

# Music and heart rate

*Physiological effects from listening to music in different tempos*

**Ulvhild Helena Tormodsdatter Færøvik**



**Masterprogram i psykologi**

**Studieretning: Åtferd og nevrovitenskap ved**

**UNIVERSITETET I BERGEN DET  
PSYKOLOGISKE FAKULTET**

**VÅR 2017**



## Abstract

Music has the power to elicit physiological responses in humans. One assumes that fast music tempo elicit faster heart rate and respiration rate and slower music tempos elicit slower respiration and heart rate. This presumption that music could alter physiological responses was tested in this study by playing different tempos to the participants while measuring respiration and heart rate.

Six different music tempos from 40 beats per minute to 200 beats per minute were presented as musical stimuli. Thirteen piano music pieces were composed at the Institute of Biology and Medical Psychology (IBMP) at the University of Bergen (UiB). The stimuli were recorded and presented in a pseudo-randomised order. White noise served as a control stimuli and was played between each stimulus. 36 participants listened to these novel music stimuli, while heart rate and respiration rate was measured.

The current study found a quadratic relationship between heart rate and music tempo, and a linear relationship between respiration and music tempo. Music tempo increased heart rate up to 136 beats per minutes, after that heart rate dropped. While respiration linearly increased up to 200 beats per minute. The hypothesis was confirmed, as this study concluded with an alteration of physiological responses while listening to different music tempos.

Keywords:

*Heart rate, respiration rate, music, white noise, physiological responses*

## Sammendrag

Musikk kan endre fysiologiske responser hos mennesker. Det antas at hurtig musikktempo gir kjappere hjerterate og respirasjonsrate enn sakte musikk tempo. Antagelsen om at musikk kan endre fysiologiske responser, ble testet i det nåværende studiet ved å spille av forskjellige tempoer mens respirasjon og hjerterate ble målt. Hypotesen var at kjappere musikktempo ville gi kjappere hjerterate og respirasjon, mens saktere musikk ville gi saktere respirasjon og hjerterate. Seks forskjellige musikktempo fra 40 slag per minutt til 200 slag per minutt ble presentert som musikkstimuli. Tretten piano sanger ble komponert på Institutt for biologisk og medisinsk psykologi (IBMP), ved Universitetet i Bergen (UiB). Musikk stimuliene ble spilt inn og presentert i en pseudo-randomisert rekkefølge. Hvit lyd ble spilt av mellom hver stimuli som en kontrollstimuli. 36 deltakere hørte på denne ukjente musikken, mens hjerterate og respirasjonsrate ble målt.

Studien fant et kvadratisk forhold mellom hjerterate og musikktempo, og et lineært forhold mellom respirasjon og musikktempo. Hjertet økte med musikken opp til 136 slag per minutt, hvorpå hjerterate gikk ned, mens respirasjon økte lineært opp til 200 slag per minutt. Hypotesen ble bekreftet for dette studiet og dataen tyder på at det forekom en fysiologisk endring mens deltakere hørte på forskjellige musikk tempo.

Nøkkelord:

*Hjerterate, respirasjon, musikk, hvit lyd, fysiologisk respons*

## Preface

In my bachelor thesis we found that what tempo music was played in, had a great effect on people's perception of the song. As a Zumba instructor I knew that some songs did just not engage the participants to dance, I presumed that this was because of the tempo.

Lullabies have been used for centuries to calm babies, and when I discovered that babies have faster heart rates than adults do, and that lullabies generally have slow tempos I started to investigate previous literature.

I told my supervisor Karsten Specht about my thoughts, and that I had found literature to exemplified this, and he supported my decision to make an experiment for my master thesis. I started doing a literature search and tried to design an experiment that would fit my hypothesis that tempo in music had the power to alter heart rate. We started the process summer 2016, but literature search and application to the regional ethics committee was not done until October the same year. Originally, we planned to do EEG as well, but we dropped it as it would complicate the design and be more time consuming. Besides, this was an exploratory research study with limited previous literature on the subject. Karsten Specht and Kjetil Vikene have been supporting me through the process and helped with forming the design, analysis, equipment and editing of the music and so on. Yves Aubert has also been helpful by composing some of the music used for the study, and he was my supervisor for my bachelor thesis. Helene Hjelmervik provided good support functioned as a sparring partner. Without any of these people the study would not have been half as good, or might not have been at all, as all their efforts has been invaluable. Helene and Kjetil were Karsten's PhD students, and Yves is a former Post doc at UiB. Karsten Specht is

Professor at the faculty of Psychology, IBMP. And a big thanks to my wife Kaya, who read grammar and was in charge of morale throughout.

## Table of content

Abstract	3
Sammendrag	4
Preface	5
Table of content	7
Figures	8
Tables	8
Introduction	9
Music theory	10
Musicology	14
The human heart	23
Respiration	28
Previous music science topics	31
Method	42
Research method and design	42
Participants	42
Stimuli	43
Instruments	45
Paradigm	46
Results	47
Discussion	52
Conclusion	64
Bibliography	65
Appendix A - Approval by REK	74
Appendix B - Informed consent form	77
Appendix C - Questionnaire	81
Appendix D - Verbal instructions for participants	82

## Figures

Figure 1. Standard ECG electrodes.	25
Figure 2. Electrode placement	25
Figure 3. Respiration rate and heart rate in BPM (relative to white-noise)	49

## Tables

Table I, Tempo expressions	12
Table II, Statistic table heart rate (relative to white-noise) and tempos	49
Table III, Statistic table respiration rate (relative to white-noise) and tempos	50
Table IV, Average heart rate in BPM	50
Table V, Average respiration rate in BPM	51



## Introduction

Music exists in every human culture, and all music have some form of musical beat. Wallin, Merker, Brown and Florentine (2000) defined music as a periodic pulse that listeners use to guide their movements and coordinating actions. In a study (Cervellin & Lippi, 2011) describes how the power of music can be used to enhance performance or affect wellbeing, for example; during the Olympic Games in ancient Greece, musicians were paid to play flute and kithara to improve athlete performance. In his book «Melancholy's Anatomy» from 1632, Robert Burton wrote: «music is the more grateful and effective remedy for sadness, fear and mood disorders». Accordingly, in an early EKG study, Hyde and Scalapino (1918) found that music affected pulse and blood pressure when their participant listened to classical songs in different tempos. The authors measured heart rate and showed that music actually changed these physiological states. Later, Krumhansl (1997) found that sad and fearful music increased the heart rate. She used emotional valance rather than tempo to alter heart rate. Hyde and Scalapino (1918) on the other hand focused their stimuli on characteristics like fast and slow beats. These two studies are 79 years apart, but both found physiological alterations for participants who listened to classical music. How does music alter physiological states such as heart rate and respiration? What is music, and how does it play into human lives? In the following sections, music theory, musicology, the heart and respiration will be described.

## Music theory

To understand what music is and how music works, it is important to understand the different elements in music. In this section, a short introduction to music theory is presented.

**Music** according to the Merriam Webster dictionary ("Merriam-Webster, ") can be defined as the sounds that are sung by voices or played on musical instruments. However, music is also the written or printed symbols, which shows how music should be played or sung. Music is also the art or skill of creating or performing music.

Music (Jeffs, 1998) is made up of several parameters like rhythm, tempo, melody, mode, accent and metre. Most important for understanding the music used in the current master thesis, is what is meant by tempo, mode and metre.

## Metre

In his book from 1998, Jeffs define pulse as the reoccurring beat in a music piece. The actual beat is often called time or rate, but when keeping time with stamping a foot or clapping in time, it is the pulse that is followed.

Jeffs (1998) defines the metre as the rhythmic structure for a musical piece, where the frequency of the music's pulse is heard. Metre includes accents and patterns, and is often given at the beginning of sheet music with two numbers, one at the top and one at the bottom. For example, 4/4 metre is the most common metre, and most music is played in this. 4/4 means that there are four beats in the time section, while 3/4 means that there are three beats for every time section.

## Tempo

In his book on music theory Jeffs (1998) explains that the **pulse frequency** in a music piece is called tempo. When the pulse has a high frequency, it sounds like the music is fast, and when it has a slow frequency, the music sounds slow. The pulse is easiest to detect when the tempo is consistent, however sometimes the pulse can be detected even though the tempo varies. In western notation, tempo can be written differently for different sheet music. Jeffs (1998) explains how **Metronomic tempo** is when tempo is given in beats per minute, while **General expression** is when tempo is given with words for a whole musical section. Changes refer to when tempo is written to be altered from the general tempo. For the current study, music was written metronomically, with complete accuracy for music speed. However, metronomic tempo is also neutral and does not say anything about the character of the music piece. Because tempo is mathematically given, many often prefer musical expressions that say something about the feeling in the music piece.

Jeffs (1998) uses the word: "General" expressions because when a tempo expression is given, what it means can be up for discussion. It is more inaccurate, but gives the feeling of the musical piece, at least if the composer and the player are from the same music tradition. The names of general expressions therefore can mean something for one who performs the music, and something else for another performer. For tempo expressions, experience is the most important part in understanding the given tempo. For the different tempo expressions see the following table I.

General tempo expressions can often be combined with other expressions (Jeffs, 1998) that defines the energy or the character, for example *adagio assai maestoso*, which means slow

and very majestic. This may in turn add to the complication of understanding how to play a music piece.

*Table I, Tempo expressions*

<b>Slow tempi</b>	<b>Middle tempi</b>	<b>Fast tempi</b>
<i>Adagio/Lento</i> - slow	<i>Adante</i> - walking	<i>Allegretto</i> - fast, but not as fast as allegro
<i>Grave</i> - very slow and serious	<i>Adantino</i> - a bit faster walking	<i>Allegro</i> - fast, but happy
<i>Largo/Largamente</i> - slow and wide	<i>Moderato</i> - moderate	<i>Presto</i> - fast
<i>Larghetto</i> - not as slow as largo		<i>Prestissimo</i> - as fast as possible

*Table, tempo expressions, from Roger Jeffs 1998 Active music learning, page 106-107.*

### **Tonality**

According to Jeffs (1998) tonality is based on which tone is the central tone. The first and the last tone in a music piece is often the central tone. For example, if a melody starts with a *c*, we often expect it to end on a *c*.

Jeffs (1998) explains how minor and major modes are often expressed as tonality or as a scale. The difference between major and minor tones are often defined by tonal structures, such as intervals between tones. In major scales, all the intervals are big or clean, which means it sounds pleasant and not dissonant. In minor scales, all but one interval is small. The largest difference between the two scales is the size of the third interval, which is big in major and small in minor.

In his book from 1998, Jeffs writes that the two most important parts of tonality is minor or major, and which tone is central in the composition. When combining this information we get

the mode of the song, which tone is central and if it is minor or major. An example of a mode can be E major, then the scale is major and the central tone is E.

When the second interval and the seventh interval is played harmonically, there is a so-called dissonance, a tonal tension. If music is just played harmonically it is called consonance.

## Musicology

“Without music, life would be a mistake” (Nietzsche, 1889). Music exists in every human culture, but how was it evolved?

The study of music as an academic subject is called Musicology ("Merriam-Webster, "). Musicology focuses on universalities by studying music across cultures, and specifics what different elements of music are studied.

In his book, *Music A Historical Overview*, Sigmund Hjorthaug (2002) explains that folk music, songs and melodies were passed on verbally. As such, there was no written tradition for music, which makes it difficult to document early music history. Often music had a function like lullabies, lyrical stories as well as uses for luring, hunting, ceremonies and so on. Music was also used to enhance the work efforts, for examples sea shanties, railway songs, and Afro-American slave music.

In a musicology literature review by Brown and Jordania (2013), they did a cross-cultural comparative study of different music in different cultures and tried to discover some universalities in music. Some of their findings were classified as a behavioural aspect of music, which is what the current study wants to investigate, as well as the physiology of music listening. Brown and Jordania (2013) found that across all the different music styles, music is often produced by a group, rather than an individual, at least this is most common. Music is also often segregated based on gender and age, for example separate songs for children, and different work-songs for females and males. While body movement and physiological changes in the listeners are universal, one can wonder about how this came to be.

### **Biomusicology**

Wallin et al. (2000) describes the field of biomusicology as a science that tries to discover how creating and listening to music were evolved.

Spencer in 1857 (Brown & Jordania, 2013), believed that music was evolved from language. In his book *The Descent of Man* from 1871, Darwin (Brown & Jordania, 2013; Patel, 2006) believed song led to the evolution of language. According to Fitch (2006) the field of biomusicology is often separated in two categories, the comparison of the biological model, using animal music, and the linguistic model, where music tries to copy language.

### **Vocal learning**

According to Merker and Bjorn (2005) humans readily learn to shape vocal outputs to match a pattern of auditory models received through the sense of hearing, this is called vocal learning. Learning a new song, how to pronounce words and imitating sounds are all examples of human vocal learning. Mammals excel in their capacity to learn, yet vocal learning is a rarity, which no ape besides humans possess.

Fitch (2006) states that language is often considered to be uniquely human, although it involves certain ancient mechanisms shared with other animals. Vocal learning in animals, including songbirds, parrots, cetaceans and some pinnipeds are sometimes paralleled with the evolution of speech/music. Fitch (2006) argues that perhaps naturally produced animal communication systems can give a better indication about the biology and evolution of human music than language can. Still, beyond a few mammals such as humans, whales and seals, no other known mammals can learn to produce a pattern of a song or other sounds from auditory

models. Merker and Bjorn (2005) points out that some types of birds, like parrots, hummingbirds and a large group of oscine (not suboscine) songbirds also have the ability for vocal learning. According to Jarvis (2004) there are many anatomical parallels between the anatomy in birds and mammals. He points out the basal ganglia, which is anatomically similar for birds and mammals, and it has been hypothesised that this specific part may have been modified by natural selection for vocal learning. In their book *Cognitive Neuroscience, the Biology of the Mind*, Gazzaniga, Ivry and Mangun (2014) states that the basal ganglia consists of caudate, putamen, globus pallidus, subthalamic nucleus and substantia nigra. Further, the authors write that this subcortical nucleus group is involved in the dopamine system, emotions, goal-oriented behaviour, memory, motor skills, learning and speech production. Jarvis (2004) write that anatomical brain similarities such as the basal ganglia may explain why vocal learning occurs for some mammals and birds.

Merker and Bjorn (2005) claims neither human song nor speech could exist without vocal learning. The two share a deep generative similarity. In nature, song, but not speech, has arisen repeatedly among animals, which was first pointed out by Darwin. Humans might once have been singing apes, in the same sense whales and songbirds are singing animals today.

### **Beat perception and movement**

Wallin et al. (2000) states that when listening to music, song, or speech the auditory cortex, the somatosensory and motor systems are activated. Activations of these systems may reflect an association between music and dancing, rhythmic tapping, clapping and similar musical associated activities.



According to Patel, Iversen, Bregman, Schulz (2009) musical beat perception is to perceive a periodic pulse in a complex sound sequence. Music perception may be expressed by head movement, tapping with feet or fingers, and so on. Does rhythm tapping occur as a consequence of motor cortex activation? Or does motor cortex activation cause movement in synchrony with the beat? According to the Action Simulation for Auditory Prediction Hypothesis (ASAP) (A. D Patel & Iversen, 2014), humans move rhythmically to music because our motor planning system in the brain wants to predict the timing of beats. If this hypothesis is true, then moving to a music-beat is a predictive action, not a reactive one. Kung et al. (2013) did a study where they concluded that the basal ganglia probably is a part of a network, which is engaged when humans tap the beat of musical rhythms. The authors noted that the basal ganglia is also involved in detecting and associating auditory stimuli with motor response. In a study (Brodal, Osnes, & Specht, 2017) listening to rhythmic music was shown to reduce connectivity within the basal ganglia and the reward system. The authors noted that previous literature have found the basal ganglia to be activated for both production of rhythmic movement and perception of rhythmic sounds. As mentioned in the above section, the basal ganglia has motor functions, and may be important for vocal learning.

In the above mentioned review by Patel and Iversen (2014) they concluded that humans prefer musical beats that are around 600 milliseconds per period or 100 beats per minute. A book on human anatomy (Bjålie, Haug, Sand, Sjaastad, & Toverud, 1999) states that the human heart, when unaltered by hormones or nerves prefers 100 beats per minute as well. Although, most of the time the heart is under the influence of hormones and nerves, especially the autonomic nervous system.

According to Demos, Chaffin, Begosh, Daniels and Marsh (2012) humans tend to spontaneously and unintentionally synchronise movements with one another to establish a feeling of fellowship when listening to music, or making music. Tarr, Launay and Dunbar (2014) presents evidence which suggests that synchronisation between humans can influence their subsequent positive social feelings towards others. They claim synchrony is a lot like mimicry, as both involves similar movements with another individual. However, synchrony adds an element of rhythmically matched timing, which requires a prediction of movements by the co-actor. Demos et al. (2012) states that music allows for social bonding with individuals who are strangers. Tarr et al. (2014) states in their literature review that synchronisation probably has a more pronounced effect on social bonding, than for example mimicry. These two studies both conclude that music can provide a situation for social bonding, and synchronisation with strangers.

### **Music and emotions**

What is an emotion? In their book, chapter 10, Gazzaniga et al. (2014) have collected many theories on what emotions are. One definition in this book states that emotions are responses to external or internal stimuli. This response can involve changes across multiple response systems, such as experiential, behavioural, peripheral, and physiological. Physiological responses like increased heart rate and respiration are often connected or a component of emotional responses. One of the most studied emotions is fear. The sympathetic and parasympathetic systems are activated by the fear response mechanism fight or flight, where the body prepares to either run, or stay and fight. The sympathetic system uses the neurotransmitter norepinephrine to increase some physiological responses, such as increasing the heart rate and

respiration. The parasympathetic system on the other hand uses acetylcholine as a neurotransmitter and decreases heart rate and respirations. Fight or flight is presumed to be an ancient fear mechanism, which very clearly shows the connection between an emotion, fear, and physiological responses like sweating, bowel movement, heart rate and etcetera. According to Gazzaniga et al. (2014) many emotion researchers believe that emotions are made up of three psychological components, a physiological response, a behavioural response, and a subjective feeling.

In an emotion review by Stefan Koelsch et al. (2015) the authors describes how the anatomy of emotions was first believed to be made up of the hypothalamus, anterior thalamus, cingulate gyrus and hippocampus. These brain parts were later named the Papez circuit. The review by Koelsch et al. (2015) explains how the original emotional system was expanded with the amygdala, basal ganglia, corpus callosum and the orbitofrontal cortex. With the new structures, it got renamed to the limbic system. Today the limbic system includes the thalamus, the somatosensory cortex, the amygdala, sensory cortices, the insula, the medial prefrontal cortex (including the orbitofrontal cortex), the ventral striatum and the anterior cingulate cortex. Research has managed to somewhat divide the different emotions with the different brain structures.

In their review Koelsch et al. (2015) suggests a quartet theory of human emotions. The authors suggest four affect systems to be the brainstem-centred, diencephalon-centred, the hippocampus-centred, and the orbitofrontal-centred systems. The brainstem-centred system is presented in all vertebrates, and works from the caudal medulla oblongata to the rostral mesencephalon, on activation and deactivation of arousal. Further, Koelsch et al. (2015) states

that the diencephalon-centred system consists of the dorsal and ventral thalamus, hypothalamus, epithalamus, habenular complex, pineal gland and subthalamic nucleus. The thalamus is responsible for pain and emotional valance, and the hypothalamus is responsible for pleasure. Still Kolesch et al. (2015) argues for a third affect system, the hypothalamus-centred system, involving the hippocampal cortex. The biggest difference between the diencephalon and hippocampus systems is that the former is about achieving homeostasis or equilibrium and is then satiated while the latter can never be satiated. The authors argue that the difference is cognition, which is present in the hippocampus-centred system. Lastly Kolesch et al. (2015) argue for a fourth system, the Orbitofrontal-centred affect system (OFC). In this system there are several functions such as automatic cognitive appraisal, somatic markers, sensitivity to reward and punishment, and generation of moral affect.

What happens if music tries to mimic different emotions? In 2017 S. Garrido published a book called "*Why Are We Attracted to Sad Music?*", Chapter four is about the physiological effects of sad music, and relevant for the current section. When humans experience fear, adrenalin or cortisol is released, and this often causes increased heart rate, faster respiration and sweat secretion. Oppositely, happiness release chemicals such as dopamine and opioids, which are involved in the reward system in the brain. These are activated when for example listening to a favourite song.

In a study (Kim & André, 2008) it was stated that a primary motive for listening to music is the emotional effect. In their study, the authors showed that there is an automatic emotion recognition system, which utilises several physiological measures. They further state that the

listener in most cases understands the intended emotion of the composer. Even children as young as three years old understand the emotion music wants to describe as well as adults do.

Garrido (2017) lists several music studies indicating that when people listen to music they like, the reward system is activated in the brain. The limbic system which consists of amygdala and hippocampus are involved in responding to stressful situations is de-activated. This occurs regardless of whether the music is of a sad or happy nature. When people listen to music they do not like, the amygdala is activated. Unlikable music is usually dissonant.

Several studies look into the physiological reactions music may elicit in humans. Panksepp (1995) had 14 undergraduate students bring 6 minute cassette tapes with them and sit for 2 hours listening to the music and rate the emotional valance. The aim of the study was to find music that induced chills, as a preset for a larger scaled survey. Over 300 participants responded to the survey, where Panksepp found that men experienced more chills for happy music, and women more for sad music. The Post-War Dream by Pink Floyd, was considered the song that induced most chills, in the study. Carol Krumhansl (1997) found that heart rate, blood pressure, skin conductance and skin temperature changed in response to sad music. Etzel, Johnsen, Dickerson, Tranel and Adolphs (2006) found that heart rate decelerate for sad music, but accelerate for fearful music. Though what exactly it is in music that makes these physiological responses occur is perhaps still unknown. Khalifa, Schon, Anton, Liégeois-Chauvel (2005) found that slow songs in major and minor were considered sad, while fast songs in both modes were considered happy. Tempo might be worth further investigations as an emotional music inducer.

According to the literature debated in this section, music may perhaps predate language. Patel and Iversen (2014) claims that some brain parts involved in music production and listening are found in other mammals and birds. While activation of music in the brain also activates motor areas, which are common with beat perception, dancing and perhaps synchronisation. The ability to synchronise movement to a beat may lead to a feeling of social bonding between music listeners or makers. Music may yield physiological as well as emotional and physical responses in humans who are listening to or making music. There seem to be some universalities in music. How music was evolved is called biomusicology, while musicology is only how music can be studied in its own right. Perhaps the two fields tend to overlap, but both give an inclination about why music may have an important role in people's daily life. The fact that humans react emotionally to music is also a topic, which can be debated. Also, that emotions yield physiological responses has long been known, such as changes in heart rate and respiration rate.

## The human heart

What is the heart and how does it work? How can music alter the heart's responses?

In their book on anatomy and physiology, chapter nine Franz Bierring and Lars Garby (1990) explains how the human heart is a double pump, where the two pumps work in perfect synchronisation. Blood is transported from the veins into the lungs, where the pressure is low, and onwards to the arteries, where the pressure is high. The heart is placed a bit to the left of the body median, meaning about two-thirds of the heart is on the left side of a human body.

In their book on anatomy, chapter seven, Bjålie et al. (1999) explains how the heart is usually the size of a fist and weighs about 300 grams. The heart starts to beat shortly after an egg has been fertilised, when the foetus is only three weeks old and a few millimetres long. This may show the necessity of a transportation system.

In their book, Bierring and Garby (1990), states that the heart consists of three layers, the inner layer endocardium, the middle layer myocardium and the outer layer epicardium. The heart is separated down the middle by a wall, called septum cordis, and this divides the heart in two halves, which both have a fore chamber, an atrium and a heart chamber, the ventriculus.

Further, the authors note that from the right atrium the blood flows through the right atrioventricular opening in the right ventricle. Then it is pumped out into the pulse vein of the lungs, and through the lung arteries. Here the blood is oxygenated and give off carbon-dioxide, before it is taken to the left ventricle where it is pumped out into the main artery (aorta). From the aorta the blood flows through the whole body until it is taken back to the right atrium and the process starts anew. The heart's task is to pump about 5 litres of blood per minute while resting,

and about 25 litres per minute during labour or exercise. For people in good physical condition, the heart can increase this rate up to 30 litres per minute during exercise.

Bjålie et al. (1999) explains how the heart has a built-in ability to beat rhythmically without any form of nervestimulation. Spontaneous depolarisation is most rapid in a small group of cells called the sinusartial node. Thus, some specialised muscle cells in the heart can depolarise themselves, which creates electrical impulses. When electrical impulses occurs in the sinusartial node, it spreads through the whole heart and causes heart contraction. Other cells in the heart are activated by the electrical impulses from the sinusartial node, and this makes these other cells reach their action potential. The sinusartial node works as the heart's pacemaker (sets the frequency). In addition to this, the heart has a system of specialised muscle cells that leads action-potential and pacemaker-potential through the heart.

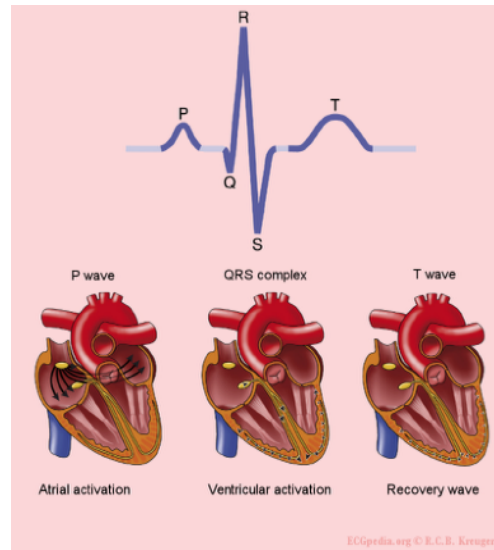
Further, the authors write how the ion-streams that crosses the cell membrane during action potential leads to tension differences and electrical impulses in the synapses outside the cells. The electrical current is strongest when the membrane potential changes most rapidly, during depolarisation and repolarisation.

We can measure the heart's electrical activities on the skin. Bierring and Garby (1990) states that this is done by measuring the electrical potential between two electrodes on different part of the body, for example the right and the left side. Bjålie et al. (1999) states that electrocardiography (ECG) is used to measure the heart's electrical activity on the skin. In principle, ECG can be measured on any part of the body, but the test has been standardised to specific locations for electrodes. A standard ECG has three electrodes which consists of the P-electrode, which represents the depolarisation of the fore chambers in the heart, the QRS-



electrode, which represents the depolarisation of the ventricles in the heart and lastly the T-electrode which represents repolarisation of ventricles (see figure 1. and 2.)

*Figure 1. Standard ECG electrodes.*



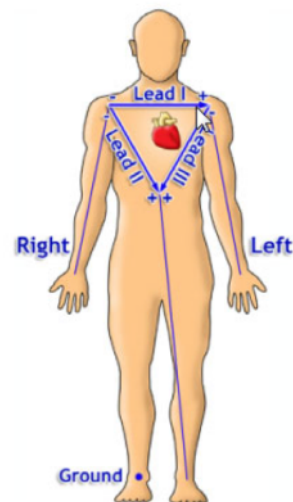
*The figure shows both the atrial, ventricular activation and the recovery wave as well as how this data is shown and read on an output.*

*Figure 2. Electrode placement*

*Electrode placement, figure 2. retrieved from*

*“Biopac”*

*<https://www.biopac.com/application-note/ecg-ekg-electrocardiography-12-6-3-lead/>*



The ECG procedure ("Wikipedia, ") is considered noninvasive and with virtually no risk for the participant. Bjålie et al. (1999) explains that during a minute the heart pumps a certain amount of blood, this information is called heart minute volume. The volume can be found by multiplying the heartbeats per minute (heart frequency) with the amount of blood pumped by each beat (beat volume).

As mentioned, the sinusartial node would keep 100 beats per minute as a frequency for heart rate, if left to its own devices. However, the frequency may alter as neurones and hormones often affect the sinusartial node. The heartbeat is especially affected by the autonomic nervous system. Gazzaniga et al. (2014) explains how the nervous system is composed of the central nervous system (CNS). The CNS consists of the brain and spinal cord, and the peripheral nervous system (PNS), with the nerves and ganglia outside of CNS. The PNS is a courier network, which delivers sensory information to the CNS and carries the motor commands from the CNS to the muscles. These activities are further divided into two systems, the autonomic nervous system and the somatic motor system. The autonomic nervous system is involved in controlling the heart and various glands. It has two subdivisions, the sympathetic and the parasympathetic systems. As mentioned in the section on emotion and music, there are other things than neurotransmitters and hormones, which alters the heartbeat.

In his book, *Physiology of Behaviour*, Carlson (2001) shows how both the heart and respiration is controlled by the medulla oblongata. Yet, sympathetic and parasympathetic activation can alter the response of the heart and respiration rate. However, in fear stimulation of the brain, the amygdala has several shortcuts to activate certain functions. In a study (Davis, 1992) found when startled, the amygdala sends out signals to the lateral hypothalamus, which

then activated the sympathetic response system. When the danger is over the amygdala sends out responses to the dorsal motor nucleus of vagus and nucleus ambiguus to activate the parasympathetic system. As mentioned earlier, the sympathetic and the parasympathetic systems alters heart rate and respiration, but according to Davis (1992) the amygdala sends a message to the parabrachial nucleus to increase only respiration.

For the current study, the medulla oblongata is perhaps the most important brain part. According to Gazzaniga et al. (2014) the medulla oblongata contains parts of the reticular formation, including nuclei that control vital functions such as the cardiovascular system. It is continuous with the spinal cord and lies in the brainstem. The medulla contains cell bodies of many of the 12 cranial nerves, providing sensory and motor innervation to face, neck, abdomen and throat, as well as to the motor nuclei that innervate the heart. Vital functions such as heart rate, respiration and arousal are all controlled by the medulla. Functionally, the medulla is a relay-station for sensory and motor information between the body and the brain. However, it also controls several autonomic functions such as essential reflexes, which determines respiration, heart rate, blood pressure, and digestive and vomiting responses.

Other brain parts, which are important for the current study, are perhaps the hypothalamus and the amygdala. Again Gazzaniga et al. (2014) explains that when the body goes into fight or flight response the amygdala sends a message to the lateral hypothalamus to increase the heart rate and blood pressure. The sympathetic and parasympathetic systems are examples on how the heart rate is altered by neurotransmitters.

## Respiration

How does breathing function? What affects the breathing of a human?

In their book on anatomy, chapter 9, Bjälile et al. (1999) states how cells in the body constantly need energy. Cells retrieve energy from organic molecules in the nutrients in a series of chemical reactions. These reactions need oxygen, and they generate carbon dioxide and water. There is a constant need for oxygen to be added and carbon dioxide to be disposed of. Exchange of oxygen and carbon dioxide between cells and the air from the atmosphere is called respiration. As mentioned earlier this process takes place in the lungs.

In their book on anatomy, chapter 10, Bierring and Garby (1990) explains that the respiration system consists of the upper and the lower airways, lungs, chest and diaphragm. The upper airways are the outer and inner nose (*nasus externes, cavitas nasi*) and the throat (*pharynx*). The mouth is included in the throat airway. The lower airways is the larynx, trachea and the bronchias. Human airways works as an air conditioning system, they humidify, filter and temperate the air on its way to the lungs. There is one lung on each side of the body, and they are shaped as half cones.

Bjälile et al. (1999) explains how the air in the atmosphere, just like the blood, moves from areas with high pressure to areas with low pressure. Inhalation starts when the respiration muscles are relaxed and the pressure is equal in the atmospheric pressure. Air does not stream through the airways, but the chest expands. The expansion of the chest seems like a suction, which draws the lungs outwards with the breast wall and the lungs expand as much as the chest. When the lungs expand the alveolus pressure sinks, and then the atmospheric pressure is greater

than the alveolus pressure. As the lungs are not a closed vacuum, but rather in connection with the atmosphere, the pressure difference means that the air flows through the airways and into the alveoli until the pressure is equalised. When the body is calm, the diaphragm is the most important inhalation muscle. When more air is needed, like during exercise, the diaphragm is strengthened and the outer intercostal muscles are utilised as well. The ribs are elevated allowing more air to fill the volume of the lungs for each inhalation.

Further, the authors explain that exhalation occurs when inhalation is over, when the diaphragm and the other inhalation muscles are relaxed. During rest, exhalation occurs passively, meaning that humans breathe out without using muscles. Exhalation occurs because the elastic forces in the lungs and the chest draws the lungs tighter when inhalation muscles are relaxed. When the pressure in the lung alveolus increases, it becomes higher than the pressure in the atmosphere, and air then streams from the alveoli through the airways and out into the atmosphere. This will occur until the pressure between the lungs and the atmosphere is equalised once more. During physical activity humans breathe faster and deeper, exhalation is then active. The inner intercostal muscles contracts and pulls the ribs downwards. At the same time, the muscles in the abdomen wall are also contracting stronger during exhalation than in rest. As pressure increases in the abdomen, the diaphragm is pushed faster upwards in the chest. This makes the chest-volume smaller, and exhalation becomes more frequent because the breathing rate increases.

Respiration rate (RR) ("Medicine, ") is the number of breaths a person takes per minute. RR is usually measured with a breathing belt and simply counts how many times the chest rises each minute.

Even though breathing is automatic some of the time, the brain, specifically the medulla, controls or regulates respiration. In his book on physiological behaviour, Carlson (2001) states that different locations in the medulla contain several nuclei with specific motor functions which are automatic like breathing, or semiautomatic such as coughing. Davis (1992) mentions that another important part is when in fight or flight modus, the amygdala sends out signals to the parabrachial nucleus to increase respiration, not heart rate.

As mentioned in the above sections, the sympathetic and parasympathetic nervous system are controlled by the hypothalamus and the brainstem. The sympathetic system increases respiration, while the parasympathetic system decreases respiration. These systems may take over control for when physiological responses such as increased heart rate and respiration rate occurs. In the current study, music is of interest as a causer of physiological alterations of respiration rate and heart rate.

### **Previous music science topics**

Thus far, heart, respiration, music evolution and science, as well as musical parameters have been presented. In this section, the different aspects of physiological reactions to music will be presented based on previous literature on the subject.

#### **Live or recorded music?**

Shoda, Adachi and Umeda (2016) showed in their study that when listening to a recording, heartbeat was not altered. However, listening to live music altered the heartbeat. They used classical piano music, and tested the recording condition after participants had heard the music live. Participants might have entrained to the music, or simply not found it as moving the second time, compared to the live piano concert. The authors also suggested that perhaps heart-rate variability to music is about communication or an interaction between the listener and the performer, rather than just a passive listening experience.

A study by Arnon et al. (2006) found that live music had a stronger effect on preterm infants, as opposed to a recording. In their study a female voice together with drum and harp was performed for the infants, and the same song was recorded for the same use. A third control condition had no music. Live music was much more efficient on lowering infant heart rates, but it was not at a statistically significant level until 24 minutes after the performance. Another study (Leila Taheri, Marzieh Kargar Jahromi, Mohammad Abbasi, & Hojat, 2016) also done on infants, specifically neonates in hospitals, found that recorded music decreased heart rate. They used a lullaby, only vocal with a male voice, to soothe neonates for a 40-minute period and heart rate were decreased for the whole period.

Other studies than Taheri et al. (2016) have used recordings and not live music and still found physiological alterations (B.S. Kisilevsky, S.M.J. Hains, A.-Y. Jacquet, C. Granier-Deferre, & Lecanuet, 2004; Bigliassi. M, Barreto-Silva V, & R, 2015; Joset A. Etzel et al., 2006; Max J. Hilz et al., 2014; Schmitz, Drake, Laake, Yin, & Pradarelli, 2012) .

In an essay in *Nature*, John Sloboda (2008) argues that researchers must study music the way people experience music. Sloboda states that music should be studied in a real-life non-laboratory setting, like a concert or music in public places, as well as music listening at home. Why would some experiments find live music to be effective and not recordings, while other studies found effectiveness of recorded music? Is science missing the ecological validity, as Sloboda ponders in his essays on music and science?

### **Genre preference**

Perhaps musical effectiveness has something to do with genre, or what type of music was used in the experiment? Music used in an experimental setting varies from composed for a specific experiment, self-selected by participants or familiar music chosen by experimenters. In the 60s or early 70s, there were some academic interest into the “rock” phenomenon, which divides the generations. Christenson and Peterson (1988) did a study where they focus on the fact that musical preference might be based on age, and that using the same genres for all ages is perhaps unwise.

A study (Jia T, Ogawa Y, Miura M, Ito O, & M, 2016) used music during exercise, and found during recovery rate that when participants picked their favourite music and did an exercise, in form of bicycling sessions, their heart rate increased. However, recovery rate after exercise was also more rapid with music, thereby the heart rate increased and decreased faster



with music intervention. The authors let participants choose their own music, which was not controlled for tempo. Both Ogawa et al. (2016) and Shoda et al. (2016) used familiar or known music, not novel music.

One study (Bigliassi, M et al., 2015) found that listening to a motivational song gave lower heart rate, rather than listening to a calm song. However, they did not specify the BPM for the motivational self-selected songs, while the calm song was 110 BPM. The authors point out that listening habits were not investigated for the participants, which are likely related to their psychophysiological response to music.

Another music-study (LeBlanc, Colman, McCrary, Sherrill, & Malin, 1988) used American pop-jazz instrumental music from 1925-1940. The experiment was not about jazz per se, but about tempo preferences for different age groups. The authors noted that their results were only valid for the jazz music genre, as results may differ for other genres.

In their paper Hilz et al. (2014) discuss if arousal responses to music may be influenced by previous or pre-existing differences in the experience with similar or the same music. For example one study by Etzel et al. (2006) used film-music, which was supposed to be novel for the participants, but what if there was a difference in arousal due to participants previous experiences with similar music? Perhaps this is why some studies focuses on music being novel for participants, while others let participants choose the music themselves?

### **Self-selected music**

A study (Dianne Smolen, Robert Topp, & Singer, 2002) investigated the effect of self-selected music for patients undergoing a colonoscopy procedure. The authors claimed that one limitation for the study included that the type of music patients choose was not controlled for, it

was only assumed that the patients choose music that would relax them. However, the authors also points out that what is considered relaxing music is individual, which is one of the benefits of letting participants choose their own music.

Another study (Yamashita, Iwai, Akimoto, & Kono, 2006) asked participants to bring their favourite music for an exercise experiment. The type of music was not controlled for and the authors noted that because the complexity of different musical metres, physiological response might have differed for the individual participants.

Yet another study (Karageorghis, Jones, & Low, 2006) let participants choose a music artist, and then the participants received three songs from each artist in different tempos for the exercise experiment. Here, music stimuli were controlled, with the benefits of self-selecting music and individual differences being supported.

In one study by Tan, Ozdemir, Temiz and Celik (2015) participants were given a list of 15 unknown pieces of folk music to choose from. Although the authors had controlled music stimuli, they did not account for genre preference. Still the authors found that the relaxing folk music they played for the participant music-group had a relaxing effect.

Self-selecting music may have many benefits, such as genre preference for participants ensures relaxation. Hyde and Scalpino (1918) points out that familiar music may cause emotional memories. Perhaps the most optimal design would be to have novel music for participants to choose in different genres.

### **Known music**

What about universalities in music emotion? Some studies choose to use Classical music for universality and to elicit emotional responses. Hilz et al. (2014) used different classical music

pieces because the music was composed to manipulate the audience towards a specific feeling. The authors had a professional conductor and musician pick out classical music pieces that was meant to give the feeling for either relaxing stimulation or aggressive stimulation.

One study (Hyde & Scalapino, 1918) used two classical songs and measured blood pressure and heart rate for listening to that specific music. In their study the authors found that minor tones increased pulse rate and lowered blood pressure, while stirring music increased both blood pressure and pulse rate. Hyde and Scalpino (1918) stated that the music they used were known with emotional valence, but that their piece was not known for the participants. They specified that using known music for participants would be associated by memory, and therefore not valid for an experiment. However, using known classical music would elicit correct and good responses, as long as they were unfamiliar to participants.

Carol Krumhansl (1997) did an experiment with the aim to find out more about musical emotions and physiology. She measured body temperature, skin conductance and heart rate for six different classical music songs. The selected music yielded a physiological reaction befitting the respective emotion, with strongest activation for sadness.

A Turkish study (Ozlem Ozkalayci, Araz, Cehreli, Tirali, & Kayhan, 2016) on sedation depth for dental procedures did not find an effect from music intervention. The study had three conditions, one with white noise (WN) and headphones, one with music and headphones and one with nothing. The music was intended to have a calming effect as were the white noise, but the authors found no difference between music, WN, or the no-intervention condition. However, they used Vivaldi's four seasons violin concertos, which have high tempo as well as being a

universally known music piece. The authors pointed out that the use of music with such a high tempo may have degraded the sedative effects of the music.

One study (Stéphanie Khalfa, Mathieu Roy, Pierre Rainville, Simone Dalla Bella, & Peretz, 2008) used several different classical music pieces to induce sadness and happiness in their participants. They measured heart rate, blood pressure, respiration rate, skin conductance and zygomatic and corrugated muscle activity. The authors noted a significant difference between the happy and sad conditions for the blood pressure, the skin conductance and zygomatic activity.

Another study (Emmanuel Bigand, Suzanne Filipic, & Lalitte, 2005) used 27 musical excerpts, with varying emotions based in key musical periods of Western classical music, to find the emotional time course responses to music. They found that emotional responses were consistent within the individual participant and between all the participants. In their study Bigand et al. (2005) stated that emotional responses occurred after 1 second of stimuli, however participants were encouraged to listen for emotional cues. Apart from Ozkalayci et al. (2016) the other studies debated in this section found classical music to target emotional and physiological effects. Classical music may then perhaps yield target emotional and physiological changes with the listeners and be suitable for music induction studies.

### **Novel music**

Another approach is perhaps to use novel music in induction studies. One experiment (James J. Kellaris & Kent, 1994) wanted to look at physiological changes when listening to musical tempo. For their study, they composed music in two genres, pop and classical. Stimuli were made in three different musical tempos; fast, slow, and moderate, and they used different

levels of tonal; atonal, minor, and major. This way the music could not hold any emotional memories for participants, and simultaneously all musical parameters were known and controlled for. Kellaris and Kent (1994) found that tempo produced a significant effect on pleasure. The authors also pointed out that how participants listen to music, as background noise versus intent listening, may yield completely different results.

An fMRI study by Brodal et al. (2017) the authors composed the music themselves, to make music befitting the scanner with continuous-stimulation and synchronised with the noises generated by the MR scanner. The authors concluded that rhythmic music have the power to interact with our emotional experiences when we listen to it. These two studies with self-composed music, supports the efficiency of novel music. When designing a study, it is perhaps difficult to know what is optimal, whether to have the participants self-select the music, to use classical emotional defined music, or to use novel music.

### **Music tempo**

Based on previous research it seems reasonable to assume that there is a relationship between music and heart rate. The current study explores the effect on rapid music (max 200 BPM) versus slow music (40 BPM).

Some studies do not relay what tempo stimuli is played in (Behzad Abedi, Ataollah Abbasi, Atefeh Goshvarpour, Hamid Tayebi Khosroshai, & Javanshir, 2017; Douglas S. Ellis & Brighthouse, 1952; Hyde & Scalapino, 1918; Iwanaga, Kobayashi, & Kawasaki, 2005; Jia T et al., 2016; Krumhansl, 1997; Leila Taheri et al., 2016; Max J. Hilz et al., 2014; Nater, Elvira Abbruzzese, Monika Krebs, & Ehlert, 2006; Patterson, 2011; Schmitz et al., 2012; Shmuel Arnon et al., 2006; Ugglä et al., 2016). BPM is sometimes only reported for heartbeats, not for music.

Sometimes general music expressions ("Wikipedia, "), like Largo, can be defined around 45-60 BPM , while Prestissimo is defined at around 200 BPM or more, and Moderato is considered at 108-120 BPM. As mentioned in the above section on tempo, general tempo terms are per definition subjective. Hence, tempo “can be defined”, with regard to the instrument and style, not the exact BPM.

In a study by Kellaris and Kent (1994) slow music was defined at 60 BPM, moderate music was at 120 BPM and fast music was at 180 BPM.

Another study done in India (Rane & Gadkari, 2016) defined slow, soft, melody music at 60-70 BPM and fast dance music at 100-120 BPM. However, the authors did not relay what type of music they used, which makes it difficult to compare to for example Kellaris and Kent (1994).

Etzel et al. (2006) used movie soundtracks ranging from 42-124 BPM. Another study (B.S. Kisilevsky et al., 2004) explained they used 69-118 BPM as the natural calm tempo Bhrams Lullaby changes in .

Bigliassi et al. (2015) used a calming song with 110 BPM. Another study (L Bernardi, C Porta, & Sleight, 2005) compared different musical genres to silence, and the authors used different tempos for each music genre, ranging from 55-150 BPM.

Karageorghis et al. (2006) defined 80 BPM as slow, 120 BPM as medium and 140 as fast music.

In a recent study by Brodal et al. (2017) dance music was defined to be at 120 BPM. A study by Khalfa et al. (2008) looked at entrainment for happy and sad music, defining happy tempo as 136 BPM, and sad tempo at 52 BPM.

LeBlanc et al. (1988) defined slow tempo to be between 57-84 BPM, slow moderate tempo to be around 94-108 BPM, fast moderate tempo was 126-147 BPM, and fast tempo was 172-271 BPM. Based on these previous studies and musical theory, the current study stimuli seem to be within the definitions of fast and slow.

### **Length of musical induction**

How much time is needed for an emotional response to music is perhaps not always relayed or debated in articles. In two studies done by Bigand et al. (2005) (summed up in one article) emotional response occurred after 1 second of listening to music. Participants in these studies were encouraged to listen for emotional cues; however, the authors did not measure heart rate. According to these authors, it is sufficient to only give 1 second of stimuli to elicit a physiological heart response. Different studies use different length for musical stimuli, Yamashita et al. (2006) for example used 1 hour and 30 minutes, while others use 30 seconds (B.S. Kisilevsky et al., 2004; Mitterschiffthaler, Fu, Dalton, Andrew, & Williams, 2007). Max J. Hilz et al. (2014) found in their heart rate analysis that only the first 30 seconds of musical stimuli showed an alteration from the baseline. Based on the research listed here, 30 seconds of stimuli seems sufficient to elicit a physiological response.

### **White Noise**

White noise is defined by Merriam Webster dictionary ("Merriam-Webster, ") as a heterogeneous mixture of sound waves extending over a wide frequency range. It can be comprehended as a constant background noise which drowns out other sounds.

White noise (WN) has been used in some musical studies (Bigliassi. M et al., 2015; Loui, Zamm, & Schlaug, 2012) to reset the heart and the brain between music. In one fMRI study by

Mitterchiffthaler et al. (2007) musical stimuli lasted for 30 seconds with 16 seconds of quiet period, rather than WN between each stimuli. While Loui et al. (2012) used 12 seconds of music and 500 milliseconds of WN bursts. Whether to use WN as a contrast can be debated, but so can the concept of absolute silence. Today noise is perhaps more common than silence, and white noise mimic all noises, while silence is never a complete silence in scientific experiments as there are always small sound from the electrical equipment. The current study wanted to have a baseline, or a measure of heart rate that was not affected by music or silence.

### **Methodical criteria**

Three problems with previous musical science is perhaps live music versus recorded music, what type of stimuli to use, novel, self-selected or known music, and genre preferences of the participants. The first problem is perhaps some discourse about the effectiveness of using recordings versus live music. The second problem might be the possibility of people having emotional memories attached to familiar music, versus universality and reliability with other music studies. The third problem, which is tied to the second problem, is that it may be beneficial to consider general preferences, to get the desired music induction.

According to a review by Koelsch and Jäncke (2015) there are several methodical criteria which people who endeavour to study music should keep in mind .

Firstly, use of music should be controlled, prepared by the experimenter, and listener should have a preference for the music. Though this must be situation based, the participants should not select music form their own music library.

Secondly, stimuli need to be characterised based on the aims and hypotheses of the study, both physical and emotional.



Thirdly, there should be an acoustical control stimulus in clinical studies. Perhaps this should apply for all studies, although the authors only specify for clinical studies.

Forth, double-blind study design if possible.

Fifth, psychologically relevant outcome variables should be included, such as musical aptitude tests, mental health and current mood.

Lastly, if relevant, economically relevant outcome variables should be included, such as medication or disease background.

The current study has tried to make the design to these criteria set by Koelsch and Jäncke (2015) as well by the literature debated in the previous sections.

### **Research goal and hypothesis:**

For this study the hypothesis is: music stimuli will alter physiological states in form of heart rate and breathing rate. Specifically, slow music will yield slower heart rate and respiration rate, and fast music will yield faster heart rate and respiration rate.

## **Method**

The two main literature searches were done on 6. October 2016 and 26. January 2017. The rest of the literature were found as sources from other papers, and special needs to look up concepts or definitions.

The first search was done on Web of Science at 6. October 2016, at 10 am. The keywords used were: heart rate variability and music. The next search was done on Web of Science at 26. January 2017, at 10 am. The keywords this time were: Heart rate music, blood pressure music. Then for Google Scholar, the same keywords were used. The study was designed in October 2016, based on the literature read during the initial literature search.

## **Research method and design**

The study was designed to be a quantitative experiment as universalities in music is what is sought after in this thesis. Although, data gathering had to be comprehensive, it also had to be doable on a limited time, which is why the goal of 40 participants were set. In this study, the tempo of the music stimuli was the independent variable, while heart rate and respiration rates were the dependent variables. WN was played between each song and served as control condition for heart rate and respiration rate compared to music condition.

## **Participants**

There were 36 participants in this study (18 female, 18 male. Mean age 26.58, Std. Deviation 5.81), and the criteria were that all participants had to be over the age of 18, and not use any neurostimulating drugs that may affect the heart rate. Participants were recruited through

flyers at Haukeland University Hospital and at the Faculty of Psychology, University of Bergen, and through Facebook forums. 34 of the participants were right handed, and two were left handed based on the participants self-reporting in the questionnaire. 41 participants were originally tested, but four were excluded due to medication use, and one because of faulty data, thus leaving 36 participants.

Personal data was coded and stored offline and thus anonymity was assured. Participants were rewarded with 100 NOK for their participation. The Regional Committee for Medical and Health related Research Ethics (REK) approved this project (see Appendix A). All participants were debriefed after their participation, and no-one guessed the hypothesis. Most participants thought the current study looked at the difference in heart rate compared with WN and music.

### **Stimuli**

MIDI files were recorded using a Yamaha P-105 digital piano (Yamaha Music Europe GmbH, Rellingen, Germany) and REAPER digital audio workstation (DAW) version 4.33/64 (Cockos Inc., New York, U.S.A.). WAV-files were then created by re-recording the MIDI data in a piano timbre, using the in-built piano setting (Grand Piano 1) of the digital piano. MIDI data were used for experimental modifications of the music, ensuring that only the music element of interest was modified through the computer software while all other elements remained unaltered, thus allowing for maximal experimental specificity and control over all music features.

The music for this study was composed by Ulvhild Færøvik (the author) and Yves Aubert (former Postdoc at UiB). Originally there were 30 possible music pieces, approximately lasting

15 seconds each. Some of the music pieces had a too complex rhythm for the purpose of the present study, thirteen out of the 30 music pieces were chosen for the current study. The stimuli were edited using Logic Pro to alter the different tempo regions, and to last for about 30 seconds. An alteration from 40 BPM to 200 BPM meant that some songs had to be doubled or even tripled to last 30 seconds, while others barely played through the original composition once.

The compositions were created with the aim to be simple in their musical structure, yet complex enough to carry ecological validity. Rhythmic features such as metre and accent patterns differed across the 13 stimuli. Melody contour lines and tonality were not restricted. Mode and consonance were matched using predominantly major mode and limited dissonance in the stimuli. The stimuli are quite different, although most of them were considered pleasant by participants. A majority of stimuli-songs were in the 4/4 metre, and major mode. This was done for ecological validity, to fit most people's music listening pattern.

Tempo was manipulated for all the songs. In total there were six tempos; two slow, two medium and two fast. These are 40 BPM, 72 BPM, 104 BPM, 136 BPM 168 BPM and 200 BPM. The six tempos were played five times, each one for 30 seconds, followed by 30 seconds of white noise in between each stimuli (except the 104 BPM tempo, which was only played four times, due to human error). Each stimulus was played twice, with a different tempo, and at different times in a pseudo randomised order. As there were thirteen music pieces, for all six tempos to be played five times, four music pieces were played three times, rather than two, like the other stimulus. All stimuli were played for 30 seconds and were novel music.

White noise was used as a control or reset stimuli between each song. The WN lasted for 30 seconds between each song.

## **Instruments**

For measuring heart rate, BIOPAC 2 Systems was used with three channels, one on the left side, one on the right and one on the foot. For respiration rate, BIOPAC 2 Systems breathing belt was used to conduct the measurement. For skin conductance, BIOPAC 2 Systems were also used, but the data was faulty, due to machine error and were not used for this experiment.

Sennheiser HD 280 Silver 64 headphones were used for the experiment. The sound was set at around 78 to 80 decibels (dB) measured with Brüel & Kjær Head and Torso stimulator, type 2128C. None of the participants complained about the volume.

Participants were not asked to refrain from caffeine or any other normal consumption habits. It was presumed that participants usually listened to music with tempo variations, so tempo variations in an experiment setting would not seem unordinary. Listening to music is an ordinary everyday activity, which many people engage in. Hence, the current study aimed to have high ecological validity as the study was made to be as close to normal day activities as possible.

To measure musical aptitude, the Profile of Music Perception Skills (PROMS) (Law & Zetner, 2012) test battery, which is an online survey tool, was used. PROMS measures how individuals percept music across tonal, qualitative, temporal and dynamic tests. These include melody, pitch, timbre, tuning, rhythm, rhythm to melody, accent, tempo and loudness. The current study used a brief version of the full PROMS test, which measures four modalities: melody, pitch, accent, and tempo. However, Law and Zetner (2012) have found that the brief PROMS correspond strongly with the full-length PROMS. PROMS were utilised to measure

musical background or skill, as this may affect the way music alters the body and mind. IBMP has translated the test to Norwegian and uses a different web page. The Norwegian test can be found here: <https://webapp.uibk.ac.at/psychologie/musiquote/index.php/30416/lang-nb>

### **Paradigm**

The study lasted about 40 minutes, including set up and debriefing. Participants were welcomed to the lab, and asked to read and sign an informed consent (see Appendix B). Afterwards, participants were asked to fill out a short questionnaire asking about their personal information (see Appendix C). Then participants went into an acoustically isolated chamber, where they put on electrodes and breathing belt. Participants got to put on the electrodes themselves with instructions from the researcher, and then they fastened the cables themselves as well. They were instructed (see Appendix D) to close their eyes, listen to the music and not tap the tempo with their fingers or feet. Then they were given headphones and the researcher closed the door so that the participants were alone during testing. The actual testing time took 29 minutes. Afterwards participants were debriefed and given 100 NOK for their participation. Then a few weeks later (which participants had been informed about both before and after the experiment) participants were given a survey to fill out online (PROMS) to evaluate their musical aptitude.

## Results

To extract heart rate and respiration rate (minus white noise), an in-house software written in MATLAB was used to analyse raw data from the respiration and heart rate measurements. The software detected each heartbeat and respiration and transformed it into heart rate (HR) and respiration rate (RR) for each stimulus separately. The data were inspected for outliers and detection errors, and respective stimuli were discarded prior to averaging. Afterwards, averaged heart rates and respiration rates relative to WN were estimated for each tempo, across stimuli.

These data were further analysed using IBM SPSS Statistics (Version 24). Descriptive statistics were used to find the mean and standard deviation for participants. One-way ANOVAs (analysis of variance) were used to test for a relationship between the heart rate and respiration rate scores and grouping variables such as gender, musical abilities and age. The significance threshold for two-tailed tests were set at  $p < 0.05$ .

There were no significant difference in heart rate or respiration rate minus white noise, between the two genders for any of the stimuli. This was analysed with a one-way ANOVA, and the result for heart rate was at  $F(1, 35) = .602, p = .443$  and respiration at  $F(1, 35) = .185, p = .670$ .

Neither were there any difference between musicians versus non musicians in how they responded to the musical stimuli. Musicians were defined as people who scored over 79 on the short version of the PROMS test battery. The cut-off at 79 was derived by taking the maximum possible score and dividing it in half, everyone above 79 was therefore deemed musicians in their

aptitude. 15 participants scored above 79, and 17 participants scored under the threshold. Three participants did not finish the online survey. A one-way ANOVA was used to analyse the result, for heart rate minus white noise  $F(1, 31) = 1.469$ ,  $p = .235$  and for respiration rate minus white noise  $F(1, 31) = .215$ ,  $p = .646$ .

There was no significant difference in HR and RR minus white noise between the different age groups, a one-way ANOVA was used to compare the mean of heart rate and respiration rate minus white noise. Heart rate did not yield significant results with regard to age differences at  $F(1, 35) = .602$ ,  $p = .443$ . Respiration rate was not significant at  $F(1, 35) = .185$ ,  $p = .670$ .

A one-way repeated measures between-within subject's ANOVA was done to compare scores on heart rate with the six different music tempos. The tempos measured were 40, 72, 104, 136, 168 and 200 BPM. The means and standard deviations are presented in Table I. There were not a significant effect for differences between tempos, Wilks's Lambda = .830,  $F(5, 31) = 1.272$ ,  $p < .30$ , and multivariate partial eta squared = .17. It was not a linear relationship for HR, but within-subjects contrast showed it to be a quadratic ( $p = .032$ ) or cubic ( $p = .050$ ) relationship, as seen in Figure 3. It was one degree of freedom for quadratic  $F(1, 35) = 4.989$  and for cubic  $F(1, 35) = 4.110$ .



Table II

Tempo	N	Mean	Standard deviation
HR_40 BPM	36	-0.5311	1.95
HR_72 BPM	36	-0.6856	2
HR_104 BPM	36	-0.0244	2.9
HR_136 BPM	36	0.2368	2.7
HR_168 BPM	36	0.0015	2.8
HR_200 BPM	36	-1.2203	2.3

Table II, Statistic table heart rate (relative to white-noise) and tempos

Figure 3.

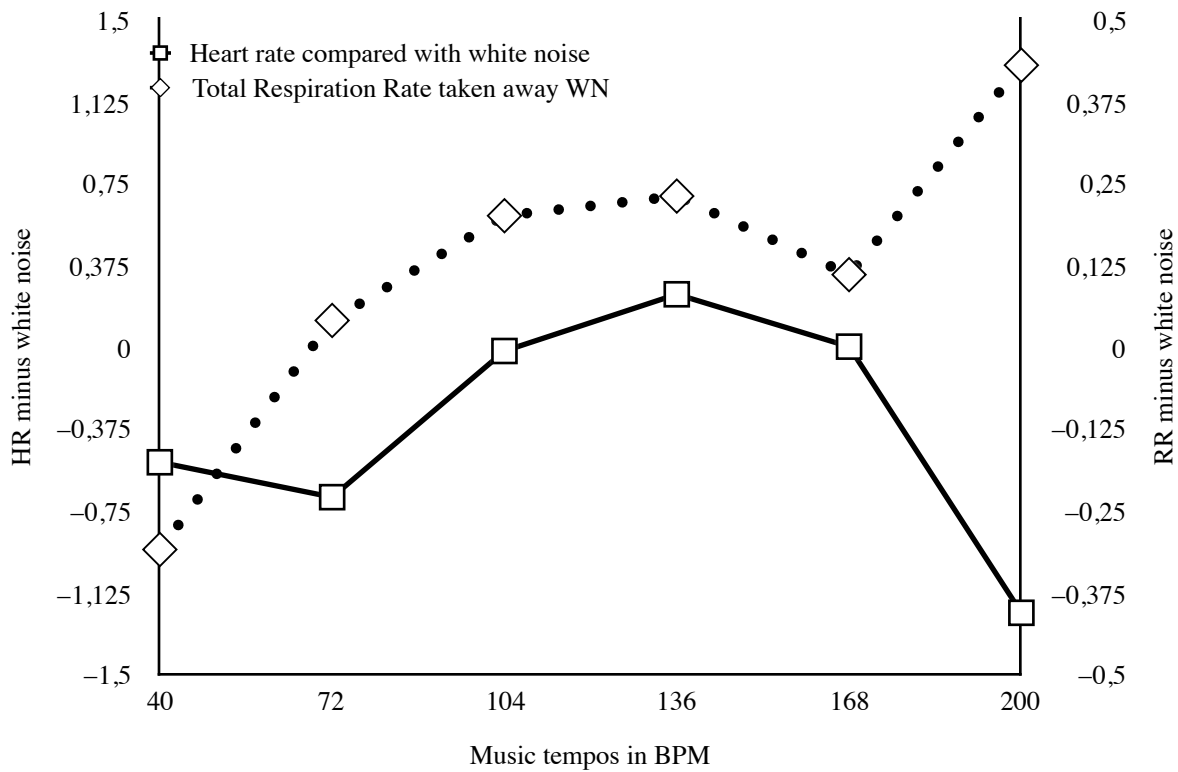


Figure 3. Respiration rate and heart rate in BPM (relative to white-noise)

A one-way repeated measures ANOVA was done to compare scores on respiration rate with the six different music tempos. The mean and standard deviations are presented in Table II. There

was a significant effect for difference between the tempos, Wilks's Lambda = 0.665,  $F(5, 31) = 3.119$ ,  $p < .021$ , and multivariate partial eta squared = .33. It was a linear relationship for RR (sig .006) with one degree of freedom,  $F(1, 35) = 8.421$ , see Figure 3.

Table III

<b>Tempo</b>	<b>N</b>	<b>Mean</b>	<b>Standard deviation</b>
RR_40 BPM	36	-0.3052	1
RR_72 BPM	36	0,0430	1.12
RR_104 BPM	36	0,205	1.18
RR_136 BPM	36	0.2149	0.82
RR_168 BPM	36	0,109	1.4
RR_200 BPM	36	0.4275	1.3

*Table III, Statistic table respiration rate (relative to white-noise) and tempos*

In Table IV and Table V the average heart rate and the average respiration rate is shown without the relation to white noise.

Table IV

<b>Tempo</b>	<b>Average heart rate in BPM</b>	<b>Standard deviation</b>
40	68.87	9.5
72	68.72	8.6
104	69.38	9.6
136	69.64	9.7
168	69.40	8.9
200	68.18	9.1
White-Noise	69.40	8.9

*Table IV, Average heart rate in BPM*

*Table V*

<b>Tempo</b>	<b>Average respiration rate in BPM</b>	<b>Standard deviation:</b>
40	15.18	2.4
72	15.53	2.7
104	15.69	2.7
136	15.70	2.5
168	15.60	2.9
200	15.92	2.8
White-Noise	15.49	2.5

*Table V, Average respiration rate in BPM*

## Discussion

The results from the current study indicate that music tempo affects both the human heart and respiration rate. The data in table II and III show that the data are spread out as the standard deviation values are larger than the mean. This is not surprising as white noise was subtracted; hence, a mean value close to zero is to be expected. A standard deviation, which is larger than the mean, is something that naturally follows this. To exemplify see table IV and V for the raw mean scores without the subtraction of white noise. The descriptive data shows that the heart rate slows down for tempos higher than 136 BPM (see figure 3), which is indicated by the quadratic shape of the curve. While for respiration, the curve is linear, indicating a continued rise of breathing rate up to 200 BPM (see figure 3). Note that for heart rate, 136 BPM was faster than white noise, while 104 BPM and 168 BPM were on the same level as white noise for heart rate. The other tempos yielded a lower heart rate than the white noise did. In contrast, respiration rate showed, except for 40 BPM, higher respiration rates to all the music tempos than white noise did (see figure 3 for a comparison of heart rate and respiration rate). The discussion that follows will mostly focus on the quadratic and linear relationships between music and heart rate and respiration rate respectively, and less on the quantitative difference to white noise.

Etzel et al. (2006) found that respiration and heart rate were synchronised in their study. The authors hypothesised that the only reason they found a heart rate increase for fear and sad stimuli were due to the driving of respiration by music tempos, which can cause changes in heart rate. Etzel et al. (2006) also used heart rate from 42 BPM for the lowest tempo and 124 BPM for the highest, which is not as high as the current study, which went up to 200 BPM. The results for the

current study is perhaps similar to Etzel et al. (2006) as both studies found synchronisation of respiration rate up to 124 BPM. As the current study went further with the music tempo, it is perhaps plausible that respiration rate did not change heart rate, but music induced both RR and HR changes through different brain-mechanisms. However, it is also plausible that respiration rate and heart rate stay synchronised only for lower tempos.

Ellis and Brighthouse (1952) found a difference only for respiration, but not for heart rate, when participants listened to music for 4 minutes. They tested three different songs and only found that respiration altered for one of the songs (Hungarian Rhapsody no 2 a classical piece by Liszt).

Watanabe, Ooishi and Kashino (2015) used a 5 minute sound sequence consisting of simple drum sounds in a constant tempo. They did several experiments with this setup and tested two drum tempos at 60 and 80 BPM, and one on 78 and 82 BPM. The authors noted that they only found a difference in heart rate and respiration for the drum tempos at around 80 BPM. They also noted that tempo is one of the most important characteristics of music, and that respiration is greatly affected by the sympathetic nervous system tone (music tempo).

Khalifa et al. (2008) defined happy music as music with tempos varying from 110 to 154 BPM and sad music from 40 to 69 BPM. In their study, they found that blood pressure and breathing rate increased for happy music, but not heart rate or skin conductance. Contrary to Etzel et al. (2006) the authors note that they did not find respiration rate differences between happy and sad music. As stated by Khalifa et al. (2008), their study demonstrates that there are several psychophysiological distinctions required to see a difference for happy and sad music, although rhythm and tempo are two of these.

Another study (Michael Haun, Rosalie O. Mainous, & Looney, 2010) used music intervention for women awaiting breast surgery, to see if music could have a calming effect. In their study, the authors did not find an alteration for heart rate in response to the music, but lower post-experiment respiratory rate. The authors pointed out that this was surprising, as respiration and heart rate are often altered simultaneously. Haun et al. (2010) did not relay which tempo the music was played in. Without the data about music-tempo, it is hard to compare this study to the current study. However, the authors also noted surprise at finding a significant difference for respiration rate and music intervention, but not for heart rate. Like the current study, respiration and heart rate differed, but unlike the current study, Haun et al. (2010) looked at one measure, not a spectrum. This may explain why the current study found heart rate and respiration contrasted to white noise to be synchronised up to 136 BPM.

Although, according to a Swedish study by Vickhoff et al. (2013) it is known that heart rate variability (HRV) and respiration rate affect each other. It is called respiratory sinus arrhythmia (RSA), and is most common to use for slow music to synchronise HRV and respiration. In their study, Vickhoff et al. (2013) found that singing produces slow, regular and deep respiration, which in turn triggers RSA. This may explain why Etzel et al. (2006) found a linear relationship for respiration and heart rate up to 124 BPM, the current study also found this. For the current study, the maximum music-tempo altered heart rate was detected at 136 BPM, it might have been higher or somewhere in-between 136 and 168 BPM, before the RSA effects subsided.

Karageorghis et al. (2006) defined slow music to be at 80 BPM, medium to be 120 BPM and fast to be 140 BPM. Their study investigated the relationship between heart rate, exercise

and the tempo preference for music used during exercise. The authors found that generally fast and medium music was preferred for exercise, contrasted to slow music. However, while participants reported a preference for fast music, it was only preferable over medium music for the highest exercise intensity. Karageorghis et al. (2006) used music from 80 to 140 BPM, while the current study used music from 40 to 200 BPM. For the fastest tempo (200 BPM) the current study did not find an increased heart rate, but rather a decrease around 136 BPM and higher, compared to white noise. This could explain why Karageorghis et al. (2006) found 140 BPM, which is very close to 136 BPM, was preferred for exercise, since the heart rate follows respiration rate up to around this point.

Kellaris and Kent (1994) did a survey on music, where they noted that only tempo, rather than tonality and texture altered the perceived feelings of pleasure. The authors used different tempos where slow was defined as 60 BPM, moderate as 120 BPM and fast as 180 BPM. The study consisted of a survey, and it did not consider physiological changes to the music, but participants still reported greater pleasure for fast music.

It is perhaps difficult to compare the current study with the previous literature, described above, as the current study explored a larger part of the heart rate spectrum. However, previous literature seems to mostly be in accordance with the current study for the different parts of the spectrum. The current study measured both heart rate and respiration rate on a large spectrum, and is an improvement on existing knowledge about music tempo and physiological effects. As mentioned the current study might have discovered a peak for heart rate somewhere around 136 BPM and 168 BPM. While for respiration, this peak was not found as it increased up to 200 BPM. Why respiration rate and heart rate is not synchronised at a higher tempo is not clear.

Although RSA might explain why HR and RR are similar up to a certain point. The current study is unique in the sense that it enables a closer look at the whole spectrum of music-tempos.

As mentioned in the introduction, Davis (1992) found that the amygdala communicates with parabrachial nucleus for increasing respiration, while the heart rate is controlled by the dorsal motor nucleus of the vagus. Perhaps the reason why some studies find a difference for respiration and heart rate is because they are activated by different parts of the brain. However, more research is needed to support this tentative hypothesis.

### **Time**

As mentioned in the introduction, it may be hard to know how much time was needed to elicit an emotional response from music. Bigand et al. (2005) suggested that one-second of active listening was sufficient to elicit emotional response to music.

Yamashita et al. (2006) did a study on the effects of music during rest, exercise and recovery phase. In their study participants started with 30 minutes of seated rest, then 30 minutes exercise on a bike and lastly a 35 minutes recovery phase, with continuous ECG and music stimuli during the whole 1 hour and 35 minutes. They also did a control setting, with the same participants, without music for 1 hour and 35 minutes. Participants choose their favourite music, with different BPM for every participant. Yamashita et al. (2006) found that heart rate was higher during exercise and after, compared to rest and the no-music condition. Another study by Rane and Gadkari (2016), used 3 minutes music induction for a music and exercise study, and found that slow music decreased the recovery rate after exercise.

Iwanaga et al. (2005) played music for 257 seconds followed by a period of quiet for 25 seconds. In their study they played the same song for four sessions, with a few days apart, they



found that repetition of music decreased heart rate. Entrainment is likely to occur for repetition, but they did not consider length in their study.

Haun et al. (2010) used 20 minutes of music based intervention before surgery. They found a lower respiration rate after surgery, but not before surgery.

Brodal et al. (2017) presented music stimuli for 10 minutes and 16 seconds. They presented the one music piece during fMRI scanning and found that compared to no music, the reward system in the brain was activated. Specifically, the right ventral striatum and nucleus accumbens were activated while listening to pleasurable rhythmic dance music.

Arnon et al. (2006) found that music only had an effect on heart rate of preterm infants after 20 minutes of live music stimulation. The authors speculated that infants might have a different reaction time than adults. Kisilevsky et al. (2004) used 30 seconds of music induction in their study about maturation of fetuses aged 35-37 weeks old. They did the same study in two places in France and one place in Canada, but they did not find an effect for tempo or volume.

The current study used 30 seconds of music stimuli and found a linear relationship for respiration and music tempo, and a quadratic relationship for heart rate and music tempo. For the current study 30 seconds seems to have been sufficient to create a music induction, although with longer stimuli, effects could perhaps have been greater or they could have been worse. 30 seconds of white noise between each stimuli were not enough to measure heart rate variability, which also would have been a good technique to use. An alternative would have been to do five minutes of white noise or silent period to get a baseline, as well as longer music stimuli. Doing so would have it feasible to measure heart rate variability. However, HR and RR are sufficient measures of their own to conduct a study as well. Based on the previous literature debated in this

section, it seems that music can elicit a physiological response after about 30 seconds based on some of the studies. Perhaps the time duration of music exposure is not a limitation for the current study, but more research is needed to investigate the time aspect of passive listening. Alternatively, too long stimuli is perhaps not optimal either, as shown by Bigand et al. (2005).

### **Age**

In a study by Hilz, et al. (2014) “relaxing” and “aggressive” music indicated group difference responses in the autonomic cardiovascular system for young and old participants. The young group (mean age 22.8) and the old group (mean age 61.7) did not differ on a subjective scale of emotional valence for the musical stimuli. The differences occurred as young participants generated an increased cardiovascular response to aggressive music, by withdrawing parasympathetic outflow. While older participants generated similar responses by increasing sympathetic tone and modulation. This difference is perhaps because of general differences between young and old, as the baselines were different as well. LeBlanc et al. (1988) looked at tempo preference for jazz music for children aged 9 to 19 years old. They used 45 different public and private schools, as well as colleges to get about 100 participants for each age group starting with 3rd grade and up to first year of college. The study found that music listeners from 3rd grade to college level had a statistical significant preference for fast tempo music. In comparison, the current study had a different age variation among for the participants, (20 to 43), however, no effect with regard to of age was found for either HR or RR.

### **Gender**

One study (Nater et al., 2006) found that women tended to show hypersensitivity to aversive musical stimuli. The authors stated that their study was in accordance with previous

literature on gender differences in emotion, and that gender should be considered when using musical stimuli for emotional induction.

Karageorghis et al. (2006) looked at tempo preference in music and heart rate, but they did not find a gender difference. This surprised the authors as they had hypothesised that there would be a gender difference.

Christenson and Peterson (1988) found a gender difference for music preference amongst American collage students; the women preferred pop, while the men preferred rock. However, this study was conducted in 1988, and “stereotypes” may be a little different now. The current study did not find any gender differences for HR or RR.

### **Expert versus novice**

Some studies are interested in the differences of music perception for musicians versus for non-musicians. In a study by Bernardi et al. (2005), music induced an arousal effect related to the tempo. However, they investigated 12 trained musicians and compared them to 12 healthy novices. In their study, they found that musicians had a greater respiratory sensitivity to the music tempo than non-musicians did. Bernardi et al. (2005) hypothesised that this occurred because trained musicians had a more focused attention on faster rhythms, and then the music induced relaxation during pauses or slower rhythms. Another experiment (Blood & Zattore, 2001) found that musicians who choose their own music to give themselves “chills”, experience both increased respiration rate and heart rate. There also seems to be a difference in how musicians versus non musicians perceive music and emotion, which may affect the heart rate. Loui et al. (2012) did an fMRI study and found that musicians had a stronger activation in the brain, both in the reward system and the emotional processing system. Another fMRI study by

Parka et al. (2014) found that musicians experienced more arousal with happy music, than non-musicians. For the current study there was no difference between musicians and non musicians, although musical aptitude was the only thing measured as a qualifier.

### **Benefits of music studies**

Music also appears to have a positive effect on lowering anxiety, recovering and heart rate levels before, during and after medical procedures (Dianne Smolen et al., 2002; Leila Taheri et al., 2016; Michael Haun et al., 2010; Shmuel Arnon et al., 2006; Uggla et al., 2016; Yusuf Ziya Tan et al., 2015).

Smolen, et al. (2002) found that patients who self-selected music to calm themselves, and listened to it during a colonoscopy, needed less medication.

Tan et al. (2015) found a significant difference between music and non-music groups in heart rate reduction during ECG Gated-myocardial perfusion scintigraphy.

Taheri et al. (2016) investigated the effect of recorded male lullabies on physiological responses of neonates at hospital. The authors found that recorded male lullabies could reduce heart rate and increase oxygen saturation for neonates in hospital.

Uggla et al. (2016) researched the effects of music therapy and heart rate on children in hospital. The children in the music therapy group had significantly decreased heart rates during the day, in contrast to the control group.

Haun et al. (2010) used alternative music to relax women awaiting breast surgery, and they found that the music group had lower respiration rate post-surgery.

One study (Ozlem Ozkalayci et al., 2016) on music sedation depth for dental procedures did not find an effect from music. The authors admit that perhaps the deep level of sedation

belittled the effect of music on the procedure. However, they did find an effect on the postoperative recovery period for the music and noise cancelling conditions, compared to having no headphones or no music.

Music may therefore have possible relaxation and healing effects. The current study supports that music can yield physiological responses in form of altering heart rate and respiration.

### **Limitations**

The largest limitation for the current study is perhaps the sample size. Only 36 participants were analysed, and it was done like this due to time and cost constraints.

Another limitation is that the current study was done on Western Educated Industrialised Rich Democratic (WEIRD) (Henrich, Heine, & Norenzayan, 2010) participants. As has been pointed out, this may be a limiting factor since most studies are done on WEIRD participants, though the majority of people do not fit the WEIRD category. It is perhaps difficult to question the universality of music induction when very few studies are done outside the Western world. One study (Behzad Abedi et al., 2017) tested the effect of traditional Persian music and heart synchronisation on Iranian women. They found that young women can synchronise their heartbeat to Persian music, and this was not a WEIRD sample. Rane and Gadkari (2016) found that slow music decreased recovery rate after exercise. This study was done in India, and did not use a WEIRD sample either. However, Rane and Gadkari did not relay what type of music they used, only the tempo. Both studies found an effect of music on heart rate, even though, Rane and Gadkari (2016) had a higher volume for the fast music, and lower volume for the slow music. Two non-WEIRD sample studies (Leila Taheri et al., 2016; Shmuel Arnon et al., 2006) done on

neonates found that music were beneficial in hospitals. These four studies in total, done on non-WEIRD samples all found a physiological effect on humans caused by music, which perhaps gives strength to the universality of music as an inducer.

Another limitation may have been the use of WN rather than a silent period. One study (Bregman, 1978) used both silence and WN as separators in an experiment where participants listened to tones. The author noted that there was no difference between the silent and the WN condition. Further, the author argued that WN has a different auditory effect compared to silence, but that they are both similar in having a bimodal distribution in the frequency domain. One study (Sokhadze, 2007) found that while WN did not enhance recovery processes after the participants were presented with stressful visual stimuli, pleasant music did enhance the recovery process. At least pleasant music, as compared to WN, were significantly different in heart rate, respiration rate and peripheral blood flow. Although the author noted that WN had a decreased HR, compared to stressful visual stimuli, the WN was somewhere between pleasant music and stressful stimuli. Perhaps then, WN is a good measure to use as for HR and RR as it is neutralising stimuli.

The use of heart rate (HR) instead of heart rate variability (HRV) is perhaps another limitation for the current study. In a review (Acharya, Joseph, Kannathal, Lim, & Suri, 2006) HRV was defined as the variation over time between consecutive heartbeats. The authors note that HRV is considered a reliable reflection of the many physiological factors that modulate the normal rhythm of the heart. Acharya et al. (2006) explains how sympathetic activity is associated with a low frequency range, whereas parasympathetic activity has a higher frequency. Further the authors states that HR contains indicators of a current disease or warnings about impending

cardiac disease, but that HR as a measure is not as time dependent as indicators may occur at random. The current study looked at immediate reactions to musical stimuli, rather than heart irregularities. HR as a measure was judged as sufficient for the current study. Although as Acharya et al. (2006) suggest, HRV which is measure against a time axis, might be a better tool for assessing the activities of the autonomic nervous system. However, then the current study would have had longer stimuli and measure five minutes of silence to create a baseline.

## Conclusion

In conclusion, the current study found that heart rate and respiration rate is altered by listening to music stimuli in different tempos. For lower tempos, HR and RR increased in a comparable way with the increasing tempo, but after 136 BPM the HR did not increase with tempo, though the RR did. Perhaps it exists two different mechanisms for what alters heart rate and respiration rate, as they did not synchronise for higher music tempos. The current study provides support for musical induction to alter physiological conditions, with tempo. Further, the current study is unique because it investigates the spectrum of tempos, showing where the heart rate peaks at around 140 BPM. A spectrum of tempos is something that has been missing from previous research, but it should be investigated further with smaller gaps between tempos for a more exact relationship between heart rate and music listening. Limitations were few participants. The current study also provides evidence for the usefulness of using novel music for music induction studies. The hypothesis was confirmed, in the fact that fast music makes the heart rate and respiration rate faster, while slow music slows the two down. However, more research is needed to gather more knowledge on how RR and HR responses differs from each other, and which mechanisms cause changes in RR and HR. The heart rate and respiration rate is affected by the sympathetic and the parasympathetic systems, but how exactly music affects them is still unknown. More research into the neuroscience of music, and specifically which parameters activate different areas or processes in the brain and body is needed. That is especially so considering the benefits music therapy and music studies yield to medicine and psychology.



## Bibliography

1. Acharya, R., Joseph, P., Kannathal, Lim, C. M., & Suri, J. S. (2006). Heart rate variability: a review. *medical and biological engineering and computing*, 44(12), 1031-1051.
2. B.S. Kisilevsky, S.M.J. Hains, A.-Y. Jacquet, C. Granier-Deferre, & Lecanuet, J. P. (2004). Maturation of fetal responses to music. *Developmental Science*, 7(5), 550-559.
3. Behzad Abedi, Ataollah Abbasi, Atefeh Goshvarpour, Hamid Tayebi Khosroshai, & Javanshir, E. (2017). The effect of traditional Persian music on the cardiac functioning of young Iranian women. *Indian Heart Journal*. doi:<http://dx.doi.org/10.1016/j.ihj.2016.12.016>
4. Bierring, F., & Garby, L. (1990). *Anatomi og fysiologi* (1 ed.). København: Munksgaard.
5. Bigliassi, M, Barreto-Silva V, & R, A. L. (2015). How motivational and calm music may affect the prefrontal cortex area and emotional responses: a functional near-infrared spectroscopy (fNIRS) study. *Perceptual & Motor Skills: Perception*, 120(1), 202-218. doi: 10.2466/27.24.PMS.120v12x5
6. Bjålie, Haug, Sand, Sjaastad, & Toverud. (1999). *Menneskekroppen Fysiologi og anatomi* (2 ed.). Oslo: Universitetsforlaget AS.
7. Blood, & Zattore. (2001). Intensely pleasurable responses to music correlate with activity in brain regions implicated in reward and emotion. *PNAS*, 98(20). doi:10.1073/pnas.191355898
8. Bregman, A. S. (1978). Auditory streaming is cumulative. *Journal of Experimental Psychology: Human Perception and Performance*, 4(3), 380.
9. Brodal, H. P., Osnes, B., & KarstenSpecht. (2017). Listening to Rhythmic Music Reduces Connectivity within the Basal Ganglia and the Reward System. *Frontiers in Neuroscience*, 11(153). doi:10.3389/fnins.2017.00153

10. Brodal, H. P., Osnes, B., & Specht, K. (2017). Listening to Rhythmic Music Reduces Connectivity within the Basal Ganglia and the Reward System. *Frontiers in Neuroscience, 11*(153). doi:10.3389/fnins.2017.00153
11. Brown, S., & Jordania, J. (2013). Universals in the world's musics. *Psychology of music, 2*(41), 229-248. doi:http://dx.doi.org/10.1177/0305735611425896
12. Carlson, N. R. (2001). *Physiology of Behavior* (7 ed.). United States of America: Allyn and Bacon.
13. Cervellin, G., & Lippi, G. (2011). From music-beat to heart-beat: a journey in the complex interactions between music, brain and heart. *European journal of internal medicine, 22*(4), 371-374.
14. Christenson, P. G., & Peterson, J. B. (1988). Genre and Gender in the Structure of Music Preferences. *Communication research, 15*(3), 282-301.
15. Davis, M. (1992). The role of the amygdala in fear-potentiated startle: implications for animal models of anxiety. *Trends in pharmacological sciences, 13*, 35-41. doi: 10.1016/0165-6147(92)90014-W
16. Demos, A. P., Chaffin, R., Begosh, K. T., Daniels, J. R., & Marsh, K. L. (2012). Rocking to the beat: effects of music and partner's movements on spontaneous interpersonal coordination. *J Exp Psychol Gen, 1*(141), 49-53. doi:10.1037/a0023843
17. Dianne Smolen, Robert Topp, & Singer, L. (2002). The Effect of Self-Selected Music During Colonoscopy on Anxiety, Heart Rate, and Blood Pressure. *Applied Nursing Research, 16*(2). doi:10.1053/apnr.2002.34140

18. Douglas S. Ellis, & Brighthouse, G. (1952). Effects of music on respiration and heart rate. *The American Journal of Psychology*, 65(1), 39-47.
19. Emmanuel Bigand, Suzanne Filipic, & Lalitte, P. (2005). The Time Course of Emotional Responses to Music. *Ann. N.Y. Acad. Sci*, 1060, 429-437. doi:10.1196/annals.1360.036
20. Fitch, W. T. (2006). The biology and evolution of music: A comparative perspective. *Cognition*, 100, 173-215. doi:10.1016/j.cognition.2005.11.009
21. Garrido, S. (2017). Physiological Effects of Sad Music. In *Why are we attracted to sad music?* : Springer International Publishing.
22. Gazzaniga, Ivry, & Mangun. (2014). *Cognitive Neuroscience, the Biology of the Mind* (4 ed.). New York: W.W. Norton.
23. Henrich, J., Heine, S. J., & Norenzayan, A. (2010). Most people are not WEIRD. *Nature*, 29(466). doi:10.1038/466029a
24. Hjorthaug, S. (2002). *Musikkhistorisk oversikt* (2. ed.). Oslo: Cappelen Damm.
25. Hyde, I. H., & Scalapino, W. (1918). The influence of music upon electrocardiograms and blood pressure. *American Journal of Physiology--Legacy Content*, 46(1), 35-38.
26. Iwanaga, Kobayashi, & Kawasaki. (2005). Heart rate variability with repetitive exposure to music. *Biological Psychology*, 70, 61-66. doi:10.1016/j.biopsycho.2004.11.015
27. James J. Kellaris, & Kent, R. J. (1994). An Exploratory Investigation of Responses Elicited by Music Varying in Tempo, Tonality and Texture. *Journal of Consumer Psychology*, 2(4), 381-401.
28. Jarvis, E. D. (2004). Learned birdsong and the neurobiology of human language. *Annals of the New York Academy of Sciences*, 1016(1), 749-777.

29. Jeffs, R. (1998). *Aktiv Musikklaere*. Oslo: Gyldendal.
30. Jia T, Ogawa Y, Miura M, Ito O, & M, K. (2016). Music Attenuated a Decrease in Parasympathetic Nervous System Activity after Exercise. *PLoS ONE*, *11*(2). doi:10.1371/journal.pone.0148648
31. Joset A. Etzel, Erica L. Johnsen, Julie Dickerson, Daniel Tranel, & Adolphs, R. (2006). Cardiovascular and respiratory responses during musical mood induction. *International Journal of Psychophysiology*, *61*, 57-69. doi:10.1016/j.ijpsycho.2005.10.025
32. Karageorghis, C. I., Jones, L., & Low, D. C. (2006). Relationship Between Exercise Heart Rate and Music Tempo Preference. *Research Quarterly for Exercise and Sport*, *2*(77), 240-250. doi:http://dx.doi.org/10.1080/02701367.2006.10599357
33. Khalifa, Schon, Anton, & Liégeois-Chauvel. (2005). Brain regions involved in the recognition of happiness and sadness in music. *Neuroreport*, *16*(18), 1981-1984.
34. Kim, J., & André, E. (2008). Emotion recognition based on physiological changes in music listening. *IEEE transactions on pattern analysis and machine intelligence*, *30*(12).
35. Koelsch, S., Jacobs, A. M., Menninghaus, W., Liebal, K., Klann-Delius, G., Scheve, C. v., & Gebauer, G. (2015). The quartet theory of human emotions: An integrative and neurofunctional model. *Physics of Life Reviews*, *13*, 1-27. doi:http://dx.doi.org/10.1016/j.plrev.2015.03.001
36. Koelsch, S., & Jäncke, L. (2015). Music and the heart. *European heart journal*, ehv430.
37. Krumhansl, C. (1997). An exploratory study of musical emotions and psychophysiology. *Canadian journal of experimental psychology*, *4*(51), 336-352.

38. Kung, S.-J., Chen, J. L., Zatorre, R. J., & Penhune, V. B. (2013). Interacting cortical and basal ganglia networks underlying finding and tapping to the musical beat. *Journal of Cognitive Neuroscience*, 25(3), 401-420.
39. L Bernardi, C Porta, & Sleight, P. (2005). Cardiovascular, cerebrovascular, and respiratory changes induced by different types of music in musicians and non-musicians: the importance of silence. *Heart*, 92, 445-452. doi:10.1136/hrt.2005.064600
40. Law, L. N. C., & Zetner, M. (2012). Assessing musical abilities objectively: Construction and validation of the profile of music perception skills. *PLoS ONE*, 7(12). doi:10.1371/journal.pone.0052508
41. LeBlanc, A., Colman, J., McCrary, J., Sherrill, C., & Malin, S. (1988). Tempo Preferences of Different Age Music Listeners. *Journal of Research in Music Education*, 36(3), 156-168. doi:doi:10.2307/3344637
42. Leila Taheri, Marzieh Kargar Jahromi, Mohammad Abbasi, & Hojat, M. (2016). Effect of recorder male lullaby on physiologic response of neonates in NCIU. *Applied Nursing Research*, 33, 127-130. doi:<http://dx.doi.org/10.1016/j.apnr.2016.11.003>
43. Loui, P., Zamm, A., & Schlaug, G. (2012). Enhanced functional networks in absolute pitch. *NeuroImage*, 63(2), 632-640.
44. Max J. Hilz, Peter Stadler, Thomas Gryc, Juliane Nath, Leila Habib-Romstoeck, Brigitte Stemper, . . . Koehn, J. (2014). Music induces different cardiac autonomic arousal effects in young and older persons. *Autonomic Neuroscience: Basic and Clinical*, 183, 83-93.

45. Medicine, H. (2017). Respiration Rate. Retrieved from [http://www.hopkinsmedicine.org/healthlibrary/conditions/cardiovascular\\_diseases/vital\\_signs\\_body\\_temperature\\_pulse\\_rate\\_respiration\\_rate\\_blood\\_pressure\\_85,P00866/](http://www.hopkinsmedicine.org/healthlibrary/conditions/cardiovascular_diseases/vital_signs_body_temperature_pulse_rate_respiration_rate_blood_pressure_85,P00866/)
46. Merker, B. (2005). The conformal motive in birdsong, music, and language: an introduction. *Annals of the New York Academy of Sciences*, 1060(1), 17-28.
47. Merriam-Webster. (2016). Music. Retrieved from <http://www.merriam-webster.com/dictionary/music>
48. Merriam-Webster. (2017a). Musicology. Retrieved from <https://www.merriam-webster.com/dictionary/musicology>
49. Merriam-Webster. (2017b). White Noise. Retrieved from <https://www.merriam-webster.com/dictionary/white%20noise>
50. Michael Haun, Rosalie O. Mainous, & Looney, S. W. (2010). Effect of Music on Anxiety of Women Awaiting Breast Biopsy. *Behavioral medicine*.
51. Mitterschiffthaler, M. T., Fu, C. H., Dalton, J. A., Andrew, C. M., & Williams, S. C. (2007). A functional MRI study of happy and sad affective states induced by classical music. *Human brain mapping*, 28(11), 1150-1162.
52. Mona Parka, Evgeny Gutyrchika, Yan Baof, Yuliya Zaytsevaa, Petra Carla, Lorenz Welkerb, . . . Meindlc, h. (2014). Differences between musicians and non-musicians in neuroaffective processing of sadness and fear expressed in music. *Neuroscience Letters*, 566, 120-124.  
doi:<https://doi.org/10.1016/j.neulet.2014.02.041>

53. Nater, U. M., Elvira Abbruzzese, Monika Krebs, & Ehlert, U. (2006). Sex differences in emotional and psychophysiological responses to musical stimuli. *International Journal of Psychophysiology*, 62, 300-308. doi:10.1016/j.ijpsycho.2006.05.011
54. Nietzsche, F. (1889). *Twilight of the Idols*.
55. Ozlem Ozkalayci, Araz, C., Cehreli, S. B., Tirali, R. E., & Kayhan, Z. (2016). Effects of music on sedation depth and sedative use during pediatric dental procedures. *Journal of Clinical Anesthesia*, 34, 647-653. doi:http://dx.doi.org/10.1016/j.jclinane.2016.07.001
56. Panksepp, J. (1995). The emotional sources of "chills" induced by music. *Music Perception: An Interdisciplinary Journal*, 13(2), 171-207.
57. Patel. (2006). Musical Rhythm, Linguistic Rhythm, and Human Evolution. *Music Perception*, 1(24), 99-104. doi:http://dx.doi.org/10.1525/mp.2006.24.1.99
58. Patel, A. D., & Iversen, J. R. (2014). The evolutionary neuroscience of musical beat perception: the Action Simulation for Auditory Prediction (ASAP) hypothesis. *Front Syst Neurosci*, 8(57). doi:10.3389/fnsys.2014.00057
59. Patel, A. D., Iversen, J. R., Bregman, M. R., & Schulz, I. (2009). Experimental evidence for synchronization to a musical beat in a nonhuman animal. *Current Biology*, 19(10), 827-830. doi:10.1016/j.cub.2009.03.038
60. Patterson, E. C. (2011). The Effect of Lullaby Music versus Rain Sounds on Inducing Sleep in the First 20 Minutes of Daycare Naptime. (Master), The Florida State University, Florida.
61. Rane, P. R., & Gadkari, J. V. (2016). The effect of slow and fast musical tempo on post-exercise recovery on recovery period in young adults. *National Journal of Physiology, Pharmacy and Pharmacology*, 7(1). doi:10.5455/njppp.2016.6.0616008072016

62. Schmitz, C., Drake, L., Laake, M., Yin, P., & Pradarelli, R. (2012). Physiological Response to Fear in Expected and Unexpected situations on Heart Rate, Respiration Rate and Horizontal Eye Movement: Wisconsin-Madison: University of Wisconsin-Madison, Department of Physiology.
63. Shmuel Arnon, Anat Shapsa, Liat Forman, Rivka Regev, Sofia Bauer, Ita Litmanovitz, & Dolfon, T. (2006). Live Music Is Beneficial to Preterm Infants in the Neonatal Intensive Care Unit Environment. *BIRTH*, 2(33).
64. Shoda H, Adachi M, & T, U. (2016). How Live Performance Moves the Human Heart. *PLoS ONE*, 11(1). doi:10.1371/journal.pone.0154322
65. Sloboda, J. (2008). Science and music: the Ear of the beholder. *Nature*, 454, 32-33. doi: 10.1038/454032a
66. Sokhadze, E. M. (2007). Effects of Music on the Recovery of Autonomic and Electrocardiac Activity After Stress Induced by Aversive Visual Stimuli. *Applied Psychophysiol biofeedback*, 32, 31-50. doi:10.1007/s10484-007-9033-y
67. Stéphanie Khalfa, Mathieu Roy, Pierre Rainville, Simone Dalla Bella, & Peretz, I. (2008). Role of tempo entrainment in psychophysiological differentiation of happy and sad music? *International Journal of Psychophysiology*, 68, 17-26. doi:10.1016/j.ijpsycho.2007.12.001
68. Tarr, B., Launay, J., & Dunbar, R. I. (2014). Music and social bonding: "self-other" merging and neurohormonal mechanisms. *Front Psychol*, 5(1096). doi:10.3389/fpsyg.2014.01096
69. Uggla, Bonde, Svahn, Remberger, Wrangsjö, & Gustafsson. (2016). Music therapy can lower the heart rates of severely sick children. *Acta Paediatrica*(105), 1125-1230. doi:10.1111/apa.13452



70. Vickhoff, B., Malmgren, H., Astrom, R., Nyberg, G., Ekstrom, S. R., Engwall, M., & Jornsten, R. (2013). Music structure determines heart rate variability of singers. *Front Psychol*, 4(334). doi:10.3389/fpsyg.2013.00334
71. Wallin, N. L., Merker, B., Brown, S., & Florentine. (2000). The origins of music. *Cambridge, Mass.: MIT Press.*
72. Watanabe K, Ooishi Y, & M, K. (2015). Sympathetic Tone induced by High Acoustic Tempo Requires Fast Respiration. *PLoS ONE*, 10(8). doi:10.1371/journal.pone.0135589
73. Wikipedia. (2016). Electrocardiography. Retrieved from <https://en.wikipedia.org/wiki/Electrocardiography>
74. Wikipedia. (2017). Tempo. Retrieved from <https://en.wikipedia.org/wiki/Tempo>
75. Yamashita, Iwai, Akimoto, & Kono. (2006). Effects on music during exercise on RPE, Heart rate and the autonomic nervous system. *J Sports med Phys Fitness*, 46, 425-430.
76. Yusuf Ziya Tan, Semra Ozdemir, Ahmet Temiz, & 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*, 21, 137-140. doi:10.1016/j.ctcp.2014.12.003

## Appendix A - Approval by REK



**Region:**

REK vest

**Saksbehandler:**

Camilla Gjerstad

**Telefon:**

55978499

**Vår dato: Vår referanse:**

10.01.2017 2016/1905/REK vest

**Deres dato:**

04.01.2017

Vår referanse må oppgis ved alle henvendelser

Karsten Specht

Universitetet i Bergen

### 2016/1905 Musikk og hjerteratevariabilit

**Forskningsansvarlig:** Universitetet i Bergen **Prosjektleder:** Karsten Specht

Vi viser til søknad om forhåndsgodkjenning av ovennevnte forskningsprosjekt og din tilbakemelding mottatt 04.01.2017. Tilbakemeldingen ble behandlet av leder av Regional komité for medisinsk og helsefaglig forskningsetikk (REK vest) på fullmakt. Vurderingen er gjort med hjemmel i helseforskningsloven § 10, jf. forskningsetikkloven § 4.

### Prosjektomtale

Prosjektet vil bruke fysiologiske mål for å undersøke effekten tempo i musikk kan ha på menneskehjertet. 40 deltakere søkes rekruttert. Disse skal måle hjerteratevariabilitet, hudkonduktans og pusterate når deltakerne hører på forskjellige musikkstykker med varierende tempo.

*REK vest ba om tilbakemelding (vedtak av 14.12.16)*

Komiteen ba om:

en forbedret forskningsprotokoll  
en forbedret begrunnelse for behovet for EEG, og en nærmere redegjørelse for utførelsen av denne et revidert informasjonsskriv

*Tilbakemelding fra prosjektleder*

Forskergruppen har valgt å fjerne EEG fra søknaden og studien. Revidert protokoll og informasjonsskriv er innsendt.

**Vurdering av tilbakemeldingen**

REK vest ved leder har vurdert tilbakemeldingen. Komiteens merknader er tatt hensyn til og det er gjort endringer i forskningsprotokollen og informasjonsskriv. REK vest har dermed ingen ytterligere merknader. Tillatelsen gjelder til prosjektslutt 20.12.2017. Ved prosjektslutt skal data slettes eller anonymiseres, evt. kan det søkes prosjektforlengelse ved behov.

**Vedtak**

*REK vest godkjenner prosjektet i samsvar med forelagt søknad og tilbakemelding.*

*Sluttmelding og søknad om prosjektendring*

Prosjektleder skal sende sluttmelding til REK vest på eget skjema senest seks måneder etter prosjektslutt, jf. hfl. §12. Prosjektleder skal sende søknad om prosjektendring til REK vest dersom det skal gjøres vesentlige endringer i forhold til de opplysninger som er gitt i søknaden, jf. hfl. § 11. Klageadgang

• • •

---

**Besøksadresse:** Telefon: 55975000

Armauer Hansens Hus (AHH), **E-post:** rek-vest@uib.no

All post og e-post som inngår i saksbehandlingen, bes adressert til REK vest og ikke til enkelte personer

Kindly address all mail and e-mails to the Regional Ethics Committee, REK vest, not to individual staff

Tverrflyøy Nord, 2 etasje. Rom 281. Haukelandsveien 28

**Web:** <http://helseforskning.etikkom.no/>

Du kan klage på komiteens vedtak, jf. forvaltningsloven § 28 flg. Klagen sendes til REK vest. Klagefristen er tre uker fra du mottar dette brevet. Dersom vedtaket opprettholdes av REK vest, sendes klagen videre til Den nasjonale forskningsetiske komité for medisin og helsefag for endelig vurdering.

Med vennlig hilsen

Marit Grønning Prof. Dr. med komitéleder

**Kopi til:** post@uib.no

Camilla Gjerstad rådgiver

## Appendix B - Informed consent form

# Musikk og hjerteratevariabilitet

## Forespørsel om deltakelse i forskningsprosjekt «Musikk og hjerteratevariabilitet»

### *EKG-undersøkelser av hjertet*

#### **Bakgrunn og hensikt**

Dette er et spørsmål til deg om å delta i en forskningsstudie basert på EKG-undersøkelse av hjertet. EKG står for elektrokardiogram, og brukes til å måle elektrisk impulsene som sendes gjennom hjertet. Denne elektrisiteten kan måles utenfor hjertet, f. eks i armene, bena og i brystveggen. Hovedhensikten er å finne ut hvordan hjertet reagerer på ulike auditive og visuelle stimuli. Utvalget av forsøkspersoner er tilfeldig og består av friske frivillige voksne personer. Universitetet i Bergen v/Institutt for biologisk og medisinsk psykologi er ansvarlig for undersøkelsen.

#### **Hva innebærer studien?**

En EKG-undersøkelse innebærer at en elektrode settes på brystveggen for å måle den elektriske aktiviteten som sendes gjennom hjertet, mens man blir presentert for ulike auditive og visuelle stimuli. Huden må renses med bakteriedrepende før elektrodene settes på. Elektrodene kan kun måle elektriske signaler, de sender ikke ut noen elektriske impulser. Parallelt med EKG måles hudkonduktans og pusterate. Dette studiet innebærer derfor tre psykofysiologiske mål, hjerteratevariabilitet som måles ved EKG, hudkonduktans med en elektrode på huden og pusterate som måles ved pustebelte rundt livet. Deltakelse vil vare ca 1 time og deltaker vil bli belønnet for deltakelse. Se Kapittel A for mer utfyllende informasjon.

#### **Mulige fordeler og ulemper**

EKG, samt mål av pusterate er bevist å være trygge uten noen kjente skadelige kort- eller langtidseffekter for deltakere. Undersøkelsen er vanligvis uten komplikasjoner. Så langt vi vet i dag er det ingen risiko eller bivirkninger knyttet til EKG, hudkonduktans og pusterate undersøkelser. Du kan noen ganger kjenne noe forbigående rødhet i huden etter renseprosessen. Musikk har derimot en bevist god effekt på hjertet og kan få deg i bedre humør.

#### **Hva skjer med informasjonen om deg?**

Informasjonen som registreres om deg skal kun brukes slik som beskrevet i hensikten med studien. Alle opplysningene og prøvene vil bli behandlet uten navn og fødselsnummer eller andre direkte gjenkjennerende opplysninger. En kode knytter deg til dine opplysninger og prøver gjennom en navneliste som oppbevares i låst skap fraskilt med annen informasjon. Det er kun

autorisert personell knyttet til prosjektet som har adgang til navnelisten og som kan finne tilbake til deg. Det vil ikke være mulig å identifisere deg i resultatene av studien når disse publiseres.

### **Frivillig deltakelse**

Det er frivillig å delta i studien. Du kan når som helst og uten å oppgi noen grunn trekke ditt samtykke til å delta i studien. Dette vil ikke få konsekvenser for din videre behandling. Dersom du ønsker å delta, undertegner du samtykkeerklæringen på siste side. Om du nå sier ja til å delta, kan du senere trekke tilbake ditt samtykke uten at det påvirker din øvrige behandling. Dersom du senere ønsker å trekke deg eller har spørsmål til studien, kan du kontakte prosjektleder for undersøkelsen, professor Karsten Specht, tlf 55586279, om du har spørsmål.

### **Hvem er ansvarlige for prosjektet og hvordan kan de kontaktes?**

*Prosjektleder:*

Professor Karsten Specht,  
Biologisk og Medisinsk Psykologi, Psykologisk Fakultet ved Universitetet i Bergen.  
BB-bygget, Johannes Lie vei 91, 5009 Bergen  
Telefon: 55586279 E-Post: karsten.specht@psybp.uib.no

*Ansvarlig for gjennomføring av prosjektet er:*

Professor Karsten Specht

*Medarbeidere:*

Mastergradsstudenter/forskningsteknikere/stipendiater/postdoktorer.

## **Kapittel A- utdypende forklaring av hva studien innebærer**

Undersøkelsen som du skal delta i er en del av forskning med bruk av metoder for å måle elektriske signaler i hjertet og andre psykofysiologiske faktorer. EKG er en metode der man måler elektrisk aktivitet i hjertet som kommer av at hjertet styres av elektriske signaler (impulser). Et ledningssystem i hjertet sørger for at impulser strekker seg til hele muskelen. Når man er rolig eller hviler utløser det ca 60-70 elektriske impulser per minutt i hjertet. Disse impulsene fanges så opp av et område som befinner seg på overgangen mellom atriene og ventriklene i hjertet. Når man er i aktivitet eller opplever noe som trigger følelser som frykt eller glede kan disse impulsene øke til ca 100-120 elektriske impulser per minutt. Elektrodene som brukes har kun evne til å måle elektrisk aktivitet, de sender altså ikke ut noen elektriske impulser. For å sørge for at den elektriske ledningsevnen mellom huden og elektrodene er høy nok må huden renses med antibakteria eller et bakteriedrepende middel. Denne renseprosedyren tar rundt 5 minutter, og deltakeren kan gjøre det selv etter instruksjon fra forskninsteknikker eller lignende personell. Noen ganger kan man oppleve noe forbigående rødhet i huden etter renseprosessen. Etter eksperimentet vil deltakeren få tilgang til et baderom og mulighet til å vaske huden der elektroder har vært.

Parallelt med EKG-undersøkelsen måles følgende psykofysiologiske faktorer:

- Hudkonduktans som er et mål på elektrisk konduktans i huden og som varierer med nivå av fuktighet (svette). Måles også med elektroder festet på huden.
- Pusterate er variasjonen i innpust og utpust. Dette måles med pustebelte rundt midjen.

Deltakelse innebærer uthenting av EKG, hudkonduktans og pusterate mens deltakere blir presentert for ulike musikk stimuli. Disse vil bli gitt over høretelefoner, og varer ca 1 time. Senere vil deltaker bli bedt om å gjennomføre The Profile of Music Perception Skills test (PROMS), hjemme hos seg selv, i løpet av uken etter deltakelse i labben.

### **Andre tester**

PROMS er en internetbasert undersøkelse som blir brukt til å kartlegge individuelle forskjeller i musikk funksjoner. Prosjektet fokuserer på musikalisk bakgrunn, mental helse, fysisk helse og språk lateralisering. Deltakere vil bli bedt om å gjennomføre denne hjemme etter eksperiment i labben er gjennomført.

## **Kapittel B - Personvern, biobank, økonomi og forsikring**

### **Personvern**

Opplysninger som registreres om deg består kun av en uendelig rekke med tall som tilsvarer de signaler som vi får fra EKG, samt data fra de psykofysiologiske testene beskrevet tidligere. Data blir lagret som rekker av datafiler på en datamaskin og deretter statistisk bearbeidet. Disse tallene har ingen betydning isolert sett og kan ikke avsløre din identitet.

### **Utlevering av materiale og opplysninger til andre**

Hvis du sier ja til å delta i studien, gir du også ditt samtykke til at prøver og aidentifiserte opplysninger utleveres til andre forskere som vi samarbeider med i inn- og utland, f. eks. i EU-sammenhenger. De får da tilgang til uidentifiserbare tall for å legge de sammen med andre tilsvarende tall fra andre undersøkelser, hvilket er en vanlig fremgangsmåte i moderne forskning der forskere fra ulike laboratorier og land samarbeider i såkalte forskningsnettverk

### **Rett til innsyn og sletting av opplysninger om deg og sletting av prøver**

Hvis du sier ja til å delta i studien, har du rett til å få innsyn i hvilke opplysninger som er registrert om deg. Dersom du trekker deg fra studien, kan du kreve å få slettet innsamlede prøver og opplysninger, med mindre opplysningene allerede er inngått i analyser eller brukt i vitenskapelige publikasjoner.

### **Økonomi**

De undersøkelser som vil bli utført vil være finansiert fra Universitetet i Bergen og Norges forskningsråd.

### **Forsikring**

Norsk pasientskedeforsikring vil gjelde.

**Informasjon om utfallet av studien**

Deltaker kan få innsyn i resultater fra undersøkelsen etter å ha etterspurt slik informasjon fra prosjektleder. Studiet avsluttes senest desember 2017.

## **Samtykke til deltakelse i studien**

Jeg er villig til å delta i studien

---

(Signert av prosjektdeltaker, dato)

Jeg bekrefter å ha gitt informasjon om studien

---

(Signert, rolle i studien, dato)



**Appendix C - Questionnaire****Spørreskjema for deltaker i Musikk og hjerterate eksperiment:**

1. Navn: \_\_\_\_\_ Deltakr nr:

2. Fødselsår og måned: \_\_\_\_\_ (måned. år)

**3. Kjønn**

Mann

Kvinne

Intetkjønn

**4. Høyre eller venstrehendt**

Venstre

Høyre

Ambidextrous

**5. Har du hørselsskader som du er klar over?**

Ja

Nei

**6. Har du hatt psykiatriske lidelse eller sykdom?**

Ja

Nei

**7. Har du hjerteproblemer som du vet om?**

Ja

Nei

**8. Bruker du beroligende eller sentralnervesystem stimulerende medikamenter?**

Ja

Nei

## **Appendix D - Verbal instructions for participants**

*Hei, velkommen. Først må du lese gjennom og signere dette skjema om samtykke.*

*Flott, nå kan du fylle ut dette spørreskjema*

*Oki, da er vi klar til å begynne. Hvis du blir med inn her, la telefon og andre ting ligge igjen ute.*

*Først skal du få et pustebelte, ta det rundt livet til det er strammet ordentlig. Det skal være ganske stramt, men ikke ubehagelig. Flott. Nå hvis du kan plassere denne klistrelappen på høyre siden ved siden av hjertet (viser på meg selv). Sånn Ja, også fester du denne på venstre side.*

*Også den siste på foten. Også skal du få feste ledningene på elektrodene. (Gir personen en ledning). Sånn ja.*

*Da skal du få høretelefoner, sånn, bare å justere dem så de passer til deg.*

*Nå skal du få sitte her inne og høre på musikk ca. 30 minutter. Bare lukk øynene, konsentrer deg om musikken og prøv å slappe av. Og ikke bruk fingrene eller føttene til å trampe i tak med musikken. Jeg kommer til å lukke døren, men jeg sitter rett utenfor, så hvis det er noe så bare skrik ut. Og du kan avbryte når du vil. Oki, da lukker jeg døren også begynner vi.*

**Appendix E - Link to some of the music stimuli**

Link to U0-40 BPM song

<https://soundcloud.com/ulvhild/u0-40>

Link to U9-168 BPM song

<https://soundcloud.com/ulvhild/u9-168>