THE EFFECTS OF SYNCHRONOUS MUSIC ON PATIENTS UNDERGOING MAGNETIC RESONANCE IMAGING

Zsuzsa Földes

Master's Thesis

Music Therapy

Department of Music

5 June 2016

University of Jyväskylä

JYVÄSKYLÄN YLIOPISTO

Tiedekunta – Faculty Humanities	Laitos – Department Music Department
Tekijä – Author Zsuzsa Földes	
Työn nimi – Title THE EFFECTS OF SYNCHRONOUS MUSIC ON PATIENTS UNDERGOING MAGNETIC RESONANCE IMAGING	
Oppiaine – Subject Music Therapy	Työn laji – Level Master’s Thesis
Aika – Month and year June 2016	Sivumäärä – Number of pages 36 PAGES

Tiivistelmä – Abstract

Anxiety and claustrophobic reactions in Magnetic Resonance Imaging (MRI) lengthen the duration of examinations through increasing need of scan repetition, furthermore the need of anaesthesia makes the process costly. The sedative and alleviative effect of music is widely used in therapeutics, but in related research, music was only used with its original tempo as an intervention to reduce anxiety among MRI patients. 60 outpatients were examined in the Diagnostic Centre of Pécs to test whether the sedative effect of music can be improved by synchronizing it to the rhythm of the gradient pulsation, therefore reducing the effect of loud noises on the perception of music. The patients were assigned into three groups, namely a non-music (control), an original tempo (random) and a synchronized (synchron) group. MAX 7 was used for time stretching.

There was a statistically significant interaction between the intervention and time (between pre- and post-intervention) on STAI-State anxiety level. Results showed that the post-intervention state anxiety score significantly decreased in both music groups (random and synchron), while it did not change significantly in the control group. Median Visual Analogue Scale (VAS) scores examining the overall experience of the examination were statistically significantly different between groups, suggesting that music intervention made the examination more pleasant for the participants. Median pre-intervention state anxiety score was statistically significantly higher in females than in males. The thematic analysis of the open-ended questions suggests that music and the headphones/earplugs work as a noise cancellation tools for the participants; furthermore, music caused a positive change in the environment and provided a help. Music distracts attention from the examination, relaxes patients and is seen as care and a desirable intervention in the future.

Asiasanat – Keywords

Magnetic Resonance Imaging, Anxiety, Music, Synchronization

Säilytyspaikka – Depository	
Muita tietoja – Additional information	

Acknowledgement

Firstly, I would like to thank to my advisors Dr. Esa Ala-Ruona and Dr. Birgitta Burger for their continuous support of my thesis, simplifying the experiment, and giving new ideas and guidance in the statistical analysis. I could always ask their help when I needed, and they made me motivated to get the most out of this study.

I would also like to thank for Prof. Dr. Tamás Dóczi, Dr. Ferenc Kövér and Prof. Dr. Péter Bogner for the opportunity to make a field experiment in the Diagnostic Center of Pécs, and Dr. Gergely Orsi and Dr. Gábor Perlaki for their knowledge and practical help throughout the whole process. I could not have conducted successfully the experiment without their support.

I would also like to thank for Dr. Marc Thompson for his help with MAX 7, giving a form of the whole experiment at an early stage of the study.

CONTENTS

1 INTRODUCTION

The last two decades have seen a growing interest in the topic of claustrophobia, panic, and anxiety during Magnetic Resonance Imaging (MRI) scans. Quirk, Latendre, Ciottone and Linley (1989) found that claustrophobic reactions in the MRI situation appear due to many reasons, such as fear of closeness, result of diagnosis, loudness of the equipment, and loss of control. Previous research by Dantendorfer (1997) has indicated that the requirement to stay still and the narrow space of the tunnel were the ”most unpleasant” features of the MRI examination (p. 304). Several studies investigating the occurrence and importance of these psychological reactions have been carried out. McIsaac et al. (1998) found 25% of the patients undergoing MRI felt moderate to severe anxiety, while 13.75% experienced panic. In a study based on pre- and post-examination questionnaires, Thorpea, Salkovskisb and Dittnerb (2008) found 53.85% of the participants were in the high-anxiety group. These numbers suggest anxiety and claustrophobia are strongly linked with the experience of MRI examinations.

These reactions lengthen the duration of the examination through involuntary movements and increasing need of scan repetition. Surveys such as the one conducted by Dantendorfer (1997) showed 12.8% of the first time MRI patients’ scan had motion artifact (MA), which cause the blurring of the image. Furthermore, patients who scored higher on the Pre-scan Imaging Distress Questionnaire had significantly more MA, showing higher anxiety level results in more unwanted motion, and also that screening patients for anxiety can be an efficient tool to identify people who might need interventions. This idea is supported by McIsaac’s et al.’s (1998) findings that higher scores on the Claustrophobia Questionnaire (CLQ) ”significantly predicted participants’ distress during the scan” (p. 255). However, they did not find a significant correlation between MA and anxiety during MRI. Patients with high anxiety and claustrophobia also need more breaks and might not be able to finish the procedure, and in many cases, they are not willing to undergo another MRI. In the large-scale cohort study of Eshed, Althoff, Hamm and Hermann (2007), 4821 patients’ 5798 MRI reports were analyzed. They found the occurrence of the claustrophobic reaction was 1.97% (95 patients), which from 59 patients (1.22%) prematurely terminated the examination, and 49 of them have not had before claustrophobic experience. In the study of McIsaac (1998), the occurrence of premature termination was 3.75%, while claustrophobia related termination was prominently high, 14% in the study of Katznelson et al. (2008).

Consequently, fewer patients can be examined during a given time, and the maintenance costs are higher (need of anaesthesia). Music is widely used in therapeutics for its alleviative effect, but in related research, only music with its original tempo was used as an intervention to reduce anxiety among MRI patients. In this thesis I elaborate the idea of tempo synchronization as a new way of increasing the sedative effect of music in this environment.

2 LITERATURE REVIEW

This chapter presents a brief introduction to topics associated with anxiety, MRI noise and musical interventions in the MRI context. Firstly, I will focus on the features and background of acoustic noise of the MR equipments, then the psychological reactions, such as anxiety, claustrophobia and fear, that are induced by these special circumstances. Followed by a short description about why certain stimuli and music can be a pleasant inducement for individuals in painful, uncomfortable situations, I will talk about the non-musical relaxation interventions that are used during MRI scans. Finally, I will explore the different aspects of musical usage: the features of relaxing music, the physiological effects of music, previous research on musical interventions in MRI and the topic of synchronization.

2.1 MRI and MRI acoustics

The technology behind the Magnetic Resonance Imaging (MRI) is a result of several researchers' work. Blosh and Purcell found that an atomic nucleus with an unpaired proton and/or neutron absorbs radio frequency energy in a magnetic field, and re-emits it when it turns back to the original state (Geva, 2006). These radio frequency photons are used to produce the detailed images of the human tissues and organs. The MRI system uses a strong, static magnet to align the nuclei of the atoms (precession). Water makes up two-third of our body weight, and this is the reason why the human body is so applicable for MRI examinations: hydrogen, as one of the components of the water molecule is a magnetically susceptible nuclide, where the proton of the hydrogen atom acts as a small magnet (Duck, 1990). The scanner uses another magnetic field as well, a radio frequency current through the gradient coils that is turned off and on (gradient pulsation or current switching) to alter the alignment of the hydrogen atoms. When this electromagnetic radiation happens in a certain frequency, the hydrogen nuclei start to *resonate* involving an energy exchange process with the environment. And as it is mentioned above, these induced radio signals are used to create the images of the examined body parts (Slichter, 1990; Schild, 1990). Lauterbur and Mansfield jointly received the Nobel Prize in Physiology or Medicine in 2003 for their contribution of the visualization of the emitted radio waves with introducing magnetic field gradients, and making the MRI technology a safe (without ionizing radiation), non-invasive diagnostic method (Press Release, 2003).

The gradient pulsation, when the force causes a knocking, clicking sound in the gradient coils, is the main cause of the *acoustic noise*. Its level depends on many aspects, such as the type of scanner, the pulse sequence used (high gradient amplitudes), the coil structure and the strength of the magnetic field (Cho et al., 1997; McNulty & McNulty, 2009). Designing new magnetic coils and imaging sequences without gradient pulsing can result in quieter equipments, as Cho et al. (1997) suggests. Examining the acoustic noise level of fast MRI pulse sequences, Price, De Wilde, Papadaki, Curran and Kitney (2001) found the noise level increase with higher magnetic field: the lowest noise level was measured on the 0.23 T system with 82.5 dBA, while the loudest was the 3 T system with 118.4 dBA. At the same time, the pulse sequence parameters caused bigger variation in the sound level than the field strength; furthermore, the scanner's design also affected how the presence of different objects or a person modified the noise level. The noise level was higher at the entrance of the bore, suggesting that patients with feet-first position require increased ear protection (Price et al., 2001). Other aspects also need to be considered in noise perception: sound is transmitted into our body not just through the auditory canal, but also through the bones and other organs and it affects the oxygenation level of the capillaries (Cho et al., 1997). The air circulation systems and helium pump cause additional noises.

According to the US Occupational Safety & Health Administration, ear protection is required above a persistent 90dBA noise level (Hearing Protection, n.d.), while in the European Union the Directive 2003/10/EC (came into force in 2006) introduced a recommendation with 80dBA for an 8-hours exposure. In McJury's study (1995) the level of the acoustic noise of MRI has ranged from 86-116 dBA also indicating that the expansion of the gradient field's strength increases the level of noise. Therefore, ear protection should be a routine protocol. Cho et al. (1997) measured 80 dBA volumes for a resting GE 1.5T scanner. Nonetheless, more sensitive pictures can be made with stronger magnetic field, and it is expected that in the future there will be stronger and louder equipments, and the demand for hearing related interventions will increase.

The MRI sequence is a set of radiofrequency pulse and gradients with their unique parameters that result in a distinct image of a specific tissue. Multiple sequences make up an MRI protocol, e.g. a brain MRI protocol can consist of spin-echo (SE) (T_1-weighted), fast spin echo (FSE) or turbo spin echo (TSE) (T_2-weighted), fluid-attenuated inversion recovery (FLAIR), and echo planar imaging (EPI) sequences (Lu et al., 2005; Poustchi-Amin, Mirowitz, Brown, McKinstry & Li, 2001). A frequency analysis and sound pressure level (SPL) measurement were made in five MRI systems and ten different pulse sequences (Counter, Olofsson, Grahn & Borg, 1997). The magnetization-prepared rapid gradient echo (MP-RAGE) (113 dBA), fast gradient echo turbo (114 dBA), and spin echo T_1 (117 dBA) were found to have the highest SPLs. In general, the sequences had low frequency energy ranging from 0.06-0.2 kHz. The gradient echo sequence showed periodicity in the noise from 0.06 to 0.1 kHz. The MP-RAGE and fast gradient echo sequences are also periodic, while the spin-echo (RF-present) sequence is aperiodic.

In conclusion, several factors can influence the characteristics of the MRI noise, such as the scanner type, the strength of the magnetic field, the structure of the coils, the type of the sequences, the position and body weight of the patient and the acoustics of the examination room itself. Therefore it is very difficult to make comparisons, each space and each scan has its unique sound quality.

2.2 Anxiety, worry and fear

As Barlow (2002, p. 3) concludes in his book, *anxiety* and *panic* ”represent the organism’s alarm reaction to potentially life-threatening emergencies”, with physical symptoms such as the activation of the cardio-vascular system, trembling, rapid breath and faint. According to Liddell (as cited in Barlow, 2002, p.9) ”anxiety accompanies intellectual activity as its shadow”, help to survive and plan the future. Among children and adolescents, anxiety disorders are the most common psychiatric disorders, and there is a prominently high rate of female individuals among patients with anxiety disorders, but the occurrence is also culturally affected (Barlow, 2002).

The phenomenon of *worry* can be described as an activity with prevalence of negative verbal thoughts about a possible future event to cognitively avoid a threat. Worry impedites the emotional processing of a threatening event, and it ”is associated with procrastination and rigid, maladaptive, interpersonal patterns often involving intrusive, overly nurturant behavior” (Borkovec, Ray & Stöber, 1998, p. 15). Furthermore, worry can also contribute to the maintenance of other anxiety disorders. According to the American Psychiatric Association (2013) ”*fear* is the emotional response to real or perceived imminent threat, whereas *anxiety* is anticipation of future threat” (p. 189).

Panic disorders can be featured with recurring unexpected panic attacks and the persistent worry about having more of them (American Psychiatric Association, 2013). Additionally it can result in maladaptive behavioural changes to avoid situations that might cause panic attacks. During *panic attacks* individuals can have symptoms, such as ”pounding heart”, ”sweating”, ”shaking” and ”fear of dying” (American Psychiatric Association, 2013, p. 208), and panic attacks can accompany other anxiety disorders as well. On the other hand, exaggerated anxiety and worry that expand to several aspects of the individual’s life (social, occupational, health) can lead to *generalized anxiety disorder (GAD).* The individual has difficulties with controlling this anxiety and ”experiences physical symptoms, including restlessness or feeling keyed up or on edge; being easily fatigued; difficulty concentrating or mind going blank; irritability; muscle tension; and sleep disturbance” (American Psychiatric Association, 2013, p. 190). Females are twice as likely to be diagnosed with anxiety disorders than males (American Psychiatric Association, 2013).

The findings of Reuman, Jacoby, Fabricant, Herring, and Abramowitz (2015) suggest that decreasing the uncertain circumstances of *MRI examinations* for the patients could contribute to lower anxiety levels. Giving detailed information about the procedure could prevent worry and overestimation of the threat, since the level of uncertainty positively correlated with the degree of perceived anxiety.

2.3 Pain and pleasure

Pain and pleasure, and the motivation to seek and avoid these experiences influence human behaviour. This motivation is crucial for survival and helps maintain homeostasis (Leknes & Tracey, 2008). According to Cabanac (1979), there are three dimensions of a sensation as a response to a stimulus: the quantitative and qualitative dimensions, which depend respectively on the intensity and nature of the stimulus, and the affective dimension that expresses the amount of pleasure or displeasure felt by a person. Cabanac (1979) in his study introduces the term *alliesthesia* (”changed sensation”), which is the ability of a stimulus to cause either pleasure or displeasure depending on the subject’s internal state (p. 9). In the case of MRI examination where the patient has to undergo a relatively uncomfortable experience, music can become a reward helping the patient to concentrate on something else than the inconvenient circumstances. As Cabanac (1979) noted, ”pleasure is a sign of a stimulus useful to the subject” (p. 1).

Investigating how music can affect the perception of pain Roy, Peretz and Rainville (2008, p. 141) found that apart from distraction, the “ability to induce strong positive emotions” is the most important analgesic quality of music. In their study, 18 participants rated the perceived thermal pain while listening to pleasant and unpleasant musical excerpts. Pleasant music reduced both pain and anxiety; furthermore, the results indicate if the arousal level induced by the music is lower, then the perceived pain is lower as well. Leknes et al. (2013) found strong evidence for the effect of context in perceiving pain. In the so called ’relative relief context’ where patients expected intense thermal pain but experienced only moderate pain, positive hedonics were induced, in some cases the pain was even found to be pleasant.

2.4 Relaxation interventions in MRI

The study of Philips and Dearyt (1995) did an exhaustive review of different anxiety reducing interventions during MRI. One of the common techniques is giving information to the patients about the upcoming process. Grey, Price and Mathews (2000) developed an anxiety reduction protocol, which contains procedural information (booklet) and sensory information (pre-recorded sound example), and a visit to the control room. According to Wilson-Barnett (as cited in Philips and Dearyt, 1995) informing the patients about the benefits and safety of the MRI procedure is also anxiety reducing. 88% of the adolescents undergoing MRI had unsatisfactory knowledge of the procedure before the examination (Mohammed, Atef, & Ellife, 2013). Health instructions, presence of relatives and teaching methods to cope with anxiety and claustrophobia could contribute to decrease the adolescents’ anxiety level.

Another option is to change the environment in a way that the patient can experience more space and see outside of the tunnel. Open designed scanner, feet-first and prone positioning, short and wider magnetic bore can help reduce the feelings of closeness (Dewey, Schink, & Dewey, 2007; Tischler, Calton, Williams, & Cheetham, 2008). To support this idea, higher subjective anxiety was reported with the head-first position than feet-first position in the study of McIsaac (1998). Other opportunities to create a more comfortable environment, such as higher lightening level and air movement in the tunnel, furthermore the presence of a familiar person in the same room with the patient can also decrease anxiety levels (Shellock & Kanal, 1994). Increasing the self-control feeling with a panic button (Phillips & Dearyt, 1995) is a commonly used technique. Another study (Enders et al., 2011b) suggests the possible advantages of open scanners in reducing anxiety, although these scanners usually work with lower field strength and thus lower image quality.

Further interventions that were studied in the topic of anxiety and MRI are psychological preparation, different therapy techniques (Klonoff & Janata, 1986), screening patients with pre-test questionnaires (Dantendorfer et al., 1997), and sedation. The latter strongly lengthen the duration and costs of the examination with the preparations and the invested work that it requires.

2.5 Music in the MRI context

2.5.1 The features of relaxing music

With the development of music psychology, many researchers have become interested in the musical features and their influence on mood, in many cases with special interest in relaxation.

Chen, Wang, Shih and Wu (2013, p. 437) used a ”slow-paced, soft, melodic music at low volume with consistent tempo and dynamics and an average 60-80 beats per minute” in their study to relax oncology patients before radiation treatment. There is a positive correlation between the *complexity of the rhythm* and blood pressure; furthermore, in terms of physiological reactions to music, *tempo has a greater effect than individual music preference* (Bernardi et al., as cited in Chen et al., 2013).

Short and Ahern (2009) analyzed the usage of a receptive music therapy tool in an emergency department, furthermore the whole process of music selection was evaluated. The environment where the intervention took place was loud: loudness ranged between 56 and 64 dBA in a 24-hours period (as cited in Short & Ahern, 2009). Four relaxation playlists were created in different genres (classical, ambient, world and modern) with the aim to reduce noise stress. They identified the following qualities of relaxing music: unvarying loudness and style, not too stimulating to induce strong emotions or associations, and it is also free from any intolerant views (vocal music). 14 out of the 15 patients have experienced a positive effect of music listening, while none of them reported disimprovement in their mood. For efficient receptive music therapy, clients should be involved in the selection of the music (Hooper, 2012).

Krout (2007) emphasizes, that the possibility for the client to choose between different music pieces is important to achieve better relaxation: client's personal music preference and existing stress level then can be matched with the music. Furthermore, the author recommend to listen to the music for 20-30 minutes in a quiet room and songs without lyrics are preferred, because words can be emotionally stimulating.

Recording the subject's amplitude preference, Staum and Brotons (2000) found music with lower volume (60-70 dBA) is more preferred for relaxation purposes than louder music (70-90 dBA), especially among female participants and subjects with a musical background. At the same time, self-reports suggest the musical selection itself is more affecting in preference for relaxing music.

McCraty, Barrios-Choplin, Atkinson and Tomasino (1998) investigated the effect of four types of music (grunge rock, classical, New Age and designer) on tension, mood and mental clarity. They found designer music is the most effective genre in improving positive aspects (caring, relaxation, mental clarity and vigour) and reducing negative effects (tension, hostility, fatigue and sadness). Designer music can be characterized with stable dynamic level and is described as "a type of music intentionally designed to have specific effects on listeners", in this case to promote mental and emotional balance (McCraty et al., 1998, p. 82). Classical music reduced, while grunge rock increased negative effects.

In the study by Wolfe, O'Connell, and Waldon (2002) participants described relaxing music with the following features: ”low bass sounds, slow tempi, small numbers of instruments, and few changes (in tempo, volume or instrumentation)”, while ”synthesized sounds”, ”loud volume and high-pitched instruments” impedite relaxation (Wolfe et al., 2002, p. 54). At the same time, personal preference for the music prominently can contribute to relaxation.

Examining the perceived emotional expressions of music Costa, Fine and Bitti (2004) found a connection between major mode, happiness and serenity. While the presence of unisons and octaves related with potency, energy and vigour, more frequent perfect fourths and minor sevenths are associated with pleasant and agreeable music.

2.5.2 Music and its physiological effects

To examine the physiological reactions to relaxing music Tan, Ozdemir, Temiz and Celik (2015) compared the heart rate's of groups with and without music listening during ECG GATED MPS (myocardial perfusion scintigraphy synchronized with electrocardiography). During this examination, similarly to MRI, patients have to remain motionless and lie in an uncomfortable position with their arms above the head (as cited in Tan et al., 2015). The tempo of the music varied between 60 and 80 BPM on the volume of 50-55 dBA, and patients could choose their preferred songs. Music listening patients had significantly reduced heart rate compared to the non-music group showing the benefits of the intervention.

Another experiment (Good, Anderson, Ahn, Cong & Stanton-Hicks, 2005) showed that jaw relaxation, music and their combination significantly reduced pain after intestinal surgery. Music (60-80 BPM) was used with the aim to relax and distract from pain with a ”sustained melodic quality, controlled volume, and without lyrics, strong rhythms or percussion” (Good et al., 2005, p. 243).

Another study to examine the physiological effects of music listening was done by Vlachopoulos et al. (2015). Aortic stiffness and wave reflection were measured after listening to classical and rock music, and both music genres reduced the symptoms mentioned above. While arterial stiffness was reduced only during the period of music listening, classical music had a long-term (30 minutes) effect on wave reflection. Music preference contributed to the effect of wave reflection, which showed a division by gender: classical music had a bigger impact on the wave reflection of female participants, while rock music on male participants.

Dillman, Carpentier and Potter (2007) measured the sympathetic arousal of 25 university students in response to increased tempo of the listened music. The results indicate that increasing tempo enhances the arousal level, and the genre of the music can influence this effect: surprisingly, classical music was found to increase the arousal level along with tempo acceleration, while rock music decreased it.

2.5.3 Music as intervention in MRI

The ability to process music is a result of early exposure (Saffran et al., 1996) and does not require specific musical training (Krumhansl et al., 1982; Toivainen & Krumhansl, 2003). The *Motivation-Decision Model* according to Leknes and Tracey (2008) allows music to have a paregoric effect in the situation of MRI examination, since it offers a pleasurable stimulus compared to the painful MRI stimulus and it helps maintain the patient's equilibrium.

In the study of Chen et al. (2013), two groups of oncology patients' reactions were compared: one of them received a 15 minutes long music listening intervention, while the other group took a rest for the same amount of time before their radiation treatment. The researchers found the music-receiving group had significantly lower state and trait anxiety level, and systolic pressure comparing to the control (resting) group. Argstatter, Haberbosch and Bolay (2006) suggested music interventions are more efficient with patients who have higher state and trait anxiety than those with lower level of anxiety.

Walworth (2010) compares the effects of live music therapy (MT) with preferred recorded music on patients undergoing MRI. The music therapist could listen to the rhythmic pattern of the gradient switching and match the songs with the specific tempo. The participant's anxiety level was measured with the visual analogue scale (VAS). Patients with MT intervention had less repeated scans because of movement (MT: 26%, while recorded music: 73%), less requested breaks (MT: 2%, while recorded music: 17.6%) and shorter examination length for the same type of scan. The freestyle narrative comments asked from the participants after the scan also support that MT made the MRI experience more enjoyable than recorded music.

Generally in the MRI related studies music appears as an intervention that tries to avert attention from the unpleasant circumstances and help to relax, but due to the hearing problems caused by the loudness of the equipment, it is not convenient (Philips & Dearyt, 1995; Tischler et al., 2008; Grey, Price, & Mathews, 2000). This music can be the patients' own tape, a radio channel or the radiographers' playlist, but what they have in common, that their tempo do not match with the rhythmical pattern of the gradient switching. In this thesis therefore I elaborated on the idea of using the MRI's own "music", the gradient pulsation switching as a rhythmical ground and synchronize music with it, therefore the loudness do not interfere with the effect of the music, instead it will create a complex musical experience.

2.5.4 Music and synchronization

As seen in previous studies, music is widely used for its physical and psychological benefits, also in hospital environments. Nonetheless, the ambient noise (gradient pulsation) has such a big influence on the overall experience of MRI examinations that it has to be considered with any auditory intervention. In this study I focus on one possible solution, namely synchronization, as a way of enhancing the relaxation effect of music and neutralizing the high sound pressure level of the noise.

Entrainment is the phenomenon when the frequencies of two oscillating bodies (e.g. clocks) become synchronous. The energy is transmitted by the common surface where the bodies are fixed (not by the air) until the bodies "find" their resonant frequency. Entrainment means the moving bodies have a common movement period, but they do not necessarily have to start and end their movements in synchrony (phase entrainment), neither in beat synchrony (Thaut, McIntosh & Hoemberg, 2015). According to Pantaleone (2002), it is the motion of the base, which on the oscillator bodies (pendulums) are placed that cause the synchronization, which is normally in-phase. Large oscillation frequencies or damping the base motion at the same time can cause antiphase synchronization.

Rhythmic auditory cues can entrain body movements and can evoke entrainment responses even in an injured brain. Auditory rhythmic cues provide external help for the brain to anticipate the time for a movement resulting in less variability in the execution, and the the entrainment effect of rhythm is immediate and not a matter of learning (Thaut, McIntosh & Hoemberg, 2015). „Sound patterns, unlike visual and other sensory information, continuously unfold and change in time, and cannot be “frozen” in time and space for a retroactive analysis” (Thaut, Kenyon, Schauer & McIntosh; 1999, p. 101), therefore the auditory system is made to be fast in recognition of any temporal, rhythm cue. A stable reference interval is created in the brain after only 2 or 3 stimuli that can then control the movements, and the synchronization of motor responses to rhythm can be a subliminal process, which explains why music can be an effective tool even with impaired cognitive functions.

Throughout the history, music has always played an important role in eliciting movements, bodily responses in different cultural, social settings. However, until very recently the emotional and motivational aspects, an interpretative use of music was in the focus of motor rehabilitation, when important discoveries were made on the physiological connections between sound and movements (Thaut et al.; 1999). Nowadays many researchers have shown that music, as a structural, timing cue can entrain motor and speech responses (Thaut, McIntosh & Hoemberg, 2015). The individual differences in the ability to synchronize to a steady beat are linked to the inferior colliculus, the midbrain auditory centre, which „integrate(s) precise timing information from throughout the auditory system and influence(s) motor output” (Tierney & Kraus, 2013, p. 14981). Tierney and Kraus (2013), using a tapping along task with 124 high-school students showed that more consistent auditory brainstem responses and less timing jitter in the inferior colliculus results in a more accurate tapping synchronization. Musical training can improve this and the reading ability as well. Interestingly, the ability of executing these movements depends on the patient’s emotional state: external triggers, such as music or other cues can enhance bodily responses.

Several researches have made on how the MRI acoustic noise affects and contaminates functional studies examining the auditory system. There are three main ways how the noise influences neural responses. First, by energetic masking (masking the target sound by noise), which reduces the sensitivity for the target stimuli in the auditory cortex. Secondly, the impaired audio stimuli may require more executive, cognitive processing, especially in speech related tasks. Finally, it causes attention challenges (Peelle, 2014; Hall, Lanting & Hartley, 2014). Di Salle et al. (2003) emphasizes the unpredictability in the way how the noise interacts with the auditory stimuli and the neural responses, which makes it hard to locate the baseline in event-related research design. These studies show that there is need for solutions that can neutralize the noise in audio-focused researches.

2.6 The profile of an anxious patient

Summarizing the literature that investigated the qualities of the patients with high anxiety and related behaviour (MA, premature termination, sedation, etc.) the following patterns emerged: older and female patients and patients with brain MRI are more likely to experience anxiety. There is no agreement on whether previous MRI experience increase or reduce anxiety (Eshed et al., 2007; Murphy & Brunberg, 1997; Thorpea et al., 2008).

3 AIM AND HYPOTHESES

The aim of this study was to compare the anxiety level of patients undergoing MRI examination in three different conditions. The control group received only a headphone or earplugs, while the two other groups listened to music. One of the music group (random) received the music in its original tempo, reproducing the condition of previous researches and how music is used in general in the MRI environment. On the other hand, the second music group (synchron) listened to music which tempo was synchronized individually to the rhythmical pattern of the gradient pulsation.

During the experiment, two alternative hypotheses were tested:

- Listening to music has better relaxation ability during MRI examination than headphone/earplugs alone.

- Synchronizing the tempo of the music with the MRI sequences has better relaxation ability during MRI examination than music that is played on its original tempo.

4 METHODOLOGY

4.1 Participants

Participants were 64 outpatients undergoing Magnetic Resonance Imaging (MRI) in January and March of 2016 in the Diagnostic Center of Pécs (Hungary). The following *exclusion criteria* were made about the participants: psychological and/or neuropsychological deficiency, being underage, the failure of filling the psychological tests, dismissive behaviour and low intellect. Only cooperative adults (over 18-years), who agreed to participate in the examination were included**.** Out of the 64 participants, n =60 were included in the experiment due to two premature terminations (one in the control, one in the synchron group), one incomplete test and a psychological deficiency in the last case. Two patients said that they could have not gone through the examination without music (one from the random, one from the synchron group).

The preliminary plan was to only include patients with skull (head-first position) examination and those who are having their first MRI, but there were not enough patients with these characteristics. Previous illnesses or expected outcomes were not criteria. Parts of the body examined in the experiment: skull, spine, joints (hip, knee, ankle, shoulder), lungs, shin and shank. Table 1 shows the frequencies of the different body parts examined during the experiment. From n=60 patients, 33 were female; Table 2 shows the gender distribution between the different conditions.

Participants ranged in age from 18 to 82 years, with a mean of 47.18 years (*SD* = 14.61). The mean number of previous MRI examination after the experiment was 2.73 (*SD* = 2.33), 37.3% of the patients had no previous experience with MRI. 67.3% of the participants had intermediate (high school or vocational school) or lower (primary school) educational background, while 32.7% had a Bachelor degree or higher. The mean time of experiment duration equaled 24.82 minutes (*SD* = 7.76).

TABLE 1. Examined body parts and their frequencies.

	Frequency	Valid Percent	Cumulative Percent
Spine	20	33,3	33,3
Skull	18	30	63,3
Knee	10	16,7	80
Shoulder	3	5	85
Spine+skull	2	3,3	88,3
Ankle	2	3,3	91,6
Knee + shin	1	1,7	93,3
Knees (both)	1	1,7	95
Shank	1	1,7	96,7
Hypophysis	1	1,7	98,4
Lung	1	1,7	100
Total	60	100	

TABLE 2. Gender distribution between groups.

	Female	Male
Control	10	10
Random	12	8
Synchron	11	9
Total	33	27

4.2 Design and stimuli

To test the hypotheses, a field experiment was made. Sixty outpatients were examined in the Diagnostic Center of Pécs to test whether the sedative effect of music can be improved by synchronizing it to the rhythm of the gradient pulsation, and whether music is stronger relaxation tool than noise cancellation devices alone. The Regional and Institutional Research Ethical Committee of the Clinical Center of the University of Pécs provided the ethical permission for the experiment. The participation in the experiment was voluntary; patients could terminate it at any time.

The patients were assigned into *three groups* (20 patients in each), one control and two music groups. The *control or non-music group* only received headphones or earplugs without music (10 patients with headphones, 1 with earplugs and 9 patients were either assigned to the 1.5 T MRI unit, where it was not possible to give any noise cancellation devices or refused to use any of the tools). The reason for giving earplugs for one patient was the type of the scan (cervical spine), where the headphone was not applicable. One of the music groups listened to a playlist with songs of several genres in their original tempo *(random group).* In the second music group *(synchron group)* the same songs were used in the same order to the random group (to exclude the effects of musical preference), but the tempo of the songs were manually adjusted to the tempo of the gradient pulsation with MAX 7. MAX 7 is a visual programming language for electronic art and music (What's new in MAX 7.2?, 2016). With the *sfplay~* and *attrui* (speed) objects in MAX 7 it is possible to stretch the time of an audio file without changing its pitch. Figure 1 shows the MAX patch that was used for time stretching. Through a microphone at the air-gate of the MRI room, I could precisely hear the rhythmic pattern of the noise from the control room, where the tempo adjustment happened. This process required high rhythmical skills, because of the frequent and rapid changes of the gradient pulsation and the relatively long period of time (20-30 minutes) of the scans, and I have long years practice of playing on hand drums and drum kit. The music stretching process was recorded. It should be noted, that there was an attempt to use the so called *Beat Seeker* device with Ableton, which was developed to automatically modulate the tempo of a given song to an outer sound source, but it did not recognize the MRI noises.

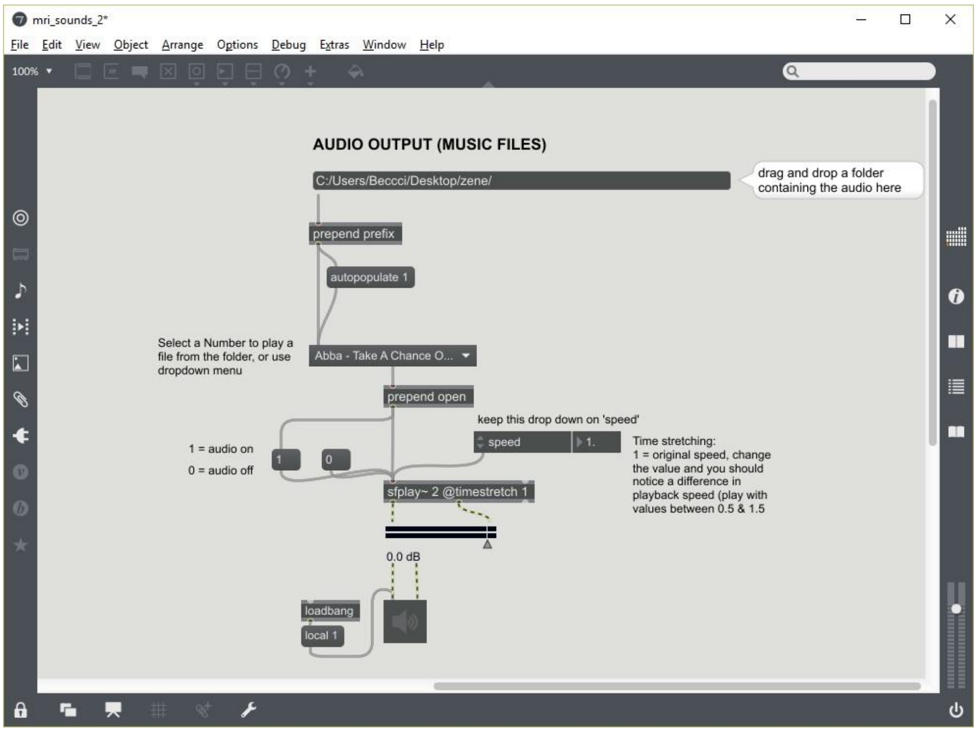

FIGURE 1. MAX 7 patch for time stretching.

A *1-hour long playlist* was created for the experiment; Table 3 shows the details of the songs. The original tempo of the songs varied between 59-140 BPM. The selection criteria for the songs were to have an easily recognizable tempo with diverse genres, with and without lyrics. The whole MRI environment with its loud, rhythmical background noise goes against the requirements of relaxing music, such as to be quiet, slow and make only few changes in tempo and volume. Therefore a new approach was required within these circumstances to provide a music that is not affected by the loudness of the equipment.

TABLE 3. The songs of the 1-hour long playlist.

	Author	Song title	Genre	Original tempo (BPM)
1.	ABBA	Take a chance on me	pop	106,6
2.	Renaud Garcia-Fons	Fortaleza	world music/jazz	120
3.	C. Young	Cindy Supermarket	synthpop	116,3
4.	Jace Everett	Bad things	country/rock	131
5.	Karl Jenkins	Tlep (Jailau)	classical/new age	140
6.	Queen	Somebody to love	glam rock	109,4
7.	Mittland och Leo	Decades	minimal electronic	88,1
8.	Michael Jackson	Will you be there	pop	82,9
9.	Nine Inch Nails	Ghosts II-13	dark ambient	59
10.	Alabama Shakes	Hang Loose	garage rock	119,4
11.	Jorge Ben Jor	Oba, la vem ela	samba	98,9
12.	Péterfy Bori és a Pluto	A nagy szívbűvölő	alternative rock	79
13.	Tashaki Miyaki	Best friend	indie pop	90
14.	Avicii	Wake me up	progressive house	124
15.	Parov Stelar	All night	electro swing	125

The process of *assigning patients* to groups was *quasi-experimental*: Every adult patient was offered to take part in the experiment on the designated days, if their examined body part were suitable (skull, spine, joints, lungs, shin and shank). After getting to know the type of examination and order of the patients for the day, a precise plan was needed to efficiently assign them into groups with the aim of alternating between the conditions. Using headphone was not possible in every case, e.g. cervical spine or any examination in prone position. The parameter that prohibited the random assignment of the groups was time: since the I had to be with the patients during (synchron group), before and after the examination to help filling out the questionnaires, it had to be considered how to examine as many patients as possible during the given time (2+1 weeks) without causing any delay in the normal procedure of the hospital unit.

The *synchron* group required the most time: because the patients constantly alternate with each others in the MRI room, the synchronization process hamstrung to talk with the next patient. With the *random* group it was easier, as it was possible to leave the control room for that period while the next patient filled out the questionnaires. A constant connection was needed with the reception to know if a patient has arrived, cancelled the appointment or transferred to the 1.5 T unit (if there was a metal in their body or there was other problems with the time schedule). My presence was important to clarify the aim of the questionnaires (e.g.the difference between state and trait anxiety) and make participants more motivated to fill every question with attention.

After finishing the pre-tests and introduction about the experiment, the patients were surveyed by the radiographer and asked to lie down on the examination table of the equipment. After the radiographer fixed the body part of interest, an emergency pump was given for the patient and the headphone (or earplugs) was superimposed. In case of emergency, by pressing the emergency pump the patient could signal to the radiographer to stop the examination. The patient could already hear a song when the headphone was put on, and I adjusted the volume as requested. The patient was asked not to move any body parts, even if the music was enjoyable. After this, I went to the control room where the radiographers work, and started to record/modulate the music, write some of the statistical data (weight, duration, position, examined body part). When it was possible (random and control group), I could go out to the waiting room and talk with the next participant. After the examination (which usually last 20-

30 minutes), the participant filled out the post-tests in the waiting room, while waiting for the result of the examination (CD). The measurements happened throughout the day between 7:30 and 22:00.

4.3 Apparatus

There are two types of earphones that can be used within the MRI environment. The *pneumatic* headphone has a poor sound quality and noise cancellation level, but it does not disturb the quality of the image itself. The *electrostatic* headphone (which was used in this study) has opposite attributions (good sound quality and noise cancellation, but it disturbs the diffusive measurements). The music was played from a PC laptop (Sony Vaio). The two MRI equipments used for examinations in the diagnostic institution were the Siemens ’MAGNETOM Avanto’ 1.5T MRI and Siemens ’MAGNETOM Trio A Tim System’ 3T MRI system.

4.4 Measures

To compare the patients’ general and present psychological wellbeing and experience of the examination, the following measurements were used: *State-Trait Anxiety Inventory (STAI)*, *Claustrophobia Questionnaire (CLQ)*, *Visual Analogue Scale (VAS)* and *open-ended questions*.

Before the MRI examination: informed consent, patient information leaflet, the State-Trait Anxiety Inventory were filled. *After the examination*: CLQ, STAI-State anxiety level, open-ended questions, VAS and demographic questions (gender, age, educational background and the number of previous MRI examinations) were recorded. The duration (min.), examined body part, position and weight were also registered.

4.4.1 State-Trait Anxiety Inventory

The State-Trait Anxiety Inventory (STAI) includes two 20-item measures that evaluate the patients’ anxiety level. The STAI-State (e.g. “I feel calm”) measures the current anxiety level “right now, at this moment”, while the STAI-Trait (e.g. “I feel like a failure”) estimates the general anxiety level (Spielberger, 1983). Participants are asked to rate themselves on each item, using a 4-point Likert scale (1=not at all, 4=very much so in the STAI-State, and 1=almost never, 4=almost always in the STAI-Trait). The individual scores are created by summing the scores for direct- and reverse worded items. Scores range from 20 to 80, where higher scores correspond to higher anxiety level. The Hungarian version was developed by Sipos and Sipos (1983). STAI is a popular psychological research tool (Mohammed et al., 2013; Dantendorfer et al., 1997), Quek, Low, Razack, Loh and Chua (2004) found that the Cronbach's Alpha for the total scores of STAI was 0.86.

4.4.2 Claustrophobia Questionnaire

Lisa and Lois' (2013) results suggest the Claustrophobia Questionnaire (CLQ) can be an efficient tool for screening patients who might not able to finish the MRI procedure due to claustrophobic reactions. In the study of Enders et al. (2011a), CLQ was used to screen patients' anxiety level and to see whether open or short-bore scanners are better in preventing claustrophobic events. They did not find significant differences. The CLQ was designed to measure two different fear components of claustrophobia: the fear of *suffocation* (e.g. ”Swimming while wearing a nose plug”) and *restriction* (e.g. ”Having your legs tied to an immovable chair”). It includes 26 items (14 items of suffocation and 12 items of restriction), and respondents are asked to rate the items from 0 to 4 according to their anxiety level in the situations (0=Not at all anxious, 4=Extremely anxious) (Radomsky et al., 2006). The overall scores range from 0 (no anxiety about claustrophobic situations) to 104 (maximum anxiety). The CLQ has a high test-retest reliability, internal consistency, discriminant and predictive validity (Radomsky, Rachman, Thordarson, McIsaac & Teachman, 2001).

4.4.3 Visual Analogue Scale

The Visual Analogue Scale (VAS) is a 10 cm long scale, where respondents are asked to mark the line to express freely their feelings about a certain stimuli. In this study VAS was used to measure the overall experience of the MRI examination. The following question was asked: *How was the overall experience of the MRI examination?* The two extremities of the scale were *very unpleasant* and *very pleasant*. The higher the score is, the more pleasant the overall experience is for the participants. Internal consistency ranged from 0.71 to 0.97 in the study of Villanueva, Del Mar Guzman, Toyos, Ariza-Ariza and Navarro (2004).

4.4.4 Duration of examination

To compare the anxiety reducing effect of the music, the amount of time each patient spent in the MRI scanner was measured. As seen in the previous literature, anxiety lengthens the scan duration by the patient's involuntary movement (motion artifact) and requested breaks.

4.4.5 Open-ended questions – thematic analysis

Thematic analysis is an essential and flexible method in qualitative research. Led by the research question, thematic analysis identifies and reports patterned meanings (themes) from the data through a 6-phases process (Braun & Clarke, 2006). It is a descriptive approach that involves low level of interpretation; furthermore, it shows similarities with content analysis, but the latter also quantifies the data, while thematic analysis is entirely qualitative (Vaismoradi, Turunen & Bondas, 2013). To measure more directly the effects of the music, patients were asked in *Hungarian* to answer questions, such as ”How difficult was for you to stay immovably in a narrow space?”, ”How did the music influence the experience of the examination?”, ”How satisfied are you with the genres of the music? What would you prefer to listen to?” and ”How did the music change your environment?”. With the non-music group the following questions were asked: “How difficult was for you to stay immovably in a narrow space?” and ”How did the headphone/earplug influence the experience of the examination?”.

4.5 Data analysis plan

In this study, the main analysis consists of a two-way mixed ANOVA to compare the pre- and post-intervention STAI-State anxiety scores in the different conditions. After this, three Kruskal-Wallis H tests compare the STAI-Trait anxiety, CLQ and VAS scores between groups. The effect of position and gender on the different measurements is tested with a series of Mann-Whitney U tests. Finally a thematic analysis is used to report the data from the open-ended questions.

5 RESULTS

5.1 Pre- and post-intervention STAI-State anxiety scores between groups

Two-way mixed ANOVA was calculated to see whether there is an interaction between the different conditions (control, random, synchron) and time (pre- and post-intervention) on the STAI-State anxiety level. There were no outliers, as assessed by examination of studentized residuals for values greater than ±3. The data was normally distributed, as assessed by Shapiro-Wilk's test of normality ($p > .05$). There was homogeneity or variances ($p > .05$) and covariances ($p > .05$), as assessed by Levene's test of homogeneity of variances and Box's M test, respectively. There was a statistically significant interaction between the intervention and time on STAI-State anxiety level, $F(2, 57) = 5.705$, $p = .006$, partial $\eta^2 = .167$. The effect size for this analysis ($\eta^2 = .167$) was found to exceed Cohen’s (1988) convention for a large effect ($\eta^2 = .14$). There was a statistically significant effect of time on state anxiety level for the random group, $F(1, 19) = 9.484$, $p = .006$, partial $\eta^2 = .333$, and for the synchron group, $F(1, 19) = 18.598$, $p < .001$, partial $\eta^2 = .495$. For the random group, state anxiety level was statistically significantly different between pre-intervention and post-intervention points ($M = 4.8$, $SE = 1.56$, $p = .006$), and for the synchron group, state anxiety level was statistically significantly different between pre- and post-intervention points ($M = 6.95$, $SE = 1.61$, $p < .001$). State anxiety level was not statistically different in the control group in the two time points ($M = .65$, $SE = 1.745$, $p = .714$). Table 4 and 5 shows the mean scores of STAI-State anxiety level in each group in the two time points.

STAI-State anxiety level slightly increased over time in the control group, but decreased in both music intervention groups. The synchronized group had the lowest STAI-State anxiety level at the end of the examination and had the biggest reduction over time. Figure 2 shows the interaction effect between the conditions and time.

There was no statistically significant difference in STAI-State anxiety level between groups at the pre-point of the intervention, $F(2, 57) = 2.483$, $p = .092$, partial $\eta^2 = .80$, and at the post-point of the intervention $F(2, 57) = .347$, $p = .708$, partial $\eta^2 = .012$.

TABLE 4. Pre- and post-intervention STAI-State anxiety level in the different groups.

Descriptive Statistics

	Group	Mean	Std. Deviation	N
Pre State	control	32.01	7.45	20
	random	37.05	8.73	20
	synchron	37.65	9.62	20
	Total	35.60	8.86	60
Post State	control	32.75	9.94	20
	random	32.25	6.50	20
	synchron	30.70	7.51	20
	Total	31.90	8.02	60

TABLE 5. Changes in STAI-State anxiety level over time.

3. Type * time

Measure: STAI-State anxiety

				95% Confidence Interval	
Group	Time	Mean	Std. Error	Lower Bound	Upper Bound
control	Pre	32.100	1.933	28.229	35.971
	Post	32.750	1.814	29.117	36.383
random	Pre	37.050	1.933	33.179	40.921
	Post	32.250	1.814	28.617	35.883
synchron	Pre	37.650	1.933	33.779	41.521
	Post	30.700	1.814	27.067	34.333

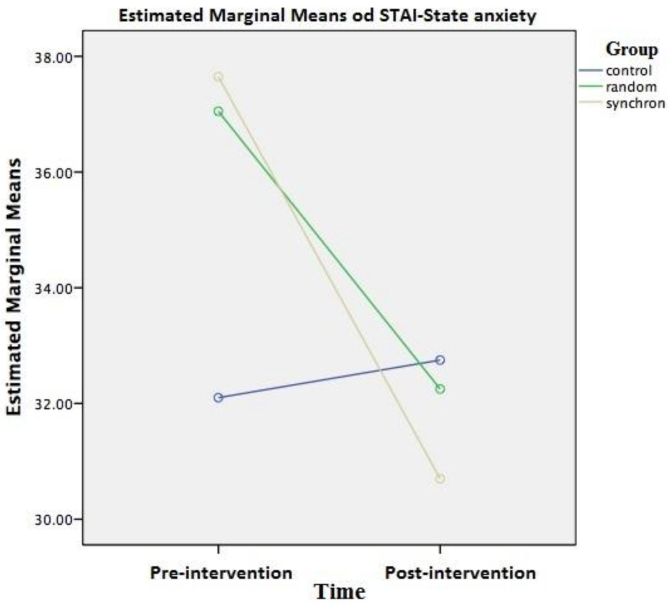

FIGURE 2. Interaction effect between conditions and time.

5.2 STAI-Trait anxiety level between groups

A Kruskal-Wallis H test was run to determine if there were differences in STAI-Trait anxiety scores between the three groups of participants with different interventions: the "control" (n=20), "random" (n=20) and "synchron" (n=20) groups. Distributions of STAI-Trait anxiety scores were similar for all groups, as assessed by visual inspection of a boxplot. STAI-Trait anxiety scores were the lowest in the control group (*Mdn* = 40.00), while the same in the random (*Mdn* = 41.50) and synchron (*Mdn* = 41.50) groups, but median STAI-Trait anxiety level scores were not statistically significantly different between groups, $\chi^2(2) = .411$, $p = .814$.

5.3 Claustrophobia Questionnaire (CLQ) scores between groups

A Kruskal-Wallis H test was run to determine if there were differences in CLQ scores between the three groups of participants with different interventions: the "control" (n=16), "random" (n=20) and "synchron" (n=19) groups. Distributions of CLQ scores were similar for all groups, as assessed by visual inspection of a boxplot. CLQ scores increased from control (*Mdn* = 18.00), to random (*Mdn* = 28.00) and to synchron (*Mdn* = 29.00) intervention groups, but median CLQ scores were not statistically significantly different between groups, $\chi^2(2) = .638$, $p = .727$.

5.4 Visual Analogue Scale (VAS) scores between groups

A Kruskal-Wallis H test was run to determine if there were differences in VAS scores between the three groups of participants with different interventions: the "control" (n=19), "random" (n=20) and "synchron" (n=20) groups. Distributions of VAS scores were similar for all groups, as assessed by visual inspection of a boxplot. Median VAS scores were statistically significantly different between groups, $\chi^2(2) = 12.1$, $p = .002$, $\eta^2 = 0.21$, indicating a fairly strong relationship between music intervention and the overall experience of the examination. Subsequently, pair wise comparisons were performed using Dunn's (1964) procedure with a Bonferroni correction for multiple comparisons. Adjusted *p*-values are presented. This post hoc analysis revealed statistically significant differences in VAS scores between the control (*Mdn* = 54.41) and random (*Mdn* = 83.82) (p = .022), and control and synchron (*Mdn* = 89.71) (p = .003) groups, but not between the random and synchron groups. Table 6 shows the medians for STAI-Trait, CLQ and VAS scores between the the three groups.

TABLE 6. Medians for STAI-Trait, CLQ and VAS scores.

Report

Group		STAI-Trait	CLQ	VAS (%)
Control	N	20	16	19
	Median	40.00	18.00	54.41
Random	N	20	20	20
	Median	41.50	28.00	83.82
Synchron	N	20	19	20
	Median	41.50	29.00	89.71
Total	N	60	55	59
	Median	40.00	25.00	82.35

5.5 Mann-Whitney U test to determine gender differences

5.5.1 Pre-intervention STAI-State anxiety level

A Mann-Whitney U test was run to determine if there were differences in pre-intervention STAI-State scores between males and females. Distributions of the pre-state anxiety scores for males and females were similar, as assessed by visual inspection. Median pre-state anxiety score was statistically significantly higher in females (*Mdn* = 36.00) than in males (*Mdn* = 30.00), U = 589.50, z = 2.142, p = .032, η^2 = .08, indicating a medium relationship between gender and pre-intervention STAI-State anxiety level.

5.5.2 Weight (kg)

A Mann-Whitney U test was run to determine if there were differences in weight scores between males and females. Distributions of the weight scores for males and females were similar, as assessed by visual inspection. Median weight score was statistically significantly higher in males (*Mdn* = 87.50) than in females (*Mdn* = 70.00), U = 131.50, z = -2.235, p = .025, η^2 = .11, indicating a medium relationship between gender and weight.

5.5.3 Post-intervention STAI-State anxiety, STAI-Trait anxiety, CLQ, examination time, VAS

A Mann-Whitney U test was run to determine if there were differences in post-intervention STAI-State anxiety, STAI-Trait anxiety, CLQ, examination time and VAS scores between male and female participants. Distributions of scores for males and females were similar, as assessed by visual inspection. There was no statistically significant difference between females and males in any of the examined measurements.

Median post-intervention STAI-State anxiety score was not statistically significantly different between females (*Mdn* = 32.00) and males (*Mdn* = 30.00), $U = 517.50$, $z = 1.072$, $p = .284$. Median STAI-Trait anxiety score was not statistically significantly different between females (*Mdn* = 42.00) and males (*Mdn* = 38.00), $U = 555.50$, $z = 1.638$, $p = .101$. Median CLQ score was not statistically significantly different between females (*Mdn* = 33.00) and males (*Mdn* = 19.00), $U = 485.00$, $z = 1.918$, $p = .055$. Median Examination time (min.) score was not statistically significantly different between females (*Mdn* = 22.00) and males (*Mdn* = 23.50), $U = 272.50$, $z = -1.530$, $p = .126$. Median VAS score was not statistically significantly different between females (*Mdn* = 75.74) and males (*Mdn* = 82.35), $U = 392.50$, $z = -.602$, $p = .547$. Table 7 shows the median scores of the above mentioned measurements between female and male participants.

TABLE 7. Median scores of different measurement between female and male participants.

Report

Median

Gender	Pre State	Post State	STAI-Trait	CLQ	Weight (kg)	VAS	Time (min)
male	30.00	30.00	38.00	19.00	87.50	82.350	23.50
female	36.00	32.00	42.00	33.00	70.00	75.735	22.00
Total	34.00	32.00	40.00	25.00	81.00	82.350	23.00

5.6 Mann-Whitney U tests to determine positioning differences

Mann-Whitney U tests were run to determine if there were differences in pre- and post-intervention STAI-State anxiety, and VAS scores between head-first and feet-first position. Distributions of scores for head-first and feet-first position were not similar, as assessed by visual inspection. There were no statistically significantly difference between head-first and feet-first position in any of the examined measurements.

Median pre-intervention STAI-State anxiety score was not statistically significantly different between head-first (mean rank = 34.00) and feet-first (mean rank = 34.00) position, U = 271.50, z = -1.128, p = .259. Median post-intervention STAI-State anxiety score was not statistically significantly different between head-first (mean rank = 32.00) and feet-first (mean rank = 30.00) position, U = 275.00, z = -1.069, p = .285. Median VAS score was not statistically significantly different between head-first (mean rank = 82.35) and feet-first (mean rank = 76.47) position, U = 300.00, z = -.523, p = .601. Table 8 shows the median scores of the above mentioned measurements between head-first and feet-first position. These results suggest, that position has no effect on the the participants STAI-State anxiety level and overall experience of the examination.

TABLE 8. Median scores of different measurement between head-first and feet-first position.

Report

Median

Position	Pre State	Post State	STAI-Trait	CLQ	VAS
Head-first	34.00	32.00	42.00	29.00	82.35
Feet-first	34.00	30.00	38.00	16.50	76.47
Total	34.00	32.00	40.00	25.00	82.35

5.7 Open-ended questions

The aim with the open-ended questions was to provide a rich, thematic description of the entire data set. The thematic analysis was made in an inductive way, without trying to fit the themes into a pre-existing coding frame. Themes were analyzed in the semantic or explicit level with a data-driven, experiential approach. The overall research question is that how hearing protection devices and music influence the MRI experience. The quotes were translated from Hungarian.

The result of the thematic analysis shows how the devices and music influenced the MRI experience on a physical, emotional and cognitive level, what makes a good music playlist and expectations about future music use in MRI examinations.

The first theme that emerged is the *Positive change and help*. This means that the participants made comparisons to cases where they could not listen to music or wear a headphone/earplug, and they found this experience better comparing to those, even if they had no prior MRI scans without these interventions. Often, the interventions changed their environment in a positive way that caused satisfaction, and most importantly, it made the examination less noisy. The majority of the participants mention the *noise cancellation effect* of the headphones and music, while music was also audible. In many cases, music or the devices were aids that helped the participants to go through the procedure. The brackets show the identification number of the participant, S means synchron, R means random and C means control group.

> It was more pleasant than without it *(music).* The noise didn't sound that much, it was better in this way. (2-S)
>
> The last minutes were hard. The headphone helped me. (6-C)
>
> Positively, since the music listening softened the MR noise; therefore the examination was more pleasant. It *(music)* was fully audible, I could hardly hear the machine, but still the music wasn't too loud. (7-S)
>
> The last time I was anesthetized, now I didn't need it. (11-S)
>
> Certainly, it was better with music than without. (27-S)
>
> It was friendlier, more tolerable; it was more cheerful *(with music).* (30-R)
>
> It wasn't good, but I could not have gone through it without music. (37-R)
>
> It wasn't unpleasant. The headphone softened the ticking noise. (48-C)
>
> It was an experience! (50-S)
>
> I think, it was much better than without it *(headphone).* It was loud even like this, but it wasn't so bad like couple of years ago. (54-C)

Many participants also used music as a *Distraction* that made it possible to concentrate on something else than the noise and uncomfortable space. Being *out of space and time* is a returning theme in the narrative. With music time goes faster, patients find themselves in a timeless, infinite space, and often, they forget where they are. Closing the eyes is common behaviour among these patients.

> It was different in this way; time went faster. (1-R)
>
> I was concentrating on the music; I didn't care about the boomy sound. (15-R)
>
> Time passed faster, I didn't listen to the machine's noise. I could think about other things. (28-R)
>
> It was good, I enjoyed it; it distracted my attention. (30-R)
>
> I could forget where I am. (35-S)
>
> Time went faster, and because of the music, it was much more pleasant. (38-R)
>
> It neutralized the waiting period, I listened to it leisurely. I didn't wait the end of the examination, just the upcoming songs. (50-S)
>
> The headphone was good, I felt the same when I listen to music, it gave protection from the outside world. (53-C)
>
> I didn't feel that I am closed. (56-S)

Another theme that emerged during the analysis is *Relaxation;* how the music made the patients calmer, less frustrated and anxious, in many cases they were even close to fall asleep. The participants in the following quotes are talking about the effect of music:

> It improved; the examination was way less frustrating. It calmed me down. (9-R)
>
> It soothed me that I don't hear the noise. (10-S)
>
> I stayed calm; it held my attention. I didn't get excited. (17-S)
>
> You could sleep on it. It's good. (20-S)
>
> I had a good time, it was pleasant, and I relaxed. (29-R)
>
> It helped to relax, I concentrated on the music and I didn't feel the incentive to make a motion. (42-S)
>
> It was good, pleasant, I almost fell asleep. It was refreshing, relaxing, which is rare in my case! (44-R)

The participant's opinion about the musical selection show, that *Diversity* of the genres caused satisfaction, and there is a desire to choose or listen to familiar music. The patients shared their advices and wishes about the preferable music styles, but there is no repeated pattern among these. Some examples of what the participants would like to listen to: more/less classical music, 90s songs, more vocal, gypsy, rock, dance music, nature sounds and radio shows.

> I was absolutely satisfied with the genres of the music. I wouldn't listen to anything else, because these were appropriate. (7-S)

> I was satisfied with the music. (9-R)

> It was good, diverse. (11-S)

> The Argentine tango was wonderful! You could have started *(the playlist)* with something less funky. All in all, I am satisfied. (13-R)

> It was just good, we need something like this. There was every kind of genres. (28-R)

> Hit songs could have better distracted the attention, music that I know. (26-R)

> More melodic music that is not so rhythmic could have put the tension out better. (43-R)

> It was good, I liked all of them. (45-R)

> High pitch was not good. Melodic, deeper music is better; no arias. (50-S)

> I like classical music, but I enjoyed the funky, faster music more here, it was playful, cheered me up. (51-R)

Common topics among the patients are the *MRI induced claustrophobic fears*. This includes the difficulties with closeness, lack of oxygen, heat, furthermore restricted movements, and fear of the unknown procedure and the diagnosis itself. All these are combined with the loud noise. Patients from the non-music group showed stronger claustrophobic reactions also in their verbal feedback.

> It was hot inside. (2-S)

> I was concentrating only on that I can't move, and my little finger started to move. The music calmed me down, but I was afraid if I don't hear the radiographer. (10-S)

> It is infinite; one can't feel the time, like you are bound. (19-R)

> I almost pressed the emergency button. It was long. (24-C)

It was very difficult, because I had to lie in a narrow space without any motion. (26-R)

There was no problem with the examination, but I am afraid of the result. (30-R)

I was concentrating very hard not to move my leg. (33-S)

It was bad, because it is unknown. It was narrow; I thought they will push me in even further. (51-R)

It was unfamiliar; I have never had any similar experience. I was never enclosed so much. I was anxious a bit at the beginning, but later the anxiety was gone. (52-C)

It indisposed me a lot, I am not sure if I am claustrophobic. There was not enough air. (54-C)

It wasn't so easy to stand the immobility. I felt like I was buried alive. (57-C)

The last main theme that rose is the *Music in future examination.* This means that the majority of the participants expressed the wish to listen to music during future examinations and praised the novelty of the intervention. One reason behind this is that the patients perceived music as an extra care from the hospital.

The person, who found this out, was clever! (13-R)

Thank you for the kind care. I will recommend the place for everybody. (32-S)

By all means, you should keep using music. Now I have a basis for comparison. (38-R)

I would prefer to do the next MR examination with music. (41-R)

I am very glad for this music thing. Thank you for the opportunity. (42-S)

This should be always part of the process, if possible. (44-R)

This system works well. (64-S)

In conclusion, positive change and help, noise cancellation effect, distraction, being out of space and time, relaxation, the need of diversity in musical genres and the hope of music intervention at future MRI examination are the main themes related to music and noise cancellation devices.

6 DISCUSSION

The present study tested the hypotheses that (1) during MRI examinations listening to music has better relaxation ability than headphone/earplugs alone, and that (2) synchronizing the tempo of the music with the MRI sequences has better relaxation ability than music that is played on its original tempo. Sixty outpatients were examined in the Diagnostic Center of Pécs to test whether the sedative effect of music can be improved by synchronizing it to the rhythm of the gradient pulsation. The patients were assigned into *three groups* (20 patients in each), a non-music (control), an original tempo (random) and a synchronized (synchron) group. Results support the first hypothesis showing that musical conditions and especially synchronization significantly lowered the participants state anxiety level after the examination, while the anxiety level did not change significantly in the control group. Comparison between the pre- and post-intervention mean STAI-State anxiety scores in the groups showed that state anxiety level statistically significantly decreased in the random group and in the synchron group, while not significantly increased in the control group. The results of the Visual Analogue Scale (VAS) also support the first hypothesis: Median VAS scores were statistically significantly different between groups; both the synchron and random groups had significantly more pleasant experience about the examination as a whole than the control group. However, there was no statistically significant difference in STAI-State anxiety level between groups at the pre-and post-point of the intervention, showing that the difference between the random and synchron conditions was not significant. Therefore there is only little support for the second hypothesis, since the synchron group had the lowest post STAI-State anxiety level and had the most pleasant overall experience about the examination.

This result can be interpreted in several ways. It may be that synchronization is really not a valuable aspect of music listening or alternately, the design of this present study was not sensitive enough to show this effect. One factor may be the quasi-experimental design that is the lack of random assignment of the patients that could bias the results. Furthermore, the quality of the synchronization was based on my rhythmic and concentration skills. The constantly changing gradient pulsation creates a very challenging environment, and some sequences were simply too fast to make proper musical adaptation.

There were no statistically significant differences in STAI-Trait anxiety and CLQ scores between groups, suggesting that the presence of music did not affect these general traits.

The results confirm previous findings on the role of gender (Barlow, 2002; Eshed et al., 2007; Murphy & Brunberg, 1997; Thorpea et al., 2008): women significantly feel more anxiety before the MRI examination, and females had higher post-intervention STAI-State, STAI-Trait, CLQ scores and found the experience less pleasant than males. The adjustment of the sequences depends on the patients parameters, such as bodyweight, but in this present study it did not influance significantly the examination time. Position had no significant effect of the patients' STAI-State anxiety level or overall experience.

The thematic analysis of the open-ended questions suggests that music and the headphones/earplugs work as a protection and noise cancellation tools for the participants; furthermore music caused a positive change in the environment and provided a help; it distracts attention from the examination, relaxes patients and is seen as care and desirable intervention in the future. All in all, earplugs and headphones appear as a protection and noise cancellation tools in the reflections, but music has an emotional, diversive effect as well. Roy, Peretz and Rainville (2008) support these findings.

Other difficulties during the experiment were the usage of contrast agent, and some unrealistic situation on the CLQ questionnaire. In many cases, contrast agents were injected during the examination that interrupted the music synchronizing and recording process. It was an additional aspect to consider when the patients were chosen for the different conditions. In the CLQ, many situations were unrealistic or never experienced by the patients, which made it harder to answer them. It should be noted that there was no official translation of the CLQ in Hungarian; a translation was made for the experiment with an advice from a Hungarian psychologist.

In conclusion, the present study is important, in that it provides support that listening to music during MRI examination significantly reduces patients' anxiety, while noise cancellation devices do not provide the same effect. Future research should investigate more about the potential in synchronization, since the synchron group had the lowest state anxiety level after the examination and the most pleasant overall procedural experience. It is recommended for future researches to make it possible for the clients to choose their own music and to focus on severely claustrophobic patients. As Argstatter, Haberbosch and Bolay (2006) suggested, music interventions are more efficient with patients who have higher state and trait anxiety than those with lower level of anxiety. Objective measurements (e.g. blood pressure, pulse rate) could increase the power of the study. The biggest challenge of the future is to find a solution for the automatic music synchronization. There are also possibilities for making the music more particular for the MRI environment: making specific music for each sequences that start and end together, concentrating more on ambient music or making a database of songs with different BPM to choose a song which tempo fits to the gradient pulsation. As Bernardi et al. stated (as cited in Chen et al., 2013), tempo has a greater effect on relaxation than individual music preferences. In the study of Bluemke and Breiter (2000) the sedation time of MRI patients varied between 23.6 - 47.3 minutes depending on the qualification of the sedation nurse. Investigating the full potential of music is important to find a cheap, fast and safe ways to relax patients within the MRI environment, since the increasing sound pressure level at future MRI equipments are expected to induce even more anxiety.

References

American Psychiatric Association (2013). *Diagnostic and statistical manual of mental disorders (Fifth edition)*. Washington, D.C.: American Psychiatric Association.

Argstatter, H., Haberbosch, W., & Bolay, H. V. (2006). Study of the effectiveness of musical stimulation during intracardiac catheterization. *Clin Res Cardiol, 95,* 1–9. doi:10.1007/s00392-006-0425-4

Barlow, D. H. (2002). Anxiety and its disorders, the nature and treatment of anxiety and panic. Second Edition. New York, NY: The Guilford Press.

Bluemke, D. A. & Breiter, S. N. (2000). Sedation Procedures in MR Imaging: Safety, Effectiveness, and Nursing Effect on Examinations. *Radiology, 216,* 645-652.

Borkovec, T. D., Ray, W. J., & Stöber, J. (1998). Worry: A cognitive phenomenon intimately linked to affective, physiological, and interpersonal behavioral processes. *Cognitive Therapy and Research, 22(6),* 561-576. doi: 10.1023/A:1018790003416

Braun, V. & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3 (2), 77-101. ISSN1478-0887

Cabanac, M. (1979). Sensory Pleasure. *The Quarterly Review of Biology, 54 (1),* 1-29.

Chen, L. C., Wang, T. F., Shih, Y. N., & Wu, L. J.(2013). Fifteen-minute music intervention reduces pre-radiotherapy anxiety in oncology patients. *European Journal of Oncology Nursing 17,* 436-441.

Cho, Z. H., Park, S. H., Kim, J. H., Chung, S. C., Chung, S. T., Chung, J. Y., Moon, C. W., Yi, J. H., Sin, C. H. & Wong, E. K. (1997). Analysis of acoustic noise in MRI. *Magnetic Resonance Imaging, 15(7),* 815-822.

Cohen, J. (1988). Statistical Power Analysis for the Behavioral Sciences. New York, NY: Routledge Academic

Costa, M., Fine, P. & Bitti, P. E. R. (2004). Interval distributions, mode, and tonal strength of melodies as predictors of perceived emotion. *Music Perception 22(1),* 1–14.

Counter, S. A., Olafsson, A., Grahn, H. F. & Borg, E. (1997). MRI Acoustic Noise: Sound Pressure and Frequency Analysis. *Journal of Magnetic Resonance Imaging, 7,* 606-611.

Dantendorfer, K., Amering, M., Bankier, A., Helbich, T., Prayer, D., Youssefzadeh, S., Alexandrowicz, R., Imhof, H. & Katschnig, H. (1997). A study of the effects of patient anxiety, perceptions and equipment on motion artifacts in Magnetic Resonance Imaging. *Magnetic Resonance Imaging, 15(3),* 301-306.

Dewey, M., Schink, T. & and Dewey, C. F. (2007). Claustrophobia during magnetic resonance imaging: Cohort study in over 55,000 patients. *Journal of Magnetic Resonance Iimaging, 26,* 1322–1327.

Dillman Carpentier, F. R. & Potter, R. F. (2007). Effects of music on physiological arousal: Explorations into tempo and genre. *Media Psychology, 10,* 339–363. doi:10.1080/15213260701533045

DIRECTIVE 2003/10/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 6 February 2003 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (noise) (Seventeenth individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC.

Di Salle, F., Espositob, F., Scarabinoc, T., Formisanod, E., Marcianoe, E., Saulinoe, C., Cirillof, S., Elefantea, R., Schefflerg, K. & Seifritzh, E. (2003). fMRI of the auditory system: understanding the neural basis of auditory gestalt. *Magnetic Resonance Imaging, 21, 1213–1224*

Duck F. A. (1990). Physical properties of tissues, a comprehensive reference book. London, UK: Academic Press Limited.

Dunn, O. J. (1964). Multiple comparisons using rank sums. *Technometrics, 6,* 241-252.

Enders, J., Zimmermann, E., Rief, M., Martus, P., Klingebiel, R., Asbach, P., ... Dewey, M. (2011a). Reduction of Claustrophobia with Short-Bore versus Open Magnetic Resonance Imaging: A Randomized Controlled Trial. *PLoS ONE 6(8): e23494. doi:10.1371/journal.pone.0023494*

Enders, J., Zimmermann, E., Rief, M., Martus, P., Klingebiel, R., Asbach, P., …Dewey, M. (2011b). Reduction of claustrophobia during magnetic resonance imaging: methods and design of the "CLAUSTRO" randomized controlled trial. *BMC Medical Imaging, 11(4).*

Eshed, I., Althoff, C. E., Hamm, B. & Hermann, KG. A. (2007). Claustrophobia and Premature Termination of Magnetic Resonance Imaging Examinations. *Journal Of Magnetic Resonance Imaging, 26,* 401–404.

Geva, T. (2006). Magnetic Resonance Imaging: Historical perspective. *Journal of Cardiovascular Magnetic Resonance, 8,* 573–580.

Good, M., Anderson, G. C., Ahn, S., Cong, X., & Stanton-Hicks, M. (2005). Relaxation and music reduce pain following intestinal surgery. *Research in Nursing & Health, 28*, 240-251.

Grey, S. J, Price, G, & Mathews, A. (2000). Reduction of anxiety during MR imaging: a controlled trial. *Magn. Reson. Imaging, 18(3),* 351-5.

Hall, D.A., Lanting, C.P & Hartley, D.E.H. (2014). Using fMRI to Examine Central Auditory Plasticity. *Functional Magnetic Resonance Imaging, ISBN: 978-953-307-669-0. InTech Open Access Publisher.*

Hearing Protection (n. d.). Retrieved from: https://www.osha.gov/SLTC/etools/shipyard/ship_breaking/ppe/general_ppe/hearing_protection.html

Hooper, J. (2012). Predictable factors in sedative music (PFSM): A tool to identify sedative music for receptive music therapy. *Australian Journal of Music Therapy, 23,* 59-74.

Katznelson, R., Djaiani, G. N., Minkovich, L., Fedorko, L., Carroll, J., Borger, M. A., Cusimano, R. J. & Karski, J. (2008). Prevalence of claustrophobia and magnetic resonance imaging after coronary artery bypass graft surgery. *Neuropsychiatric Disease and Treatment, 4(2),* 487–493.

Klonoff, E. A., Janata, J. W., & Kaufman, B. (1986). The use of systematic desensitization to overcome resistance to magnetic resonance imaging (MRI) scanning. *J. Behav. Ther. Exp. Psychiat., 17,* 189-192.

Krout, R. E. (2007). Music listening to facilitate relaxation and promote wellness: Integrated aspects of our neurophysiological responses to music. *The Arts in Psychotherapy 34,* 134–141.

Krumhansl, C.L., Bharucha, J.J., & Kessler, E.J. (1982). Perceived harmonic structure of chords in three related musical keys. *J. Exp. Psychol. Hum. Percept. Perform., 8,* 24–36.

Leknes, S., Berna, C., Lee, M. C., Snyder, G. D., Biele, G. & Tracey, I. (2013). The importance of context: When relative relief renders pain pleasant. *Pain, 154(3),* 402–410. doi: 10.1016/j.pain.2012.11.018

Leknes, S., & Tracey, I. (2008). A common neurobiology for pain and pleasure. Nature Reviews: *Neuroscience, 9,* 314-320.

Lisa, B. & Lois, B. (2013). Screening for Claustrophobia in MRI – A Pilot Study. *European Scientific Journal, 9(18).*

Lu, H., Nagae-Poetscher, L. M., Golay, X., Lin, D., Pomper, M., Van Zijl, P. C. M. (2005). Routine Clinical Brain MRI Sequences for Use at 3.0 Tesla. *Journal of Magnetic Resonance Imaging, 22,* 13-22.

McCraty, R., Barrios-Choplin, B., Atkinson, M. & Tomasino, D. (1998). The Effects of Different Types of Music on Mood, Tension, and Mental Clarity. *Alternative Therapies, 4(1),* 75-84.

McIsaac, H. K., Thordarson, D. S., Shafran, R., Rachman, S., & Poole, G. (1998). Claustrophobia and the Magnetic Resonance Imaging Procedure. *Journal of Behavioural Medicine, 21(3).*

McJury, M. J. (1995). Acoustic Noise Levels Generated During High Field MR *Imaging. Clinical Radiology 50,* 331-334.

McNulty, J. P. & McNulty, S. (2009). Acoustic noise in magnetic resonance imaging: An ongoing issue. *Radiography, 15,* 320-326.

Mohammed, E. K., Atef, J. & Ellife, H. A. (2013). Effectiveness of health instructions on reducing anxiety levels and claustrophobia among female adolescents undergoing Magnetic Resonance Imaging. *American Journal of Research Communication, 1(5),* 43-64.

Murphy, K. J. & Brunberg J. A. (1997). Adult claustrophobia, anxiety and sedation in MRI. *Magnetic Resonance Imaging, 15(1),* 51-54.

Pantaleone, J. (2002). Synchronization of metronomes. *Am. J. Phys. 70 (10). DOI: 10.1119/1.1501118*

Peelle, J. E. (2014). Methodological challenges and solutions in auditory functional magnetic resonance imaging. *Frontiers in Neuroscience, 8 (253). DOI: 10.3389/fnins.2014.00253*

Phillips, S. & Dearyt I. J. (1995). Interventions to alleviate patient anxiety during Magnetic Resonance Imaging: A review. *Radiography, 1,* 29-34.

Poustchi-Amin, M., Mirowitz, S. A., Brown, J. J., McKinstry, R. C. & Li, T. (2001). Principles and Applications of Echo-planar Imaging: A Review for the General Radiologist. *RadioGraphics, 21,* 767-779.

Press Release (2003, October 6). Retrieved from: http://www.nobelprize.org/nobel_prizes/medicine/laureates/2003/press.html

Price, D. L., De Wilde, J. P., Papadaki, A. M., Curran, L. S. & Kitney, R. I. (2001). Investigation of Acoustic Noise on 15 MRI Scanners from 0.2 T to 3 T. *Journal of Magnetic Resonance Imaging, 13,* 288–293.

Quek, K.F., Low, W.Y., Razack, A.H., Loh, C.S. & Chua, C.B. (2004). Reliability and validity of the Spielberger State-Trait Anxiety Inventory (STAI) among urological patients: a Malaysian study. *Med. J. Malaysia. 59 (2),* 258-67.

Quirk M, Letendre A, Ciottone R, & Lingley J. (1989). Anxiety in patients undergoing MR imaging. *Radiology, 170,* 463-6.

Radomsky, A. S., Rachman, S., Thordarson, D. S., McIsaac, H. K. & Teachman, B. A. (2001). *The Claustrophobia Questionnaire. Anxiety Disorders, 15,* 287-297.

Radomsky, A. S., Ouimet, A. J., Ashbaugh, A. R., Paradis, M. R., Lavoie, S. L. & O'Connor, K. P. (2006). Psychometric properties of the French and English versions of the Claustrophobia Questionnaire (CLQ). *Anxiety Disorders, 20,* 818–828.

Reuman, L., Jacoby, R. J., Fabricant, L. E., Herring, B. & Abramowitz, J. S. (2015.) Uncertainty as an anxiety cue at high and low levels of threat. *Journal of Behavior Therapy and Experimental Psychiatry, 47,* 111-119.

Roy, M., Peretz, I., & Rainville, P. (2008). Emotional valence contributes to music-induced analgesia. *Pain, 134,* 140–147. doi:10.1016/j.pain.2007.04.003

Schild, H. H. (1990). MRI Made easy. Berlin, Bergkamen: Schering AG.

Saffran, J. R., Aslin, R. N., & Newport, E .L. (1996). Statistical learning by 8-month-old infants. *Science, 274,* 1926–1928.

Shellock F & Kanal E. (1994) Magnetic resonance. bioeffects, safety and patient management. New York, NY: Raven Press.

Short, A. & Ahern, N. (2009). Evaluation of a systematic development process: Relaxing music for the emergency department. *Australian Journal of Music Therapy, 20*.

Sipos, K., and Sipos, M. (1983) *The development and validation of the Hungarian form of the State-Trait Anxiety Inventory*. In: C. D. Spielberger and R. Diaz-Guerrero (Eds.) Cross-cultural Anxiety. Vol. 2, Hemisphere, Washington, D. C., 27-39. Retrieved from: http://www.drsiposkornel.com/publikaciok.html

Slichter, C. P. (1990). Principles of Magnetic Resonance: Edition 3. Berlin: Springer.

Spielberger, C. D. (1983). *Manual for the State–Trait Anxiety Inventory (Form Y*). Palo Alto, CA: Mind Garden.

Staum, M. J. & Brotons, M. (2000). The effect of music amplitude on the relaxation response. *Journal of Music Therapy, 37(1),* 22-39.

Tan, Y. Z, Ozdemir, S., Temiz, A. & Celik, F. (2015). The effect of relaxing music on heart rate and heart rate variability during ECG GATED myocardial perfusion scintigraphy, Complementary Therapies in Clinical Practice, *http://dx.doi.org/10.1016/j.ctcp.2014.12.003*

Thaut, M.H., Kenyon, G.P., Schauer, M.L. & McIntosh, G.C. (1999). The Connection Between Rhytmicity and Brain Function; Implications for Therapy of Movement Disorders. *IEEE Engineering in Medicine and Biology, 101-108*

Thaut, M.H., McIntosh, G.C. & Hoemberg, V. (2015). Neurobiological foundations of neurologic music therapy: rhythmic entrainment and the motor system. *Frontiers in Psychology, doi: 10.3389/fpsyg.2014.01185*

Thorpea, S., Salkovskisb, P. M. & Dittnerb, A. (2008). Claustrophobia in MRI: the role of cognitions. *Magnetic Resonance Imaging, 26,* 1081–1088.

Tierney, A., & Kraus, N. (2013). The Ability to Move to a Beat Is Linked to the Consistency of Neural Responses to Sound. *The Journal of Neuroscience, 33(38),* 14981–14988.

Tischler V., Calton T., Williams M., & Cheetham A. (2008). Patient anxiety in magnetic resonance imaging centres: Is further intervention needed? *Radiography, 14,* 265-266.

Toivainen, P., & Krumhansl, C.L. (2003). Measuring and modeling real-time responses to music: the dynamics of tonality induction. *Perception, 32,* 741–766.

Vaismoradi, M., Turunen, H. & Bondas, T. (2013). Content analysis and thematic analysis: Implications for conducting a qualitative descriptive study. *Nursing and Health Sciences, 15,* 398–405.

Villanueva, I., Del Mar Guzman, M., Toyos, F. J., Ariza-Ariza & R., Navarro, F. (2004). Relative efficiency and validity properties of a visual analogue vs a categorical scaled version of the Western Ontario and McMaster Universities Osteoarthritis (WOMAC). *Osteoarthritis and Cartilage,* 12 (3), 225–231. doi:10.1016/j.joca.2003.11.006

Vlachopoulos, C., Aggelakas, A., Ioakeimidis, N., Xaplanteris, P., Terentes-Printzios, D., Abdelrasoul, M., Lazaros, G., & Tousoulis, D. (2015). Music decreases aortic stiffness and wave reflections. *Atherosclerosis, 240,* 184-189. http://dx.doi.org/10.1016/j.atherosclerosis.2015.03.010

Walworth, D. D. (2010). Effect of live music therapy for patients undergoing Magnetic Resonance Imaging. *Journal of Music Therapy, XLVII(4),* 335-350.

What's new in MAX 7.2? (2016, April 16). Retrieved from: https://cycling74.com/max7/

Wolfe, D. E:, O'Connell, A. S., & Waldon, E. G. (2002). Music for relaxation: A comparison of musicians and nonmusicians on ratings of Sslected musical recordings. *Journal of Music Therapy, 29,* 40-55.