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Absorption
Somewhere between the heart and the brain

An empirical investigation of absorption using qualitative and quantitative methods.

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Abstract

Absorption, the state of mind that is fully devoted and engaged with an attentional object, was empirically investigated using a multimethod approach including quantitative and qualitative methods. Participants (*N*=20) with a music education attended a classical concert and were equipped with wireless sensors measuring heart rate. Further, participants were asked to self-report after experienced absorption. Heart rate variability, a non-invasive tool for measuring the activity of the autonomic nervous systems was computed and shown to decrease significantly during instances of self-reported absorption compared to a control period, suggesting an increase in mental effort. Furthermore, the participants were interviewed before and after the concert. Five themes and 15 subthemes emerged from thematic analysis of the interviews in accordance with literature on altered states of consciousness. The self-reported instances and thematic analysis allowed for an accurate location of experienced absorption and suggest that certain compositional devices may predict absorption such as loudness, dynamic and timbral changes and harmonic tension and release.

Foreword

I want to dedicate this thesis to my beloved Mamie who tragically fell victim to the second wave of the corona virus in Paris. Mamie was a passionate artist and I thank her for showing us that it is ok to follow our own path.

Firstly, I want to thank my supervisors, Erling Guldbrandsen and Jonna Vuoskoski. Thank you both for sharing your knowledge, insight, and teaching me how to carve a master thesis out of an abstract idea. I also want to thank Olivier Lartillot. You are wizard in computer programming, and I thank you for generously sharing your expertise, time and enthusiasm for this project. Without your help this thesis would not have been possible.

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Joachim Dalgard

Table of content

1. Introduction

Absorption is the state of mind that is fully devoted and engaged with an attentional object. Although the state of absorption shares many characteristics with other altered states of consciousness, absorption involves a non-volitional *engagement* with an object of attention. In other words, it involves an *effortless* attention that is *captivated* by a stimulating object such as music.

The effects of music on consciousness have interested thinkers and philosophers at least since antiquity (Sundberg, 2000) and they continue to do so. Since the second part of the 20th century, modern science has increasingly investigated the cognitive and psychological effects of music. As music seems to simultaneously involve many important cognitive functions such as attention, expectation, emotion, learning and memory, music-related research has proven to be fertile for furthering the understanding of the brain and its processes (Pearce & Rohrmeier, 2012).

1.1 Thesis statement

There are inherent difficulties in trying to objectively measure a subjective experience like absorption. However, research has found that altered states are associated with physiological changes such as heart rate variability.

Heart rate variability (HRV) is a measurement of the constantly modulating distance between heart beats. This variability reflects the interplay between the sympathetic and the parasympathetic nervous systems which increase and decrease the frequency of the heart rate. HRV has been shown to be a non-invasive tool for measuring the activity of the autonomic nervous systems. Further, the neurovisceral integration model proposes that HRV is associated with cognitive functions (Thayer et al., 2009). Although many studies have investigated music's effect on HRV (Mojtabavi et al., 2020), I am not aware of any studies that explore the effects of absorption on HRV.

Studies have shown that absorption is important for determining musical preference (Hall et al., 2016) and is an important part of everyday music listening (Herbert, 2011). However, little research exists on mapping the subjective experiences of absorption during musical listening. Høffding (2019) investigated absorption of string quartet players during a performance through phenomenological interviews. Similarly, Herbert investigated absorption in 20 participants during everyday life and found that music was an effective agent for inducing altered states (Herbert, 2012) and live music has been shown to elicit strong experiences with music (Gabrielsson & Wiik, 2003). However, no studies have been found to qualitatively investigate absorption during long-term listening in a naturalistic setting, such as during a live concert.

For this thesis I have empirically investigated absorption using a multimethod approach with quantitative and qualitative methods. Heart rate variability of 20 participants with a music education was measured while they were attending a classical concert. The participants were asked to self-report after they experienced absorption. Furthermore, the participants were interviewed before and after the concert and asked to fill out a Tellegen absorption scale questionnaire. Finally, the interviews were investigated using thematic analysis.

1.2 Disposition

This thesis will first describe the theories, literature backgrounds and research on absorption and heart rate variability. Next, a methods chapter will describe the procedure for the conducted experiment, the equipment that was used to measure heart rate variability and for self-reporting and the Tellegen absorption scale questionnaire. Further, an analysis chapter will describe the transcriptions of the interviews and the thematic analysis. Then, a chapter is devoted to explaining the pre-processing involved in cleaning up the electrocardiogram used for measuring heart rate variability. Next, the results section will describe the different data gathered from the experiment such as time and frequency domain analysis of heart rate variability, the self-reported instances of absorption, the scores from the Tellegen absorption scale and the thematic analysis of the interviews, as well as the results from statistical tests investigating the main research questions. Finally, the last section discusses the results from the experiment in relation to literature and current research on heart rate variability and absorption and concludes with suggestions for future research.

2. Literature background

2.1.1 Absorption and other altered states of consciousness

Absorption is a mental state that is characterized by an "effortless, non-volitional quality of deep involvement with the objects of consciousness" (Jamieson,2005:120). A loss of time, space, and self-awareness and an intrinsically rewarding state of mind are shared commonalities between many altered states of consciousness such as peak experience (Maslow, 1962), ecstasy (Laski, 1961), flow (Csikzentmihalyi, 1990; Peifer, 2012) and absorption (Herbert, 2011). Though these states share many characteristics, absorption investigates the experience of sustained and focused attention that can often be evoked when subjects are listening to music (Ibid). It has therefore become one of the most prominent altered states in music-related research (Ibid, 2011: 26; Vroeghs, 2019: 156).

Throughout the 20th century, many altered states of consciousness were examined in an attempt to explain the phenomenon scientifically and bridge the gap between the subjective mystic world and the positivistic objective world. Following is a short review in chronological order of some altered state of consciousness.

In 1902 William James, a philosopher and pioneering psychologist, published a collection of lectures titled, *The Varieties of Religious Experience*. James describes experiences of mystical consciousness as a psychological state containing many characteristics such as ineffability, deep, illuminating knowledge from the experience, transient and short duration and non-volitional passive qualities (James, 1902: 380). James explicitly allows for "gradations and mixtures" of these experiences. Although preliminary, these early classifications are recurring in future descriptions of altered states.

In the early 1960s, Laski, an atheistic writer and journalist (Herbert, 2011: 86), investigated experiences of *ecstasy* in 63 friends and acquaintances through questionnaires. Although her study is of dubious scientific quality, her results are salient classifications of ecstasy that share many characteristics with other altered states of consciousness and have inspired other researchers to investigate them (Maslow, 1964: xvi). Intrinsic to ecstasy is the preceding of "triggers". Classifications of triggers include "nature, sexual love, childbirth, exercise, religion, art, creative work, recollection, introspection and beauty" (ibid: 490). These triggers can either result in a loss of "difference, time, place, self", or they can result in feelings of gain, such as, "feelings of unity, eternity, release, or ineffability." Laski also found that ecstasy was a rare occurrence among the participants with mostly "momentary" durations of "an instant or a split second" (ibid: 43).

Inspired partly by Laski's research on ecstasy, Maslow, an American psychologist, established the concept of *peak experience*. Peak experiences are "secularized transcendent experiences" (ibid: xii), characterized by a passive and receptive state of mind including a forgetting of the self and a disorientation of time and space. (ibid: 63) In line with Laski's research, peak experiences are dependent on a long list of "triggers"; sex and music are described as the most potent. (Maslow, 1968: 167). This "fully attended state" (ibid: 60) is "non-judgemental, (…) poignantly emotional and climactic" (Maslow, 1971: 348) and involves a "tremendous concentration of a kind which does not normally occur" (Maslow, 1964: 60). Maslow denies that transcendent experiences can only be dramatic, transient, and "peaky" moments and also suggests the concept of *plateau experiences* that are longer lasting and intellectual rather than emotionally poignant (Maslow, 1971: 349).

Introduced in 1975 by Csikzentmihalyi, *flow* is a state experienced when the level of challenge demanded by a task and the skill level required from the subject is balanced (Sveen, 2020). Csikzentmihalyi described flow as "the state in which people are so involved in an activity that nothing else seems to matter; the experience itself is so enjoyable that people will do it even at great cost, for the sheer sake of doing it" (Csikzentmihalyi, 1990: 4). However, flow, with its focus on active task completion (Stavrou, 2015), differs from absorption which is described as more passive and not goal-oriented. Further, Csikzentmihalyi describes experiences of flow from music and distinguishes between three modes of listening according to musical training and sophistication: the sensory, the analogic, and the analytic listening modes (Csikzentmihalyi, 1990: 110).

2.1.2 Strong Experiences with Music

Connecting the dots between music and ecstasy, peak experience, and flow, Gabrielsson undertook the project of researching "*Strong Experiences with Music*" (SEM). Building on Maslow's foundations of peak experience, the purpose of SEM was to "describe what reactions may occur in particularly strong experiences with music, to explore which factors

can elicit such reactions, and to consider what consequences the experience may have for the individual" (Gabrielsson, 2010: 546). Gathering data from 953 participants via questionnaires, interviews and written reports, Gabrielsson made comprehensive classifications and descriptions of strong experiences with music. SEM provokes changes of cognition, sometimes ineffable, that involve a loss of control (non-volition), time and space, body and mind, associations, memories and thoughts. It can involve mental imagery and is often described as mostly positive, intense powerful feelings and feelings of transcendence or of a religious character. Also reported is a loss of ego with a sense of disappointment when the subjects "return to reality" (ibid: 558). Quasi-physical reactions are also described, like being "lifted up from the music" or being "captivated" by it. SEM can demand full attention, where the subject is "totally absorbed by the music, and nothing else matters. There are no thoughts, no analyses, just presence, the here and now" (Ibid: 557).
"the timbre of an instrument or voice, intonation, sound level, dynamics, tempo, mode, rhythmic/melodic motive, harmonic progressions, themes, phrases, movements text/lyrics, and various formal aspects" (Ibid: 568) were all important musical factors for eliciting strong experiences. Acoustic conditions were triggers as well; an important aspect was the sensation of being "encapsuled by the music" resulting from a "good diffusion of sound" (Ibid: 569). Reports about the appearance of the performers and audience suggests that visual impressions were also a factor for eliciting SEM in the participants. Classically oriented music comprised almost half of the surveys. SEM was most often reported by older participants and female participants, where 74.4 % of the older women reported that SEM was elicited by classical music (Ibid: 567).

2.1.3 Non-musical Absorption

Theories on absorption were developed in the early 1970s by Tellegen who described absorption as "a state of "total attention" during which the available representational apparatus seems to be entirely dedicated to experiencing and modelling the attentional object, be it a landscape, a human being, a sound, a remembered incident, or an aspect of one's self" (Ibid: 274). The Tellegen Absorption Scale (TAS), originally developed as a tool for measuring trait susceptibility to hypnosis, investigates different personality characteristics and personality dimensions, and ultimately a subject's "openness to absorbing and self-altering experiences" (Tellegen & Atkinson, 1974: 268).

Tellegen distinguishes between two hypothetical temporary mental sets in an absorption-evoking context. The experiential set is described as "a state of receptivity or openness to experience" with a tendency to effortlessly and involuntarily "dwell on, rather than go beyond the experiences themselves and the objects they represent". The instrumental set is "a state of readiness to engage in active, realistic, voluntary, and relatively effortful planning, decision making, and goal directed behaviour" (Tellegen, 1981: 222). One is thus either receptive and open to be involved with the attentional object or one is rational and goal oriented. Tellegen clearly distinguishes between both mental sets and implies that they are mutually exclusive. However, a recent study (Jamieson & Loi, 2015) found that it is possible to be in both sets at the same time, at least intermittently during the same time frame (ibid:32). This allows for new, non-dichotomous classifications of state absorption with different qualities and intensities including characteristics from both the instrumental and the experiential mental sets.

2.1.4 State vs Trait Absorption

Tellegen distinguished between absorption as a trait and absorption as a state. He described *trait* as a predisposition to engage with an attentional object with an absorbed and experiential *state* of mind. Thus, subjects with a high trait score have an increased probability to experience state absorption. However, according to Tellegen, the manifestation of the trait is still dependent on certain conditions like the circumstances, the quality of the attentional object and the personal characteristics of the subject (Ibid: 219).

Contrarily, since a low TAS-score can exclude subjects that often experience state absorption, Herbert suggests that the TAS indicates a too narrow understanding of absorption that only involves certain dimensions of the subject's characteristics (Herbert,2011:103). As trait absorption and the intensity and frequency of state absorption don't necessarily correlate, Herbert suggests that one should consider absorption not as a "discrete trait, but as a form of attention" (ibid:104).

2.1.5 Musical absorption

Research on the correlation between music and absorption has proven to be salient because of music's unique ability to capture our attention through "multiple entry points to involvement" such as "acoustic attributes, source specification, entrainment, emotion and fusion of modalities" (Herbert, 2012: 1). Most experiments on music and absorption are performed in controlled laboratory settings and rely on short musical stimuli (Rhodes et al., 1988; Kreutz et al., 2007; Hall et al., 2016). Attempts have also been made to classify it along a spectrum of intensity during state absorption (Høffding, 2018; Vroegh, 2019). The following section is a review of studies that investigate music and absorption.

2.1.6 Classifications of musical absorption

In accordance with Jamieson and Loi's hypothesis (2015) of simultaneous instrumental and experiential mind sets , Vroegh (2019) expands the classifications of musical absorption mind sets into four groups. (i) "Concentrators" are similar to Tellegen's instrumental mental set; they have a low mean on altered state, and a high level of attentional-focus and self-awareness. (ii) "Mind-wanderers" have the lowest mean of attentional-focus and a medium mean on self-awareness, "suggesting that people were aware of themselves wandering off". (iii) Labelled as "zoning-in", this mental set is characterized by a low level of self-awareness, a high level of attentional focus, "considerable altered awareness" and a high level of intensity. (iv) Finally, "tuning-in" is similar to "zoning in" with a high level of attentional focus and altered awareness but with a higher level of self-awareness. (Vroeghs, 2019: 161)[1]

Similarly, after investigating the players of a string quartet during performances, Høffding (2018) proposes a taxonomy of absorption into different mental sets based on intensity and characteristics. Although they are performing – an activity including a set of skills matching a set of challenges – Høffding denies that the players are experiencing flow. He argues that with flow states there is a loss of "narrative self" but not necessarily a loss of consciousness and the self, like there is with absorption. (Høffding, 2018: 141). Høffding suggests three different modes of absorption: "Standard absorption"; "Absorbed-not being there"; and "Ex-static absorption". (i) "The standard absorption" is a "default mode of performing" where one is focused on not overly challenging music without any unusual intensity of attention, but while still recognizing "a pleasant feeling of satisfaction" that is proportional to the amount and execution of the skills required (ibid: 76). (ii) The "absorption-not being there" mode is characterized by an intense experience of great "emotional and existential significance", but that the subject is unable to recollect afterwards. It includes a loss of the self, but also of a "blurring" of the attentional object (ibid: 81). (iii) The "ex-static absorption"' mode dually involves a feeling of distance and overview of the situation, and non-judgemental, detailed awareness of one's own actions as if the subject is not responsible for them (ibid: 85).

Dissociation has been described as an "altered state of consciousness that is not organically induced, that does not occur as part of a dissociative disorder, and that involves the temporary alteration or separation of normally-integrated mental processes in conscious awareness" (Butler & Palesh, 2004: 66). Further, non-pathological dissociation has been found to be a common occurrence present in activities such as "daydreaming, imaginative engagement, meditation, formal hypnosis, and pastimes that capture attention and oblate self-awareness, such as reading an engrossing book or watching a riveting film" (ibid: 66).

Although recognizing Tellegen's descriptions of absorption, Herbert suggests that absorption should be understood as subordinate to "trance" and that it should be distinguished from "dissociation" (Herbert, 2011: 87). Trance is defined by Herbert as a "process characterized by a decreased orientation to consensual reality, a decrease critical faculty, a selective internal or external focus, together with a changed sensory awareness and – potentially – a changed sense of self" (Herbert,2011:5). Herbert argues that "trance" is a better term than "altered states of consciousness" as it encompasses a broader connection with the referencing literature. Herbert emphasises the *activity* of "trancing", described as "a *process* and not a static *thing*" (Herbert, 2011: 44, emphasis added), as it is more compatible with the normal daily activities that induce altered states.

2.1.7 Studies on musical absorption

Through interviews, Herbert investigated the role of music in the everyday lives of participants from different generations. "Everyday trancing" is shown to be an important aspect of people's lives and an escape from everyday life. The ability of trancing to music is thus suggested as a "coping mechanism" that helps subjects to "decrease activation, thought levels and critical awareness" (ibid: 115) and "perhaps offers relief/freedom from thinking in ways shaped by verbal language, i.e. an alternative mental space in which to function" (ibid: 117). Interestingly, Herbert raises awareness on the differences in generational listening habits. The older generations "may expect to give music their direct, undivided attention, influenced by attendance at live events where music forms the central focus" (ibid: 87), compared to younger generations that have access to technology that allows for music listening at all times. This access changes the "goals" of listening, allowing the subjects to intentionally dissociate and "block out surroundings" (ibid: 95), but also to act as a mediator and a pleasant backdrop between the self and the surrounding everyday life.

A number of studies have been made relating absorption to enjoyment of music and musical genres, and emotional arousal. Rhodes et al. (1988) found a correlation between the trait absorption score and the mean rating of short (4 min) musical examples of different genres in 35 participants. The study concluded that classical and new-age music had much higher correlations than rock and country music. They suggest that the complexity and format of classical and new age music is more suited for absorption as it demands greater imaginary and emotional involvement, compared to the "redundant structure" of rock and country music (Ibid: 737). A study by Kreutz and colleagues (2007) showed that trait absorption correlated with arousal rating of music and a higher intensity of emotions when listening to music.
A study conducted by Hall et al. (2016) found that trait scores informed whether subjects enjoyed "negative emotions" in music. High trait absorption subjects were more likely to experience arousal from "negative emotions" such as sadness, in the music, as «they may be particularly proficient at disconnecting from unpleasant aspects of negative emotion in music and instead, becoming highly immersed in the pleasurable aspects of the music» (Hall et al., 2016: 11). Interestingly, they found that experiencing state absorption was the most important factor when determining musical preference as opposed to only having a high trait absorption score.

A study on eye-tracking and absorption found that the microsaccade rate decreased when absorbed by short musical examples (43-61s) on 31 participants (Lange et al., 2017). Microsaccades are small involuntary eye movements that are affected negatively by higher cognitive processing loads. Complimentary to their hypothesis, the study concluded that absorption demanded a substantial cognitive load and that it could be quantitively measured by the microsaccade rate.

A recent study (Merrill et al., 2020) investigated the correlations between the «aesthetic experience» and physiology during a live concert. This study is one of few that have explored the experience of music in a naturalistic setting (see also Egermann et al., 2013; Baltes & Miu, 2014). During three chamber music concerts with identical programs, 98 participants were asked to self-report between movements and pieces while physiology was continuously measured. After each movement they were asked to fill out a questionnaire on state absorption (Vroegh, 2018, unpublished) and a self-report on their enjoyment of the music. The self-reported results were then compared with physiological measurement of skin conductance, heart and respiration rate and electromyography of the facial muscles. The study concluded that items on the self-report lists could be predicted by physiological measurements, especially skin conductance and facial EMG.

2.2 Physiological aspects of musical absorption

2.2.1 Heart rate variability

Normally, heart rate (HR) is used to denominate the frequency of the heart muscle's contractions, measured in beats per minute (BPM). However, instead of indicating the average number of BPM, heart rate variability (HRV) indicates the ever-varying distance between each beat. As the heart rate increases the inter-beat interval becomes shorter and vice versa. These beat-to-beat variations increase and decrease non-linearly (Malik, 1996). Research indicates that this constant fluctuation of intervals reflects oscillations by the autonomic nervous system (Sevre & Rostrup, 2001). HRV is mostly calculated through time domain analysis and frequency domain analysis.

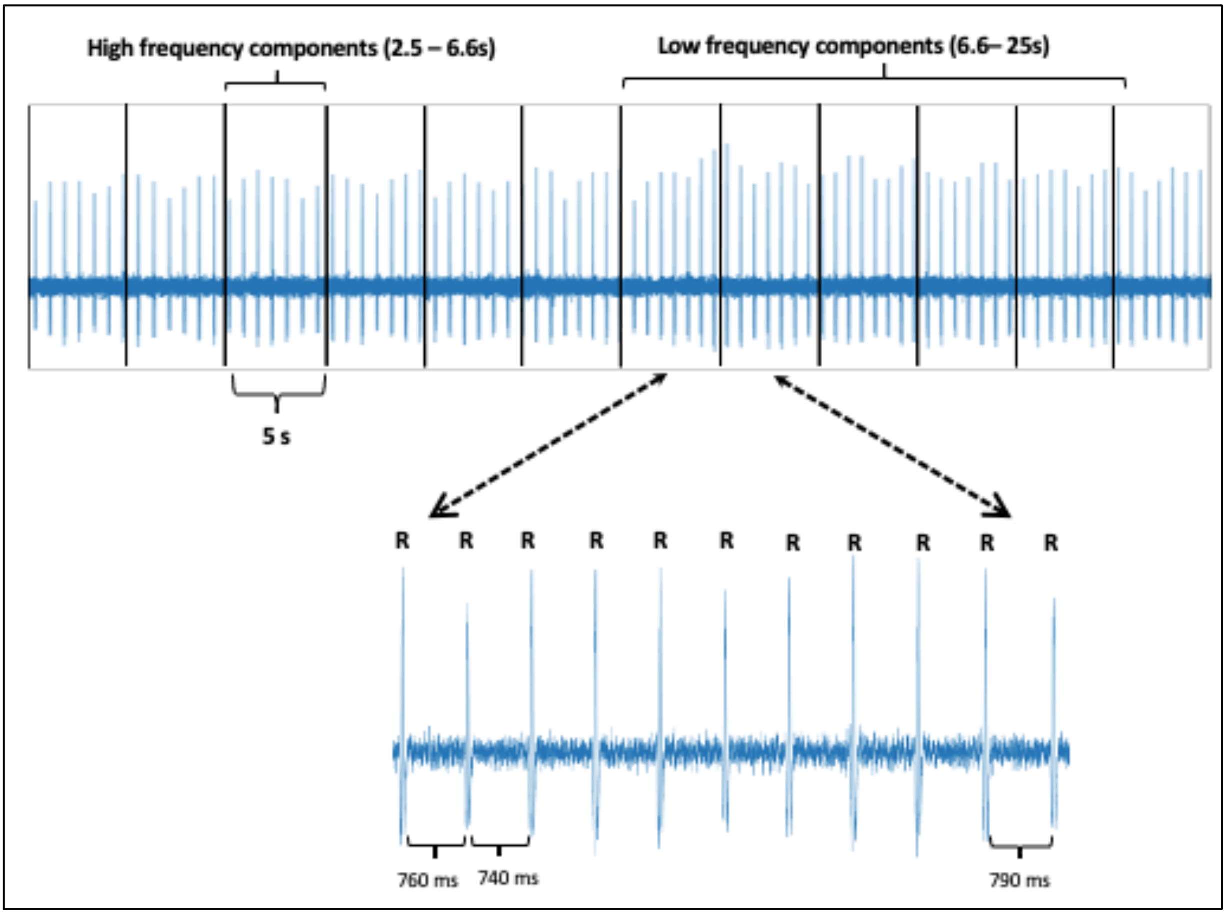

Figure 2.1 Heart rate variability is a measurement of the constantly fluctuating interval between heart beats. Each heartbeat is illustrated by an R-peak. Frequency domain analysis of HRV is divided into low frequency and high frequency variability (figure modelled after Sevre & Rostrup, 2001).

2.2.2 Frequency domain analysis

Built on Newton's studies on the decomposition of white light into its composite colours, a spectral analysis is a method for estimating the distribution of power of different frequencies composite in a signal such as in a soundwave or a series of heart beats (Stoica & Moses, 2005; Li et al., 2019). By performing a spectral analysis of the distances between each successive heartbeat it is possible to study in detail the variations of the heart rate over a period of time. These variations, distributed as power (in ms^2) over different frequencies, indicate the effects of the autonomic nervous system (Nesvold et al., 2012). The power of the frequencies are grouped into distinctive frequency bands that reflect autonomic stimulation. A high frequency (HF) band stretching from 0.15-0.4 Hz is affected by respiration and parasympathetic activity, these periods last 2.5 to 6.6 seconds. A band from 0.04-0.15 Hz largely indicates sympathetic activity, but mixed with parasympathetic activity, and is named the low frequency band (LF), these periods last 6.6 to 25 seconds. (Sevre & Rostrup, 2001). Their ratio (LF/HF) represents the sympathovagal balance (Nesvold et al., 2012). An increase in lf/hf ratio indicates a shift toward sympathetic activity.

2.2.3 Time domain analysis

Time domain calculations of the variations in R-R peaks are commonly used in order to accurately describe changes in heart rate variability. A task force of cardiologists established a standard for HRV-calculations that captures its different facets (Malik, 1996):
SDNN - Standard deviation of all Normal to Normal (N-N) heart beats is used to determine the variance in heart rate in defined segments of time.
RMSSD - Square root of the mean squared difference of successive intervals measures the differences between consecutive intervals between heartbeats measured in milliseconds. Because of the rapid periods of the high-frequencies it can be measured in 1-5-minute windows, and it is considered an accurate measurement of high frequency (HF) components of HRV less sensitive to artefacts and respiration (Quintana, D. personal communication. 02.05.20; Penttilä et al., 2001: 1).
NN50 – The number of adjacent N-N intervals that differ by more than 50ms in a defined 1 to 5-minute window.
***p*NN50** –Percentage of all adjacent N-N intervals that differ by more than 50ms. As it shows the changes between inter-beat intervals in a given window, it is also considered a reflection of HF components of HRV.

2.2.4 Respiratory Sinus Arrythmia

There is a well-documented connection between respiration rate and depth, and heart rate (Quintana et al., 2016). The parasympathetic nervous system (PNS) reacts to changes of pressure in the chest cavity due to respiration. During inhalation the heart rate increases and vice versa decreases during exhalation (Sevre & Rostrup, 2001). This is called the respiratory sinus arrythmia (RSA). RSA thus coincides with the HF components of HRV that are considered to be reflections of the parasympathetic nervous system. Further, slow respiration rate (below 0.15hz) will result in an overlap with the low frequency components of HRV, an issue during relaxing experimental conditions (Quintana & Heathers, 2014). Continued breathing in the same pace will also result in resonant frequencies on the frequency spectrum (Lehrer, 2013). However, research indicates that RMSSD is less affected by RSA and is a reliable assessment of HRV (Penttilä et al., 2001: 1).

2.2.5 Autonomic nervous system

The autonomic nervous system consists of the sympathetic (SNS) and the parasympathetic (PNS) nervous systems. Being autonomic, this nervous system can't be directed or wilfully controlled, and it directs the neural activity of organs and smooth muscles. Both branches of the nervous system try to maintain a balanced state called homeostasis, but each are still capable of dominating over the other according to what the situation demands. As the vagus-nerve largely controls the parasympathetic nervous system, the balance between the two branches of the ANS is known as the sympathovagal-balance.

2.2.6 Sympathetic nervous system

The sympathetic nervous system is responsible for preparing the body for alert responses and mobilizing energy to fit situational needs such as a fear or a threat. It is therefore known as the «fight or flight» mode. Increased sympathetic activity elicits higher blood pressure, faster and stronger heartbeats, and dilatation of the pupillae (Jansen & Glover, 2019).

2.2.7 Parasympathetic nervous system

Contrarily, the parasympathetic nervous system dampens the body and preserves its energy and has therefore become known as the «rest and digest» mode (Jansen & Glover, 2019). Not only does the PNS counteract many of the SNS's effects like decreasing the heartrate, contracting the pupillae and increasing the production of saliva, but it also stimulates other bodily functions like the stimulation of tear ducts, as well as facilitating secretion and sexual arousal (Ibid).

2.2.8 Neurovisceral integration model

The neurovisceral integration model suggests that there is a tonic parasympathetic inhibition of bodily functions that is regulated by the pre-frontal cortex (PFC) through the vagus-nerve (Thayer & Lane, 2000). It is thus suggested that there is an important connection between executive cognitive functions and heart rate variability. The PFC is involved in many important cognitive tasks such as autobiographical memory retrieval (McDermott et al., 2009), outcome expectancy (Schoenbaum et al., 2009) and generation and regulation of emotions (Wager et al., 2008); three important components of fear assessment, but it is also involved in the processing of music (Koelsch, 2014; Mansouri et al., 2017) and in the processing of highly pleasurable experiences such as chills (Blood & Zatorre, 2001). As there is a constant flux of positive and negative emotions felt as reactions to changes in the internal and external environment (Svartdal, 2018), the neurovisceral integration model suggests that the PFC perceives and reacts to the environment by influencing the interplay between the SNS and PNS (Thayer et al., 2012). For example, when a threatening condition is recognized, the PFC helps exercise control of the body by dis-inhibiting the sympathetic nervous system and increasing the heart rate (Thayer & Lane, 2000: 214).

2.2.9 Meditation and heart rate variability

Many studies have investigated the effects of meditation on the autonomic nervous system through analysis of heart rate variability (Nesvold et al., 2012; Reddy & Kuntamalla, 2011; Peng et al., 1999; Ditto et al., 2006; An et al., 2010). Studies have found that the power in both the low and high frequency bands significantly increases during meditation, indicating a shift in both sympathetic and parasympathetic activity.

2.2.10 Hypnosis and heart rate variability

Similarly, some studies have established a relationship between heart rate variability and hypnosis (Diamond et al., 2007; Boselli et al.,2018; Ramazan et al.,2013). Compared to a resting baseline, hypnosis considerably affected the autonomic nervous system by increasing the HF variations and stimulating parasympathetic activity.

2.2.11 Flow and heart rate variability

Only a few studies were found to have been investigating physiological changes during flow states (Keller et al., 2011; DeManzano et al., 2010). Results show that experienced flow during piano playing and during cognitively demanding tasks increased activation of the sympathetic branch and decreased the parasympathetic components of HRV. This indicates a mental strain involved during experienced flow. These studies propose that any perceived feelings of effortlessness during flow are only subjective as the objective measurements indicate mental effort.

2.2.12 Effects of music on heart rate variability

Music-related research on HRV seems to indicate that music can influence the interplay between the parasympathetic and sympathetic nervous systems. Although many of the studies concentrate on the effects of music therapy or mood or emotion inducing features of music, most studies show a consistent increase in HF variations and a stimulation of the parasympathetic nervous system while listening to sedative music, and an increase in LF and sympathetic activity during excitative music (Mojtabavi et al., 2020). Further, most studies were found to investigate HRV in laboratory settings and featured short music segments of no more than 5 minutes per piece of music (Ibid).

Iwanaga and colleagues (2006) found an increase in LF and HF variation during music listening compared to silence. Further, they found an increase in HF during sedative music compared to excitative music, suggesting that excitative music decreases the activity of the PNS. A study comparing HRV during classical and heavy metal music found that HF and LF decreased during heavy metal and that classical music increased variations in HF (Dasilva et al., 2014). One study found greater HF variations during soft passages of music compared to the louder passages, indicating higher PNS during sedative passages in the music (Cheng & Tsai, 2016). Another study found that soft music increased HF variations and thus stimulated PNS activity (Peng et al., 2009). One study found a correlation between tempo and HRV, where faster tempi significantly increased LF variations and decreased HF variations (Bernardi et al., 2006), indicating that faster tempo excites the listener and stimulates the

SNS. Only a few studies were found to have investigated the physiological effects of music in a naturalistic concert situation. One study on group synchronization to music during a live organ concert found that both HF and LF increased during music compared to baseline (Bernardi et al., 2017). Although not investigating heart rate variability, one recent study investigated aesthetic experiences through music-induced emotions and absorption in a naturalistic concert setting and found a small increase in heart rate during absorbed moments compared to dissociating, bored or mind wandering instances (Merrill et al., 2020)

3. Aims and methods

3.1 Aims

This study uses a multimethod approach to empirically investigate musical absorption using both quantitative and qualitative methods.

The primary quantitative aim is to assess absorption's effect on heart rate variability during music listening in a naturalistic concert setting. Although this study is exploratory in nature and no hypothesis was formed in advance, it was assumed that absorption's effect would be similar to either experienced flow during which parasympathetic activity decreases indicating mental effort, or to the experience of meditation and hypnosis where research has found parasympathetic activity to increase, indicating a mental relaxation. Further, it was assessed whether trait absorption would determine the frequency of experienced state absorption.

The secondary qualitative aim is to investigate by thematic analysis the subjective experience of musical absorption in 20 participants with a musical background and to compare it to established characteristics of musically induced altered states of consciousness. Further, self-reported instances are used to accurately locate musical absorption and compositional devices present during or prior to absorption.

3.2 Methods

This was an exploratory study of measured state absorption in a naturalistic setting. Participants attended a live performance by the Oslo Philharmonic orchestra performing Richard Strauss' "an Alpine Symphony" in the Oslo Konserthus while their heart rate was wirelessly measured. Participants were asked to self-report after experienced state absorption by tapping on a sensor. Further, pre- and post- concert interviews were conducted, investigating the participant's listening habits and experience of state absorption in everyday life, but also during the concert experiment. Trait absorption was also measured by the modified Tellegen Absorption Scale. Finally, the interviews were transcribed and analysed using a thematic analysis method and heart rate variability was computed from the heart rate measurements.

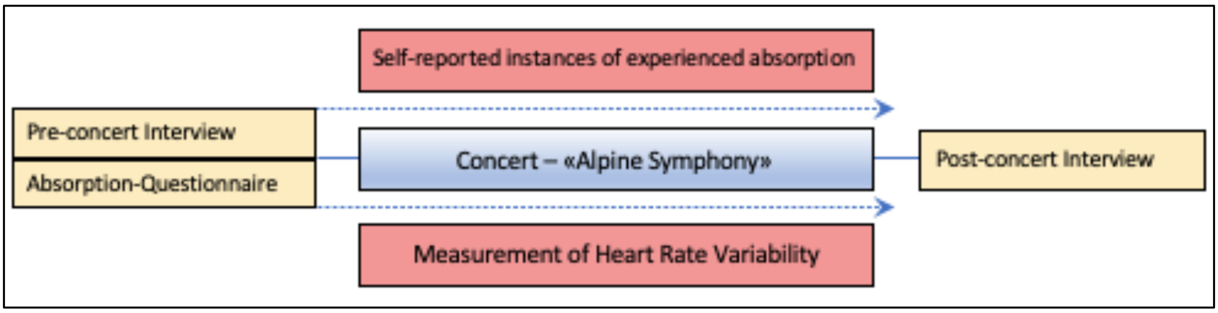

Figure 3.1: Flowchart of the timeline of concert experiment.

3.3 Participants

Twenty participants with intermediate to expert listening skills took part in the study. In order to facilitate a salient and in-depth interview about the concert, the project relied on participants' prior experience with in-depth listening to classical music and a general knowledge about musical rhetoric. It was preferable that the participants could articulate nuances from the music and accurately locate the absorbed moments experienced during the concert. It was assumed that subjects without prior experiences with classical music would find the experiment and concert overwhelming and would not be able to distinguish the absorbed moments from each other and thus not be able to accurately describe them.

The advertising poster invited participants to join an experiment where they would get insight into psychophysiological measurement of their listening experience as well as free tickets to a concert with the Oslo Philharmonic in the Oslo Konserthus the 3rd or 4th of April. The advertisement was posted at the Institute of Musicology at the University of Oslo, at Barratt-Due Institute of Music and at the Music Conservatory of Oslo. The poster also explicitly encouraged participants to not listen to the music programmed for the concert dates. Some relevant subjects were also personally invited to participate in the project.

Twenty-five subjects replied in total to the experiment invitation, but as only ten wireless sensors were available per concert, the slots were filled by the first respondents. Two participants dropped out last minute and the two slots were filled by subjects without a music-related education, but who were avid listeners of classical music. Among the participants with music-related educations were professional composers, professional performers, students of performance, philosophers of music, researchers of musicology and students of musicology.

Sex m/f	Age Mean	Age Std	Age Median	youngest	oldest	Participants with Music education	Participants with Other education
13/7	39.9	19.054	34	19	80	18	2

Table 1: Descriptive statistics of participants.

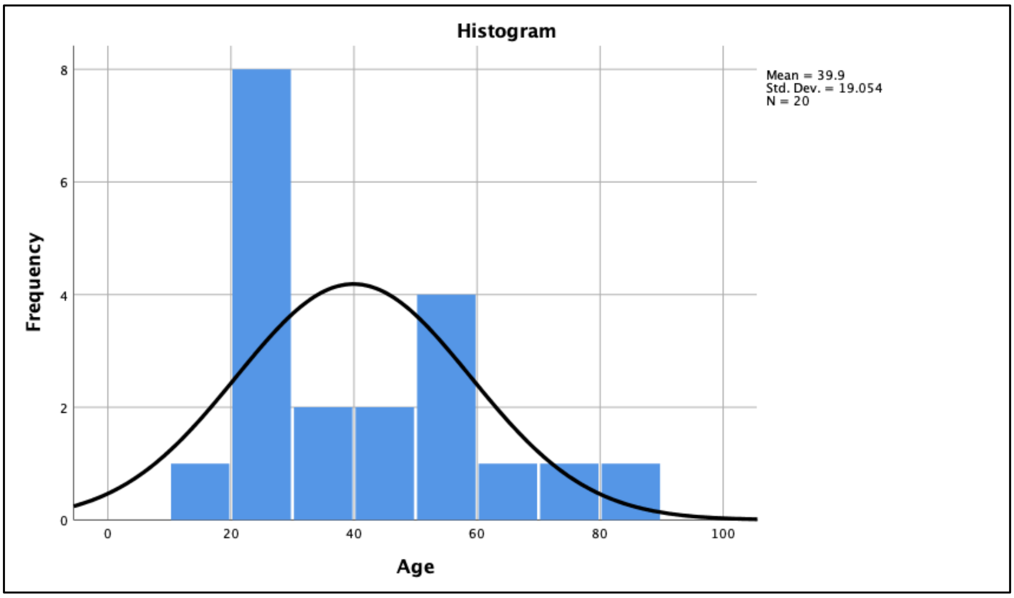

Figure 3.2: Distribution of age among the participants.

3.4 Ethics

The study was approved by the Norwegian Centre for Research Data (NSD). All the participants signed an informed consent form based on the template obtained from NSD. This form included descriptions of the aims of the project and of the physiological measurements and their anonymization and storage.

3.5 Setting

The Oslo Philharmonic generously provided the experiment with 12 tickets to each concert, ten tickets for participants and two tickets for a researcher with an assistant, with all the seats in pairs. The first evening we were offered tickets on the floor in front of the stage, the second evening on the left balcony.

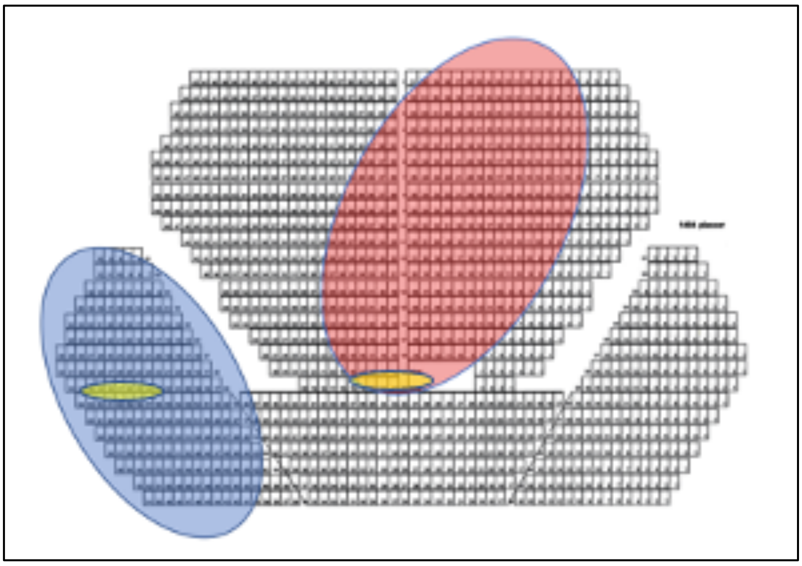

Figure 3.3: Seating map of the Oslo Konserthus with stage on top. Red circle indicating seating area for Wednesday 3rd April, blue circle seating area for Thursday 4th April and yellow circle indicating location of the researcher with the wireless receiver.

3.6 Musical material

Music in the classical genre was used as it usually affords comfortable seating arrangements and was considered to offer a more concentrated listening situation than other genres. Furthermore, visual and aural disturbances were considered to be more prevalent during jazz or popular music concerts than during classical concerts. The relaxed and fixed seating was also favourable for the streaming quality of the wireless physiological sensors.

There were some prerequisites for choosing the right concert for the experiment. The music had to be neutral to the participants, ideally as unfamiliar as possible. Performances during the spring of 2019 included Chopin's "Second Piano Concerto for Piano and Orchestra» (28.03.2019), Verdi's "Requiem" (11-12.04.2019), Schubert "Fifth Symphony" (02.05.2019) and Beethoven's "Fifth Symphony" (8-9.05.19), all popular and accessible works by household composers in the established Western music canon. There was a high probability that the participants would already have an intellectual or emotional connection to this music. These concerts, because of their popularity, would probably also be sold-out.

On the 3rd and 4th of April, the Oslo Philharmonic was scheduled to perform Richard Strauss' tone-poem "An Alpine Symphony". As this work distinguished itself as being relatively unknown compared to the other works performed this spring, it was deemed probable that most participants would not be as familiar with the music. Furthermore, it was likely that the concert would have more unsold tickets and available seats.

"An Alpine Symphony" (Op. 64) is a late-romantic tone-poem depicting a journey through the alps from sunrise to sundown and was written between 1911 and 1915. The music aims to describe sensations and observations that stayed with the composer ever since he went on a mountain-journey as a boy, where his party got lost and overtaken by a thunderstorm. As soon as he got home, he started sketching out ideas, and, as he wrote to his friend, "naturally it had conjured up a lot of nonsense and giant Wagnerian tonepainting" (Del Mar, 1986: 105). The symphonic tone-poem is a one-movement composition that is tied to a program or an idea that influences the form and contour of the music. (Symfonisk dikt, 2020) The program in this symphony is separated into 22 continuous sections, each representing hours and events in the course of a 24-hour journey up and down an alpine peak. Lasting around 50 minutes, the piece demands a large orchestra of 125 players, including a wind-machine, a thunder-machine and an organ. The "Alpine Symphony" is romantic programme-music, and it is emotionally suggestive, evoking peaks and valleys, sunshine and rainstorms as well as cows grazing on alpine meadows. The music was deemed well suited to the experiment because of its picturesque and thought-provoking nature, qualities that were considered to help arouse state absorption.

3.6.1 Description of "an Alpine Symphony"

I. Nacht - Night

The symphony opens in obscurity with an ominous B-flat played in unison, followed by a slow stepwise descent down the B-flat minor scale. Each step of the scale is sustained until all the notes ring out in a cluster chord. Out of this, a Wagnerian chordal motif is introduced by the brass. The mountain theme represents the peaks of the alps solemnly looming in the night. Swelling arpeggios in the strings follow as rays of dim sunlight appear out of the waking horizon.

II. Sonnenaufgang - Sunrise

The sun rises with a thundering climax, the flutes and violins soaring high while turning the descending opening scale from a shadowy wisp into an auspicious melodic motif. The sunrise-theme is developed by the strings and woodwinds before the theme is reiterated by the horns.

III. Der Anstieg - The Ascent

The sunrise-theme ends abruptly as the basses introduce a marching-theme and the journey begins. In a true operatic fashion, twelve horns play a fanfare outside of the concert hall, raising questions that are answered by the strings on the stage.

IV. Eintritt in den Wald - Entry into the Woods

The final cadence of “the ascent” ends on a loud C-minor chord and we enter the murky woods at the foot of the mountain. The outcome is uncertain as the strings arpeggiate and the basses and horns accompany the melody through the depths of this dark forest. Fragments of the marching theme are echoed, while flutes chirping like birds hail the wanderer’s clearing with a move to A-flat major.

V. Wanderung neben dem Bache - Wandering by the side of the Brook

A peaceful stream passes by, represented by textural rushes of water. The marching theme indicates that the mountaineers are walking alongside it, as it picks up speed and hastens towards the side of the cliff.

VI. Am Wasserfall - At the Waterfall

The music builds up in speed and tension into a boisterous drop down a waterfall. The violins and flutes tumble down with repeating hypnotic patterns, endlessly falling until the passage fades out with sprinkling high-pitched arpeggios in the harps.

VII. Erscheinung - Apparition

Through the cascading water dew, a fairy of the alps with its accompanying theme appears, with dreamy harp and flute runs. The marching theme is stated as the mountaineers pursue the fairy who flees with pizzicato footsteps into the misty vapor.

VIII. Auf blumigen Wiesen - On Flowering Meadows

The journey continues through a meadow with singing birds. The beauty of the emerging flowers overtakes the wanderers. A variation of the marching theme is interpolated by soaring melodies. A crescendo rises in proportion with the expansion of the orchestras register until the section ends in full romantic bloom.

IX. Auf der Alm - On the Alpine Pasture

A pastural and dance-like theme in 6/8 time is introduced. A herd of cows appear, and the bells on their necks ring as they bend down to graze on the alpine pastures, each at their own pace.

X. Durch Dickicht und Gestrüpp auf Irrwegen - Through Thicket and Undergrowth on the Wrong Way

Panic ensues as the mountaineers take a wrong turn. The precipice stares threateningly back at them through shrill chords played by the horns which increase in tempo. Rocks tumble down the mountainside as the mountaineers struggle to find their way. A new set of triumphant Wagnerian chords swell up as our travellers finally find their way back to the path.

XI. Auf dem Gletscher - On the Glacier

The travelers pass a glacier, the rising horns indicating its majestic size, while chromatically moving chords and dissonances remind the listener of the ever-present cold and threat.

XII. Gefahrvolle Augenblicke - Dangerous Moments

Climbing towards the summit, the music becomes quiet and concentrated. Interspersed single melody lines are played by a solo violin; a cello; and finally, a trombone indicates that the top is getting closer. Falling staccato triplets indicate the steepness that surrounds the path while, slowly entering out of nowhere, tremolo violins grow in intensity as the travellers approach the peak of the mountain.

XIII. Auf dem Gipfel - On the Summit

The mountaineers reach the top, arguably the most important moment of the piece, with an initial chord built on the first interval of the marching theme that quickly fades out. It is quiet on the top, a single lyrical oboe illustrating this unity with silence before triumphant chords recap the journey, timpanis rolling and violins soaring. Fragments of the apparition-theme are played before the horns state the marching-theme in pregnant ritardando. Finally, the glorious mountain-theme from the beginning is played, this time in C-major and slightly varied.

XIV. Vision - Vision

The ecstasy and thrill of being on top of the alps is maintained in this section. As if the mountaineers were looking back down the mountain and the landscape, many of the central themes already heard are developed in a dreamy patchwork. Interchanging between high diatonicism and piercing chromaticism, sometimes blending the two into a heterogenous mixture. The music is dynamically and melodically rising and falling, perhaps like the outline of the alpine peaks. The organ and tubas supply a deep pedal point, expanding the spectrum of the orchestra until it includes both extremities of its range.

XV. Nebel steigen auf - Mists rise
Clouds fog up the spectacular vision in this short and gloomy section.

XVI. Die Sonne verdüstert sich allmählich - The Sun gradually becomes Obscured
Fragments of the sunrise-theme are echoed in the violins and organ while the flutes signify obscurity and fog with chromatically rising scales. The atmosphere seems to be hazy, lingering between reality and the land of fairy tales.

XVII. Elegie -Elegy
Harmonies are played by the organ while a new theme is introduced. Played in unison by the strings, it features chromatic neighbouring notes, giving it an oriental character.

XVIII. Stille vor dem Storm - Calm before the Storm
The atmosphere is quiet, interspersed lyrical melodies are played by solo woodwinds. High-pitched staccato oboes suggest droplets of rain. Their increasing frequency points out that more weather is about to follow. We hear the opening descending B-flat minor scale that ends in a long-held cluster, while quick chromatic arpeggios increase in speed and dynamic.

XIX. Gewitter und Sturm, Abstieg - Thunder and Tempest, Descent
A storm takes the stage with full vigour as the mountaineers descend from the mountain. The wind-machines and percussions represent the thunder and wind. The thunder strikes in the cymbals and timpani while the flutes and strings rapidly fall. There is chaos in the ranks of the orchestra as fragments of melodic motifs are spread out in all the different instrument groups. Alarming clusters quickly blaze out in the horns. The rhythms and melodies slowly assemble as the storm reaches a loud, climactic flash of thunder. The droplets of rain in the oboes are all that remain as we hear the thunderstorm disappearing in the distance with a lone rolling timpani.

XX. Sonnenuntergang - Sunset
An augmented variation of the sunrise theme is heard, each chord prolonged as the strings play rising and falling melodies until they join in and embellish the theme. The sunrise theme is played again, this time with the string rising chromatically underneath, creating a tension that longs to resolve.

XXI. Ausklang - Waning tones

A psalm-like choral is played by the organ and a solo trumpet. The apparition-theme is restated in the flutes and then in the horns. A slow nostalgic passage recaps fragments of the journey with its themes, ending with short snippets from the marching-theme and the sunrise-theme.

XXII. Nacht - Night

Finally, we hear the sombre introduction descending into the cluster again. The mountain re-emerges from the depths with one final breath before ending on a sustained B-flat note.

3.7 Experiment procedure

3.7.1 Pre-concert interview

Once the participant was approved for the experiment, an initial meeting was set up. The participant was first asked to fill out a MODTAS-questionnaire (see section 3.10), and then a semi-structured interview was conducted with its audio recorded with an iPhone. A basic set of prepared questions were used for each participant:

-How do you experience listening to music?
-How do you experience listening to performed music versus listening to recorded music?
-How do you experience the notes of the music in your consciousness?
-Where is your «self» when you listen to music?

These questions were intentionally vague, and the participants were encouraged to be as open as possible and to freely associate.

3.7.2 Concert-experiment

The order of events varied between the two nights. On Thursday, “An Alpine Symphony” was played after the intermission, while on Wednesday it was the only piece in the programme.

On Wednesday, the participants were asked to meet at 18:15 in the foyer of the concert hall. There, they were handed their tickets, and the researcher attached the sensor to their chests. 15 minutes before the concert started, the participants and researchers walked together upstairs to the concert hall where the Trigno wireless receiver (Delsys, 2013) was placed along with a laptop running the DELSYS EMG-systems software(ibid). Here they were again reminded of the task of the experiment: to relax, enjoy the concert as normal and to self-report after they had experienced moments of captivation by the music by tapping five times on the sensor. After these instructions, the sound recording was started on a Zoom H4n recorder (Zoom, 2009), and a sound intervention was made by counting down from 3 in order to accurately time the start of the EMG-recording with the ensuing concert-recording. After it was confirmed that the EMG-software started recording, the participants were asked to find their seats.

On Thursday, the protocol differed only in that they were asked to meet at 19:10 in the foyer and walked up into the concert hall during the intermission. However, the Norwegian broadcasting company, NRK, was recording the concert this evening (Oslo Philharmonic, 2019: available online). There were cameras and microphones in the room, perhaps a stress factor for the participants who were instructed to relax during the performance.

3.7.3 Post-concert questionnaire

After the concert, the participants were presented a questionnaire with questions related to the concert experience and finally inviting for an open-ended description of their concert experience. The questions included:

-How was your concert experience?

-Did you experience moments of effortless attention where you were captivated by the music?

-Did it happen multiple times? For how long?

-If you reported moments of effortless attention (being captured by the music), how would you describe this state?

-If there were moments when your attention needed effort, how would you describe this state?

-How did you experience the compositional means and how did they affect the form and time span of the piece?

3.7.4 Post-concert interview

Post-concert interviews were conducted during a two-week period following the concert. However, five participants were not able to schedule a second interview.

During this interview, the participant was first given their post-concert questionnaire and asked to read it in order to re-familiarize themselves with their concert experience. The self-reported targets were also plotted alongside an audio recording of the concert. The participants would listen to the audio recording of their self-reported sections and were asked to describe what they heard prior to their self-report, to elaborate on the musical aspects that caught their attention and finally to manually pinpoint the temporal area where they experienced state absorption. A semi-structured interview was conducted with the same set of questions from the post-concert questionnaire as a basis.

3.8 Heart Rate Variability

The heart rate of the participants was measured using Trigno Avanti wireless electromyographic (EMG) sensors (Delsys, 2013). These bipolar sensors are normally used to measure the electrical activity in skeletal muscles. However, when placed in the chest region the EMG sensors can accurately measure the current from the cardioid muscles of the heart. These sensors are small in size (27 x 37 x 13mm) and non-invasive. On the male participants the sensors were placed left of their right nipple (from 3rd person perspective). Participants with hairy chests were asked to shave this area before the concert. Female participants were equipped with modified sensors featuring a smaller less intrusive "mini-head" connected to the main unit. These were placed below the collarbone, with the main unit placed on the collarbone. All chests were wiped with alcohol in order to clean off dead skin cells and improve skin contact.

Time domain analysis was calculated using the MHRV toolbox (Behar & Rosenberg et al., 2018). The window length for the time domain analysis is one minute where a mean is created for each window. One minute was chosen as it is the minimal window length for accurate vagal tone measurement (Laborde et al, 2017), and two-minute windows were considered too long compared to the often reported "momentary" durations of altered states of consciousness (See chapter on absorption). The data was exported to Microsoft Excel where all the time domain analyses were gathered for each participant. Mean RMSSD (see section 2.2.3 for definition) for each participant's target and control was calculated and then exported into SPSS.

3.8.1 Data Reduction

Although HRV was calculated and measured for the entire duration of the concerts for all 20 participants, the self-reported areas of experienced absorption were isolated and used as target periods. A custom script was written in MATLAB to collect a sample of data starting one minute before the self-reported instance, as well as a control sample of one minute, starting one minute after the self-reported instance (See fig. 3.4). Additionally, a one-minute baseline was recorded while the participants were seated before the start of the concert.

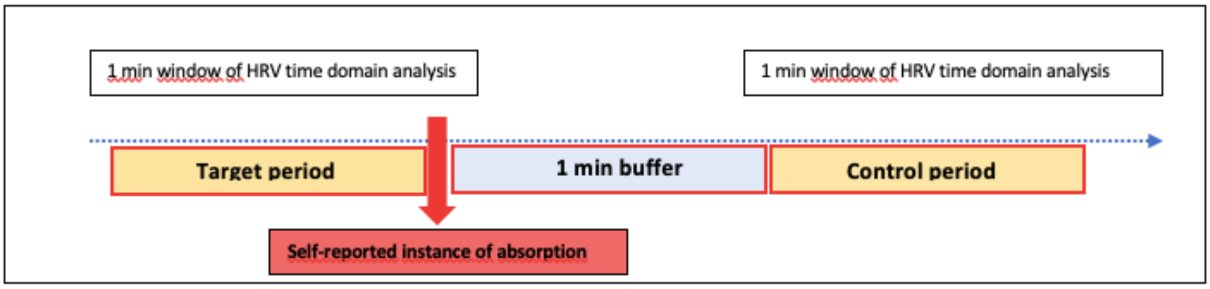

Figure 3.4: Diagram of the measured segments before and after self-reported instances of absorption. RMSSD was calculated for target and control period.

3.9 Self-reported instances of absorption

During the concert, participants were asked to self-report after they had experienced effortless attention or felt captivated by the music. The Delsys EMG sensors that were used for recording ECG signals contain an accelerometer, so they were also used for self-reporting. The accelerometer registers movement or speed in a three-dimensional space (Andresen, 2017). The participants were seated during the whole concert, thus a gentle tap on the sensor would cause a slight movement that could be distinctly read in the accelerometers signal (See figure 3.5 and 3.5). Gentle taps on the sensors did not affect the ECG-signal.

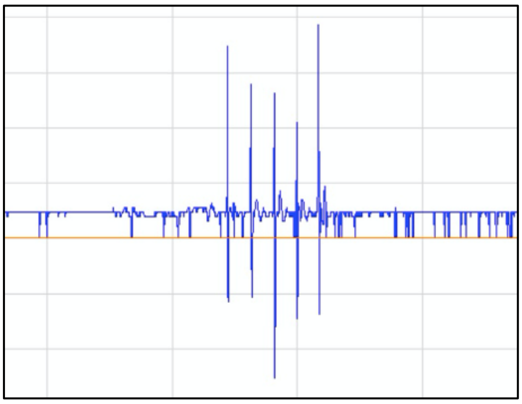

Figure 3.5: Data of accelerometer showing the signal made by five gentle taps during self-reporting.

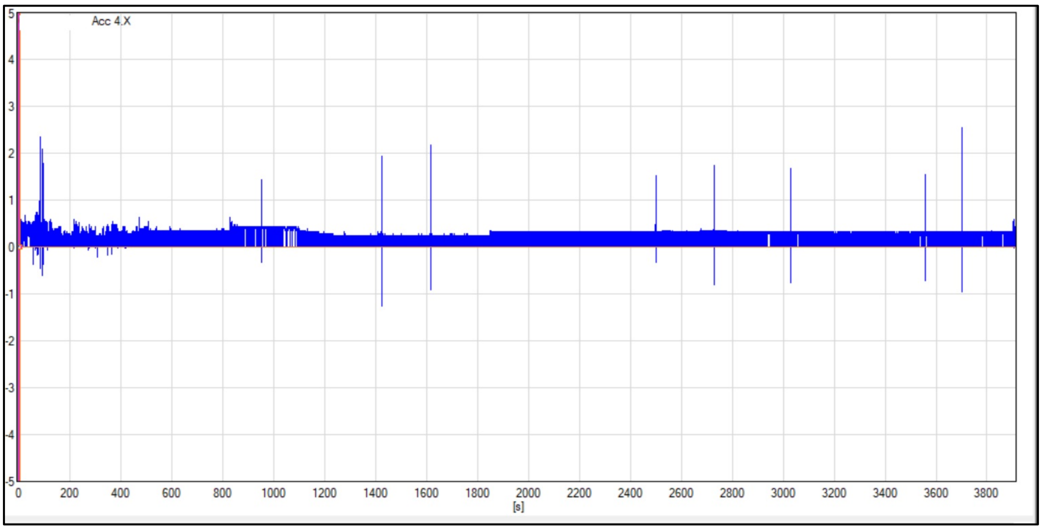

Figure 3.6: Data of accelerometer for one participant's self-reported instances of absorption during the course of entire concert

An important feature of the experiment was that it was as non-intrusive and natural as possible as the participants' main objective was to listen to the music being performed as they normally would. If they noticed that they had been especially captivated by the music, to the point of letting go of self-awareness or getting the feeling that they had been "away", they were asked to self-report.

Researchers explained about the characteristics of state absorption during the preliminary interviews. Participants were asked to tap five successive times on the sensors immediately after "returning" from a captivating moment. The participants were explicitly told that the self-report had to happen *after* the experienced absorption, as it would be contradictory to self-report *during*.

3.10 Modified Tellegen Absorption Scale – Questionnaire

Originally a dichotomous, true or false questionnaire, the Tellegen Absorption Scale (TAS) features 34 items investigating "the openness to absorbing and self-altering experiences" and measures trait absorption (Tellegen & Atkinson, 1974). For this thesis a Modified Tellegen Absorption Score scale was used (Jamieson, 2005). The MODTAS is different from the TAS as it is non-dichotomous and instead uses a five-point Likert scale ranging from 0 (never) to 4 (very often).

The questionnaire addresses the following aspects (Tellegen, 1982):

- Is responsive to engaging stimuli.
- Is responsive to "inductive" stimuli.
- Often thinks in images.
- Can summon vivid and suggestive images.
- Has "crossmodal" experiences (e.g., synesthesia).
- Can become absorbed in own thoughts and imaginings.
- Can vividly re-experience the past.
- Has episodes of expanded (e.g., ESP-like) awareness.
- Experiences altered states of consciousness

The scoring of the scale is done by adding up all the answers (0 to 4) of the questionnaire where the maximum score is 136. No population norm is available, but a study featuring 352 first year psychology students had a mean of 65.35 (median 65.18, SD = 20.55) (Jamieson, 2005), and another study (Glisky et al., 1991[2]) (*N* = 426) had a mean of 84 (*SD* = 18.02).

3.11 Statistics

A paired samples t-test was used to test for possible differences in RMSSD during baseline and target, baseline and control and between target and control. As the variables had a non-normal distribution, a Wilcoxon matched-pair signed-rank sum test was also used to test for differences between the conditions. An analysis of covariance (ANCOVA) was used to investigate the effects of age and trait absorption on RMSSD across the different conditions (Field, 2013). SPSS version 26.0.0.1 was used for the statistical analyses.

4. Analysis and pre-processing

4.1 Pre-processing of heart rate data

Electromyographic signals had to be processed and cleaned prior to analysis. Recorded at 1900hz, the EMG signal offers a graphical representation of the electrical activity in muscles (the heart muscle in this case) in millivolts (mV) over time. The data was transferred to Matlab as CSV files where the MIR toolbox (Lartillot et al., 2007) and the mHRV toolbox (Behar et al., 2018) were used for cleaning of artifacts and analysis.

4.1.1 Electrocardiogram

In a medical context, a detailed electrocardiogram (ECG) can be crucial for discerning minute nuances. ECG is therefore normally measured using 12 methodically placed sensors with positive and negative polarity in different regions of the body in order to get an accurate measurement (Thaler, 2017). However, as only the temporal qualities of heart rate were needed to perform analysis of HRV, and only 10 sensors were available per concert, one sensor per participant was considered enough to conduct the experiment. Unfortunately, many of the resulting measurements turned out to be very noisy. Without alternative sources for HR, a lot of work had to be performed in order to clean up the data.

4.1.2 The QRS-complex

The heartbeat is a result of a recurring wave of electrical activity in the heart muscle. The discharge of current through the cells of the heart that leads to a contraction of the muscle is the consequence of a depolarization. The tempo of the firing of these cells is largely determined by the autonomous nervous system (Arnesen, 2020). Parasympathetic stimulation slows the heart rate down, while sympathetic stimulation increases it. Three main waves of current across the muscle are known as the QRS complex (see figure 4.1). Where Q and S represent small depolarizations, the R wave indicates the ventricular depolarization, a bigger wave of current that is very clearly visible as a peak on graphical representations (Ibid). Because of their clear visual identity, the R-peaks are used to determine each heartbeat in the detection of HRV and are also known as normal to normal beats (N-N).

4.1.3 Matlab script for beat detection

A custom made Matlab script was designed for the project to chronologically spot the R-peaks of heartbeats. The script identifies the first couple of R-peaks by considering their amplitude. The distance between the identified R-peaks determines the location for consecutive peaks (see figure 4.3). The script automatically identifies R-peaks by filtering out other peaks with a considerably smaller amplitude or by considering if the distance between consecutive beats does not resemble the preceding interval by a ratio of at least 80%.

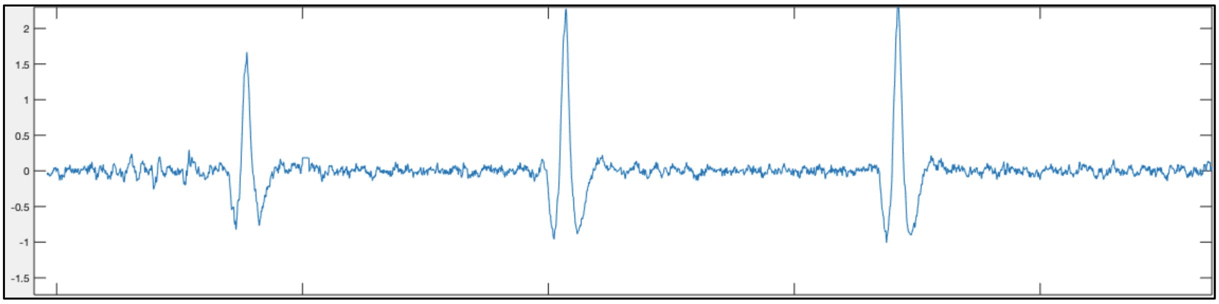

Figure 4.1: The electrocardiogram represents each heartbeat graphically, the QRS complex is clearly visible.

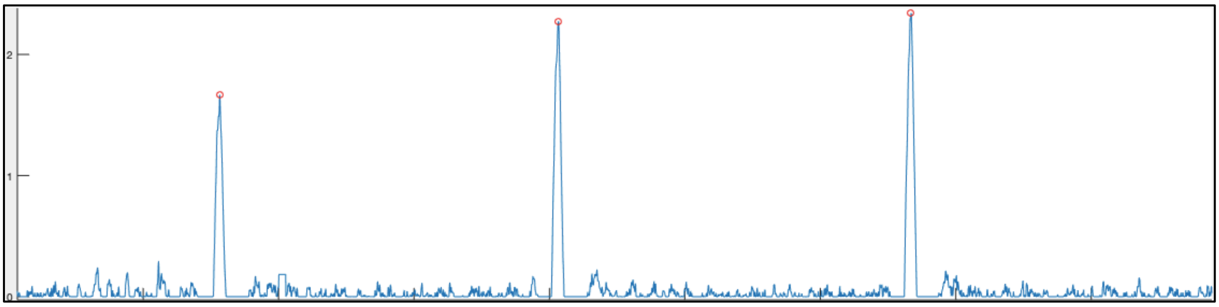

Figure 4.2: The negative values are omitted by the MIR-toolbox and the positive R-peaks are identified and marked with red circles.

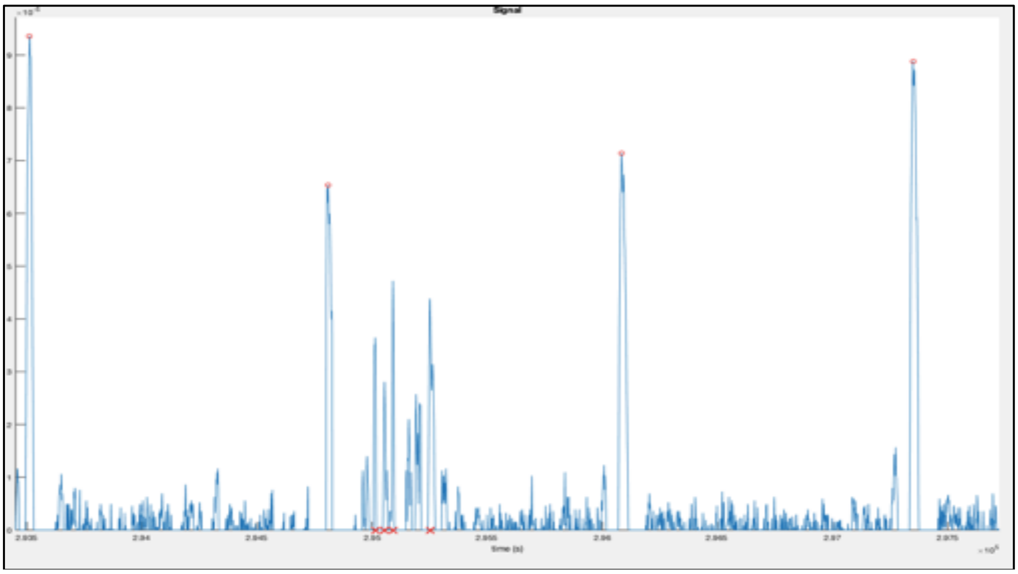

Figure 4.3: Marked with red crosses, artifacts are considered, but filtered out as they don't fit the criteria for the interval percentile (80%). Correctly identified R-peaks are represented with red circles.

However, although the tempo changes in heart rate are usually incremental, a few of the participants had sudden bigger leaps of changes in heart rate. In these particular participants, the ratio for the interval recognition was increased up to 50 %. This would, on the other hand, allow the script for more options when considering R-peaks as it would then be searching for peaks in a bigger area. In order to assure that the R-peaks were correctly identified, erroneous artifacts had to be deleted manually. This was done by measuring the distances between preceding and following beats, visually identifying QRS-complexes and then indicating temporal location of erroneous intervals which were then deleted by the script.

The script would err or stop analysing for peaks after not finding matches that follow the guidelines of amplitude and interval ratio. It would then either loop until stopped manually or recalculate with larger erroneous intervals. These errors are consequences of noise and other artifacts that need to be corrected in order to continue analysis (See figure 5.6).

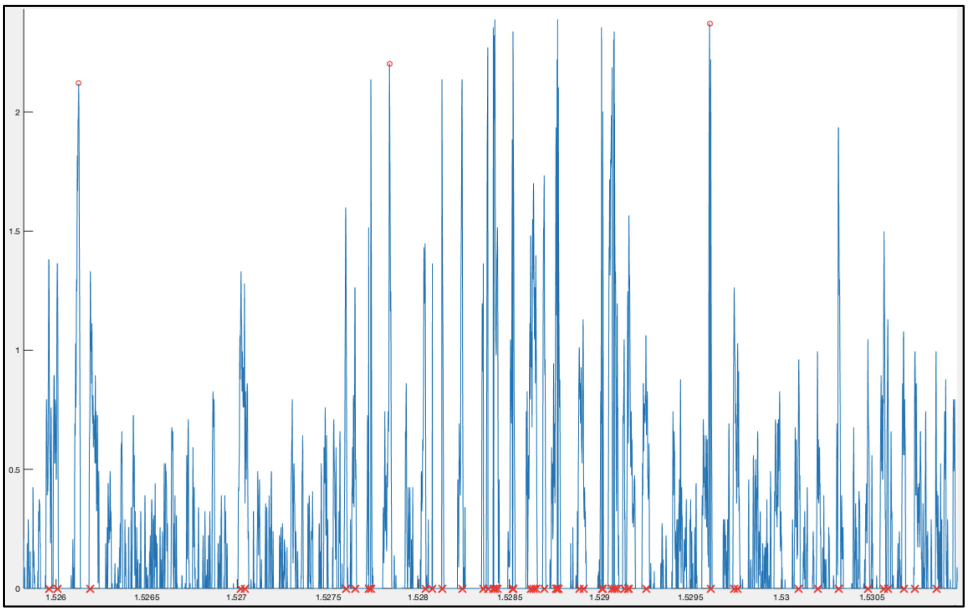

Figure 4.4: In noisy areas the script would wrongly identify artifacts as peaks.

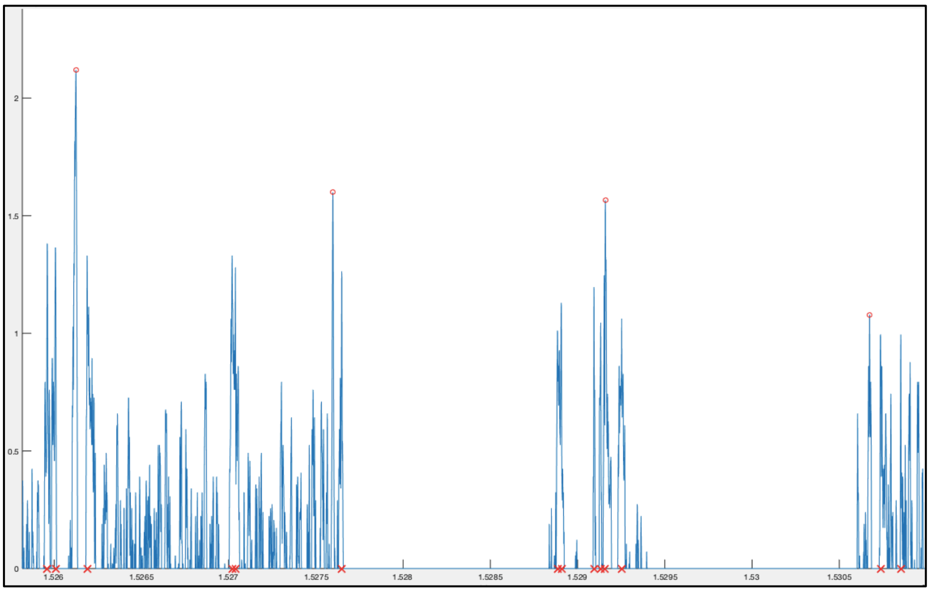

Figure 4.5: The correct R-peaks are identified with red circles as the surrounding noise has been manually deleted.

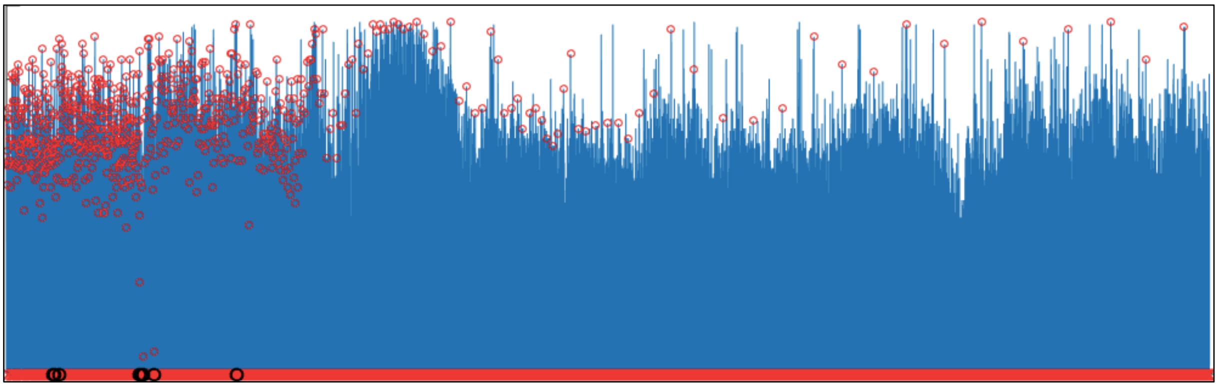

Figure 4.6: An erroneous analysis. Notice the increasing intervals between identified peaks marked as red circles.

4.1.4 Ectopic beats

Ectopic beats are heart beats that are irregular and outside of the normal established pattern. They are often registered as an early beat followed by a compensating pause before continuing on a previously established regular rhythm (Thaler, 2017: 106). Ectopic beats can have a large impact on HRV as the resulting shift in interval between R-peaks introduces non-existing frequencies to the heart rate variation. A linear interpolation method was used accordingly by generating a beat on the precise middle point between the preceding and following beat (see figure 4.7) (Morelli et al.,2019). This method was also confirmed as acceptable by a senior consultant cardiologist at Rikshospitalet (Sevre, K. personal communication. 23.01.20). Morelli et al. (2019) also found that one could interpolate as much as 30% of heart beats in 5-minute windows without affecting much of the power spectral density. However, I have chosen to follow the guidelines of a Norwegian review on HRV that states that no more than 10% of the heart beats should be interpolated in order to get an accurate analysis (Sevre & Rostrup, 2001). None of the participant's data reached 10% of interpolation, the maximum percentage for one file was 2.46% of interpolation.

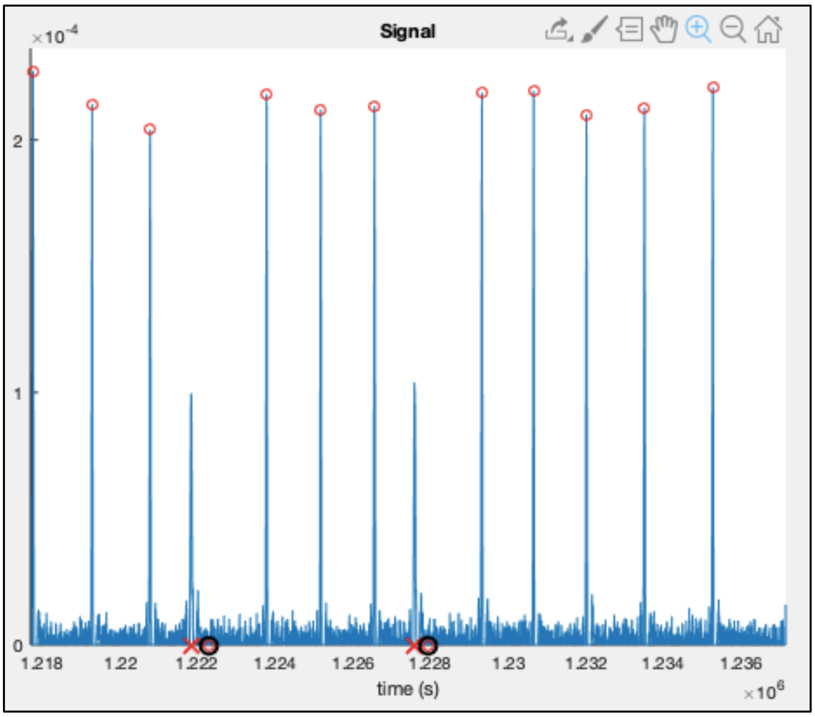

Figure 4.7: Ectopic beats are identified with red crosses; the interpolated beats are represented by black circles.

4.1.5 Inverted ECG

As some of the participants had excessive amounts of noise in the positive signal, but not in the negative signal of their ECG, a function was developed to invert the polarity of QRS complex. The positive values would then be negative and vice versa. The MIR-toolbox script would then proceed with analysis of what was originally the negative values of the signal. Thus, instead of having clearly identifiable R-peaks, there was Q and S peaks. Q and S peaks differ from R peaks in amplitude, but more problematically, there are two peaks close in proximity instead of one. The script had problems with discerning the Q and S peaks from each other. Accurate measurements of the intervals are crucial for a correct identification of peaks. In these cases, Q and S peaks thus often had to be manually discerned from each other (see figures 4.8 and 4.9).

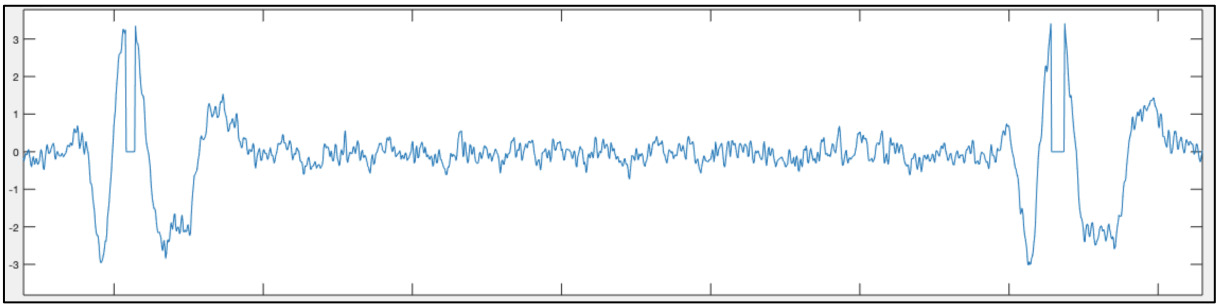

Figure 4.8: The R-peaks are distorted and will not be correctly identified by the script.

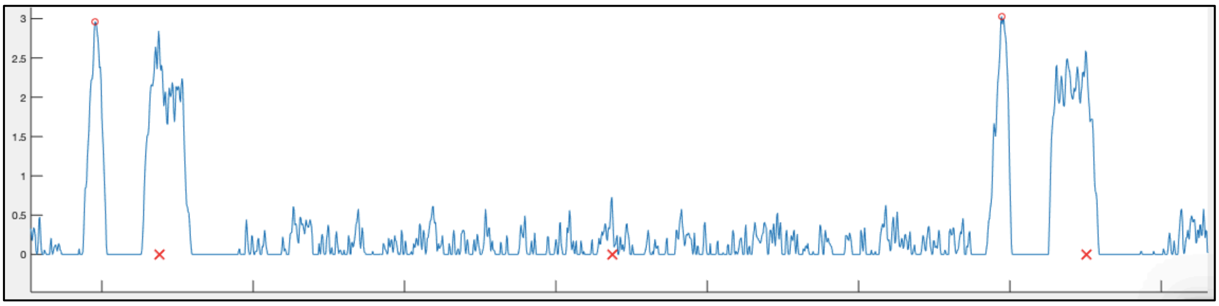

Figure 4.9: The ECG is inverted, and the Q and S peaks are converted into positive values. The Q peaks are then used to measure the heart rate. Note how the script could easily wrongly identify the S-peak as the Q peak.

In excessively noisy areas where it was impossible to distinguish between heart beats and noise, beats were manually generated following the linear interpolation method (see figures 4.10 and 4.11).

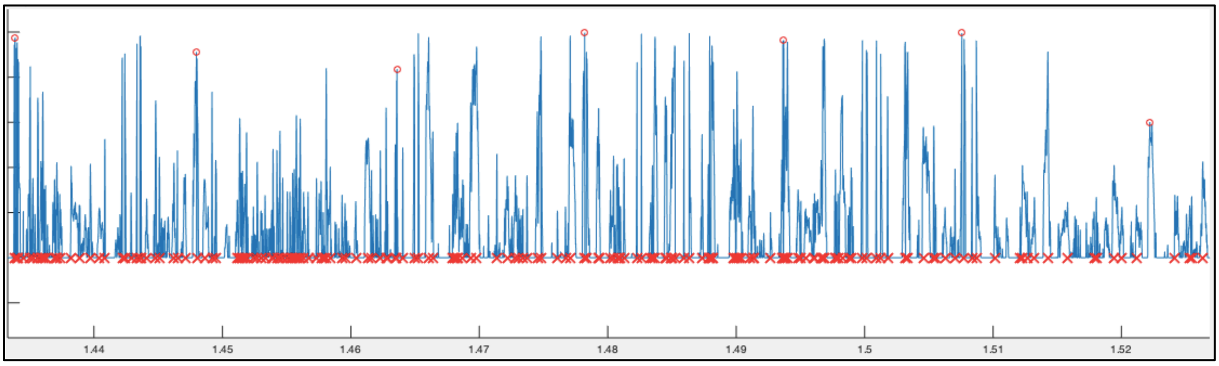

Figure 4.10: Excessive noise makes it very hard to confidently identify heart beats.

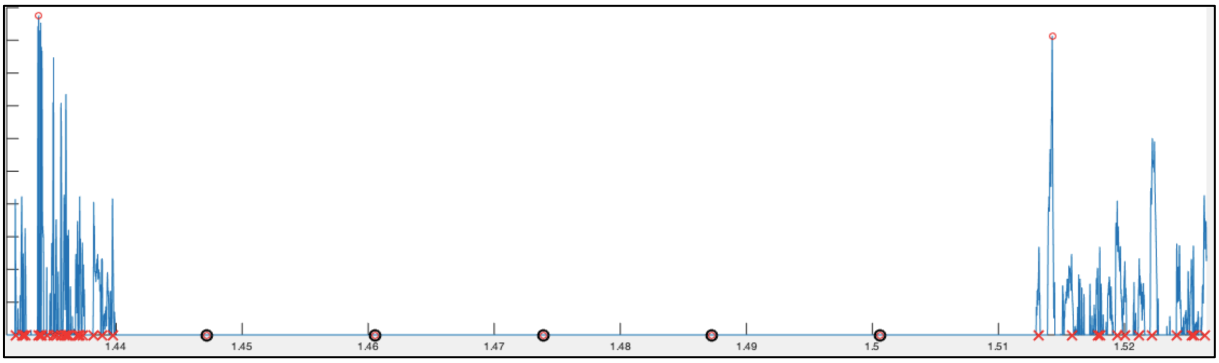

Figure 4.11: The noise is deleted and replaced by interpolated beats.

4.1.6 Peak-index

Following the finished identification of all the peaks, an index was created. This index is represented graphically with the distance between consecutive R-peaks on the Y axis and the chronological peak number on the X-axis (see figures 4.12, 4.13 and 4.14).

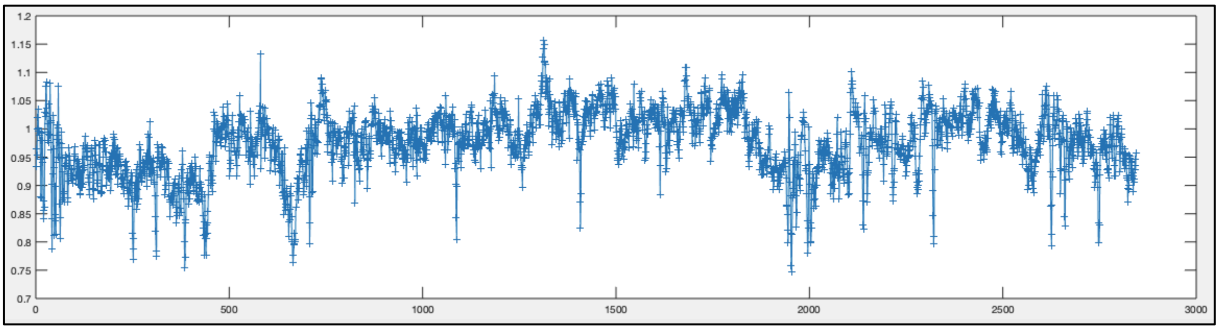

Figure 4.12: An index of all the identified R-peaks is created, represented chronologically with R to R distance on Y axis.

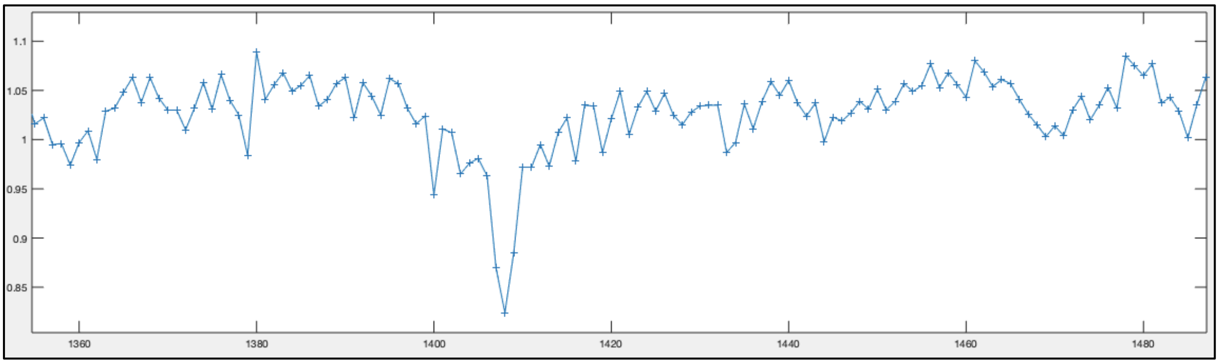

Figure 4.13: The index clearly illustrates the minute variations of the heart rate, as well as respiratory sinus arrythmia caused by respiration.

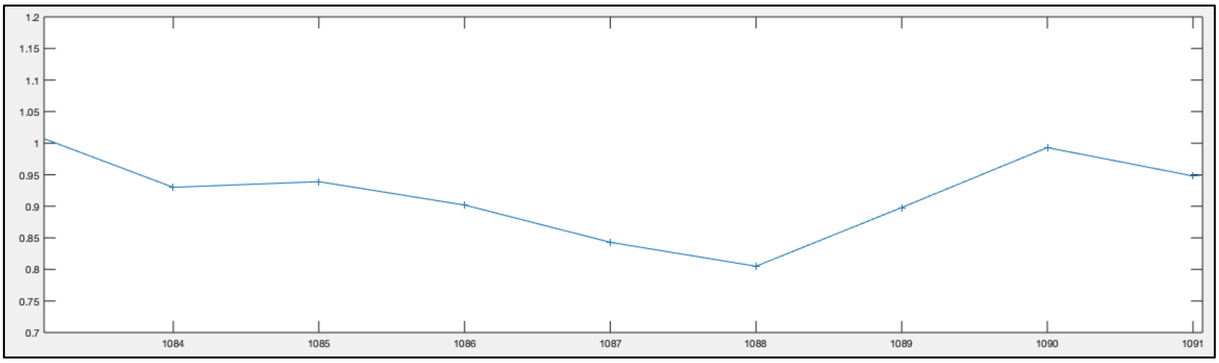

Figure 4.14: The index numbers the R peaks chronologically. Notice the incremental changes in R-R distance.

4.2 Transcribing the interviews

The 13 hours of interviews were anonymised and transcribed according to the transcription guidelines provided by Braune and Clarke (2013) and were thematically analysed in their original language before the quotes that were relevant were translated to English.

4.3 Thematic analysis

The Thematic Analysis method (TA) (Braun & Clark, 2013) was used for analysis of the collected qualitative data. Braun and Clarke suggest TA as a method appropriate for students and beginning researchers because of its flexibility and because the data it generates is "accessible to an educated wider audience" (ibid p 180). TA is also characterized as especially fitting when it is used to interpret data according to a theoretical framework. Thus, musical absorption is used as a theoretical framework for thematic analysis of the qualitative data gathered for this project. The method is separated into seven steps:

1. Transcription
2. Reading and familiarisation
3. Coding
4. Thematising
5. Reviewing themes
6. Defining and naming themes
7. Writing

TA involves the categorisation of instances that are relevant to the research question. By transcribing the interview and reading the transcription multiple times, the researcher is familiarized with the gathered data and different themes emerge. After doing this with many different sets of data, similar emerging themes are linked across the entire dataset, thus creating a basis for interpretation.

The coding process is the initial identification of meaningful instances in the data. Braun and Clarke differ between selective and complete coding and between data-derived and research-derived codes (Ibid, 231). "Complete coding" involves a search for *all* the data that is relevant to the research question in the *entire* data set. "Selective coding" on the other hand, has a narrower scope, and only looks for a *specific* kind of data while disregarding everything else. The framework of how meaningful data is notated can either be data-derived, relying solely on the participants language and concepts, or it can be researcher-derived, allowing for an implicit meaning in the instances investigated, where the concepts are derived from a relevant theoretical framework. In this thesis a "complete coding" is performed and is analysed with "researcher-derived" codes.

As the nature of the project is closely linked to phenomenology and the investigation of an experience, Interpretative phenomenological analysis (IPA) was considered as a method. However, because TA facilitates the incorporation of theoretical categorizing, it was estimated as more fitting for the project.

5. Results

5.1 Thematic analysis of the interviews

Analysis of the interviews is organised by five main themes arching over 15 more precise but overlapping subthemes. These themes derive from the codes that emerged from the transcripts and from literature on altered states of consciousness (see section 2.1).

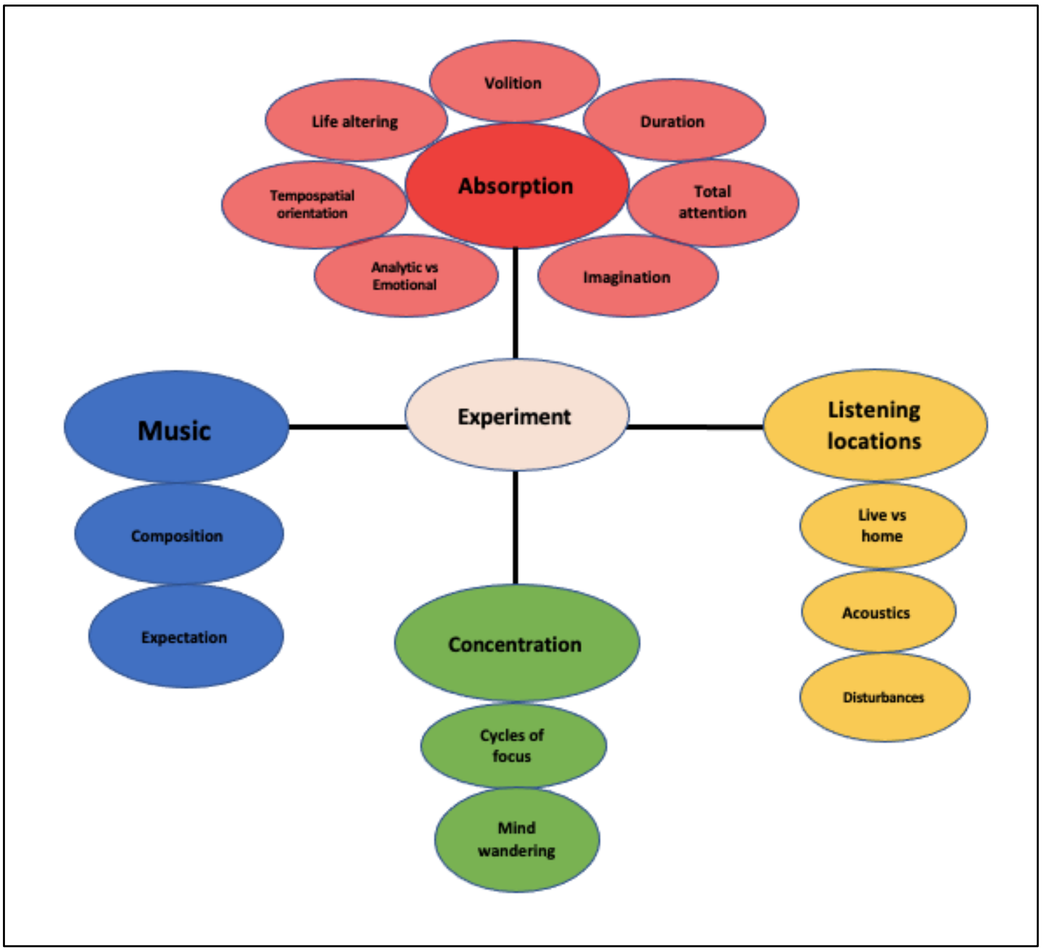

Figure 5.1: Map of thematic analysis with each colour representing main themes and its subthemes underneath

5.1.1 Absorption

5.1.1.1 Total attention

"*It is like watching a beautiful avalanche from a distance. When you look at it, time stops a little and you observe this captivating vision.* […] *Then, that is what one experiences and nothing else there and then.*" (participant nr 6: interview nr 2)

Participants described the absorbed state as involving total attention to the music where one forgets about trivial thoughts and ultimately self-awareness. Many of the participants describe a state of total attention where the music is all consuming to the point of symbiosis between the ego and the music.

"*Then there is nothing between me and the music. The music is directly available inside of me, a like I said, this is what one hopes for. To forget about oneself and go all the way into the zone where you are directly… almost feel as one with the music.*" (p4:i1)

5.1.1.2 Analytic vs Emotional

The participants often had a clear separation between an analytic and an emotional mind set when they were listening to music. Some participants felt that an extensive musical education often made it hard to escape the analytical mind set and described a yearning and sense of relief when they experienced emotional mind sets when listening to music. The analytical mind set was described as an hinderance to an otherwise "pure" and natural emotional enjoyment of the music unmediated by rational thoughts and technical evaluations. Many participants defined the emotional mind set as the main motivator for having started with music in the first place, but also for staying involved with it.

"*When I listen to symphonic or choral music or something similar, I often have, what I call a professorial, or analytic attitude, sitting with my arms crossed and "now I am going to listen and see if it is well played", even though it is classical, meaning that it's things I have heard before. But if it captivates me, if the music takes a hold of me and it is moving, then I let my shoulders down and I can participate in the music with the same mindset as an amateur or* *someone who is without a musical education. And that is a relief to me because that is the reason why I started with music.* “(p12:i1)

However, some participants seem to not dichotomize between the analytic and emotional mind set and described how both mind sets could happen at the same time or offer the same amount of enjoyment.

“When it [state absorption] happens, I try to not understand the music and just take it in and what is funny is that, then I don’t try to understand what chords or what intervals and so on, but still it is as if I take in so much more information automatically, as if it is just processed without me trying to capture it.” (p17:i1)

5.1.1.3 Volition

Being absorbed by the music seems to be involuntary and can sometimes involve quasi-physical feelings like being pulled, dragged or lifted by the music and into an altered state. However, some participants feel that volition is involved; they had to be available, give “permission” and leave their heads open before the music could enter and take a hold of them. Further, the aesthetic appeal of the music also seems to be a requirement as state absorption didn’t happen with all kinds of music or auditory stimuli.

“In the best cases I notice how the music sort of invites me to go all the way onto its premises, that it sort of manages my conscious completely to the point that I am devoted, aware […] *and it is the music that is responsible for me being completely soberly* [Norwegian: saklig] *devoted to it*.” (p15:i1).

5.1.1.4 Spatiotemporal orientation

Most participants described captivating moments with music involving a loss of time and space orientation. Further, a few participants explained how in these moments their attention excludes everything but the music itself, and that the moment is an experience of the “now”.

“*those experiences are farther in-between these days, but I have recently had some of those experiences where time and space just stop existing and it is just an experience there and* *then. Without me thinking a single word or analytic thought and just pure emotion and feeling, a really strong experience.* "(p19:1)

5.1.1.5 Duration

The duration of state absorption seems to be short in its intensity following an envelopment according to all of the participants. These moments seem to generally last between 20 seconds and one minute, with only a few participants describing moments lasting more than a minute up to five minutes. According to some participants the envelope of intensity and duration was related to the musical phrases or sections and included a stronger intensity in the beginning of the state before the concentrated attention slowly decayed.

"*I experienced deep periods that could last 1 minute or could last 5 minutes, where I at the end of period noticed "oh, I can breathe again.*"" (p12:i2)

"*so those great moments they last a very short time, we are talking about seconds, between one minute and a couple of seconds*" (p19:i2)

5.1.1.6 Imagination

A few of the participants experience vivid imaginations while they listen to music. These include visions of shapes, colours and lines that are sometimes static or moving and shapeshifting in relation to the music, but they can also be visions of natural landscapes. One participant described these imagined visions as entertaining in themselves like a game:

"It is a game to me, with dots and lines and planes of different colours, with different thickness and everything that an image can illustrate and also dynamic shapes that just float. I often have very abstract images that are just very floating… all the time and shifting colour and light." (p12:i1)

5.1.1.7 Life altering

"I remember people have been calling it a "near death experience" […]*, but I call it a "near life experience" when you get those experiences from music."* (p16:i1)

Moments of absorption seem to be life-altering as their intensity can sustain a motivation for music involvement and can even result in a life devoted to music. Some participants describe how deep musical experiences had the ability to connect them to a "core of life" and help them see life from new angles. Like a dependency on drug-induced highs, some participants seem to be hooked on feelings of intense musical enjoyment where one loses one's self completely in the music. That feeling can resonate deeply in the participants and has the ability to change the mood or change a dire outlook on life for the better. When some of the participants feel worrisome or sad, these state absorptions can help them forget everything but the music they are experiencing.

"It is where one really wishes to end up, or it is what I have been hoping for as long I can remember, to get musical experiences that are in a way that you just want to be there and want more and want to continue deeper into the music. One doesn't automatically end up there, it belongs to the exceptions. Often you are distracted, or you can't let go or enter it that way, but those times when it does it is really strong. Very important experiences." (p4:i1)

5.1.2 Concentration

5.1.2.1 Cycle of focus

Many participants considered their attention to have cyclical phases. Further, attention seems to range on an intensity scale with mind wandering on one end and total attention on the other. The participants explained that their attention shifted between going in and out of focus on the music, but also altered between emotional and analytical listening modes. Further, some participants described a sense of disappointment when their self-awareness returned after experienced absorption. Many participants felt that these cycles of attention are influenced by the quality of the music, by rumination on stressful everyday thoughts and by surrounding disturbances.

"*Often during the course of a concert it might start and I am very ready to take it* [the music] *in… it depends on what kind of music it is, but regardless… if there is some length to the piece I go in and out of concentration*."(p17:i1)

5.1.2.2 Mind wandering

Mind wandering was generally described as an unwanted negative experience. Many participants connected mind wandering to rumination on stressful everyday problems that inhibited their ability to fully devote their attention to the music. One participant likened attention to be something fleeting that needed to be captured in order to maintain enjoyment to the music, while some felt that music initiated a faster and more associative stream of thoughts. The aesthetic quality of the music was frequently linked to mind wandering and many described fleeting thoughts during music that bored them.

"During a bad concert I'll think myself away, think about things, forget that I am there and not pay attention to what is happening. I am rather wandering in my thoughts, while at a good concert I feel like I get absorbed in a way and feel that I have my feet on the ground..." (p5:i2)

Contrarily, mind wandering was also described as a positive side-effect to music that can relax the listener and inspire constructive reflections.

"It is easy for me to start thinking about other things during a concert, but I see that as something good. It is like being there without listening to the music, it is like I am not thinking about what is happening in the music. […] *The best thing is when it establishes something that makes you… it might sound corny… but it allows you to relax and get in touch with your thoughts, because we live busy lives and so on, but that's at its best. At its worst the same thing happens, but then it's because you are bored."* (p14:i2)

5.1.3 Listening situations

5.1.3.1 Live vs Home

The participants were divided in their preference of attending concerts compared to listening to recordings at home. A few participants prefer listening at home as it assures a comfortable listening position with fewer disturbances. However, participants commonly felt that live concerts afford a motivation for concentrated listening that is not easily achieved at home.

Further, many participants related how the possibility of failure involved with live concerts also provides an excitement. Live music was by many participants described as having ritualistic elements because of the shared common experience during which the audience members empathized with the performers and felt a sense of unity and nervousness that could not be experienced by themselves at home.

When concert experiences are good, they are a better than anything else, but the problem is that you are usually not undisturbed. At home you can instal yourself alone with headphones and you can make sure that you are completely undisturbed and know that it's just you and the sound, but then you lose ... When you sit and listen to CDs or stream music you lose the visual aspect of the orchestra, so you lose something, you lose the nerve, you lose the risk involved with a live situation, because it can actually go wrong." (p4:i2)

5.1.3.2 Disturbance

Many of the participants described how disturbances disrupt their attention to the music. Ringing cell phones, restless audience members or audience members leaving mid-concert were recurring disruptions to many of the participants who felt that these disturbances often could result in a loss of attention to the music and ultimately mind wandering. Many participants shared that they improved their attention to the music by closing their eyes during concerts.

"[after experienced absorption] *my attention becomes more wandering* [Norwegian: flakkende]*, my attention starts to register something strange happening in the orchestra, a movement by the conductor or tumult in the hall… stupid things. Like I wrote in the self-report, I often find that it is hard to concentrate or listen properly during a concert. Because there are a lot of things, people, a lot is going on, a lot of disturbances quite frankly."* (p19:i2)

5.1.3.3 Acoustics

Good acoustical properties seem to contribute positively to the listening experience, with many participations describing how they enjoy feeling enveloped by the music in good venues.

" *Nice speakers are good, but there is something about the acoustics when you get the sound of the room all around you"* (16:i2)

5.1.4 Experiment

The experiment was for many of the participants a hindrance to fully engage with the music and to let their minds go. The task of self-reporting posed a problem as the participants had to consciously give a signal when they experienced a loss of consciousness. Some participants felt pressure to deliver results to the experiment and felt that effortfully trying to experience effortlessness was a contradictory task. Some participants were not confident about the task and were unsure about the threshold for self-reporting.

Social expectancy also hindered many participants who felt too aware of the participant sitting next to them. These participants related how they were either paying too much attention to the quality of the music in the areas where the co-participant self-reported, or that they felt self-aware of the quality of the areas where they themself self-reported. On the other hand, some participants felt that the experiment gave them an incentive for focusing on the music, and their minds wandered less than they might have otherwise.

"I remember thinking about a few times, being aware of having these sensors on and kind of restricting my movements and… also kind of feeling a little bit of a pressure to experience something, to get into the flow. So, it's a bit like the saying "the harder you are trying to fall asleep you know, the more impossible it becomes", sort of like this struggle. "ok, ok, ok stop thinking about it, just listen to the music, forget about the stuff" and at the same time being... kind of monitoring your own reaction at the same time. So, I think that was the challenging bit, that maybe whatever happened, didn't happen as naturally or maybe so spontaneously as it otherwise would have." (p20:i2)

5.1.5. Music

In these sections, the self-reported instances are elaborated upon by the participants after hearing a recording of the concert along with timestamps from the self-reported instances.

5.1.5.1 Composition

The participants shared many preferences and instances of interest from the concert experiment. Dynamic and timbral contrasts seem to be recurring fascinations among most participants, who often self-reported after sudden contrasting changes such as timbral, dynamic or harmonic changes. The size of the orchestra was also captivating. The sound intensity of the horn section was especially satisfying and instigated attentive listening in many of the participants. Many participants also emphasized how much they enjoyed the orchestration and the timbral colours of the piece. Melodic movement and forth-spinning also engaged the attention of many of the participants, who often used visual metaphors to describe the melodic trajectories. Further, counterpoint that could be clearly perceived and followed in the different instrument groups was, according to many participants, exciting and often likened to quasi-human terms such as conversations and quarrels between the instruments.

"A lot of places there are these very sudden harmonic contrasts, shifts, where you suddenly are in a completely new place without knowing exactly what happened. I thought that was very nice and I was always captured by it in a way. I pictured that he is like a manipulator of the light and he keeps changing it to other colours. It is very fascinating when it happens so suddenly." (p17:i2)

Section V, 12:56 *"When they started playing those bright things falling down it really captures you. It is also kind of surprising and he doesn't stop doing it. It is repeated not just three times but like seven times. Those roaring brass-things are also great. And this is the Wagner-effect. Those unresolved things that never reach an ending, deep, broad strokes that just move on in the depth and never really end."* (p16:i2)

Section XIII, 25:23 *"One aspect here is quite simply the incredibility* [Norwegian: vannvittige] *of the sound* [Norwegian: klangen] *of the orchestra, that universe with all of those horns. What is it like eight horns? And those amazing string sections and how he uses the woodwinds. It is all so delicately done, there is so much space in the music."* (p19:i2)

Section XIII, 25:06 *"I think that it is maybe "the majestic" that is very high in the soundscape, so I was saturated* [Norwegian: mettet] *by that impression. "* (p6:i2)

Section XIII, 25:00. *"I think this was the contrast of the oboe having just one instrument and this sort of contrast of really having the horns… well, all the brass basically with such high intensity is one of those things that you cannot escape being affected by. "(*p20:i2)

Section XIX, 39:12: "*I self-reported then because It is amazing. It was like a real cascade and the use of that piccolo flute on top and things just rushing through the orchestra from side to side, it was very much a high point. There were numerous of those high points, but this was a place where I was really captivated."* (p6:i2)

Section XIX, 27:01: *"This is a section where there is an unbelievable and incredibly captivating intensity in the violins and with those crazy big leaps, these melodic leaps , he can send the violins up to the roof and then deep down in the same phrase, so that it becomes a very extreme expression. I would call it expressionism. And at the same time there is this polyphony there. I think it is so good that one creates… one manages to create these countermelodies that live their own life and have their own gravitation point and the combination of these lead to enormous grindings and dissonances, this again leads to this limitless major chord"* (p4:i2)

Section XX: *"When that main theme came for the last time and it lifted a little extra, that was a neck-hair place. It surprised me that I reacted in that way because it was one of those things that I knew would come or that you see coming because it is it's very simple that main theme. So, the first time you hear it, it is like a natural fact but, it is the way in which he uses it and the recognition and the instrumentation that makes it lift. And I found that to be very well done at that concert and it affected me strongly."* (p19:i2)

5.1.5.2 Anticipation and Expectation

The anticipation and fulfilled or unfulfilled expectation of the music seem to be recurring criterion for self-reported instances by many of the participants. Elongated and slowly developing sections triggered a curiosity for what is forthcoming during an unknown piece of music. Some participants described sitting on the edges of their seats during these sections as they were curious to see where the music lead. The unexpected recognition of a theme was also fulfilling for many participants. However, if the participants felt the music was predictable or they already knew the piece and therefore no longer had the ability to be surprised, the music would no longer be as exciting, reported by some participants as a negative side-effect of being professionally involved with music.

"It's clear that there is something in music about not knowing what is coming the surprise element, that something unexpected happens, that is a very important feature of music, I think. That you create expectations that are either fulfilled or unfulfilled. That game. And if you know a piece very well that element disappears because now you know "okay, they're building up to an expectation that I'm going to get fulfilled" or "now they're building up to that expectation and something else is going to happen, but I already know what that something else is", those two experiences are not the same." (p19:i2)

Section XIV, 29:33 *"Here I was thinking "stay here", keeps this unresolved vague* [norwegian: svevende] *situation. Right here I was thinking "where are we going now? We are you going?" because it's been building up and "is there nothing more happening? Is thing going to hold up?". There is a moderate suspense. "* (P14:i2)

Section XVIII, 35:55: *"The thing that is happening here is that…firstly, he [Strauss] holds the expectation…he creates an expectation by holding back… He dampens it down. Secondly, there are conflicting* [norwegian: mostritende] *things happening in different levels of the orchestra. There are these points that are very sharp and against them there are these recumbent* [norwegian: liggende] *surfaces. And there are these long lines that go their own way and are unpredictable. So, it very exciting to listen to where this is leading to. He manages to create what I call a forward-leaning situation. Where it is pointing ahead… you are not in a static picture, but one is going somewhere and there is a momentum that I find powerful to follow… you are going somewhere but you don't where you will end up. Unpredictable.* (p4:i2)

Section XXI 42:22: *"Sounds almost like a Wagner opera or something. I think it's this feeling of uncertainty, you're never quite sure where it's going. There seems to be this theme with a little bit more light in it and then this dark undertone. More harmonically and emotionally* *dark. And this feeling of it not resolving, you're not quite sure where it's going and it's kind of interesting. "(*p20:i2)

5.2 Heart Rate Variability

From the initial 20 participants, 16 participants were included in the time domain analysis. One participant had a badly connected sensor, two participants self-reported 40 times or more and were considered to have misinterpreted the task and one participant forgot to self-report. 19 participants were included in the frequency domain analysis.

5.2.1 Time domain analysis

In order to investigate whether there were differences in the participants' heart rate variability (operationalized as RMSSD, see section:2.2.3) between baseline (silence), self-reported period (target), and control period (see section 3.8.1 and figure 3.4, for an explanation of target and control periods), three paired t-tests were run. The results revealed a significant difference in HRV between the baseline and self-reported instances (*target*) $t(13) = -3.255$, $p = .006$ with a large effect size, $d = 0.84$. Interestingly the HRV during *control* was not significantly different from baseline. The difference between *target* and *control* did not quite reach statistical significance; $t(14) = -1.92$, $p = .074$; Cohen's $d = 0.48$.

Descriptive statistics show that RMSSD during the target was lower, $M = 29.16$, 95 % *CI* [22.49, 35.84], $SD = 12.52$, than RMSSD control, $M = 32.11$, 95 % *CI* [24.2, 40.02], $SD = 14.85$. RMSSD during baseline was $M = 34.78$, 95 % *CI* [25.62, 43.94], $SD = 16.55$. The distributions of all three variables are shown in figures 5.2, 5.3 and 5.4.

Because the sample size was small ($N = 16$) and the data was not perfectly normally distributed, non-parametric related-samples Wilcoxon signed rank tests were run. The results revealed a very similar pattern as the T-tests showing that there was a non-significant difference between the RMSSD-baseline and target ($Z = 107$, $p = .008$) and RMSSD-baseline and control($Z = 37$, $p = .191$) and that there was a significant difference between RMSSD-target and control, ($Z = 36$, $p = .098$).

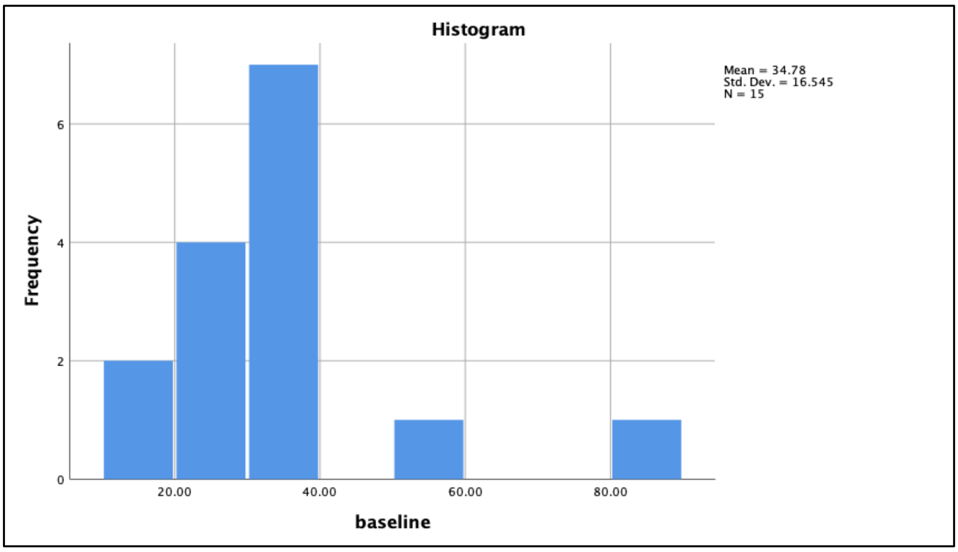

Figure 5.2: Distribution of RMSSD during baseline.

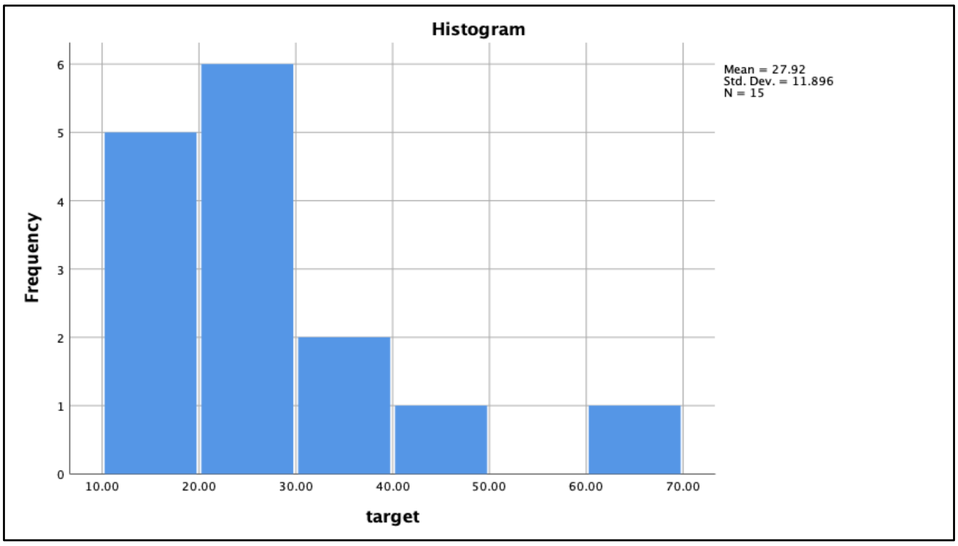

Figure 5.3: Distribution of RMSSD during target period.

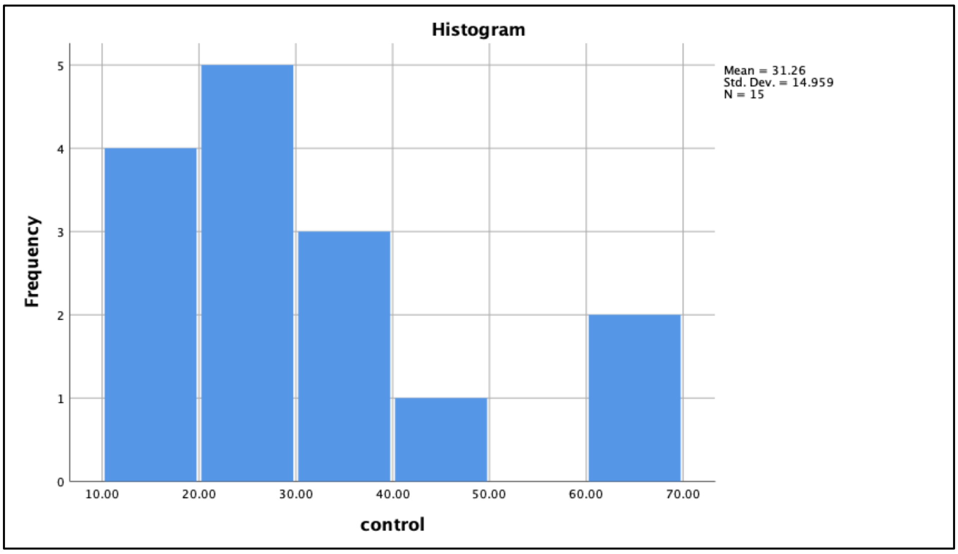

Figure 5.4: Distribution of RMSSD during control period.

Heart rate variability has been shown to decrease with age (Hilz et al., 2014; Abhishekh et al., 2013; Zhang, 2007), and thus age might introduce additional variance in the HRV data. In order to account for the effect of age, a repeated-measures analysis of covariance (ANCOVA) with *condition* (target vs. control) as the within-subjects factor and *age* as a covariate was run. The results revealed a significant effect of *condition*; $F(1,14) = 11.32$, $p = .005$, as well as a significant interaction effect of *condition* and *age;* $F(1,14) = 7.11$, $p = .018$*;* and a non-significant main effect of age $F(1,14) = .616$, $p = .446$

Source	df	F	Sig.
RMSSD Condition	1	11.32	.005
RMSSD Condition * Age	1	7.11	.018
Error	14		

Table 2 Results from ANCOVA, difference of RMSSD between conditions with age as covariate.

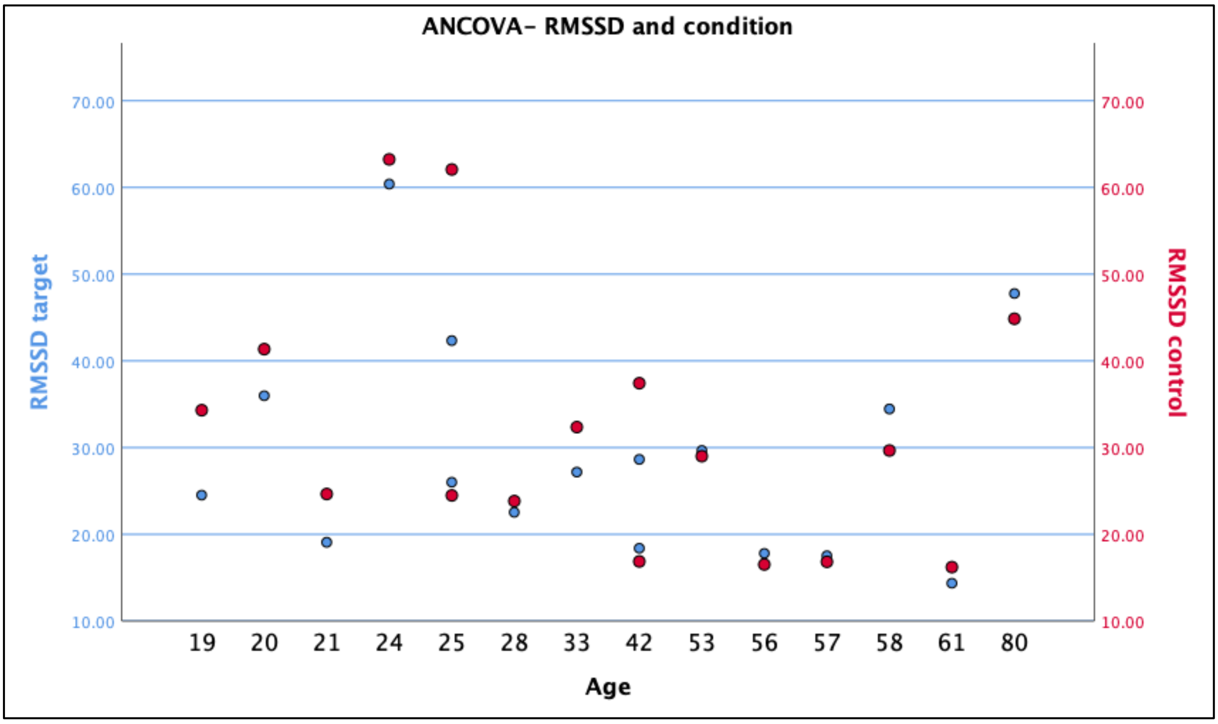

Figure 5.5: Graphical representation of RMSSD changes during target period (in blue) and control period in red) on Y-axis and age on X-axis. RMSSD is shown to slow down during target period in younger participants. Notice how difference between RMSSD during target and control is greater in younger participants and decreases with age. RMSSD is greater during target than control in two participants.

As research has found a link between openness to experience and HRV (Čukić & Bates, 2014), and since people with high trait absorption might experience more intense episodes of state absorption, an ANCOVA with the MODTAS-score as a covariate and *condition* (target vs. control) as the within-subjects factor was performed. The results did not reveal any significant main or interaction effects. The results revealed a non-significant effect of *condition*; $F(1,14) = 1.04$, $p = .325$, as well as a significant interaction effect of *condition* and *TAS-score;* $F(1,14) = .428$, $p = .524$*;* and a non-significant main effect of *TAS-score* $F(1,14) = .242$, $p = .631$

Source	df	F	Sig.
RMSSD Condition	1	1.04	.325
RMSSD Condition * TAS	1	.428	.524
Error	14		

Table 3: Results from ANCOVA, difference of RMSSD between conditions with TAS-score as covariate.

5.2.2 Frequency domain analysis

Frequency domain analysis was calculated using the mHRV toolbox (Behar et al., 2018). I used a Fast Fourier Transform (FFT) calculation with five-minute window lengths for the low frequency information and two-minute window lengths for the high frequency information according to task force guidelines (Malik, 1996) and recommendations by Laborde et al (2017). Each window calculates a mean value for the power of the defined frequency bands. The value associated to each window is represented at its ending time point as the computed value cannot be known before that point. The resulting value is therefore moved ahead half a window length (60 seconds for hf and 150 seconds for lf/hf ratio) in order to synchronize it with musical events. The hop size, indicating the temporal distance between the starting point of successive windows, is set to 10 seconds.

Because of the often-reported momentary duration of altered states two-minute and five-minute windows were deemed too long for accurate attribution of the frequency domain results to the described momentary duration of experienced state absorption (see section 2.1.1 and 5.1.1.5). Further, as there is no comparable measurement of respiration rate it is not possible to distinguish parasympathetic stimulation from respiratory sinus arrythmia (for description of RSA see section 2.2.4). Therefore, any similarities in HF components between participants may be due to synchronization of their respiration rate.

The frequency domain analysis shows that there is an apparent synchronization of lf/hf-ratio components between many participants. An increase in the lf/hf ratio suggests activation of the sympathetic nervous system. The "mirrms"-function from the MIR-toolbox (Lartillot et al., 2007) was used to calculate the dynamics and loudness. Figure 5.6 and 5.7 demonstrate how sympathetic activity closely follows the dynamics of the music in some participants.

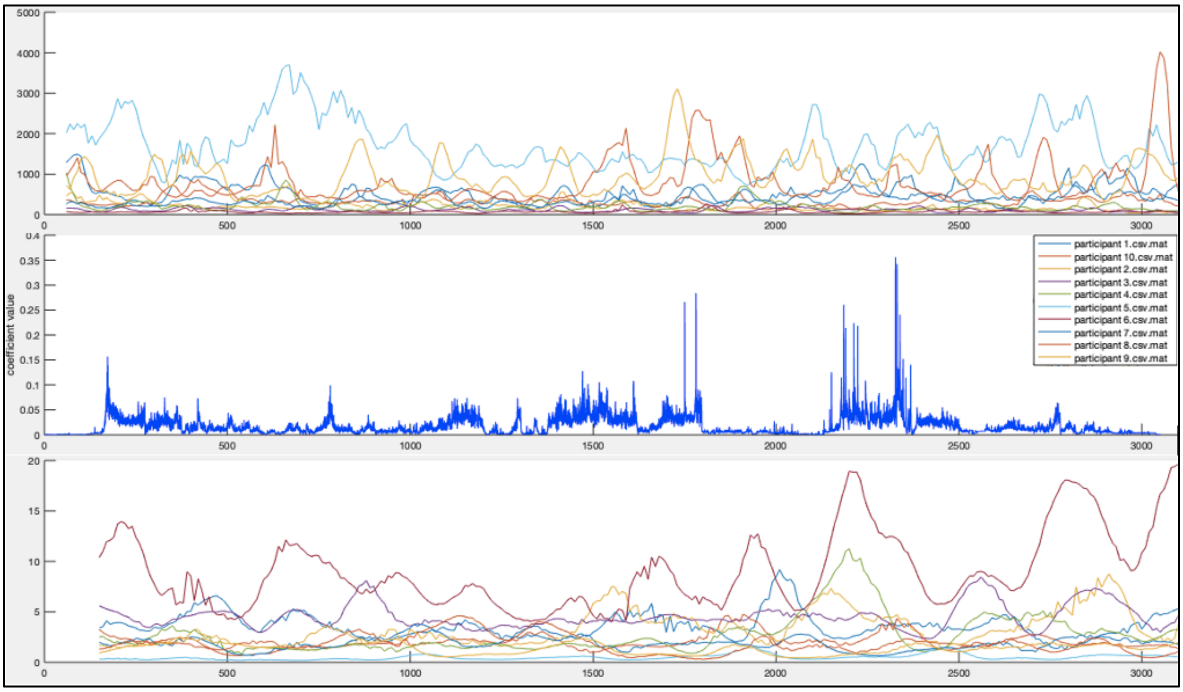

Figure 5.6 Dynamics and loudness of Wednesday concert synchronized with graphs showing HF power(above) and LF/HF ratio(below), each participant represented with a different colour.

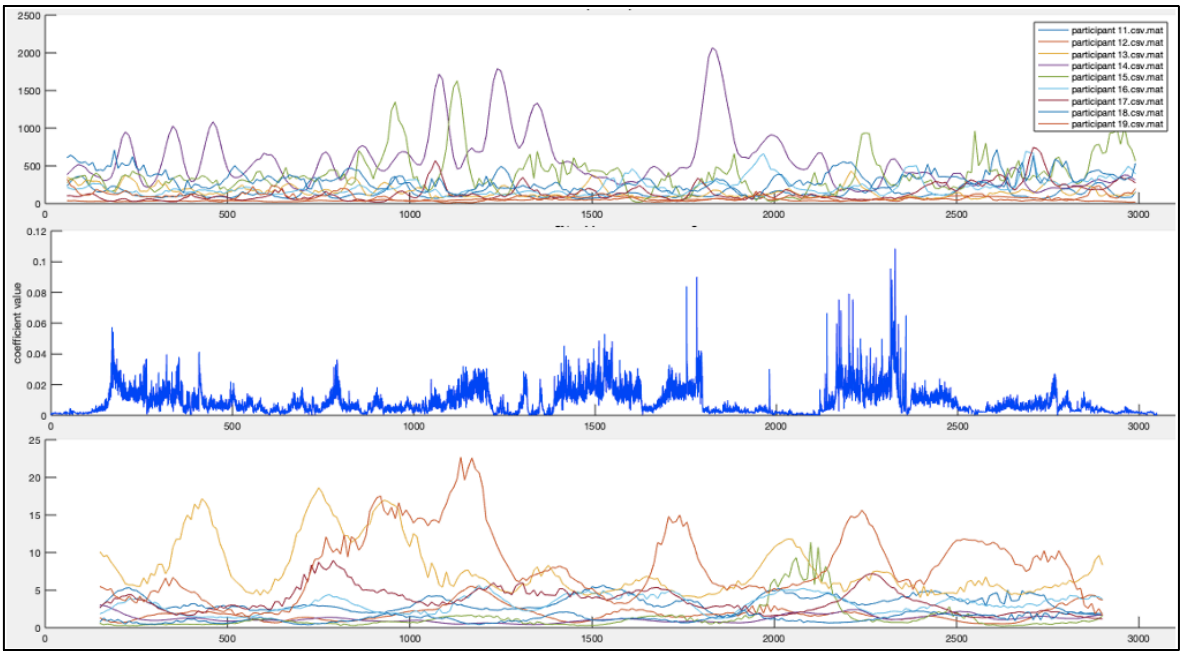

Figure 5.7 Dynamics and loudness of Thursday concert synchronized with graphs showing HF power(above) and LF/HF ratio(below), each participant represented with a different colour.

5.3 Self-reported instances of absorption

Nearly all the participants self-reported at least once, except for one who forgot to self-report, two outliers self-reported more than 40 times and were therefore omitted from the time domain analysis of HRV (See figure 19 for distribution). After removing outliers, the descriptive statistics were: $M = 3.35$ $SD = 2.55$, *Min/Max* [1, 9] $Md = 2$. 25 self-reports were given on the Wednesday performance, and 27 self-reports given on the Thursday performance, with a total of 52 self-reports for both concerts.

Figures 5.10 and 5.11 illustrate the self-reported instances coordinated with the two concerts. The two concerts respectively lasted 50:48 (Wednesday) and 50:49 (Thursday) and were thus only different by 1 second, however the duration of the different sections varied slightly between the concerts (see table 4)

Section	1	3	5	7	9	11	13	15	17	19	21	end
Time in seconds Wednesday	0	275	736	797	907	1130	1293	1797	1872	2180	2529	3040
Thursday	0	265	740	805	918	1147	1305	1796	1865	2167	2531	3042

Table 4: Timestamps of different sections demonstrating the difference of duration between sections during Wednesday and Thursday concert-experiments.

The waveform of the concert visualizes the dynamic variations of the piece. The 22 sections of the alpine journey (See description of musical material in section 3.6.1) are illustrated by changing colours. Although the actual duration of the self-reported instance varies, the self-reported instances are all visually represented by one-minute bands. Most of the self-reported instances were done in the last ten sections and included 78.8% of total self-reports (see figure 5.9). Many of the self-reported instances are consistently concentrated in the same sections as demonstrated by the vertical alignments of self-reported instances between participants. Notable sections include the 13th, 14th, 19th and 21st. Self-reports in these four sections contain 55.8% of the total self-reported instances. Sections 13 “On the summit”, 14 “Vision” and 19 “Thunder and tempest, descent” are among the more dynamic sections of the “Alpine Symphony” with sparsely instrumented quiet passages that quickly rise to become some of the loudest sections of the piece, as demonstrated by the waveforms (Section 19 contrasts the previous quiet section 18 “Calm before the storm”). These sections feature consistent similarities between the participants for both concerts (For further descriptions from the participants see thematic analysis section 5.1.5)

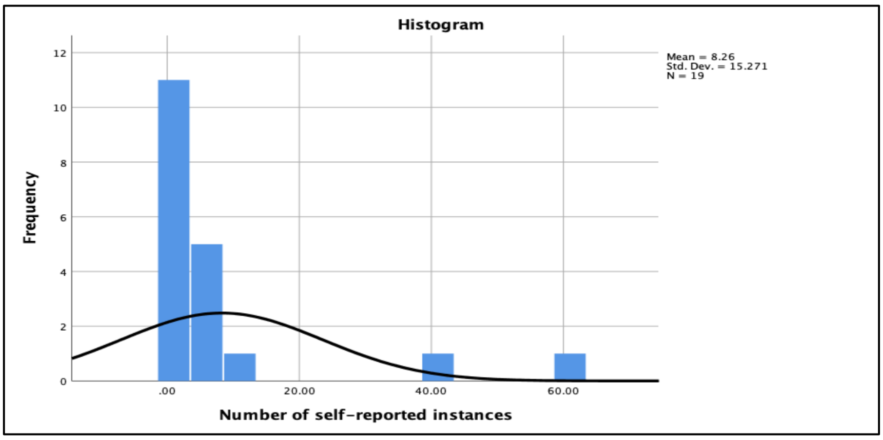

Figure 5.8: Distribution of the self-reported instances with omitted outliers included in graph.

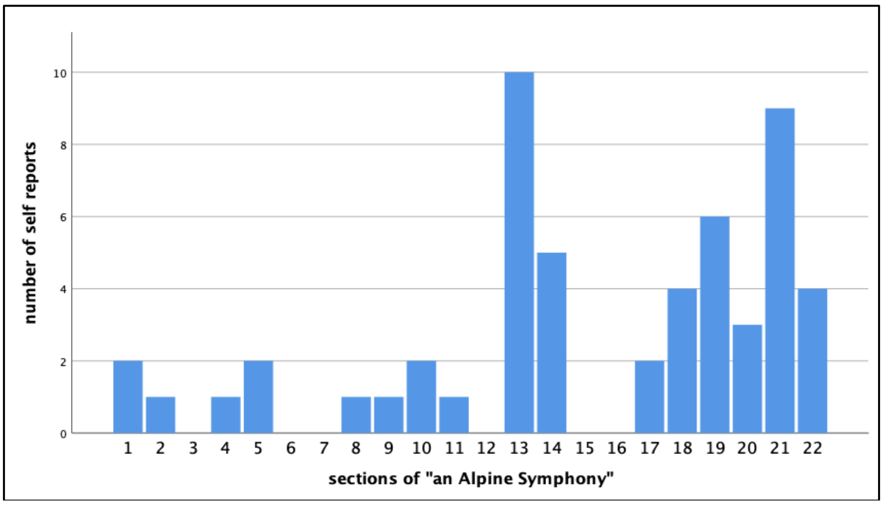

Figure 5.9: Total number of self-reported instances of absorption according to the 22 sections of "an Alpine Symphony".

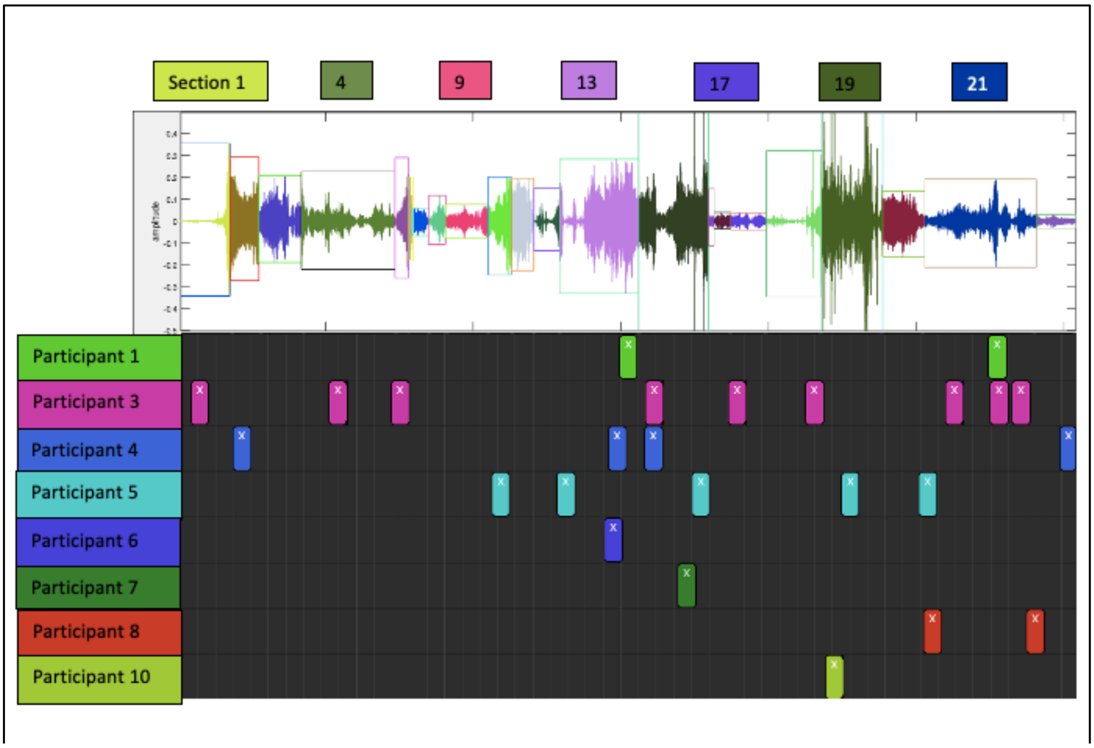

Figure 5.10: Waveform of Wednesday concert synchronized with the self-reported instances of absorption, each row representing a participant, each colour in waveform representing a musical section.

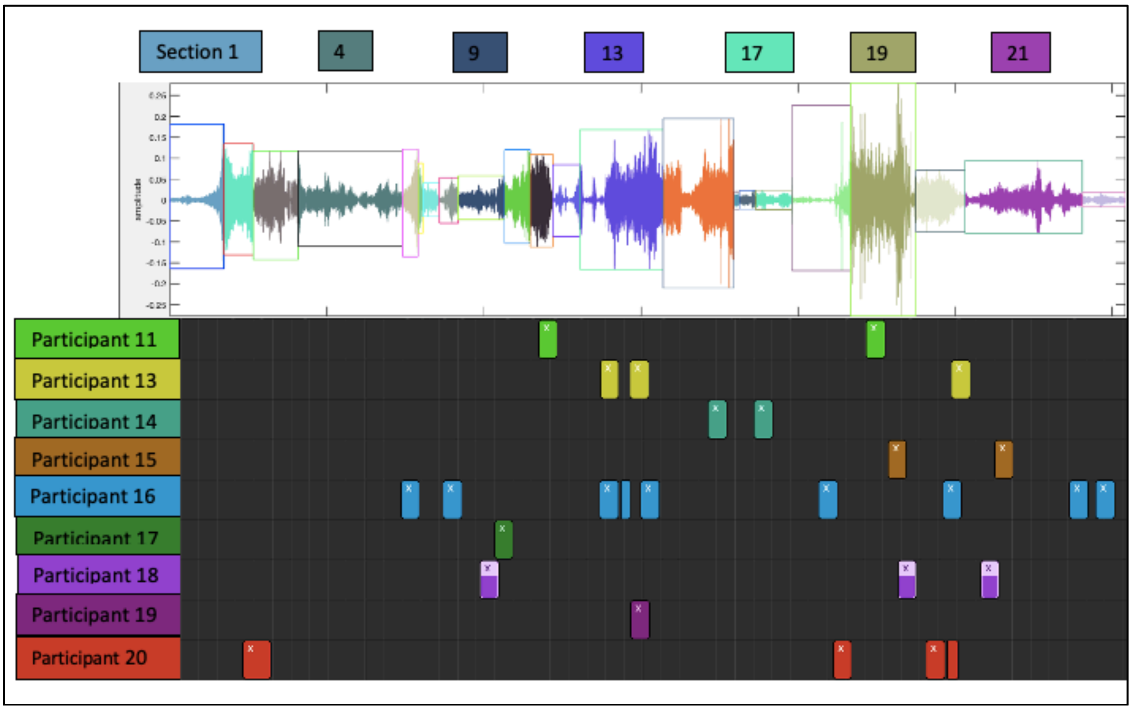

Figure 5.11: Waveform of Thursday concert synchronized with the self-reported instances of absorption, each row representing a participant, each colour in waveform representing a musical section.

5.4 Modified Tellegen Absorption Scale – questionnaire

The results from the questionnaires were varied, M = 75.90, SD = 16.71, *Md = 78.5, min/max [42, 106], 95% CI* [68.08, 83.72] (See figure *5.13)*. As the max score of the MODTAS is 136 points, a mean of 75.90 represents 56.7% of the total, and thus indicates a moderate level of trait absorption for the entire group, comparable to the mean from other studies (see section 3.10). A bivariate correlation test was performed on the MODTAS-score and the number of self-reported incidences (targets) with a Spearman's Rho in order to minimize the effect from outliers. Results of the Spearman's rho correlation indicated that there was a non-significant positive association between the trait absorption score and the number of self-reported targets, (r (17) = .184, p = .451).

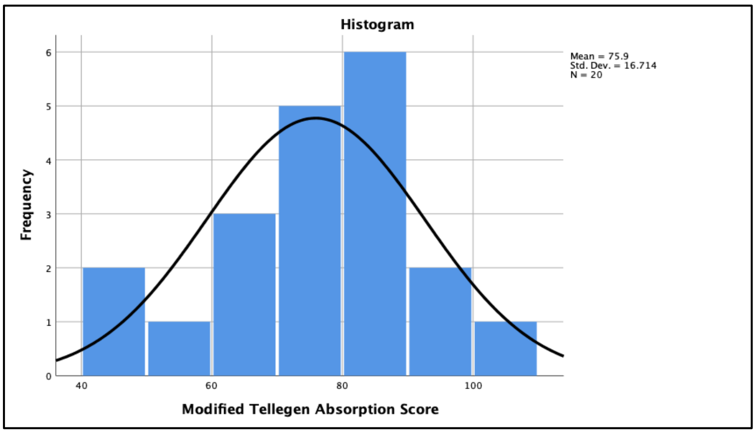

Figure 5.13: Distribution of normality of modified Tellegen absorption scale

6. Discussion

In this thesis I have shown an effect of musical absorption on heart rate variability. To my knowledge, this is the first study to empirically investigate musical absorption during listening with both qualitative and quantitative measurements in a naturalistic concert setting. The results show that there is a significant difference in heart rate variability during self-reported instances of absorption compared to a control period when age is an adjusting covariate. Further, a thematic analysis of pre- and post-concert interviews with the participants generated five major themes and 15 subthemes that largely correspond between participants and with the characteristics described in literature on altered states of consciousness. As the instances of self-reported musical absorption could be exactly located and were consistent between participants, these results suggest that certain compositional devices may act as predictors for musical absorption

An ANCOVA with age as covariate revealed a significant difference in heart rate variability (RMSSD) during self-reported absorption compared to a control period. Figure 5.5 shows that heart rate variability consistently decreased in younger participants. As the age increases the difference between conditions become smaller and sometimes even reversed as illustrated by two of the oldest participants. The high frequency components of HRV reflect stimulation of the parasympathetic nervous system and have been shown to be accurately measured by RMSSD (Penttilä et al., 2001: 1). It can therefore be assumed that the lower heart rate variability observed in younger participants during musical absorption indicates a reduction in parasympathetic stimulation. This shows that state absorption not only affects the listener psychologically, but also physiologically in accordance with the neurovisceral integration model (Thayer & Lane, 2000).

These results are consistent with previous research that shows that heart rate variability decreases with age (Hilz et al., 2014; Abhishekh et al., 2013; Zhang, 2007). These findings are also further strengthened by research on physiological measurements during flow that suggest that decreased parasympathetic activity is indicative of mental effort during experienced flow (Keller et al., 2011; DeManzano et al., 2010) and that the experience of effortlessness during absorption is a subjective sensation, as the objective measures indicate a relative mental effort. Previous research on eye-tracking during absorption has also found that absorption demands a “substantial cognitive load” (Lange et al., 2017). However, these results differ from observations from studies of HRV during meditation (Nesvold et al., 2012; Reddy & Kuntamalla, 2011) and hypnosis (Diamond et al., 2007; Boselli, 2018) that show an increase in HF components during experienced altered states. In contrast with the relaxing effects of hypnosis and meditation, my observations suggest that experienced state absorption may demand a mental effort. Herbert's findings on the differences in listening habits between older and younger generations (2011: 87) confirm the disparities found in RMSSD between age groups. Thus, older and more experienced participants may experience less mental effort during absorption than younger participants.

Baseline measurement of HRV was only significantly different from the self-reported instances of absorption and not from the control period, indicating that the heart rate variability outside periods of absorption was not different from silence. This contrasts findings of previous research (Bernardi et al., 2006) suggesting that music increases HRV compared to silence. One explanation of the discrepancy may be that the baseline was not measured according to the methods described by Quintana (2014).

Results from the frequency domain analysis (figure 5.6 and 5.7) show that sympathetic activation often closely follows the dynamics of the music in some participants. This is consistent with a study that showed that group synchronization of HRV was significantly influenced by simple loudness structures in the music (Bernardi et al., 2017). However, synchronized peaks of lf/hf ratio were also observed between participants during quieter sections, suggesting that parameters other than loudness influence the sympathetic nervous system.

As respiratory rate has been shown to influence respiratory sinus arrythmia (RSA) and respiratory rate has been shown to be influenced by tempo (Gomez & Danuser, 2007; Bernardi et al., 2006), it is not possible to distinguish an eventual entrainment to tempo from stimulation of the parasympathetic nervous system. Future research should therefore measure the tempo of the music. Furthermore, as the window length of the frequency domain analysis was two to five minutes long and represented a mean for the window, they were considered inaccurate, and were thus not used to investigate the effects from absorption.

Instances of self-reported absorption were consistent between participants who particularly reported experienced absorption during the 13th, 14th, 19th and 21st sections during both concerts (see figures 5.9, 5.10 and 5.11). Interestingly, most of the participant's self-reporting happened beyond fifteen minutes from the concert start, suggesting that it may take some time for a subject to get into a mindset that is open for absorption. This illustrates the potential importance of longer lasting musical material in future research on absorption.

The modified Tellegen absorption score did not show any significant effects on HRV. Furthermore, although showing a weak positive trend, the MODTAS was not a predictor for state-absorption or the number of self-reported instances. These results substantiate Herbert's argument; that trait absorption is not an accurate predictor for state absorption as subjects have been found to often experience state absorption despite of low TAS-scores (Herbert,2011:103).

The qualitative results of the thematic analysis show consistency with the characteristics described in the literature on altered states of consciousness. According to the interviews, state absorption was highly valued by the participants and sometimes even a main motivator for both playing and listening to music. This is consistent with research that found that experienced state absorption is an important factor when determining musical preference (Hall et al., 2016) and with research that found that trait absorption was important for emotional arousal (Kreutz et al., 2007). The reported ambivalence towards live listening situations caused by disturbances is interesting as it demonstrates the important pre-conditions that are necessary for concentrated listening, and ultimately for absorption. Many of the participants found it hard to relax enough in order to experience an effortless state of absorption during the experiment and felt monitored by the co-participant as they were seated in pairs. Further, they also reported a Hawthorne-effect (Halle & Tjora, 2014) as they were aware that their self-reported areas would be examined by the researcher. This illustrates the difficulties that are involved in scientific investigation of absorption. Future research on state absorption might experiment with other listening locations such as participants' own living rooms, in order to ensure relaxed and concentrated listening.

State absorption seems to have been stimulated by certain compositional devices that initiated an attentive and emotional listening state in the participants. The musical sections that invoked absorption seem to involve dynamic and timbral contrasts in either direction. According to the thematic analysis, a contrasting change happening in the music would catch the listeners attention. Dynamically quiet to loud or from loud to quiet, a lyrical solo instrument to a full orchestral timber, harmonic tension and release or legato to staccato playing; contrasting changes seem to focus the attention of the listener and instigate states of absorption and peak experiences. For some participants the orchestration also seemed to be pivotal for an absorbed state, as the clarity and simplicity of the single melodic lines could make them easier to follow when other melodies were woven in contrapuntally. This is also apparent from the visual representation of the instances of self-reported absorption (see figures 5.10 and 5.11). Self-reported instances of absorption were prevalent in louder sections that were preceded by quiet passages. Further, according to the participants, the volume of the music can also be influenced by the acoustical properties of the location, but also from the size of the orchestra. Many participants enjoyed the unpredictable aspects of the composition. Anticipation and expectation for the forthcoming music was exciting for the participants that felt that their curiosity and attention was sparked by musical sections where they could not foresee the development. Unfulfilled and fulfilled expectations presented similar reactions in many of the participants. On the other hand, the recognition of a theme or a motif that had previously been stated in the piece was also a source of enjoyment and stimulated the participant's attention. These absorption-inducing compositional devices parallel the results from research on musical chills and thrills (Sloboda, 1991; Panksepp, 1995) that found that physiological reactions were elicited by specific compositional means such as new or unprepared harmony or sudden dynamic or textural changes (Sloboda, 1991: 114).

Gabrielsson's (2010) characteristics of "Strong Experiences with Music" are comparable to the emerged themes from the thematic analysis. Quasi-physical reactions that suggest non-volition, mental imagery, the importance of good acoustic conditions and the sense of disappointed after a "return to reality" are recurrent in the interviews from this thesis and in the literature on SEM. The poignant and brief nature of the most intense moments described in the interviews resemble Maslow's "Peak Experience" (Maslow, 1964). On the other hand, many of the participant's characteristics of the deeply emotional mindset, where one is totally attentive, is also consistent with Tellegen's descriptions of absorption where one is fully devoted to the attentional object (Tellegen, 1974). Interestingly, participants reported both simultaneous and intermittent experienced analytic and emotional mindsets, consistent with Jamieson and Loi's hypothesis (2005). Further, some participants described an envelope of intensity where the strongest experiences are unexpected, brief but remain before they dissipate over time. This supports Vroegh's and Høffding's distinguishing between different modes and intensities of absorption. The cycle of attention described in the interviews opens up for a range of intensities of absorption where loss of spatiotemporal and ego awareness, and a purely emotional mindset represent the deepest and most intense states of absorption, reminiscent of Vroegh's concept of "zoning in". Similarly, the analytic mindset described, where attention is devoted to details in the music, resembles Vroegh's concept of "concentrators" (2019). Although mind wandering was a common phenomenon among the participants, it is interesting how the positive and meditational aspects of it were enjoyed and sought after by some. Mind wandering as instigation of thoughts and associations may be a valuable addition to the list of positive effects of music. Mind wandering should perhaps even be positively reframed as an internally focused absorption that is beneficial and relatable to the presently increased interest in mindfulness and awareness meditation in Western societies.

6.1 Future research

Future research should include other physiological parameters such as respiration rate and respiration depth in order to properly investigate frequency domain properties of HRV as it could provide interesting second by second insight into the autonomic nervous system's response to music. As musical tempo has been shown to influence HRV (Bernardi et al., 2006), it should be computed to further explore its influence on the oscillations of the autonomic nervous system.

6.2 Limitations

Musical absorption is a subjective experience that shares many characteristics with other similar altered states of consciousness. As there are no established, objective biomarkers that could verify subjectively experienced absorption, it was difficult to decide whether participants met the necessary criterion for self-reporting or if they "merely" found the music aesthetically or emotionally pleasing. The small sample size allows for a low statistical power and high risk of type I errors (incorrectly rejection of the null hypothesis). However, other studies on HRV and music have used comparably small sample sizes (Keller et al., 2011; Etzel et al., 2006; Iwanaga et al., 2005).

An additional measurement of respiration rate would have strengthened the results of frequency domain analysis and corrected for respiratory sinus arrythmia. Although respiration rate was recorded during the experiments, the FLOW-sensors by Sweetzpot that were used did not function properly. Malfunctioning Bluetooth connections caused the signal to drop out and ultimately all of the recorded respiration rates were unusable. Future research should incorporate non-obtrusive measurements of respiration rate to further explore physiological aspects of musical absorption.

7. Conclusion

In this thesis, effects of absorption on heart rate variability have been shown. Twenty participants with a music education attended a classical concert in a naturalistic setting, while unobtrusive sensors wirelessly measured heart rate. Participants were asked to self-report after experienced absorption. Pre- and post-concert interviews were conducted investigating the participants subjective experiences. Trait absorption was measured in all participants using a modified Tellegen absorption scale questionnaire and shown to not be a significant predictor for state absorption. High frequency components of HRV were shown to significantly decrease in younger participants during self-reported instances of absorption compared to a control period suggesting an increase of mental effort. Although HRV has been shown to decrease with age, a resulting increase in HRV in some older participants may suggest a difference of cognitive load during absorption between younger and older age groups.

Self-reported instances of absorption were consistent between participants and most frequently reported during the loudest sections of the music if preceded by a quiet passage. Most self-reported instances happened beyond 15 minutes, suggesting that future research on absorption should include longer lasting musical material. Five themes and 15 subthemes emerged from thematic analysis of the interviews. Thematic analysis shows consistency within participants and with characteristics described in literature on altered states of consciousness. State absorption was highly valued among participants, sometimes even a main motivator for playing or listening to music. State absorption may be predicted by certain compositional devices such as dynamic and timbral contrast in either direction and harmonic tension and release. Anticipation, expectation and unpredictable aspects of the music stimulated the participant’s attention. Mind wandering was characterized as valuable and sought after by many of the participants because of its meditational effects. Many participants felt disturbed during live concerts and preferred listening at home, future research might benefit from being conducted in more controlled locations.

List of tables

List of figures

Reference list

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