45]. At this last level, conceptual relationships are made between the syntactic or notational information of the score and other elements associated with the piece, such as certain extra-musical elements.

Given these antecedents, this project was necessary in order to explore if it is possible to link the cognitive processes involved in music reading and reading comprehension of verbal text. Given that there is no standardized test of comprehension of musical texts to our knowledge and that the scientific evidence that allows affirming the existence of a close relationship between the processes of verbal and musical comprehension is under construction, it has seemed pertinent to define an ecological task (in the musical field) that enables distinction of certain common domains of comparison. To our knowledge no previous studies have investigated the association between sight-reading and reading compression of written texts among preservice music teachers. From this perspective, and as consulted in the bibliography, we believe that sight-reading, could represent a good compromise between an ecological task and at the same time containing outputs of the musical domain. The theories of syntactic processing (Dependency Locality Theory) [27], and of tonal processing (Tonal Pitch Space Theory) [23] can be sited as a relevant framework in the comparison between musical and language processing at the syntactic level.

2. Methods

2.1 Participants and stimuli

Fifteen Music Pedagogy students from the Music Institute of the Pontificia Universidad Católica de Valparaíso participated in the experiment. The average age of the participating students was 23 years (*SD* = 4.9). All participants had completed their training in Musical Language (solfege) which lasts 3 years, with 3 sessions per week.

2.2 Materials

2.2.1 Reading comprehension task

A comprehension test that had been used previously in academic and technical-professional courses was applied [46]. The text was of an argumentative nature (332 words, 6 paragraphs) written in participants' native language, Spanish. Participants had to read the text, construct a coherent mental representation, and then answer eight questions. The test offered two indicators: Literal Comprehension (4 questions) and Inferential Comprehension (4 questions).

2.2.2 Articulation task

The test collected information on musical decision-making (detecting the stylistic features of a score). The participants observed a score containing only the pitch of the notes and the rhythmic figurations, into which they had to incorporate all the requested elements (i.e. add articulations and identify the meter and the style). Two extracts were presented, one from Mozart and the other from Schöenberg (see **Figure 1**). The test points awarded to participants were calculated by adding up the total number of correct features reported. To be considered valid, each articulation incorporated had to match the articulation present in the original score. These included dynamics, slurs, and tempi.

2.2.3 Sight-reading task

The sight reading task consisted of Beethoven's Lied "Urians Reise um die Welt". To calculate the test points, 3 types of errors were considered: omissions, substitutions and additions. Music flow (stops) and code changes (see below) were also included (see **Figure 2**).

It should be noted that at the PUCV Music Institute, music theory and reading classes are taught using the Kodály method. This method is based on a note-phoneme conversion system. The principle starts from the basic structures of the scales in which, regardless of the initial pitch, the tone and semitone relationships are maintained. Thus, for example, the C major scale shares the same number of notes, and the same relationships between them, as the D major scale. Therefore, a student who was

Figure 1.
Excerpts of (a) Mozart and (b) Schöenberg scores from the articulation task.

Figure 2.
Sight-reading task.

taught the Kodály method would be asked to perform a D = C conversion, singing the note D on the staff as C, E as D, F# as E, G as F, and so on until the tonic is reached.

Code errors are emissions of an incorrect phoneme that does not correspond to the same degree of the corresponding scale. For example, if a score is sung in A major, the note C# (III degree with respect to A) is expected to be sung as E (III degree with respect to C). The code error appears when this note is sung as any other phoneme of the major scale.

2.2.4 Cross-modal task

This task was adapted from the material used by Drai-Zerbib and Baccino [47]. Participants had to listen to a melody and then decide if the score presented subsequently corresponded to what was heard (note modification condition, original stave vs. modified stave). Thus, the points awarded in the cross-modal task represented the student's ability to identify whether there was a difference between a short audio and its corresponding notational representation (the score).

2.3 Procedure

In the first part of the experiment, participants took the reading comprehension test. The test consisted of reading a text (maximum 10 minutes of reading time) and then answering eight questions. The text was taken away from the participant once he was ready to answer the questions.

The articulation task was then applied, in which the participant had to add the articulations to a score that had been modified (slurs, accents and dynamics removed). The test was carried out on a sheet with the modified score in which the participant had to add the requested information using a counterbalanced order according to the two styles evaluated (classical vs. contemporary). Participants had 20 minutes to perform the test, 10 minutes for each score.

The cross-modal integration task was performed in an insulated room with a computer. Participants listened to the melodic sequences with Sennheiser HD 203 headphones. Immediately after listening to the audio, they viewed the score and had to decide whether what they had heard matched what they saw. If it matched, they had to press the left mouse button; if it did not match, they pressed the right button. If the participant decided that the audio matched the image, he immediately started a new audio (next question). If the participant decided that the audio did not match the image, he was diverted to a new screen in which 4 buttons appeared (each button corresponding to 1 of the 4 bars) in which he had to indicate in which measure he identified the error (or wrongly matched note), using the mouse. Once this was done, the participant continued with the next test item. This cycle was carried out similarly for the 48 musical stimuli.

The-sight reading task was administered individually. The experimenter showed the score to the participant, who had a maximum of 20 seconds to preview it before starting the solfege. The score was read from beginning to end, without repeating any passage. The audio recording of the test was administered using a Tascam DR-40 digital recorder. The errors, stops and code errors were subsequently counted by an advanced music student.

3. Results

One student was eliminated from the sample because he exceeded the reading time of the verbal comprehension test and presented outliers in the music theory tests. The dependent variables correspond to the total score obtained in each test. Descriptive statistics are shown in **Table 1**.

Measures	*M*	*SD*	95% CI
Sight-reading task (Beethoven)			
Add	16.14	15.54	[7.17–25.11]
Sub	2.36	3.82	[0.15–4.56]
Del	1.50	0.76	[1.06–1.94]
Stop	4.64	4.72	[1.92–7.37]
Code	0.43	0.65	[0.6–0.8]
Sight-R	25.07	20.66	[13.14–37]
Reading comprehension task (Ginseng)			
Lit-C	3.36	0.75	(2.93–3.79]
Inf-C	2.36	1.01	[1.78–2.94]
T-Score	5.93	1.21	[5.23–6.63]
Articulation task			
Mozart	13.29	10.02	[7.5–19.07]
Schöenberg	10.86	5.8	[7.51–14.21]
Cross-modal task			
Cross-M	9.21	1.42	[8.39–10.04]

Note. CI = confidence interval; Add = additions; Sub = substitutions; Del = deletions; Stop = stoppings; Code = code error; Sight-R = sight-reading; Lit-C = literal comprehension; Inf-C = inferential comprehension; T-Score = reading comprehension total score; Cross-M = cross-modal.

Table 1.
Descriptive statistics.

3.1 Principal components analysis (PCA)

In order to obtain more information about the relationship between the different studied variables a PCA was performed. Variables included explain 91.2% of the variance (see **Figure 3**).

A total of six active variables and two supplementary variables were selected. Inferential compression (Inf-C) and deletions (Del) are included as supplementary variables. In fact, these variables do not contribute to explaining a large percentage of the variance. However, we included inferential comprehension because we did not want to isolate both reading comprehension indicators. In case of deletions, the variable correlates significantly with literal comprehension, similarly to the other error types (additions and substitutions). For this reason, it seemed pertinent to include it as a supplementary variable. Other variables such as Schöenberg articulation task score, code error or the cross-modal task scores were not included in the ACP as these variables do not correlate with any other variable analyzed in the present study. The correlations matrix is presented below (see **Table 2**).

ACP results can be interpreted considering the presence of two axes, where one axis related to the music performance, particularly with sight-reading, and the second axis related to reading comprehension of verbal texts. The Mozart articulation task seems to be independent of both axes (Mozart), but associated with relevant aspect of performance (substitutions). Inferential comprehension, despite not correlating with the ensemble of variables, is further associated with the reading comprehension axis, and similarly occurs with deletions and the music performance axis.

As can be seen in **Table 2**, there are significant correlations between literal comprehension and the musical tasks, particularly the sight-reading task, and music flow (i.e., stoppings). It is also important to highlight that the existence of

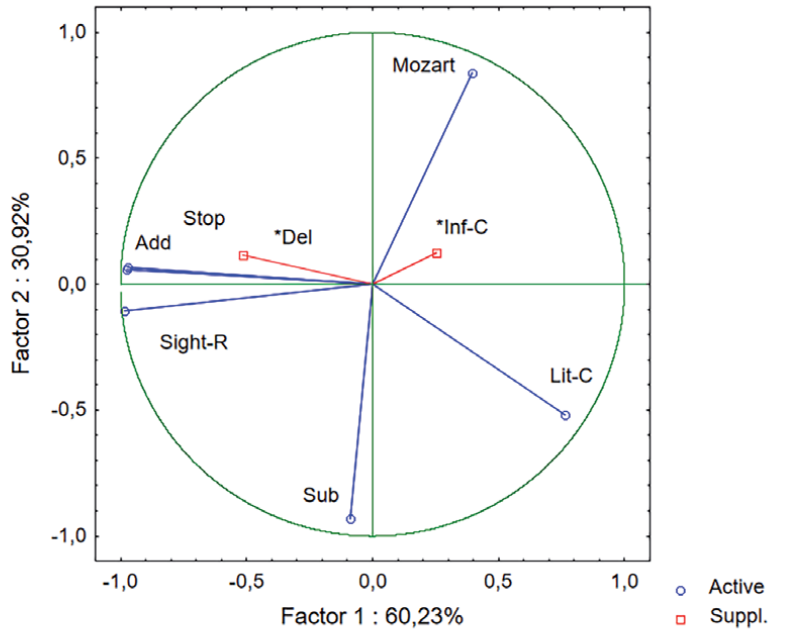

Figure 3.
Principal component analysis.

	Lit-C	Sight-R	Add	Sub	Stop	Mozart	Del	Inf-C
Lit-C	1	−.66*	−.71**	.36	−.75**	−.11	−.61*	.12
Sight-R	−.66*	1	.98**	.12	.95**	−.44	.47	−.31
Add	−.71**	.98**	1	.004	.94**	−.30	.44	−.33
Sub	.36	.12	.004	1	.02	−.70*	−.01	−.24
Stop	−.75**	.95**	.94**	.02	1	−.33	.46	−.15
Mozart	−.11	−.44	−.30	−.70**	−.33	1	−.14	.09
Del	−.61*	.47	.44	−.01	.46	−.14	1	.15
Inf-C	.12	−.31	−.33	−.24	−.15	.09	.15	1

Note. Lit-C = literal comprehension; Sight-R = sight-reading; Add = additions; Sub = substitutions; Stop = stoppings; Del = deletions; Inf-C = inferential comprehension; Cross-M = cross-modal.
$^{*}p < .05$.; $^{**}p \leq .005$.

Table 2.
Correlation matrix.

correlations between literal comprehension and the different types of errors, suggests that the underlying cognitive processes could be common.

4. Conclusion

To explore the relationship between music and language processing, different music reading tasks and a reading comprehension test were applied to preservice music teachers with at least three years of music reading experience. A principal components analysis was performed in order to compare the different variables in the factorial plane. The interpretation of PCA results indicates the existence of two axes, one representing each domain, and particularly in the case of music, variables relate to sight-reading performances.

In fact, in the correlation matrix (see **Table 2**) we can observe significant correlations between errors, stoppings, articulations and the literal comprehension indicator. It is important to clarify that the correlation is negative since a lower number of errors ($r = -.62$) and stopping ($r = -.75$) is associated with a better score in literal comprehension. In particular, one type of error (substitution) does not correlate with the reading comprehension test. Stoppings are independent of the reading comprehension results if we consider both indicators (literal comprehension and inferential comprehension) as a whole. However, the same does not happen if we consider them separately. This specificity of the comprehension processes observed with the sight-reading task could indicate the occurrence of common processes between both domains.

We observed a strong association between stoppings and additions as well as between deletions (included as supplementary variable in the PCA) and literal comprehension.

The above is not easy to interpret, in fact, the studies that address the neuronal activity linked to the generation of inferences and its different indicators in a comparative way are relatively scarce [48, 49]. However, there is evidence that the superior temporal gyrus, as well as the inferior frontal gyrus, would be involved in generating inferences during the understanding of short stories presented in auditory modality [50]. The same activation of the superior temporal gyrus has been observed in musical perception tasks, particularly in those where the use of analytical strategies is not necessary but rather a visual imaginary [51]. The mentioned association could also be a type of far transfer, however it is difficult to confirm it, since we lack sufficient evidence. If this is the case, it is unclear why only the literal comprehension have a greater representativeness in the factorial plane. A possible explanation is related to the fact that in the practice, in reading comprehension evaluations, literal comprehension has a tendency to score better than inferential comprehension.

Concerning the correlation between the Mozart articulation task and substitutions, it is important to note that these variables come from different musical tasks (substitutions are related to the Beethoven sight-reading task). In any case, it would be possible to suggest that there is a stylistic relationship between both pieces, since in the case of Beethoven it is a work from his first compositional period, more related to the classical period. This could be reinforced if we consider that the task of articulation in the Shöenberg piece is not associated with the variables mentioned previously. Moreover, previous findings show that substitutions in sight-reading allow experts musicians to continue with the musical flow (sacrificing accuracy) when cognitive load increases [52]. To achieve this process musicians must have some knowledge of the musical style [53, 54] and generate related musical expectations [55]. It should also be noted that in the context of the present study, preservice music teaching curriculum, particularly the acquisition and learning of musical language (e.g., music reading) is oriented towards classic-romantic music. Contemporary music skills are developed mostly based on analytical and theoretical aspects. Therefore, they cannot mobilize that knowledge as they simply do not have it.

On the other hand, the fact that substitutions are further away in the factorial plane from the other two types of errors (additions and deletions) is probably due to the observed variability (see **Table 1**), which could ultimately explain, to some extent, the correlation with the Mozart task. Moreover, the independence in the factorial plane of the Mozart task from both axes, which suggest that the nature of the process involved is different as is the type of task. The articulation task involves a series of complex processes, were the stylistic musical background is essential, but not sufficient. In order to be able to retrieve all the missing features of the modified score, it is required to elaborate a complete mental representation of the musical piece. In fact, the artistic idea of a musical piece to some extent depends on the extraction of musical structure features [56]. Future research may address this issue by investigating how musical expectations influences the performance of musical tasks of different cognitive hierarchy.

Another interesting result is related to the absence of associations between the cross-modal task and sight-reading. The consulted literature [6, 47], points out a link between expertise and the high-level knowledge structures in memory that support cross-modal integration capacities or cross-modal competences related to music reading tasks. It should be noted that music students, who participated in the present study, do not have such expertise (at least 12 years). They could not even reach the group of the less expert musicians (between 5 and 8 years of academic practice in music). Therefore, it is possible that the absence of association between the cross-modal task and sight-reading is due to the lack of musical experience of the musicians. The above could be affirmed by observing the descriptive statistics in **Table 1**.

Limitations of the present study are linked with the exploratory approach. Music reading tasks could be refined, the sample of musicians could be enlarged, and qualitative information could be included in order to better understand the link between their musical backgrounds and performance of the different tasks.

In summary, the results of the conducted study allow us to suggest that the sight-reading task is a pertinent task for making comparisons with tasks of the verbal domain, particularly with regard to literal comprehension and inferential comprehension. However, according to the musical practice approach, the sight-reading task specificity (vocal or instrumental), the skill level, as well as the professional task orientation, can generate variations in the music information processing mechanisms. This suggests, on the one hand, that the results obtained in the sight-reading task could not be generalized to any other sight reading-task. On the other hand, and according to the theory of shared resources between both domains [1] it is possible that this specificity is reflected in the same way in the verbal domain. Indeed, the correlations observed between the sight-reading task and the verbal comprehension task, suggest the existence of shared resources between both domains.

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It is well recognized that music is a unique and cost-effective solution for the rehabilitation of patients with cognitive deficits. However, music can also be used as a non-invasive and non-pharmacological intervention modality not only for the management of various disease conditions but also for maintaining good health overall. Music-based therapeutic strategies can be used as complementary methods to existing diagnostic approaches to manage cognitive deficits as well as clinical and physiological abnormalities of individuals in need. This book focuses on various aspects of music and its role in enhancing health and recovering from a disease. Chapters explore music as a healing method across civilizations and measure the effect of music on human physiology and functions.

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