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The role of Absorption in the influence of Relaxing Music on Stress Recovery

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Abstract – English version

Music listening has been repeatedly observed to have beneficial effects on stress recovery, with relaxing music having particularly stress-reducing effects, both psychologically and physiologically. There are individual differences in the effects of music listening on stress recovery. One way to look at these differences is considering absorption, the capacity to become fully engaged or immersed in a particular activity in an effortless way. The objective of this thesis was to investigate the role of absorption in the effectiveness of music listening for stress relief. In a laboratory experiment, 45 female healthy participants (mean age M = 24.42, SD = 4.14) completed a stress inducing procedure, the Trier Social Stress Test (TSST). Afterwards, they either listened to relaxing music for thirty minutes, or sat in silence, a condition they were randomly assigned to. Heart rate variability (HRV) and subjective relaxed positive affect (RPA) were measured before and after the music, or control, intervention. It was hypothesized that the music group would exhibit greater stress recovery, compared to the control condition, and that trait absorption would moderate this effect. Further, it was hypothesized that state absorption would mediate the association between trait absorption and stress recovery. No significant effects were found of music listening on stress recovery and no moderating effect of trait absorption, as well as no mediating effect of state absorption could be reported. The results indicate that music listening during recovery from the TSST has no advantage for stress recovery. Due to the small sample size the results should be interpreted with caution. Nevertheless, this thesis contributes to the research field of music, stress and absorption and may instigate possible future research directions.

Keywords: stress recovery, relaxing music, trait and state absorption, relaxed positive affect, heart rate variability, musical enjoyment

Abstrakt – Deutschsprachige Version

Zahlreiche Forschungsergebnisse haben gezeigt, dass sich Musikhören positiv auf das Stressempfinden auswirken kann. Insbesondere entspannende Musik weist eine stressreduzierende Wirkung auf, sowohl psychologisch als auch physiologisch. Es gibt individuelle Unterschiede wie Musik wahrgenommen wird und wie sich das Musikhören auf die Stressregeneration auswirken kann. Absorption beschreibt die Fähigkeit zu vertieften Aufmerksamkeitszuständen bei der Wahrnehmung von Aspekten der inneren und äußeren Realität und scheint das Wahrnehmen von Musik zu beeinflussen. Ziel dieser Arbeit ist es, die Rolle der Absorption bei der Wirksamkeit des Musikhörens auf die Stressregeneration zu untersuchen. In dieser experimentellen Laborstudie wurden 45 gesunde weibliche Teilnehmerinnen (Durchschnittsalter M = 24,42, SE = 4.14) einem standardisierten psychosozialen Stresstest (Trier Social Stress Test, TSST). unterzogen und anschließend per Randomisierung der experimentellen Kondition (30 Minuten lang Entspannungsmusik hören) oder der Kontrollkondition (in Stille liegen) zugeteilt. Die Operationalisierung erfolgte durch die Messung von RPA, HRV vor und nach der Musik- bzw. Kontrollintervention. Es wurde angenommen, dass die Versuchsteilnehmerinnen in der Musikgruppe eine größere Stressregeneration erleben würden und dass Absorption diesen Zusammenhang moderieren würde. Entgegen den Erwartungen wurden keine signifikanten Zusammenhänge zwischen Musikhören, RPA, HRV und Absorption festgestellt. Die Ergebnisse deuten darauf hin, dass das Hören von Musik nach dem TSST keinen Vorteil für die Stresserholung hat. Aufgrund der geringen Stichprobengröße und der damit einhergehenden geringen Power sind die Ergebnisse mit Vorsicht zu interpretieren. Dennoch leistet diese Arbeit einen Beitrag im Forschungsfeld von Musikinterventionen und Stressregeneration unter Berücksichtigung von Absorption und zeigt mögliche zukünftige Forschungsrichtungen auf.

Schlagwörter: Stresserholung, Entspannungsmusik, Absorption, positiver Affekt, Entspannung, Herzratenvariabilität, Musikvergnügen

Introduction

Living in our contemporary society is marked by constant demands that can lead to the experience of stress. As stress has become so pervasive in daily life, stress-related diseases increased over the previous decade (Cullen et al., 2020). This development underscores the importance of methods that facilitate stress-recovery. Music has the capacity to evoke a wide range of emotions and is used universally across many cultures to influence one's mood and arousal, making it a powerful tool for self-regulation (Sloboda, O'Neill & Ivaldi, 2001; Thayer, Newman & McClain, 1994). From an anthropological perspective, music has been used for healing practices since humankind and even now, decades later, music continues to be used to promote health and well-being (Chanda & Levitin, 2013). Music listening may have a modulatory effect on the human stress response and stands to be a promising strategy to facilitate adequate stress recovery (DeWitte et al., 2020; Thoma et al., 2013). Instrumental music with slow pace, low arousal and positive emotional valence has been identified as relaxing music (Sandstrom & Russo, 2010; Chanda & Levitin, 2013). Listening to relaxing music can reduce subjective stress ratings, feelings of anxiety and decrease heart rate (Chanda & Levitin, 2013). On a physiological level, relaxing music can modulate heart rate variability, which is a measure of the balance of parasympathetic and sympathetic activity, pulse, blood pressure and muscle tensions, body functions that are well known to be involved in a stress response (Chapados & Levitin, 2008). Relaxing music has been shown to activate positive emotions (Torre-Luque, Diaz-Piedra & Buela-Casal, 2017). Relaxed positive affect (RPA) is a state characterized by low arousal and high positive affect (Gilbert et al., 2008). The activation of RPA is a significant predictor of stress reduction.

There are individual differences in how music is experienced and in the intensity with which music can influence emotions (Sandstrom & Russo, 2013). One approach to capture these differences is the consideration of the level of absorption. Absorption refers to the degree to which an individual becomes fully engaged or immersed in a particular experience or activity (Tellegen & Atkinson, 1974). State absorption refers to a temporary and situation-specific increase in absorption characterized by an ability of intensive and focused perceptiveness and high emotionality in response to a stimulus. The trait absorption is characterized by a natural inclination towards being fully immersed in experiences, having a propensity for self-transcendence and heightened sensitivity to stimuli (Shea, Burton & Girgis, 1993; Tellegen & Atkinson, 1974; Yaden et al., 2017). Referring to music, absorption influences the intensity and range of emotions in persons while listening to music through a "willingness to allow music to draw them into an emotional experience" (Sandstrom & Russo, 2013, p. 216). The present thesis aims to investigate the role of trait absorption in the effects of music listening on stress recovery. Individuals high in trait absorption are assumed to benefit more from music interventions through their presumed intense reaction to music. The study also aims to look at the role of state absorption, i.e. the extent to which the participants felt immersed in the musical experience, in the relationship between trait absorption and stress recovery.

Theoretical background

Stress

The experience of stress is a universal phenomenon. Yet, subjective descriptions of stress differ from person to person, as well as theoretical definitions among researchers. For example, the Australian Psychological Society (APS) describes stress as "feeling overloaded, wound-up, tense and worried, and occurs when we face a situation, we feel we can't cope with" (APS, 2017).

Homeostasis is one of the earliest concepts linked to stress. It refers to an organism's process of maintaining a dynamic equilibrium by adapting to constantly changing internal and external conditions that is vital for survival (Cannon, 1929). Thus, stress arises when an organism senses a disruption, or a threat of disruption, to homeostasis (Goldstein et al., 2015). *Stressors* are any stimuli that induce stress. The processes that underlie the stress response to return to homeostasis have been collectively termed *allostasis* (de Kloet et al., 2015). Lazarus and Cohen (1977) describe three types of stressors, namely, cataclysmic events, which are major changes that collectively affect large number of persons, such as our ongoing climate crisis and its devastating consequences for living beings and the earth, stressful life events are major incidents that individual persons are experiencing, such as a sudden death of a loved one, and that require personal adaptive responses, Lastly, daily hassles are minor everyday events that can cause frustration or irritation, such as interpersonal problems or work issues (Evans & Cohen, 2004).

The activation of a stress response by a stressor depends on a complex interaction of various factors. The response is shaped by objective aspects of the stressor, such as its duration, intensity, and frequency, as well as subjective characteristics of the individual. These include coping strategies, personal sensitivity to stress, individual perceptions of what is considered stressful, and the surrounding social environment (Nater et al., 2011).

According to the *transactional stress model* (Lazarus & Folkman, 1984), stress arises through the dynamic interplay between an individual and its environment, asserting that the stress response is significantly shaped by the person's cognitive evaluations. According to Lazarus and Folkman (1984), situations can be evaluated as positive, irrelevant or stressful. When confronted with a stressor, individuals undergo a two-step appraisal process. First, they evaluate the significance of the stressor (primary appraisal), and then they evaluate their personal available resources to cope with the stressor (secondary appraisal). After the situation is resolved, the situation is reevaluated based on new information from the environment or one's own reactions, which is called reappraisal. Simply put, stress typically occurs in situations in which the demands of the situation outweigh the resources of the individual if the situation is of importance. The appraisal processes rely on previous encounters with similar stressors. The limbic brain structures, including the hippocampus, amygdala, and prefrontal cortex, form the interface between incoming sensory information and the appraisal process (De Kloet et al., 2015).

When facing a stressor, an organism's response is to return to homeostasis, which is accompanied by psychological, physiological and behavioral responses, also described as stress responses (de Kloet et al., 2015). These systems trigger short-term adaptive behaviors (Chanda & Levitin, 2013). The *fight-or-flight response* can be seen as a prototype short-term stress response. It consists of an intense set of behavioral and physiological changes carried out in the interest of maintaining life in threatening circumstances, that include arousal, vigilance, and focused attention (Chanda & Levitin, 2013). During that response, the body activates a series of rapid automatic changes, particularly the liberation of energy stores, which includes a faster heartbeat, increased blood flow to skeletal and cardiac muscle, high blood glucose concentration, to prepare for either confronting the threat (fight) or fleeing from it (flight). The fight-or-flight response is often accompanied by feelings of anxiety, manifesting in an anticipation of harm, and fear, manifesting in an aroused state (Lovallo, 2016). Experiencing anxiety and negative affect in response to a stressor is thought to prompt behaviors aimed at reducing these unpleasant states (Adiasto et al., 2022). In fact, state anxiety has been defined as an emotional response to an individual’s perception of stressful stimuli and operationalized as one of the psychological stress-related outcomes (DeWitte et al., 2020). Another primary characteristic of the fight-or-flight situation is an individual's thinking of limited control over the outcome (Lovallo, 2016).

Physiology of stress

What happens in our bodies when we experience acute stress? The stress system has two modes of operation. In the following, I present the two main pathways involved in the physiological stress response, that work together. The fast mode works through the autonomic nervous system (ANS), which is an extensive network of interconnected neurons that are widely distributed throughout the body. The slower pathway works through the hypothalamic pituitary adrenocortical (HPA) axis.

The autonomic nervous system (ANS)

The sympathetic-adrenomedullary system (SAM) is a component of the sympathetic division of the ANS. The ANS is separated into the sympathetic and parasympathetic branch. Autonomic functions are usually carried out automatically, without conscious, voluntary control (Baer et al., 2017). During a stress response, the ANS suppresses parasympathetic activity and promotes sympathetic activity. When we are confronted with a stressor, the ANS immediately triggers the activation of the SAM system (Gunnar & Quevedo, 2007). This happens as the hypothalamus and brainstem send activation signals through the spinal cord, which in turn activates the adrenal medulla, causing its cells to release stored catecholamines, predominantly epinephrine, into the circulation. Increased levels of circulating epinephrine facilitate rapid mobilization of metabolic resources, as they increase heart rate and blood pressure, trigger the release of fuel stores from adipose tissue and the liver, and enhance skeletal muscle strength. These changes ensure blood supply to the brain and muscles, facilitating the body to prepare the body for fight-or-flight and ensuring an optimal short-termed stress reaction (Lovallo, 2016; Turner et al., 2020).

The hypothalamic-pituitary-adrenocortical-axis (HPA-axis)

The limbic HPA axis is another key element of the physiological stress response. It works as the slower mode that promotes adaptation and recovery (DeKloet et al., 2005). When confronted with a stressor, the HPA-axis is activated, initiating a series of events. It starts with cells in the paraventricular nuclei of the hypothalamus secreting corticotropin-releasing hormones (CRH) and arginine vasopressin (AVP) into the pituitary gland. These hormones then stimulate the release of adrenocorticotropic hormone (ACTH) (Gunnar &

Quevedo, 2007). ACTH interacts with receptors on the cortex of the adrenal gland to stimulate the production and release of glucocorticoid receptors.

One of the most common glucocorticoids (GC) is *cortisol*, a stress hormone. Cortisol can act directly on hypothalamic neurons, as well as on other neurons elsewhere in the brain. Corticosteroids operate in both stress-system modes through mineralocorticoid and glucocorticoid receptors (MRs and GRs, respectively), which are co-expressed abundantly in the neurons of limbic structures (DeKloet et al., 2005). MRs play a role in the appraisal process and the onset of the stress response. GRs, which are only activated by large amounts of corticosteroid, help to terminate stress reactions, mobilize the necessary energy resources required for this purpose and facilitate recovery. Additionally, GRs promote memory storage in preparation for future events. Therefore, the two stress systems form interacting signaling networks that underlie adaptive processes ranging from the appraisal of an unfamiliar stimulus to memory storage and retrieval (DeKloet et al., 2005). Cortisol levels can be measured in blood or saliva, and they begin to rise gradually within a few minutes (typically less than 10 minutes) after the onset of a stressor, reaching peak concentrations 10 to 30 minutes after the stress ends. The stress response starts to wind down when cortisol levels peak, as this activates low-affinity corticosteroid receptors. Cortisol binding to these receptors inhibits further autonomic activation (DeKloet et al., 2005).

As mentioned above, the costs imposed by frequent or prolonged stress responses can lead to an accumulation of physiological strains, described as *allostatic load*. Both chronically low and high levels of GCs are associated with nonoptimal adaptation. In contrast, moderate (or controlled elevations) are associated with physical and behavioral health (Gunnar & Quevedo, 2007). Although reliably detected in groups of healthy individuals, the cortisol response to acute psychosocial stress shows considerable variation between individuals (Foley & Kirschbaum, 2010). These variations can be partly explained by demographic, biological and psychological variables (Foley & Kirschbaum, 2010).

Stress recovery

Effective coping implies that the stress response is activated rapidly when it is needed and is efficiently terminated afterwards (de Kloet et al., 2005). Thus, the adaptive nature of the stress response is characterized by its short duration, swiftly followed by a recovery phase upon the cessation of the stressor. During this interval, ANS- and HPAA-mediated changes that have occurred in response to a stressor revert to pre-stress baselines (Adiasto et al., 2022). There is currently no unified operational definition of stress recovery (Song et al., 2023).

Hence, stress recovery may be conceptualized as the process of unwinding that is opposite to the neuroendocrine, physiological, and psychological activation that occurs during the stress response. It is a process that helps the individual to recover from the loss of equilibrium or balance, to regain homeostasis, and to readjust to the environment after the exposure to stress, that usually involves the action of the parasympathetic system and/or the inhibition of the sympathetic activity (Thayer & Lane, 2009). The restoration of parasympathetic activity is marked by a slowing down of heart rate and respiration rate, increase of heart rate variability, lower blood pressure, decrease of muscle tension and relaxation of muscles that were tensed during the stress response. At a psychological level, stress recovery typically shows in a reduction of unpleasant states and emotions, as demonstrated by lower ratings of self-reported stress, anxiety and negative affect in healthy individuals after a stress test (Adiasto et al., 2022). Similarly, higher ratings of relaxation and positive affect accompany stress recovery (Adiasto et al., 2022). As the emotional experience of stress is characterized by high arousal and negative affect (NA), one of the core functions of stress recovery is mood regulation, aiming to increase positive emotions (Radstaak et al., 2014).

In the following, I will present two markers, heart rate variability and relaxed positive affect, which are often used to operationalize certain aspects of stress recovery, and then go further into detail how they might accompany the process of stress recovery.

Heart rate variability (HRV)

The human heart, which is about the size of a closed fist, beats approximately 100.000 times per day (Shaffer et al., 2014). Its main functions are to receive blood from the body's tissues and pump it to the lungs, as well as to collect blood from lungs and circulate it throughout the body's tissues (Weinhaus & Roberts, 2005). Heart rate (HR) refers to the number of heart contractions per minute and is measured in milliseconds (ms). A complex and steadily changing heart rate indicates healthy regulatory systems that are capable of effective adaptation to sudden psychological and environmental challenges (Pham et al., 2021). *Heart rate variability (HRV)* refers to the change in time intervals between consecutive heartbeats, known as Interbeat Intervals (IBI) (Shaffer, McCraty & Zerr, 2014). The behavior of the heartbeat is irregular, and these fluctuations result from complex, non-linear interactions between a number of different physiological systems, about which I will briefly give an overview in the following (Reyes Del Paso et al., 2013).

The functioning of the heart and heart rate is significantly influenced by the autonomic nervous system and is dually innervated by its sympathetic or parasympathetic activity. Their interaction is crucial for our survival, and the sympathetic nervous system (SNS) and parasympathetic nervous system (PNS) alternate between each other to maintain regulatory balance in physiological autonomic function (Pham et al., 2021).

The muscular heart is composed of two atria (right and left atrium) and two ventricles. The ventricles pump blood from the heart into the lungs and arteries. Deoxygenated blood enters the right atrium and is then pumped to the lungs for waste removal and oxygen replacement. Subsequently, oxygenated blood is pumped back into the arterial system through the left ventricle (Shaffer et al., 2014). The heart contains autorhythmic cells that function as pacemakers. The sinoatrial (SA) and atrioventricular (AV) nodes are the two internal pacemakers and are primarily responsible for initiating the heartbeat. These nodes receive input from autorhythmic cells within the heart, which spontaneously generate pacemaker potentials, leading to the initiation of the heartbeat. In a healthy heart, the cardiac cycle begins as the SA node initiates depolarization in its autorhythmic fibers.

The electrocardiogram (ECG) records the action of this electrical conduction system, allows the measurement of the heart's electrical conduction and contraction, providing a visual representation of the heart rate. Heartbeat evoked potentials (HEPs) are segments of electroencephalogram (EEG) that align with the heartbeat. R-to-R peaks refer to the time intervals between successive R-waves, which are the sharp, upward spikes of an ECG, representing the contraction of the heart's ventricle (Shaffer et al., 2014). The longer the R-to-R interval is, the slower the heartbeat (Kim, 2018). Hertz (Hz) is the unit of sound frequency equivalent to cycles per second (Bear et al., 2017).

In a healthy individual, there is a dynamic relative balance between the SNS and the PNS. At rest and in relaxing states, PNS activity predominates, resulting in an average HR of 75 beats per minute (bpm) (Opthof, 2000). The SNS predominates during elevated activity and stressful states, its stimulation results in an increase in HR (Pham et al., 2021). Thus, relative sympathetic increases cause the IBI to become shorter and relative parasympathetic increases cause the IBI to become longer (Thayer et al., 2012). The vagus nerves are the primary nerves for the parasympathetic system, connecting to key areas such as to the SA node, AV node, and atrial cardiac muscle. Increased activity in these nerves results in the release of acetylcholine, which binds to muscarinic receptors. This binding, in turn, causes a decrease in the rate of spontaneous depolarization in both the SA and AV nodes, leading to a reduction in heart rate (Shaffer et al., 2014). Simply put, the HR estimated at any given time represents the combined impact of the neural output of the parasympathetic vagus nerve, which slows HR, and the sympathetic nerves, which accelerate HR.

HRV is considered a key indicator of neurocardiac functioning, reflecting the interactions between the heart and the brain, as well as the dynamics of the ANS (Shaffer et al., 2014). A high HRV signifies a more flexible and adaptive cardiovascular system, whereas low HRV suggests a less flexible, more rigid system. HRV is unevenly distributed across various frequency bands, with high and low frequency variations corresponding to different neurophysiological mechanisms. High HRV indicates heightened parasympathetic control of the nervous system (Heiss et al., 2020).

Regarding stress recovery, HRV plays a crucial role in it by reflecting the body’s ability to adapt and return to homeostasis after experiencing stress. In fact, in psychological research, HRV is often used as an indicator of healthy stress recovery, or, in contrast, abnormal HRV as a biobehavioral marker of diverse psychopathologies.

For example, in a study by Weber et al. (2010) that investigated stress response during a mental stress test and afterwards stress recovery in healthy men, HRV significantly decreased under stress and increased with recovery. In another study that investigated the effect of relaxation on HRV, including a nature-based movie intervention aiming to induce relaxation, a link has been found between high HRV and subjective measures of relaxation and well-being during and after the intervention (Benz et al., 2022). Another study that looked at emotional responses to stress demonstrated that individuals with higher HRV experienced more positive moods compared to individuals with lower HRV (Geisler et al., 2010). An association between HRV and subjective well-being has been found in a clinical setting, supported by an inverse relationship between perceived emotional stress and HRV (Dishman et al., 2000). In contrast, a diminished heart rate variability is indicative of a consistently steady heart rate. Additionally, low HRV is linked to compromised regulatory and homeostatic functions of the autonomic nervous system, diminishing the body's capacity to effectively manage both internal and external stressors (Kim et al., 2017).

In fact, meta-analyses in clinical research show that abnormally low resting HRV is related to anxiety disorders (Chalmers et al., 2014), major depressive disorders (Kemp et al., 2010), as well as schizophrenia (Clamor et al., 2016). On the other hand, highly elevated HRV is often seen in persons with eating-related disorders (Mazurak, 2011). These findings might give a link to the notion that there is an "ideal range" of HRV that predicts healthy functioning (Heiss et al., 2020).

Relaxed positive affect (RPA)

When talking about the experience of stress and its impact on our bodies, one must also highlight the interplay of emotions and affect in this process. In the field of positive psychology and (stress) resilience, *positive affect (PA)* is often considered as a boosting factor in enhancing resilience and psychological well-being (Seligman & Csikszentmihalyi, 2000). *Affect* encompasses consciously accessible feelings. PA refers specifically to the extent to which an individual subjectively experiences positive moods such as joy, interest, and alertness (Clark, Watson & Leeka, 1989). The experience of emotions is typically brief, while affect is considered more long-lasting than emotions (Fredrickson, 2001). PA reflects the level of pleasurable engagement one has with their environment. This engagement through positive feelings can significantly contribute to an individual's ability to cope with stress and maintain overall well-being.

Positive emotions are shown to positively influence attention, cognition, action as well as physical, intellectual and social resources (Fredrickson & Joiner, 2002). Positive emotions can potentially enhance individual resilience (Aspinwall, 1998). The broaden-and-build theory by Fredrickson suggests that positive emotions help people broaden their thought-action repertoires, encouraging them to discover novel lines of thought or action, build their resources, and help cope with (future) adversities (Fredrickson, 1998, 2001). Consequently, this broadening can initiate upward spirals towards increasing emotional well-being and offers not only immediate advantages but also indirect and lasting adaptive benefits. By expanding individuals' perspectives, positive emotions help build lasting personal resources, which become valuable assets for handling future challenges. In the context of stress, positive affect has been shown to alleviate stress and its impact on the body by reducing stress reactivity and accelerating stress recovery (Pressman & Cohen, 2005). PA also seems to facilitate cardiovascular recovery (Radstaak et al., 2014).

According to the circumplex model of emotions, affect can be organized along two continua: positive versus negative valence, and high versus low arousal or activation (Russell, 1980). In fact, neuroscientists have proposed that there may be different types of positive affect. One is linked to activation, drive and seeking, enabling approach to reward and incentives. This system may be dopaminergic mediated and is arousing and activating with the function of driving behavior, anticipating reward and success. It is also associated with the SNS. In contrast, another PA system, the contentment/soothing system, is behaviorally de-activating, and is turned on after a goal has been obtained, inducing feelings of soothing and contentment. This system is believed to be opiate/oxytocin mediated and can be described as an affect-regulation system, including different affects such as contentment, feelings of safe-ness, well-being and social connectedness. It is associated with the PNS (Depue & Morrone-Strupinsky, 2005).

In an aim to develop a scale that focuses on the two types of positive affect regulation systems (types of positive affect scales), Gilbert et al. (2008) found not only two but three underlying factors of PA. These are activated positive affect (APA; energetic, lively, adven-turous, active, enthusiastic, dynamic, excited, eager) *relaxed positive affect* (RPA; relaxed peaceful, calm, tranquil, laid back, serene) and safeness and contentment positive affect (safe, content, secure, warm). RPA captures PA in the absence of activity. Gilbert et al. (2008) explored positive affects in relation to the psychopathology variables of depression, anxiety and stress. All three forms of PA were significantly negatively related to depression. Safe/content PA and RPA were significant predictors of reduced stress. McManus, Siegel and Nakamura (2018) assessed the unique contribution of low arousal positive affect (LAPA) in predicting variance in measures of well-being and mental health. To measure PA, they used the types of positive affect scales (Gilbert et al., 2008). LAPA significantly predicted lower levels of stress. Thus, based on the findings, one can assume that RPA is attributed to relaxa-tion in particular, making it an interesting measure for stress recovery.

Music interventions

The use of music to improve health and well-being has a long history (Yehuda, 2011). Music is associated with a broad range of positive outcomes in the domains of health and well-being. As the use of music is an easy, cost-effective and non-invasive way to influence well-being and stands to be a promising tool for stress recovery, research into music interven-tions has gained increasing attention (Adiasto et al., 2023, de Witte et al., 2020). Listening to music is a commonly used tool for self-regulation (Thayer, Newman & McClain, 1994). Individuals intentionally and non-intentionally use music to change, create, maintain, enhance or release emotions and moods on a daily basis (Juslin & Västjäll, 2008; Schramm, 2005). One of the widely studied effects of music is its ability to reduce stress, modulate arousal levels, facilitate recovery, and affect several physiological health-related parameters, that I will discuss in more detail below (Chanda & Levitin, 2013; Koelsch et al., 2015). In fact, relaxation is one of the main reasons why individuals listen to music (van Goethem & Sloboda, 2011). Also, Greasley and Lamont (2011) found that listening to music for the purpose of pleasure and relaxation were the most frequent reasons that participants reported in their daily life. There is a growing number of evidence demonstrating stress-reducing effects of music listening in a variety of settings and populations, though there are also inconsistent findings (Adiasto et al., 2022; Chanda & Levitin, 2013). For example, music interventions are frequently used in clinical settings to reduce anxiety, pain, and stress in patients undergoing surgical procedures (Nilsson, 2008).

Before I go into detail about the impacts of music on health and well-being, one should clarify and take into account the different methodological parameters of (using) music in psychological research. Music interventions can be regarded as purposeful musical exercises or methods in which music listening, music making, or singing is central (de Witte et al., 2020). Music interventions are found to vary among different factors, such as type of intervention (passive listening vs active performance), type of music (stimulating vs relaxing), locus of control (experimenter-selected vs participant-selected) and social context (individual vs group activity) (Chanda & Levitin, 2013). In both literature and practice, music interventions offered by a trained music therapist are distinguished from music interventions offered by other healthcare professionals or without any support (de Witte et al., 2020, Magee et al., 2017).

Music listening simply involves the mere listening to a particular musical piece and is the most commonly used music intervention (deWitte et al., 2020). Studies have repeatedly demonstrated beneficial effects of music listening for stress and health. De la Motte-Haber (2017) showed that exposure to background music can affect mood and relaxation. Additionally, effects of music listening on the stress response have been studied both in experimental settings and in everyday life (Thoma et al., 2013; Linneman et al., 2015). Several stress-related outcomes, subjective and physiological parameters, seem to be affected by music listening. Research suggests that music listening has the potential to reduce stress, both subjectively and physiologically. Yet, not every kind of music has been attributed to have beneficial effects on the stress response (Yehuda, 2011). For example, in a study by Labbé et al. (2007), stress was induced and afterwards, participants listened to different kinds of music. Listening to heavy metal, compared to classical music, self-selected relaxing music or sitting in silence, increased feelings of stress after stress induction.

Research has specifically looked onto characteristics of *relaxing music* and identified certain musical characteristics. Music with fluid melodic movement, pleasing harmonies and regular rhythm without sudden changes has been demonstrated to induce relaxation (Yehuda, 2011). Regarding tempo, slow pace (about 60 to 80 beats per minute) seems to be relaxing (de Witte et al., 2020). The combination of low arousal and high positive emotional valence has been found to have a relaxing effect (Chanda & Levitin, 2013; Sandstrom & Russo, 2010). Regarding instrumental or vocal music, research has shown mixed results as both comforting and distracting effects have been demonstrated for lyrics in music (de Witte et al., 2020). Regarding the use of music in experimental settings, self-selected rather than prescribed music may be more relaxing as it allows the person more control (Labbé et al., 2007).

In the following sections, I will give an overview of the research findings about the effects of music listening on certain physiological and psychological components of stress.

Music listening and the physiological stress response

Effects of music listening have been investigated for different physiological stress parameters in clinical contexts and in daily life. These include indicators related to ANS and HPA-axis activity, such as cortisol, heart rate (variability) and blood pressure (Adiasto et al., 2022). Music has been shown to decrease physiological and psychological stress-related parameters in different clinical settings, such as in mental health care, medical settings, and surgery, in clinical and healthy individuals (Chanda & Levitin, 2013; de Witte et al., 2022; Wong et al., 2021). Music listening has been associated with a down-regulation of the HPA axis, as shown via reductions in the concentrations of cortisol in various experimental and clinical contexts (deWitte et al., 2022). Furthermore, alterations of the ANS activity have also been observed as shown with decreases of heart rate and blood pressure (de Witte et al., 2022).

For example, i**n clinical contexts,** in a meta-analysis by Chanda & Levitin (2013), the exposure to experimenter-selected relaxing music postoperatively has been shown to lead to a decrease in cortisol in patients undergoing heart surgery, as well as a reduction in heart rate, blood pressure, and respiration rate (Nilsson, 2009). In a systematic review, Fancourt, Ockelford and Belai (2014) investigated a range of effects of music, including on physiological and endocrinological stress responses. In many studies, relaxing music was shown to decrease blood pressure, heart rate and respiration rate. Music also reduced levels of cortisol in both active participation in music and listening to recorded music. In an experimental study, Fu et al. (2019) investigated the effects of perioperative soft and relaxing music in subjects undergoing different surgical procedures, ranging from minor to major interventions. Results showed that listening to that music was also associated with significantly lower cortisol levels postoperatively in the music groups compared to non-music control conditions.

Experimental studies using stress inducing procedures have demonstrated that music listening appears to reduce the cortisol response, lead to a faster cortisol recovery (Khalfa et al., 2003) and modulate heart rate (Labbé et al., 2007). For example, Sandstrom and Russo (2010) found that music high in valence and low in arousal positively affected recovery of heart rate and skin conductance levels after a stressor in healthy subjects. In another experimental study, Labbé et al. (2007) investigated the effects of listening to classical music, self-selected relaxing music and heavy metal music after exposure to a stressor on anxiety, sympathetic arousal and relaxation. Results showed that individuals who were exposed to classical music or self-selected music demonstrated significant reductions in anxiety, increase in feelings of relaxation and greater reductions in heart rate after being stressed than the heavy metal and silence control condition. Also, de la Torre-Luque et al. (2017) demonstrated that persons who listened to preferred relaxing music after stress exposure showed higher parasympathetic activity in the stress recovery phase compared to a silence-control condition.

In daily life, listening to music has been shown to induce feelings of calmness and relaxation (Juslin et al., 2008). Linneman et al. (2015) investigated the potential stress-reducing effect of music listening in everyday life in healthy subjects using both subjective and objective indicators of stress. Results suggested that mere music listening led to lower subjective stress levels, but there was no association with cortisol levels, which were used as a physiological stress parameter. When music listening was used for the purpose of relaxation, it was associated with a reduction in stress independent of stress intensity (Linneman et al., 2015).

However, some studies failed to find an effect of music on stress-related physiological changes or show a discrepancy between subjective and physiological measures of stress. Chlan et al. (2013) found that music listening had no effect on cortisol levels in mechanically ventilated patients. However, Han et al. (2010) reported that music listening positively influenced parameters of the autonomic nervous system in similar patients. Numerous studies, whether involving patients or healthy participants, have shown inconsistent results when comparing self-reported stress to physiological stress markers. For example, Thoma et al. (2013) found that relaxing music was less effective at reducing cortisol levels than the sound of rippling water, despite no difference in subjective stress levels. Similarly, DeMarco et al. (2012) observed that music reduced subjective stress but did not affect heart rate and blood pressure in surgical patients. These varied findings are likely due to methodological differences, such as the type of music selected and the intensity of stressors, highlighting the need for further research on the influence of contextual variables on the stress-reducing effects of music listening. In sum, it seems that listening to music has the capacity to decrease the psychobiological stress response. However, due to research findings that did not find a beneficial effect of music listening on the physiological stress parameters, no final conclusion can be drawn yet.

Music listening and the psychological stress response

Numerous studies have demonstrated beneficial effects of music listening on psychological stress parameters, such as on measures of perceived relaxation, anxiety, mood and affect (Adiasto et al., 2022; Fancourt et al., 2014; de Witte et al., 2020). For example, De Witte et al. (2020) conducted a meta-analysis on the effects of music interventions on psychological stress-related experiences in various populations and settings, by including studies with randomized controlled trials. A significant medium-to-large effect of music interventions was found on measures of state anxiety, nervousness, restlessness and feelings of worry. In a systematic review, Fancourt et al. (2014) showed that state and trait anxiety scores decreased when listening to relaxing recorded music in multiple studies focusing on anxiety and stress. Linneman et al. (2015) specifically looked at the effects of mere music listening on measures of psychological stress in daily life. A stress-reducing effect of music listening was found on subjective stress levels, and the effect was particularly strong when music listening was used for the purpose of relaxation in the late afternoon and evening.

Experimental studies that used stress-inducing procedures, music listening interventions have been found to effectively increase positive emotions and decrease negative emotions. For example, Groarke & Hogan (2019) demonstrated efficacy of self-chosen music listening in reducing negative affect following a psychosocial stress test, compared to a non-musical control group. Despite the number of studies demonstrating positive effects on music listening on different stress-related psychological measures, some studies did not find significant effects on ratings of stress and relaxation (Thoma et al., 2013). For example, De Zepetnek and Fiocco (2021) investigated the effects of experimenter-selected and self-selected relaxing music on the acute stress response, compared to white noise, using visual analogue scales (VAS) assessing self-reported momentary feelings of discomfort. No effect of condition was found. It is important to note that the respective studies differ regarding the measurement approaches, sample characteristics and experimental designs. Due to this heterogeneity, research findings must be interpreted with caution.

Music listening and stress recovery

Music listening may also beneficially influence stress recovery, though research findings here are also inconclusive. Some experimental studies have shown that music listening can facilitate recovery of the stress response following exposure to an acute laboratory stressor (Sandstrom & Russo, 2013). Results suggest that listening to music is more beneficial than silence or an audio control in promoting heart rate, blood pressure, anxiety and mood recovery following a stressor (Adiasto et al., 2023). Still, a comparable number of studies could not replicate these findings (Adiasto et al., 2023). For example, De la Torre-Luque, Díaz-Piedra and Buela-Casal (2017) investigated the effects of a music intervention based on preferred relaxing music on the recovery after stress exposure, looking at affective states in the recovery process. A significant positive effect of the music condition was found on measures of anxiety and negative affect, and higher positive affect during the recovery period. Participants in the silent-control condition reported greater negative affect (de la Torre-Luque et al., 2017). Thoma et al. (2012) also investigated the effects of music across emotional measures of the stress response after exposing participants to a psychosocial stress test. Participants were randomly assigned to either listening to relaxing music, the sound of rippling water, or rest without acoustic stimulation after the stress test. The subjective perception of stress, as well as state anxiety changed over time, but no significant difference between groups was found (Thoma et al., 2012). Another study that looked at the effects of music listening on stress recovery after an acute stressor was conducted by Song et al. (2023). Stress recovery was compared between participants who frequently listened to music for relaxation purpose and those who did not, the study was conducted with either women or men, respectively. In both women and men, subjective stress levels did not significantly differ between the participants with a frequent use of music and those with no music use. Chikahisa et al. (2006) investigated the effect of sedative music on subjective and physiological stress recovery in participants after an acute stressor. A control condition, participants sitting in silence, was included. The music condition showed a significant decrease in subjective anxiety, blood pressure and heart rate.

Empirical support for the notion that music listening is beneficial for stress recovery is inconsistent potentially due to the methodological diversity with which the effects of music on stress recovery have been investigated, and the measures used to assess stress recovery itself

(Adiasto et al., 2023). In general, numerous studies suggest that listening to music aids in the recovery of heart rate, blood pressure, anxiety, and mood following a stressor. However, an equal number of studies do not report these findings. This discrepancy may be due to the high heterogeneity in current research on music listening and stress recovery (Adiasto et al., 2023). Therefore, a thorough examination of the existing research findings is necessary, as well as a detailed examination of the underlying mechanisms of action for stress recovery.

Underlying mechanisms of music listening for stress recovery

Although research has repeatedly demonstrated stress-reducing effects of music listening, there is no comprehensive model to explain these effects (Yehuda, 2011). The modulatory effects may occur through different neuroendocrine, physiological, and psychological changes that are considered beneficial for stress recovery (Adiasto et al., 2022; Thoma et al., 2013). In the following, I will present some of the believed underlying mechanisms.

A widely studied mechanism of how listening to music may play a role in affecting the stress response is by inducing emotions. Emotion contagion describes the phenomenon where a piece of music elicits an emotion in a listener because the listener interprets the emotional expression conveyed by the music and subsequently mirrors this expression internally. This can occur through either peripheral feedback from muscles or a direct activation of corresponding emotional representations in the brain, resulting in the induction of the same emotion (Juslin & Västjfäll, 2008). Brain stem reflexes may also play a role here, especially in scanning musical properties as pleasant or unpleasant. Certain sound qualities are indicative of change, for example sudden or extreme sounds. On the other hand, soft and relaxing music induces pleasant emotions (Juslin & Västjfäll, 2008). Through that, music listening may promote affective changes and allow variations within the valence and arousal experience of feelings. The broaden-and-build theory of positive emotions suggests that positive experiences can counteract the negative emotions caused by stress, thereby helping to prevent the harmful effects of stress. Additionally, this theory proposes that positive emotions promote novel, exploratory thoughts and behaviors, which over time improve an individual's ability to manage stressors (Adiasto et al., 2023).

Music may also act as a distractor, shifting attention away from post-stressor ruminative thoughts or negative affect states to more pleasant stimuli, thereby possibly reducing stress levels and preventing a lengthening of physiological stress activation (Adiasto et al., 2023, Vaajoki et al., 2011). The distractive potential of music is used as an explanation for stress-reducing effects of music listening in clinical settings (Nilsson, 2008). By that, music can decrease anxiety by occupying attention channels in the brain with meaningful, distractive, soothing auditory stimuli rather than stressful environmental stimuli (Yahuda, 2011). In addition to the psychological mechanisms that might influence the effects of music listening on the stress response, underlying physiological processes might also play a key role in that.

The potential therapeutic effects of music listening have been largely attributed to its ability to reduce stress and modulate arousal levels (Chanda & Levitin, 2013). Listening to pleasant music increases the release of serotonin, which may contribute to a positive mood (Evers & Suhr, 2000; Yehuda, 2011). Additionally, endorphin levels, which promote feelings of well-being and relaxation, increase with pleasant music (Yehuda, 2011). Research indicates that both musical improvisation and listening can deactivate the amygdala, a part of the limbic system that plays a crucial role in regulating emotional processes, potentially reducing stress-related emotional states and physiological arousal. This can result in feelings of pleasure and happiness. In fact, recent neuroimaging studies on music and emotion have shown that music can significantly influence the amygdala by releasing endorphins (Yehuda, 2011). These neurotransmitters are vital in enhancing a sense of well-being (DeWitte et al., 2020). Listening to music also appears to affect neurochemical systems that are also activated when experiencing reward and pleasure, releasing hormones such as serotonin and dopamine, which help downregulate the physiological and psychological load reactions that are part of the stress response (Adiasto et al., 2023, Chanda & Levitin, 2013).

Music-induced relaxation is closely linked to anxiety reduction. Music with a slow, steady, and repetitive rhythm is believed to have a hypnotic effect, promoting relaxation and reducing anxiety by quieting the mind and inducing altered states of consciousness. Since physiological relaxation cannot coexist with anxiety, music can lower perceived anxiety levels while encouraging more relaxed bodily responses (Yehuda, 2011).

Another proposed explanation for the ability of music to modulate the physiological stress response is through the process of entrainment. This refers to a process by which independent rhythmical systems interact with each other (Clayton, 2013). Both musical stimuli and physiological processes, such as heart rate and respiration, are composed of vibrations that occur in a regular manner and consist of oscillations (Yehuda, 2011). Through musical entrainment, the rhythm and tempo of music can act as synchronizers and physiological processes of the ANS are assumed to synchronize with musical characteristics (Yehuda, 2011). In that way, the use of certain music can be directly used to elicit relaxation and help regulate physiological processes (Yehuda, 2011). Also, the change of physiological rhythms can lead to a change in the listener's affective state through proprioceptive feedback (Juslin, 2013). Numerous studies on music listening and stress recovery indicate that slow-tempo music, usually between 60-80 beats per minute, is most effective for stress reduction due to its similarity to the human resting heart rate (Adiasto et al., 2023, DeWitte, 2020). These effects are mainly linked to the music's tempo: slower music and pauses are associated with lower heart rate, respiration, blood pressure and muscle tension, while faster music increases these parameters. This is likely because brainstem neurons often sync their firing patterns with the music's tempo (Chanda & Levitin, 2013).

It is most likely that a combination of the mechanisms contributes to the relationship between stress, music and stress recovery, necessitating further comprehensive research. Finally, it is an oversimplified view to assume that people respond similarly to relaxing music.

Absorption

Although music can be a powerful source of emotions, some people show little interest in it while others demonstrate intense emotional responses to music (Sandstrom & Russo, 2013). There are individual differences in how music is experienced and in the intensity with which music can affect emotions. One way to specifically look into the differences (in the emotional responses) to music is considering the level of absorption. *Absorption* refers to an openness to absorbing and self-altering experiences and was initially considered a personality trait (Tellegen & Atkinson, 1974).

The trait of absorption is viewed as a spectrum, and it describes the degree to which an individual can become fully engaged or immersed in a particular experience or activity in an effortless way. The concept was originally developed by Tellegen and Atkinson (1974) in the process of creating a questionnaire aiming to identify individuals with a hypnotic susceptibility. The cognitive mechanism behind absorption can be described as the involvement of a "total attention, involving a full commitment of available perceptual, motoric, imaginative and ideational resources to a unified representation of the attentional object" (Tellegen & Atkinson, p. 274, 1974). That is one of the most enduring definitions of trait absorption. The difference with other cognitive phenomena describing attentional engagement that is goal-directed and may also fully occupy attention is the prominent characteristic of absorption that the immersion happens in an effortless way. So, the attention is highly centered and amplifies the experience of one part of reality, while other aspects of reality can recede from awareness. States of absorption alter how people experience reality and themselves (Tellegen & Atkinson, 1974). The cognitive component of this trait also appears to include the ability to operate several representational modalities synergistically, so that a fully and unique experience is perceived. Tellegen and Atkinson (1974) laid the groundwork for absorption research by identifying both the phenomenon of total attentional engagement and a personality trait characterized by a disposition for absorption experiences.

The concept of absorption received a lot of research attention, underwent further development and some researchers now distinguish absorption into trait and state-like states. For example, Shea, Burton and Girgis (1993) define *trait absorption* as a natural inclination towards being immersed in experiences, showed in a general heightened sensitivity towards stimuli and seen in daily life through fantasy proneness and individuals having a wide mental imagery. In comparison, *state absorption* refers to a temporary, situation-specific increase in absorption that is characterized by an ability of intensive and focused perceptiveness and high emotionality as a response to a stimulus (Hall, Schubert & Wilson 2006). An analogue for state absorption is flow (Hall et al., 2016). Flow is the "holistic sensation that people feel when they act with total involvement" (Csikszentmihalyi, 1990, p. 36). Characterized by disorientation of time and space, a loss of fear, anxiety, and inhibition, and total absorption by the phenomenon, flow has been shown to be promoted by musical activity (Chirico et al., 2015).

High absorption has been shown to correlate with openness to experience, heightened emotional reactivity to stimuli, predisposition to hypersensitivity, flow states and aesthetic experiences, and synesthesia (cross-modal experiences) (Tellen & Atkinson, 1974; Shea, Burton & Girgis, 1993). For example, individuals high in absorption have been found to be emotionally responsive to engaging sights and sounds, are readily captured by entrancing stimuli, and tend to think in images (Tellegen & Atkinson, 1974). Absorption has been viewed as facilitating positive emotional experiences, such as enjoyment of music and art (Wild, Kuiken & Schopflocher, 1995). For example, in a study with healthy graduate students, Kwekkeboom, Huseby-Moore & Ward (1998) demonstrated that individuals high in absorption showed a strong association to the effective use of guided imagery to relieve anxiety.

In general, absorption may not only facilitate positive emotional experiences, but also negative ones and is also viewed as a predisposing factor for stress-related physical symptoms (McClure & Lilienfeld, 2002). Several researchers suggest that individuals with high absorption are prone to hypersensitivity, as they often intensely focus on physiological responses to stressors, sometimes in a negative way (Shea, Burton, & Girgis, 1993). This heightened sensitivity may predispose people high in absorption to amplify even minor unpleasant bodily sensations, facilitating anxiety sensitivity. In fact, research has shown that absorption may be related to certain forms of psychopathology. Lilienfeld (1997) found that absorption correlated positively with a history of panic attacks in the past year. According to Wickramasekera (2000), the personality trait of absorption appears to have a dual nature. On one hand, persons with high absorption are able to respond more quickly to interventions that aim to activate creative processes, on the other hand, this ease of response could be a risk factor for hypersensitivity.

Absorption and musical experiences

People who have a propensity for being drawn in by sensory stimuli may have strong emotional responses to music. In fact, Sandstrom and Russo (2013) demonstrated that absorption influences the intensity and range of emotions while listening to music. They specifically created the *Absorption in Music Scale (AIMS)* to measure an individual's ability and willingness to enter states of absorption during engagement with music, as well as to predict differences in the depth of emotional responses to music (Sandstrom & Russo, 2013). The researchers found that people who scored high on absorption appeared to have stronger emotional responses to music compared to individuals low in absorption (Sandstrom & Russo, 2013). Strong emotional reactions to music are usually accompanied by behavioral (intense feelings of pleasure), psychophysiological (altered breathing, heart rate) and neural mesolimbic dopaminergic reward activations (Cardona et al., 2022). Supporting research has found that absorption is correlated with the ability of music to influence one's mood, as well as with the level of one's involvement with music, specifically the amount of time spent listening to music each day and an individual's judged importance of music (Wild, Kuiken, & Schopflocher, 1995). Herbert (2012) investigated the ability of music to induce absorption states and demonstrated that music may be a particularly effective agent in the facilitation of absorption because it offers multiple potential entry points to involvement, simply through the multi-modal acoustic attributes of music, such as timbre, resonance, rhythm and pitch.

In a study by Kreutz et al. (2000), measures of trait absorption and emotions ratings, induced by 25 excerpts of music that represented happiness, sadness, fear, anger and peace, were collected. Individuals high in trait absorption demonstrated more intense emotional reactions in response to music compared to those low in trait absorption. Additionally, trait absorption was positively correlated with arousal induced by music, with the highest correlation for music that induced sadness (Kreutz et al. 2000). Building on these results**,** Hall and colleagues (2016) investigated the impact of both state and trait absorption upon preference for music, particularly music that evokes negative emotions. Hall and colleagues (2016) hypothesized that state and trait absorption may favor one another on their influence on a listener’s music experience. Participants were instructed to listen to two pieces of self-selected music (powerful and boring) and rate the music on preference on felt and expressed emotions. In general, there was a higher preference for the powerful music piece compared to the boring music piece. Individuals high in trait absorption were more likely to report negative emotions while listening to powerful music than individuals low in trait absorption. State absorption was related to music preference, suggesting that participants who entered an absorbed state were more likely to rate their chosen piece of music as highly loved. The results suggest that state absorption was the primary mechanism of music enjoyment in the moment, whereas trait absorption appears to be important for determining music preference based on its emotional valence (Hall et al., 2016).

Absorption, stress and music

Regarding the influence of absorption on the effectiveness of music interventions for stress recovery, research is scarce. In one experimental study, Sandstrom and Russo (2010) investigated the ability of music to help people recover physiologically and subjectively after experiencing an acute stressor. After stress induction, participants either listened to happy, peaceful, sad or agitated music, or white noise (control condition). Results revealed that participants recovered better when the music was low in arousal compared to high in arousal. Recovery was also better when the music had a positive valence rather than a negative valence. Peaceful music, characterized by positive valence and low arousal, was the most effective music to promote both subjective and physiological recovery. Absorption was a significant predictor of post-stressor physiological recovery in the peaceful music condition. The researchers suggested that the emotions induced by music may facilitate recovery after stress and that individuals possessing high absorption may have a stronger emotional response to music, since they exhibited a more complete recovery (Sandstrom & Russo, 2010). They suggested that through deep engagement, high absorption allowed individuals to immerse themselves in the music, leading to greater emotional and physiological relaxation. To date, the study by Sandstrom and Russo (2010) is the only one investigating the effectiveness of music listening on stress recovery, inducing acute stress in a laboratory setting, while considering the level of absorption.

To recap, one’s level of absorption is believed to influence the experience of music and predisposes individuals to experience sensory input in an intensive way. The use of absorption questionnaires tends to emphasize absorption more as a trait rather than a state, though research has demonstrated that trait and state absorption measure different absorption qualities (Herbert et al., 2012). Research mainly focused on the link between emotionally activating music and absorption, demonstrating strong emotional responses to music in people with high absorption, accompanied by physiological and behavioral activation (Cardona et al., 2012). One study demonstrated a moderating effect of absorption on the effectiveness of listening to peaceful music on stress recovery, calling for more research attention on the effects of relaxing music on stress recovery while considering the level of absorption for a more tailored use of music interventions for stress reduction.

The research gap

To summarize, listening to relaxing music stands to be a promising tool in facilitating stress recovery: modulating effects on physiological stress markers and on subjective stress experience have been demonstrated (Adiasto et al., 2023). HRV is frequently used as a biomarker for a healthy relative balance between the SNS and the PNS in stress research. Higher HRV indicates heightened parasympathetic control of the nervous system, and regarding stress recovery, HRV seems to increase during recovery and decrease during the experience of stress (Weber et al., 2010). As a psychological stress measure, RPA has been shown to accompany stress recovery, with relaxing music inducing feelings of RPA. However, some studies could not replicate these findings, calling for more thorough investigations into how music listening enhances stress recovery.

While there is a lot of research on the general effects of music on stress recovery, there is a lack of studies focusing specifically on how individual differences in absorption moderate these effects. As people high in absorption have been shown to experience music differently, for example by demonstrating stronger emotional reactions to music that are accompanied by physiological arousal, this could stand in contrast with the notion that especially music with low physiological arousal is effective for stress recovery. Thus, the role of absorption in facilitating stress recovery still remains unclear; understanding this interaction could provide insights into personalized stress management strategies. Additionally, state absorption is believed to function as the primary mechanism of music enjoyment in the moment, and trait absorption appears to be important for determining music preference based on its emotional valence (Hall et al., 2016). Although trait absorption, as a stable personality characteristic, is often studied, the role of state absorption, a temporary, situation-specific engagement, in stress recovery during music listening is less understood. Research is needed to clarify if state absorption could mediate the relationship between trait absorption and stress recovery. In addition, only one study by Sandstrom and Russo (2010) specifically investigated the impact of music listening on stress recovery by inducing acute stress in a laboratory setting, taking into account the level of absorption of the participants. In the light of the scarcity of studies investigating the associations of music listening, stress recovery and absorption, this association requires more elaboration. Thus, I aim to explore the potential of high absorption to enhance stress recovery to gain knowledge for tailored use of music-interventions.

Research questions and hypotheses

The objective of the present thesis is to investigate whether listening to music, compared to silence, after acute stress influences stress recovery and if trait absorption moderates this effect. Therefore, two conditions, music listening (experimental condition) and sitting in silence (control condition) are compared regarding the recovery from acute stress. Measures of HRV and RPA are collected as markers of stress recovery, allowing for both objective and subjective stress recovery parameters. Additionally, I investigate if the effect of trait absorption on stress recovery is mediated by state absorption. Accordingly, the following research questions and hypotheses are specified:

Research question 1: Does music listening after acute stress influences stress recovery and does trait absorption moderate this effect?

H1: Music listening, compared to silence, amplifies relaxed positive affect after acute stress.

H2: Music listening, compared to silence, amplifies heart rate variability after acute stress.

H3: Trait absorption increases the effect of music, with respect to silence, on relaxed positive affect.

H4: Trait absorption increases the effect of music, with respect to silence, on heart rate variability.

Research question 2: Is the effect of trait absorption on stress recovery within the music condition mediated by state absorption?

H5: The effect of trait absorption on relaxed positive affect is mediated by state absorption “being immersed”.

H6: The effect of trait absorption on heart rate variability is mediated by state absorption "being immersed".

For illustrative purposes, two hypotheses are translated and shown in graphs in the following.

Figure 1

Moderation model of hypothesis 3

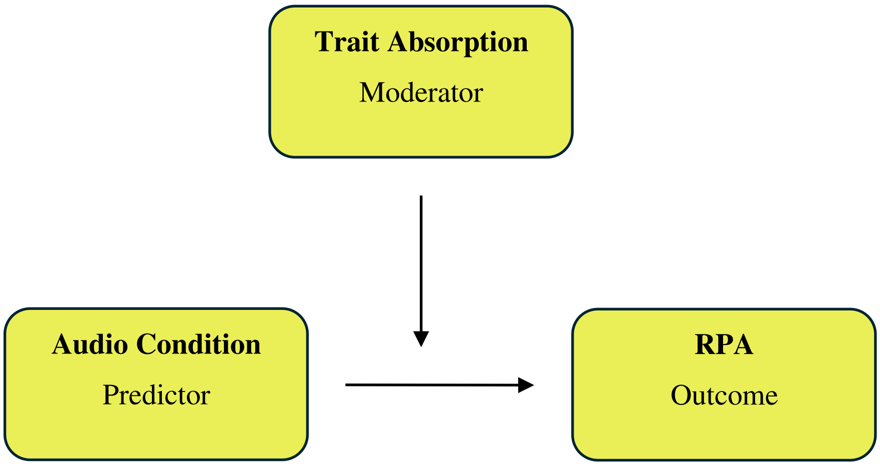
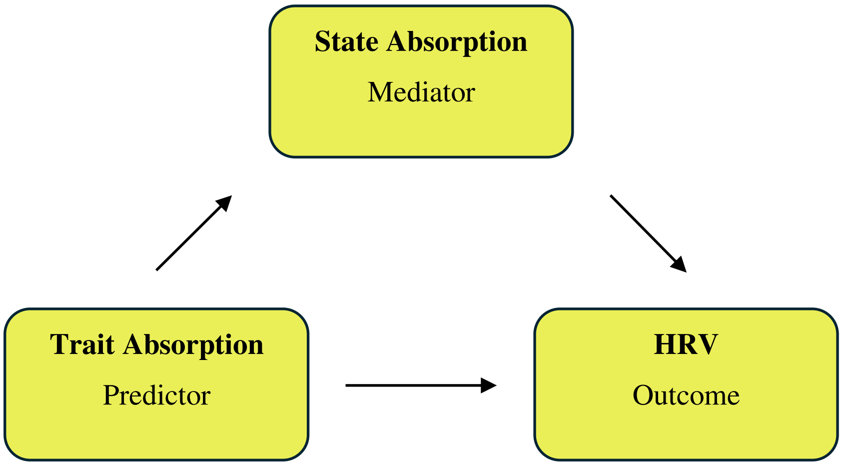


Figure 2

Mediation model of hypothesis 6



Methods

Study design

This master thesis was carried out within the overarching research project *"Muskiba: Effects of music listening on stress and skin barrier recovery"* led by Dr. Jasminka Majdandžić. Therefore, the contents of this thesis may incidentally show overlap (in terms of e.g. appendices) with theses by other students co-supervised by Dr. Jasminka Majdandžić.

The data for this master's thesis was gathered at the Music and Health Lab at the Department of Clinical and Health Psychology at the University of Vienna. The project examines a wide range of variables concerning the effects of music listening on skin barrier recovery and stress recovery mediated by stress. For clarification, for the purpose of investigating skin barrier recovery, a tape stripping procedure is performed on the skin, but not used for my research questions (see figure 3). Various self-report state and trait like variables such as positive affect, subjective stress and absorption, as well as biological parameters of stress including salivary cortisol, heart rate (variability) and electrodermal activity were obtained during the laboratory study. The *Trier Social Stress Test* (TSST, Kirschbaum et al. 1993) was conducted to induce psychosocial stress and will be addressed in detail further below.

Since not the whole project and associated variables are relevant for my research questions and hypotheses, only crucial parts of the study will be discussed in detail, in addition to a general study description offering an understanding of the relevant time points (see figure 3). The focus of this investigation lies upon audio condition (music listening/sitting in silence) and trait absorption as independent variables, depending on the research question, and change in heart rate variability and change in relaxed positive affect as dependent variables. Also depending on the research question, trait absorption is treated as a moderator and state absorption as a mediator variable.

The project was devised as a randomized controlled trial (RCT). Participants were randomly assigned to a music listening group, functioning as the experimental condition, or to either an audiobook listening or a silence group, both being used as control conditions. For the investigation of my research questions, only the silence condition is being used as a control condition.

Ethical Approval

The study protocol was approved by the ethics committee of the University of Vienna. Written informed consent was obtained from all participants before the experiment.

Recruitment and Sample

Participants were recruited with the help of social media platforms (e.g. posting the study flyer on Facebook), a mailing list of the University of Vienna and the manual distribution of flyers in different study-related spaces, such as in libraries or at university spaces. First communicated information consisted of the topic of the study (Stress and music and audiobook listening), basic inclusion and exclusion criteria (female gender, age between 18 – 35 years, no use of hormonal contraception, having a regular menstrual cycle, no regular smoking behavior, no under- or overweight, no physical and psychological diseases and being fluent in German) and expense compensation of 45€ was offered, and general information about the study procedure (completion of online questionnaires – 1 hour, study appointment at the faculty of psychology – 4 hours, giving saliva samples and measures on the skin) was given. Potential interest was expressed via email, and possible participants were asked for a phone number and possible timeslots for a twenty-minute telephone screening to assess their compatibilities with the studies inclusion and exclusion criteria. Instructed members of the study team then conducted the telephone interview following a standardized manual.

Before arranging an appointment for the study, several circumstances had to be addressed concerning the biomarkers and psychological markers of the stress reaction. To minimize the known impact of gender and hormonal influences on the stress reaction, only female participants, who must not use hormonal contraception, were included. To further limit potential variations, information concerning the menstrual cycle of the participants was gathered to ensure that the test date would take place during their follicular phase (Kirschbaum et al., 1999). The sample was selected following certain recommendations for measurements of cortisol and alpha amylase (Strahler, Skoluda, Kappert & Nater, 2017). Participants had to be between 18 and 35 years of age, physically and psychologically healthy, assigned the gender female at birth and not define their gender identity otherwise, not be pregnant or breastfeeding, not use hormonal contraceptives or other medication affecting hormonal levels, not be in menopause or climacteric, have a regular menstrual cycle and be in their follicular phase during testing. In addition to that, participants had to be free from **somatic illnesses** including cardiovascular diseases, respiratory diseases, hearing impairments, inflammatory diseases, allergies, liver diseases, chronic pain, high or low blood pressure, kidney or urinary diseases, metabolic diseases, diseases of digestive tract, neurological diseases, infectious diseases, thyroid diseases, auto immune diseases, muscular diseases and blood disorders. Further, no tropical stay in the last six months, no vacation in the last two weeks and no dental operation in the last eight weeks had to be ensured. Regarding **psychological health**, only participants were included who had no current mental disorder or psychiatric illness, including major depression, eating disorder, anxiety disorder or schizophrenia/psychosis within the last five years and who did not use psychopharmaceutic medication in the last fourteen days. Plus, the participants must not have been in psychotherapeutic treatment. Concerning **drug use**, only participants were included that did not consume alcohol excessively, and who did not consume substances such as amphetamines, MDMA, barbiturates, benzodiazepines, cocaine or opiates in the last year or cannabinoids in the last fourteen days.

In addition, to control for confounds through special/unusual experience of music, participants with music-related profession, music related studies or an absolute hearing were excluded.

Lastly, to control for potential social support, it was ensured that the participants did not know a person from our study team on the day of the experiment. Also, participants who already had experiences with the TSST were excluded in the first place.

All participants were tested in their respective follicular phase to obtain a similar hormonal level across the participants. To calculate a possible date for testing, they were asked about the regularity and average time of their full menstrual cycle and the start of their last menstrual cycle.

Before the testing date, participants were asked to complete a battery of online questionnaires that were sent to them via mail. Two days before the testing date, an additional email was sent to the participants to remind them of the testing date, to fill out the online questionnaires and to not consume any alcoholic or caffeinated drinks within 48 hours prior to the study as well as to avoid intense physical exercise 24 hours before the experiment.

Power analysis

With SPSS, power analyses were conducted a priori for the independent-samples t-tests for hypotheses 1 and 2 to obtain the required sample size. For change in RPA as the outcome variable, to be able to reliably find an effect of a small effect size of 0.3, an α of 0.05 and a power of 0.7, a sample size of $N = 154$ participants per group would be required. For change in HRV as the outcome variable, to be able to reliably find an effect of a medium effect size of 0.6, an α of 0.05 and a power of 0.7, a sample size of $N = 43$ participants per group would be required.

Trier Social Stress Test (TSST)

Stress was induced using the Trier Social Stress Test (TSST). The TSST (Kirschbaum, Pirke & Hellhammer, 1993) is a tool to induce moderate psychosocial stress in laboratory settings, it combines high levels of social-evaluative elements and uncontrollability and is a reliable and validated acute stressor (Dickerson & Kemeny, 2004). The TSST consists of a preparation period of three minutes and a test period of ten minutes, in which the subject must deliver a free speech concerning their suitability for employment in a mock job interview and perform a mental arithmetic task in front of an audience.

In detail, the participant is instructed that she is about to perform a job interview for a self-selected dream job while being observed by an audience. The participant is told that the audience, which consisted of an active stressor perceived as male and a passive stressor perceived as female, are trained behavioral analysts. Also, the participant is told that the whole procedure will be recorded using a video recorder and a microphone and that the material will be used for later analysis purposes. The active stressor gives verbal instructions to the participant while the passive stressor stays silent and assists in handing the equipment and stopping the time. The stressors are briefed to not show emotions towards the participant, to remain a neutral facial expression, to only talk to the participant when the job presentation discontinues, and to take fake notes of the participant’s behavior during the testing. The active stressor’s role also included to actively increase the stress. After five minutes of the job interview, the participant is confronted with an unannounced mental arithmetic test in which she is instructed to serially subtract 17 from the number 2043. Whenever an error occurs, the active participant interrupts and the participant must start over from the beginning. The active stressor is instructed to remind the participant to look directly into the camera and speak clearly into the microphone to remind her of being recorded.

The TSST has been shown to elicit psychological stress on various measures, such as a two- to threefold rise in salivary cortisol levels in 70-85% of tested subjects, increases in heart rate measures and subjective stress measures (Foley & Kirschbaum, 2010; Kudielka et al., 2007).

Operationalization

All questionnaires are administered in German language.

Relaxed Positive Affect (RPA)

To measure RPA, a subscale of “The Types of Positive Affect Scales” (TTPAS, Gilbert et al., 2008) was used. It is a self-report questionnaire to specifically assess relaxed positive affect. It includes five items asking how “relaxed”, “peaceful”, “calm”, “laid back” and “serene” the respondent is feeling on a five-point level scale ranging ascendingly from “not at all” to “very”. RPA is measured right before the music or silence intervention (RPA 1) and right after the intervention (RPA 2). The scale showed good psychometric reliability with a Cronbach's α of .83 (Gilbert et al., 2008).

Heart Rate Variability (HRV)

HRV is quantified via parameters that are calculated from electrocardiogram (ECG) data and is calculated from temporal variations in the heartbeats. The Root Mean Square of Successive Differences between successive R-R intervals (rMSSD) is a time-domain analysis and reflects parasympathetic influence on the ANS and has been shown to have good psychometric properties (Kim et al., 2018). RMSSD is measured by taking the square root of the mean of the squared differences between consecutive normal-to-normal (NN) intervals (Heiss et al., 2021). The rMSSD is calculated with four-minutes segments compared to a one-minute segment as a reference using the Data Analyzer Software (Moviesens GmbH, Karlsruhe, Germany). It has been shown that rMSSD is one of the most fitting methods for quantifying short term HRV (Kim et al., 2018). Change in HRV is taken from the difference between HRV 2 (five minutes after the end of experimental or control intervention) and HRV 1 (five minutes before the start of the experimental or control intervention).

The ECG data was collected by a moviesens sensor strapped to the chest of the participant during the testing. A marker was set by the participant via double tapping the EDA sensor, the marker was later visible in the data and provided a time point.

Trait Absorption

The “Modified Tellegen Absorption Scale” (MODTAS, Jamieson 1986; Tellegen & Atkinson, 1974) is used to measure trait absorption. The scale consists of 34 items with a five-point level scale ranging from “not applicable” to “is totally true”, tackling different absorption phenomenon. The sum of all items builds a total score, with a possible range from 34 to

170. Four of the items address music absorption experiences specifically. A factor analysis of all the items yielded 11 primary factor scales from the questionnaire items: 1) Reality Absorption "(a tendency to become immersed in movies, acting, nature, voices, past events, etc.)," 2) Fantasy Absorption, 3) Dissociation, 4) Sleep Automatism, 5) Openness to Experience, 6) Devotion and Trust, 7) Autonomy-Skepticism , 8) Optimism-Placidity, 9) Aloofness-Reserve, 10) Caution vs. Impulsiveness, and 11) Relaxation (Tellegen & Atkinson, 1974, p. 270).

State Absorption

State absorption is captured with the item "How much did you feel immersed in the music while listening to it?" ("Wie sehr fühlten Sie sich versunken in die Musik während des Musikhörens?") with a five-point level scale ranging from "not at all" to "very". The item is self-defined, not validated and is used as an approach to state absorption, measuring a situation-specific level of absorption in the present moment. It is administered right after music listening.

Audio condition

The implemented audio intervention in the study consisted of two conditions the participants were randomly assigned to. The music listening condition represents the experimental condition of the study. In a pre-study to the present study, different music playlists, all containing musical properties of calming music, were developed. Stress-reducing effects of the playlists have been demonstrated on psychological and physiological stress parameters. The styles of the final playlists can be described as Ambient, Lofi, Classical, Guitar, Jazz and Lounge. The music was played through headphones, which were placed on the participants' heads by the experimenter at a comfortable volume preselected by each participant. Before deciding on one of the playlists, participants could listen through samples, which were 30 seconds segments of the respective music. The length of the playlists was 30 minutes. Thus, the choice of music represents a combination of experimenter-selected and self-selected music. During music listening, the participants sat on a lounge chair that was leaned back and were instructed to remain awake and calm during the listening part. The control condition encompassed sitting in silence for 30 minutes with headphones on and positioned in a leaned back lounge chair, to keep both conditions comparable.

Study procedure

The participant is asked to fill out a battery of online questionnaires, including the MODTAS, at the latest one day before the laboratory date.

Every test session was conducted by two teams of two individuals of the research group. One team consisted of one study leader who gave the constructions and led through the experiment, and one study assistant who was responsible for carrying out the skin measurements. The study assistant had to be female read, as she would need to touch or be in close physical proximity to the participant to do the skin measurements. This was implemented because a study assistant read male could have potentially induced stress through feelings of discomfort in some participants, so we tried to control for this bias by deciding on female-read study assistants. The other team consisted of the TSST committee, also consisting of one male-read and one female-read person.

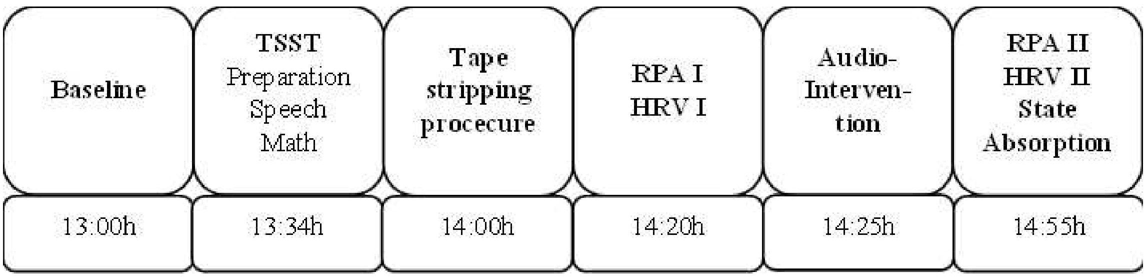
The tests were carried out constantly between 12:50 o'clock and 16:15 o'clock to control for diurnal fluctuations of cortisol secretion (Foley & Kirschbaum, 2010). On the test day, participants arrived at 12:50 o'clock and were picked up by the study leader in front of the faculty of Psychology, University of Vienna (in the Liebiggasse 5, 1010 Vienna), and were then brought to the test room on the second floor of the building. There, the acclimation phase of 30 minutes took place which was used to give the participant the possibility to calm down due to possible previous stressors and to ensure a stress reduced baseline measurement. During this time, the participant was instructed to complete an initial questionnaire and to read and sign the consent form. In addition, the test administrator verbally explained that the study could be terminated at any time, that the stress test consisted of a test similar to a school examination and that a saliva sample had to be provided 9 times during the test. The belt that contained the sensors for electrocardiogram data (ECG) was placed on the chest by the female read study assistant. In addition, the participant could hear into the six music samples and then decide for one playlist they were later about to hear when in the music condition.

After the acclimation phase, the participant was brought into another test room where the TSST committee already waited and where she then underwent the TSST. After the TSST, she was brought back into the first test room and the stress recovery phase started. The tape stripping procedure was carried out. After, the first time markers were set for HRV and RPA which collected the first measurements (HRV I and RPA I). Then, the participant proceeded to listen to music, an audio book or sit in silence, according to the assigned condition. For that, the participant was invited to lay on a lounger, find a comfortable position and leave her eyes open or closed, depending on preference. The participant was instructed to not fall asleep. Headphones were put on. During this intervention, the study leader turned off the lights and left the room. After half an hour, the study leader came back and asked the participant how she was doing. Then, the second time markers were set (measurement of HRV II and RPA II). State absorption was also measured, if the participant was in the music condition.

In the remaining time, the participant was asked to provide other measures, which were relevant for other research questions concerning the overarching study, in timespans of half an hour. In between these measurements, nature magazines were provided for reading or skimming through. At the end of the experiment, the physiological sensors were detached, the participants were debriefed by the study lead about the goal of the study and were also offered room for questions. In addition, they were informed that they were not being videotaped during the TSST and that the TSST committee consisted of study assistants, not being experts in behavioral analysis. The participant was thanked for the study participation and was asked to give details about a bank account to receive an expense allowance for participation. The relevant time points of the experimental procedure for my research questions are illustrated below.

Figure 3

Overview of the study procedure



Results

Statistical analyses

Statistical analyses were performed using IBM Statistics SPSS 29 and the PROCESS macro tool by Hayes (Field, 2018). Before statistical analyses were conducted, the variables *trait absorption*, *state absorption*, *change in relaxed positive affect* and *change in heart rate variability* were investigated regarding range, distribution and outliers. Possible outliers were checked with boxplots and no outliers were found. Normality distributions were checked with histograms and the variables were normally distributed.

For the evaluation of change in relaxed positive affect over time, the outcome variable was created from the difference values of the level of RPA at time point 1 (before music listening/sitting in silence) and the level of RPA at time point 2 (after music listening/sitting in silence). For the calculation of change in heart rate variability, the outcome variable was calculated by subtracting the mean heart rate variability of five minutes immediately before the music or silence intervention (time point 1) from the mean heart rate variability during the last five minutes after the intervention (time point 2).

To test the proposed hypotheses, two independent-samples t-tests are conducted with change in HRV and change in RPA as the dependent variables (H1, H2), respectively. Moderation analyses are carried out for H3 and H4. Lastly, mediation analyses are performed for H5 and H6. For all analyses, p-values $<.05$ were considered statistically significant (two-tailed). If not stated differently, all results are given as means (M) ± standard deviations (SD).

Sample description

For this thesis, a total of $N = 45$ participants were included and analyzed. Participants were randomly assigned to the experimental (listening to music) or control condition (sitting in silence), resulting in $N = 23$ participants in the experimental condition and $N = 22$ participants in the control condition. Regarding HRV data, thirteen data cases had to be excluded from the analysis as the ECG sensor measuring heart rate was damaged during a certain time period, consequently, HRV data could not be collected. This results in $N = 16$ participants for the experimental condition and $N = 16$ participants in the control condition for the analysis of heart rate variability.

All participants identified as female and were assigned female at birth. Participants had a mean age of 24.42 (*SD* = 4.14), ranging from 18 to 33. Participants had a mean Body Mass Index (BMI) of 20.91 (*SD* = 1.76), ranging from 17.67 to 24.68. Most participants reported an Austrian nationality (69.7%) or German nationality (17.1%). Other participants reported an American, Chinese, Columbian, Hungarian, Luxembourgish, Serbian or Ukrainian nationality (in total 13.2%). 97.8% of the participants reported finishing at least Abitur/Matura, while the remaining 2.2% reported finishing “mittlere Reife”. 80% of the participants reported having finished a university degree, while 6.6% reported having another professional education and 13.3% reported having no professional education. Regarding work activity, 2.2% of participants reported working full-time, 22.2% working at least part-time, 28.9% working less than part-time, 35.6% reported being in a job training and 11.1% reported not working. Concerning relationship status, 51.1% identified as single, 46.7% as partnered, and 2.2% as something different.

Regarding the variables of interest for the analyses, the mean score for the MODTAS, representing trait absorption, was 108.56 (*SD* = 25.38), ranging from 59 to 168. The average score for state absorption (in the music condition) was 3.68 (*SD* = 1.13), ranging from 1 to 5.

In the following section, I will present the main results of the conducted inferential tests regarding my hypotheses.

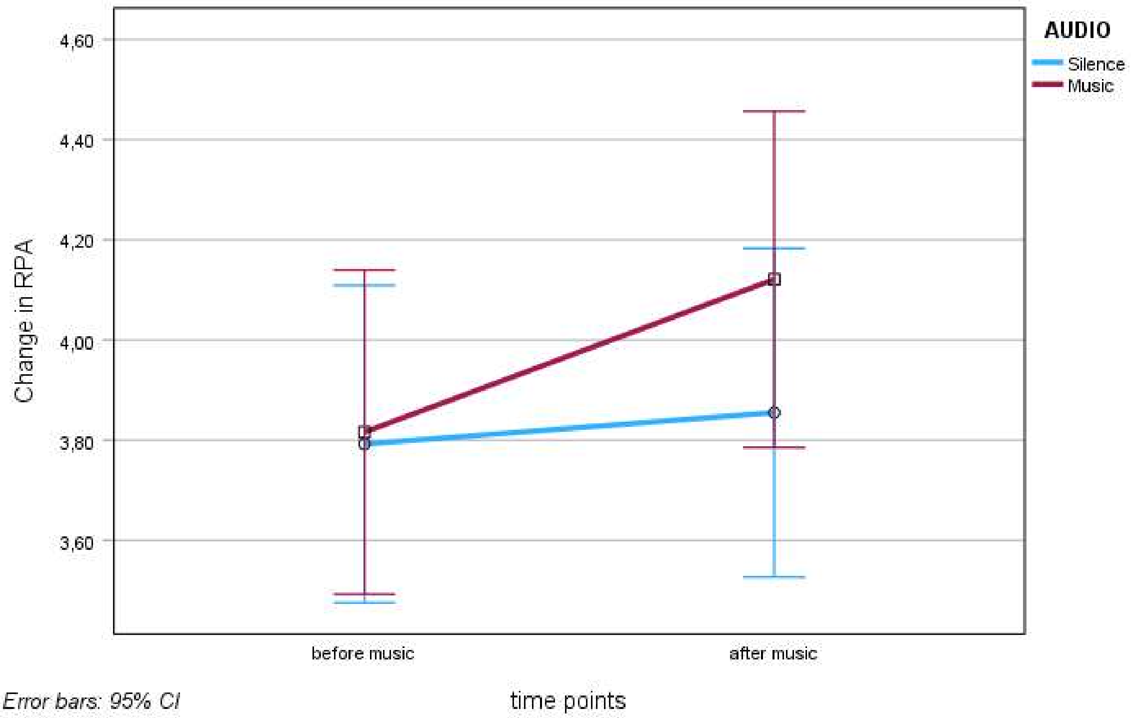
Main results

Differences between the music and silence group regarding change in RPA

To test hypothesis 1, an independent samples t-test was conducted with *change in RPA* as the dependent variable and *audio condition* as the independent variable. On average, participants in the music condition exhibited a bigger increase in relaxed positive affect (M = 0.31, SE = 0.90) compared to the silence condition (M = 0.06, SE = 0.88) after acute stress. This difference, 0.25, BCa 95% CI [-0.30, 0.78], was not significant $t(43) = 0.91$, $p = .37$.

Figure 4.

Illustration of the group differences regarding change in relaxed positive affect over time.



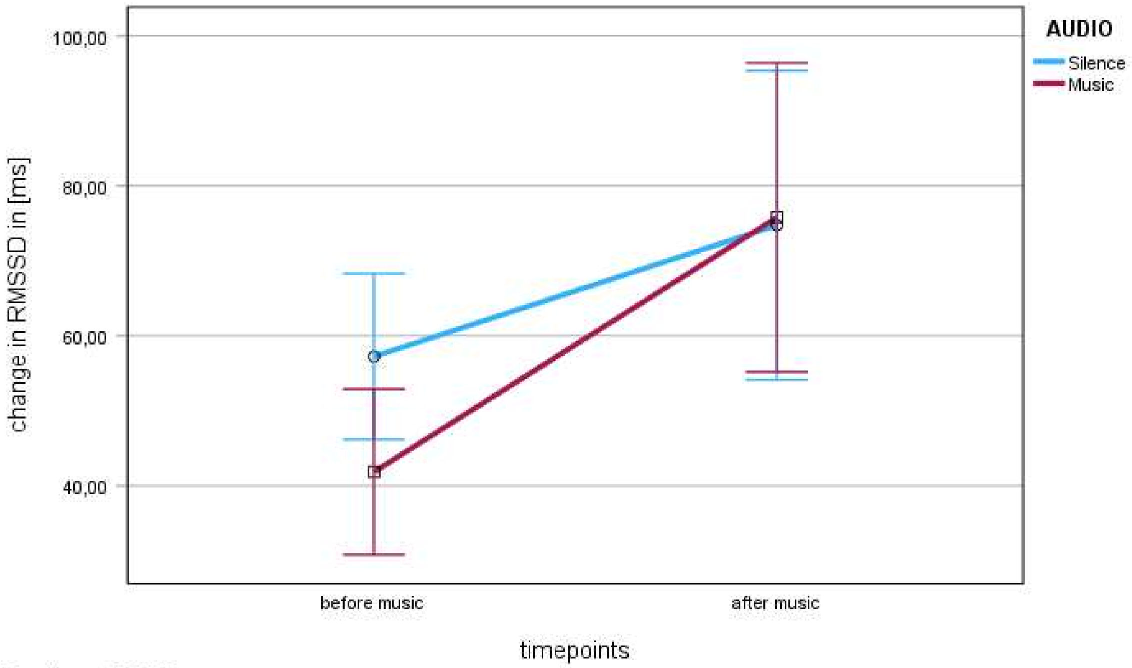
Error bars: 95% CI

Differences between the music and silence group regarding change in HRV

To test hypothesis 2, an independent samples t-test was conducted with *change in HRV* as the dependent variable and *audio condition* as the independent variable. On average, participants in the music condition exhibited a bigger increase in heart rate variability (M = 33.95, SE = 29.01) compared to the silence condition (M = 17.52, SE = 32.31) after acute stress. This difference, 16.43, BCa 95% CI [-5.68, 37.07], was not significant $t(30) = 1.51$, $p = .15$.

Figure 5.

Illustration of the group differences regarding change in heart rate variability over time.



Error bars: 95% CI

Is the effect of music listening after acute stress on stress recovery moderated by trait absorption?

Moderation analyses were conducted using the PROCESS macro by Hayes (2022), which uses ordinary least squares regression and produces unstandardized coefficients for all effects. Model 1 was used to examine whether trait absorption moderated the relationship between the audio condition (music vs silence) and change in relaxed positive affect and heart rate variability. To compute the confidence intervals of the interaction effect, we utilized bootstrapping with 5000 samples and heteroscedasticity consistent standard errors (HC3; Davidson & MacKinnon, 1993). The variable *audio condition* has been dummy-coded (silence = 0, music = 1). Trait Absorption has been mean centered prior to the moderation analyses. Level of confidence for all confidence intervals is 95. The assumptions of a moderation (e.g. linear relationship between the independent and dependent variable, no multicollinearity in the data, no significant outliers, normal distribution of the variables) were checked prior to the analysis. Two moderation analyses were run, with *audio condition* as the independent variable, *trait absorption* as the moderator and *change in RPA* and *change in HRV* as the dependent variable, respectively.

A moderation test was run, with *audio condition* as the predictor, *change in relaxed positive affect* as the dependent variable, and *trait absorption* as a moderator. There was no significant main effect found between audio condition and change in relaxed positive affect, b = 0.26, SE = 0.27, t(41) = 0.97, p = 0.34, as well as no significant main effect of trait absorption on changes in relaxed positive affect b = 0.001, SE = 0.01, t(41) = -0.30, p = 0.76. The interaction between audio condition and trait absorption was not significant, B = -0.02, SE = 0.01, p = .0.17, 95% CI [-0.04, 0.01]. This suggests that the effect of audio condition on change in relaxed positive affect does not depend on the level of trait absorption. Given the non-significant interaction, no further simple slopes analysis was conducted.

A moderation test was run, with *audio condition* as the predictor, *change in heart rate variability* as the dependent variable, and *trait absorption* as a moderator. There was no significant main effect found between audio condition and changes in heart rate variability, b = 15.76, SE = 11.36, t(28) = 1.39, p = 0.18, as well as no significant main effect of trait absorption on changes in heart rate variability b = 0.06, SE = 0.22, t(28) = 0.26, p = 0.801. The interaction between audio condition and trait absorption was not significant, B = 0.42, SE = 0.44, p = 0.35, 95% CI [-0.48, 1.33]. This suggests that the effect of music listening on change in heart rate variability outcome does not depend on the level of trait absorption. Given the non-significant interaction, no further simple slopes analysis was conducted.

Is the effect of trait absorption on stress recovery within the music condition mediated by state absorption?

First, to ensure the requirements for the mediation analyses are fulfilled, I analyzed the main effects of the two models using a linear regression analysis with the participants trait absorption scores as the independent variable and the change in RPA and HRV before to after music listening as the dependent variables, respectively. According to Baron & Kenny (1986), a significant total effect between independent and dependent variable is a precondition for performing a mediation analysis. However, other researchers state that even when the total effect is not significant, a mediation analysis could still be performed (Rucker et al., 2011). Therefore, the full mediation analyses are reported.

From a simple mediation analysis conducted using ordinary least squares path analysis (performed by the PROCESS SPSS macro, Hayes, 2022), no support was found for the hypothesis that *state absorption* mediated the relationship between *trait absorption* and *change in relaxed positive affect* from pre- to post music listening. The indirect effect of trait absorption on change in relaxed positive affect through state absorption was not significant, *B* = 0.001, *SE* = 0.03, 95% CI [-0.005, 0.009], based on 5000 bootstraps resamples. The total effect of trait absorption on change in relaxed positive affect was not significant, *B* = -0.010, *SE* = 0.009, *p* = 0.276, 95% CI [-0.030, 0.009]. A bootstrap confidence interval for the indirect effect (*ab* = .001) based on 5000 bootstrap resamples contained zero (-.005 to .009), suggesting that the indirect effect is not significant. The results are summarized in Table 1.

Table 1

Results of Mediation Analysis 1

		M (State absorption)					Y (Δ Relaxed positive affect)			
		B	*SE*	*p*	*β*		*B*	*SE*	*p*	*β*
X	*a*	.007	.012	.609	.135	*c′*	-.010	.009	.276	-.235
M		-	-	-	-	*b*	.092	.179	.551	.114
		R^2 = .018					R^2 = .068			
		F(1, 20) = .370, *p* = .550					*F*(2, 19) = .695, *p* = .511			

Note. X = music condition; *N* = 23; *B* = unstandardized coefficient; *SE* = standard error; *β* = standardized coefficient.

From a simple mediation analysis conducted using ordinary least squares path analysis (performed by the PROCESS SPSS macro, Hayes, 2022), no support was found for the hypothesis that *state absorption* mediated the relationship between *trait absorption* and *change in heart rate variability* from pre- to post music listening The indirect effect of trait absorption on change in heart rate variability through state absorption was not significant, *B* = 0.009, *SE* = 0.17, 95% CI [-0.255, 0.445], based on 5000 bootstrap samples. The total effect of trait absorption on change in heart rate variability was not significant, *B* = 0.261, *SE* = 0.368, *p* = 0.491, 95% CI [-0.533, 1.055]. A bootstrap confidence interval for the indirect effect (*ab* = .009) based on 5000 bootstrap resamples contained zero (-.255 to .445), suggesting that the indirect effect is not significant. Table 2 summarizes the results of the mediation analysis.

Table 2

Results of Mediation Analysis 2

		M (State absorption)					Y (Δ Heart rate variability)			
		B	*SE*	*p*	*β*		*B*	*SE*	*p*	*β*
X	*a*	.012	.012	.956	.248	*c'*	.261	.368	.491	.199
M		-	-	-	-	*b*	.727	7.644	.095	.027
		R^2 = .061					R^2 = .043			
		F(1, 14) = .913, *p* = .355					*F*(2, 13) = .291, *p* = .753			

Note. X = music condition; *N* = 16; *B* = unstandardized coefficient; *SE* = standard error; *β* = standardized coefficient.

Discussion

The present thesis aimed to investigate the influence of listening to relaxing music on change in heart rate variability and relaxed positive affect after acute stress induction, considering the level of absorption, both state and trait, of the participants. As music has been shown to reduce stress and enhance stress recovery, beneficial effects of music listening on stress recovery were expected (DeWitte et al., 2020). Considering that people high in absorption tend to get immersed fully in musical experiences, it was assumed that they benefit more from music interventions compared to people lower in absorption (Sandstrom & Russo, 2013; Shea, Burton & Girgis, 1993). Below, the results and their implications for the hypotheses stated above will be discussed, followed by possible limitations and shortcomings. Further, some suggestions for further research will be given.

Summary of results

Hypotheses 1 and 2 postulated a beneficial effect of listening to relaxing music on relaxed positive affect and heart rate variability, compared to a silence control condition. However, the expected main effects of the first two analyses, regarding the effects of the music condition on change in HRV and RPA, compared to the control condition, could not be demonstrated. Thus, the data does not support hypotheses 1 and 2. Though participants in the music condition exhibited a bigger change in RPA and HRV in response to the intervention, compared to participants in the silence condition, and this pattern in the results indicated the expected direction, claims are not possible as no significant effect has been found.

Regarding the assumed moderating effect of trait absorption on the relationship between music listening and stress recovery, hypotheses 3 and 4 postulated that trait absorption increases the effect of music on relaxed positive affect and heart rate variability, respectively. Physiological data suggested that HRV increased in both audio conditions over time, in the music condition even stronger, as the baseline HRV was lower in the music condition compared to the silence condition. Still, the results of the moderation analyses showed no significant effect of the interaction between trait absorption and music listening, on both measures of change in HRV and change in RPA. Therefore, hypotheses 3 and 4 must be rejected.

Lastly, regarding the assumed mediating effect of state absorption on the association of trait absorption and stress recovery within the music condition, hypotheses 5 and 6 postulated that the level of "being immersed" in the music as a proxy for state absorption would mediate the effect of trait absorption on change in RPA and HRV, respectively. However, the results of the mediation analysis yield no significant effects on both measures of HRV outcome and RPA outcome. Therefore, also hypotheses 4 and 5 must be rejected.

Interpretation of results

Music listening and stress recovery

The influence of listening to relaxing music on stress recovery was the first examination and was built on previous research that repeatedly showed that listening to relaxing music would have beneficial effects on stress recovery. For example, the study by de la Torre-Luque, Diaz-Pedra and Buela-Casal (2017), which had a comparable study design as ours, demonstrated beneficial effects of music listening on measures of positive affect during stress recovery compared to a silence control condition. These findings could not be replicated with our data. There might have been various reasons for the failure to replicate possible effects of listening to relaxing music on stress recovery.

First and foremost, it is important to mention our small sample size. To recap, for investigating change in RPA between the experimental and the control group, a priori power analysis was conducted using a small effect size (Cohen's $d = 0.3$) and a desired statistical power of 0.7, which indicated that 154 participants per group were needed to reliably detect an effect. However, the actual sample size in this study consisted of only 23 participants in the music group and 22 participants in the silence group. This substantial difference between the intended and actual sample sizes has several implications. Most notably, the reduced sample size decreases the study's statistical power, which reduces the likelihood of detecting a true effect if one exists. As the group sizes for HRV were even smaller due to a damaged ECG sensor, 16 participants resulted in per group. A priori power analysis yielded the necessity of at 43 participants per group to find a medium effect size (Cohen's $d = 0.6$) with a power of 0.7 to reliably detect change in HRV across the groups. Also here, due to the reduced sample size, it might have been more difficult to detect an effect of music listening on changes in HRV. Consequently, non-significant results in this study should be interpreted with caution, as they may be due to insufficient statistical power rather than the absence of an effect. The small sample size prevents definitive conclusions regarding the absence of an effect in the population.

In line with previous research, Brannon and Fiest (2017) emphasized that perceived control over situational factors is an important determinant in reducing the stress response.

This can be applied to the selection of music. Though the participants had some control over choosing a preferred music playlist by listening through the six music samples we offered, research has shown that fully self-selected music is considered as having the most relaxing effects on emotions, mood, and stress reduction, compared to listening to experimenter-selected music (DeWitte et al., 2020). Looking at the research findings by Thoma et al. (2013), who demonstrated that listening to relaxing music was less effective in reducing cortisol levels after a stress induction than the sound of rippling water and thus also did not find a beneficial effect of music listening on stress recovery, it would be interesting to compare study designs and sample characteristics of studies that are in line with our research findings and those who are not.

Concerning our data, it is important to highlight that the participants in the music condition, compared to the control condition, demonstrated a lower HRV at time point 1, directly before the experimental manipulation. This observation could give a hint for a possible higher baseline sympathetic activity and lower parasympathetic activity in the participants in the music condition. This different HRV baseline level across the groups might have influenced the possible impact of listening to relaxing music on HRV and calls for a thorough examination of factors influencing baseline measures of HRV.

Listening to music, trait absorption and stress recovery

As absorption influences the intensity and range of emotions during the experience of music, it was expected that participants high in absorption would benefit better from music listening and show a bigger change in stress recovery in response to the music intervention than participants rather low in absorption. The expected findings could not be confirmed with our data.

First, to interpret the results of the moderation analyses, it is crucial to highlight also here the small sample size and following from this the decreased power to reliably detect an interaction effect of audio condition and trait absorption on measures of stress recovery.

Further, it is important to note that previous research about the role of absorption during the experience of music primarily looked at emotionally activating music, possibly highlighting the potential of people high in absorption to experience a wide range of emotions during the music experience (Cardona et al., 2022). Absorption has been associated with openness to experience, heightened emotional reactivity to stimuli and preference for music with different emotional qualities (Shea, Burton & Girgis, 1993). The utilized relaxing music in our study might have been too under stimulating for participants high in trait absorption.

Similarly, Rentfrow & MacDonald (2010) also demonstrated that absorption is associated with an interest in the arts and preference for a wide range for musical styles. This stands in line with the research findings of Hall et al. 2016 that showed that participants high in trait absorption favored powerful over boring music, even if the powerful music induced feelings of sadness. This might give a link to the phenomenon that individuals high in trait absorption want to experience deep and intense emotions, and that listening to music could be one way to induce these. Herbert (2012) proposed that, because these negative emotions are experienced in an aesthetic context, they can become activated without their unpleasant effect and be thoroughly enjoyed.

Interestingly though, regarding stress recovery, Sandstrom and Russo (2010) demonstrated in a study that music low in arousal and high positive emotional valence was the most effective music in predicting stress recovery in participants undergoing an acute stressor, and that absorption was a significant predictor of post-stressor physiological recovery. The music in our study showed comparable musical characteristics as in the study by Sandstrom and Russo. This calls for more thorough investigation of the effects of relaxing music on stress recovery.

Another crucial point is that studies that specifically looked at musical experience and absorption rather used the AIMS (Absorption in Music Scale, Sandstrom & Russo, 2010), which specifically tackles musical experiences in high absorbers. The MODTAS, which was used in our study design, includes 4 items that particularly tackle musical experience, possibly lacking construct validity and thus contributing to finding no association between relaxing music, trait absorption and stress recovery.

Trait absorption, state absorption and stress recovery

As no moderating effect of trait absorption has been found on the effects of listening to relaxing music on stress recovery, it seemed likely that no mediating effect of state absorption would appear in the relationship between trait absorption and stress recovery with our data. The ability to enter an absorbed state, or flow, is situation specific which highlights the importance of the musical cue. As Hall and colleagues (2016) pointed out, state absorption seems to be related to music preference, which is the preference or liking of music that an individual is listening to. State absorption is regarded as a primary mechanism of music enjoyment, suggesting that music preference might play an important role if individuals enter an absorbed state and in which intensity the absorbed state is experienced. Music preference is also closely related to the intensity of emotional arousal (Chanda & Levitin). It thus might be important to take into account the role of music preference in the investigation of the relationship between music, trait and state absorption and stress recovery.

Strengths and limitations

When discussing the results of the presented thesis, some limitations should be considered in the interpretation of the results. The limitations concern the study design, operationalization, generalizability and validity, which I will discuss in more detail in the following. Strengths of the study design are also highlighted.

Study design

In the first place, the study was not specifically designed to answer the research questions and the hypotheses deriving from these, as the thesis was embedded in the superordinate project *"Effects of music on stress and skin barrier recovery"*. Thus, some study elements are included in the study design that are not relevant for my research questions but could still potentially influence their results.

For example, the tape striping procedure and measures on the skin, which last approximately 10 – 20 minutes, happen between the stress induction and the music or silence intervention. During this time, the process of stress recovery has already begun, which probably influences measures of RPA and HRV. All participants eventually regress to their baseline physiological and psychological levels following an acute stressor. This could lead to a *floor-effect*, making it difficult to detect a further decrease in stress and whether this is affected by the audio condition. Also, as the participants are sitting during the tape striping procedure, this state could potentially be perceived as relaxing to some participants, which is not being controlled for.

In addition, given the general design of the superordinate study, a highly controlled experimental design was implemented. This also includes the way the participants are listening to music, such as in the selection of the playlists but also situational factors such as in which position they are seated while music listening. As demonstrated in current research, music listening primarily takes place in everyday life and in private settings of individuals. The artificial laboratory setting of the current study might have had an influence on how the music listening is perceived by the participants.

Music selection

Regarding the musical stimuli, six pre-selected pieces of music were offered to the participants that allowed for controlling comparable musical properties among them, such as tempo, melodic dynamics and emotional valence, across the music playlists. The music varied in style, and in a pre-study to the current study, calming and stress-reducing effects of the music has been demonstrated, which is a strength to highlight for our study. However, the pre-selection offered only partial control for the participants in choosing the music, which might have influenced stress recovery as self-selection of music has been demonstrated to be an important variable in predicting stress recovery in experimental settings (DeWitte et al., 2023). Though the pre-selection of music allows for comparability on the effects of the music pieces, it would be interesting to also include music with different emotional properties, such as with a sad, happy or peaceful emotional valence, to offer the participants music that might be more in line with their current mood. Research has demonstrated that individuals also rate their music preference based on the experience if the emotions conveyed by the music match their current feelings (Van Goethem & Sloboda, 2011). It would be interesting for future research to also investigate if the participants felt the emotions induced by the music were in line with their current feelings and whether that influenced the level of state absorption.

Sample size and characteristics

One of the primary limitations lies in the small sample size which influences the statistical power of the analysis and thus limits the ability to detect significant effects. Due to the strict inclusion and exclusion criteria for persons eligible for the study, the sample size was small ($N = 45$) and homogenous. Participants were only included when they had been assigned female at birth and did not identify their identity otherwise within the age range of 18 and 35. This specific homogeneous sample characteristic affects the generalizability of the findings of the total population. As stated above, the sample size failed to reach the minimum needed sample size based on a calculated power analysis, making it more likely that no significant effect of music listening on stress recovery would be found with our data.

The restrictions regarding age, sex, mental and somatic health conditions allow for high controllability, however, the homogeneity of the sample leads to limited generalization of the results beyond this specific sample. For example, younger adults generally consider music to be an important part of their lives, compared to other age groups, which has been shown to influence the effectiveness of music interventions (Yehuda, 2011). It remains to be seen if other age groups show another pattern.

Participants were excluded on the basis of having a diagnosis for a mental disorder or doing psychotherapy. As individuals with high absorption has been shown to be prone for hypersensitivity and for having a predisposition for anxiety disorders due to heightened sensitivity towards stimuli, participants high in trait absorption could have been potentially excluded, diminishing the variance of the trait absorption in the study (Shea, Burton & Girgis, 1993).

Also, individuals that had a music-related profession or were in music related studies, which probably comes with a higher sensitivity to music, were excluded. As absorption has been shown to be strongly associated with enjoyment of art, creativity, and music making itself, as well as a stronger response to musical cues and music-induced emotions, the exclusion of that person group might have also excluded individuals with a higher trait in absorption. This exclusion may also systematically eliminate individuals with high absorption, potentially diminishing variance in the sensitivity of music experience.

Measurement sensitivity

The MODTAS was used to measure trait absorption (Jamieson, 2005; Tellegen & Atkinson, 1974). Though the MODTAS reliably measures trait absorption and openness for self-altering experiences, only four of the 34 items specifically tackle musical experiences associated with absorption. This leaves the question of whether the MODTAS is sensitive enough to detect musical absorption, possibly giving a hint of lacking construct validity.

Regarding state absorption, the used item might not have fully captured all aspects of the absorbed state. As Csikszentmihalyi (1991) stresses the link between state absorption and flow, where states of total immersion in an activity are associated with maximal enjoyment, taking into account the characteristic of musical pleasure might offer a more complete picture of state absorption.

Unfortunately, as stated above, due to difficulties with the ECG sensor, through which data for HRV was obtained, a great number of data cases had to be excluded from the analysis due to missing data, leading to a very small data size of HRV.

COVID-19 pandemic

Another important factor that influenced the course of the study and the data collection was the COVID-19 pandemic. It is well documented that there has been a rise in mental health problems since the beginning of the COVID-19 pandemic, which goes along with increased feelings of stress and a higher number of mental illnesses (Cullen et al., 2020).

During this time, increased stress was reported in society, potentially introducing confounding factors for the presented thesis. Because of the precautions that had to be considered in order to stop the virus from spreading, a new normality emerged that was characterized by contact restrictions and lockdowns. Reported feelings of isolation and loneliness increased during the pandemic, potentially influencing the social evaluation of the test situation.

As it is safe to say that also stress recovery might have been affected by increased stress levels due to the pandemic, results need to be regarded with caution. Also, depending on the current governmental rules, some participants and study assistants had to wear FFP2 masks during the laboratory sessions, while others did not except for the TSST. This lead to differences during the course of data collection and interactions between participants and experiments, manifesting in non-consistent test conditions.

Implications and suggestions for future research

Although beneficial effects of listening to relaxing music on stress recovery, with trait and state absorption playing a crucial role in that relationship, have been demonstrated in several studies, research findings are still inconsistent (DeWitte et al., 2020; Hall et al., 2016; Sandstrom & Russo, 2010). The present thesis yielded only non-significant and underpowered results, yet, the use of music interventions still is a prominent and useful tool due to its cheap and non-invasive nature, and prior research results showing stress-reducing effects of music listening.

As music interventions often vary widely among different parameters, potentially leading to mixed results about their effects, more research about the influence of music listening on stress recovery is needed. For a better understanding of the moderating role of trait absorption, and mediating role of state absorption, in the relationship between music listening and stress recovery, it is important to further systematically test different aspects of this complex interplay.

In the following, I will give some examples for possible future study designs.

In investigating the role of trait absorption in the relationship between music listening and stress recovery, it is crucial to specifically investigate how individuals with different absorption levels experience music. The AIMS (Absorption in Music Scale, Sandstrom & Russo, 2013) was developed to identify individuals with strong emotional responses to music. It is a 34-item measure of an individual's ability and willingness to allow music to draw them into an emotional experience and could be a well-suited measure for research about absorption and music.

Concerning the sample characteristics, future studies should aim for a larger sample size to increase power to detect possible effects of music listening on measures of stress recovery.

Further, a more diverse sample would allow for more variance for the variables of interest. For example, with the inclusion of individuals with strong connections to music, such as people with music-related professions, or musicians, I presume that a larger variance of trait absorption could appear in the sample, as absorption has been associated with interest in music and arts. Also, a more diverse sample would allow for better generalizability. The inclusion of all genders would also allow more generalizable findings for the population.

For future research on listening interventions, it would be valuable to examine specific genres of music chosen by the study participants themselves. As Herbert (2012) pointed out, music may be a particularly effective agent in the facilitation of absorption because it affords multiple potential entry points to involvement, simply through the multi-modal acoustic attributes of music, such as timbre, resonance, rhythm and pitch. Since providing music to patients is both cost-effective and easy, exploring this aspect further is very compelling. The genre of music could significantly impact stress reduction outcomes. For instance, classical music has been found to aid cardiovascular recovery following a stressor, whereas jazz did not have the same effect (Chafin et al., 2004). Therefore, considering the type of music when studying the relationship between music, stress recovery, considering absorption, could yield important insights.

Conclusion

In my master thesis, I aimed to investigate the impact of listening to relaxing music on stress recovery, measuring changes in RPA and HRV as a proxy for stress recovery. I further considered the influence of trait and state absorption of the participants in the relationship between music listening and stress recovery. Psychosocial stress was induced with the TSST. After that, participants either listened to relaxing music (experimental condition) or sat in silence (control condition). No significant effects of listening to relaxing music were found on measures of RPA and HRV. Regarding absorption, no significant interaction effect was found between trait absorption and the audio condition on stress recovery. Also, no mediating effect of state absorption was observed on the relationship between trait absorption and stress recovery. Even though no significant effects were found within our data, listening to relaxing music might have a beneficial effect on stress recovery as research has repeatedly demonstrated that relaxing music would enhance HRV and subjective ratings of RPA. Given the non-significant effects and limitations of our study, one of the important ones having a small sample size, no definite conclusions can be drawn from our study. Further research is necessary to investigate the potential of listening to music on stress recovery, and in which way absorption plays a role in that relationship. Also, in determining the differential experience of music in individuals with high absorption, it remains still open to explore which music is most suitable for stress recovery and what role state absorption and musical pleasure plays in that interplay.

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Appendices

Appendix A. Abstract (English)

Music listening has been repeatedly observed to have beneficial effects on stress recovery, with relaxing music having particularly stress-reducing effects, both psychologically and physiologically. There are individual differences in the effects of music listening on stress recovery. One way to look at these differences in considering absorption, the capacity to become fully engaged or immersed in a particular activity in an effortless way. The objective of this thesis was to investigate the role of absorption in the effectiveness of music listening for stress relief. In a laboratory experiment, 45 female healthy participants (mean age M = 24.42, SD = 4.14) completed a stress inducing procedure, the Trier Social Stress Test (TSST). Afterwards, they either listened to relaxing music for thirty minutes, or sat in silence, a condition they were randomly assigned to. Heart rate variability (HRV) and subjective relaxed positive affect (RPA) were measured before and after the music, or control, intervention. It was hypothesized that the music group would exhibit greater stress recovery, compared to the control condition, and that trait absorption would moderate this effect. Further, it was hypothesized that state absorption would mediate the association between trait absorption and stress recovery. No significant effects were found of music listening on stress recovery and no moderating effect of trait absorption, as well as no mediating effect of state absorption could be reported. The results indicate that music listening during recovery from the TSST has no advantage for stress recovery. Due to the small sample size the results should be interpreted with caution. Nevertheless, this thesis contributes to the research field of music, stress and absorption and may instigate possible future research directions.

Keywords: stress recovery, relaxing music, trait and state absorption, relaxed positive affect, heart rate variability, musical enjoyment

Appendix B. Abstract (German)

Zahlreiche Forschungsergebnisse haben gezeigt, dass sich Musikhören positiv auf das Stressempfinden auswirken kann. Insbesondere entspannende Musik weist eine stressreduzierende Wirkung auf, sowohl psychologisch als auch physiologisch. Es gibt individuelle Unterschiede wie Musik wahrgenommen wird und wie sich das Musikhören auf die Stressregeneration auswirken kann. Absorption beschreibt die Fähigkeit zu vertieften Aufmerksamkeitszuständen bei der Wahrnehmung von Aspekten der inneren und äußeren Realität und scheint das Wahrnehmen von Musik zu beeinflussen. Ziel dieser Arbeit ist es, die Rolle der Absorption bei der Wirksamkeit des Musikhörens auf die Stressregeneration zu untersuchen. In dieser experimentellen Laborstudie wurden 45 gesunde weibliche Teilnehmerinnen (Durchschnittsalter M = 24,42, SE = 4.14) einem standardisierten psychosozialen Stresstest (Trier Social Stress Test, TSST). unterzogen und anschließend per Randomisierung der experimentellen Kondition (30 Minuten lang Entspannungsmusik hören) oder der Kontrollkondition (in Stille liegen) zugeteilt. Die Operationalisierung erfolgte durch die Messung von RPA, HRV vor und nach der Musik- bzw. Kontrollintervention. Es wurde angenommen, dass die Versuchsteilnehmerinnen in der Musikgruppe eine größere Stressregeneration erleben würden und dass Absorption diesen Zusammenhang moderieren würde. Entgegen den Erwartungen wurden keine signifikanten Zusammenhänge zwischen Musikhören, RPA, HRV und Absorption festgestellt. Die Ergebnisse deuten darauf hin, dass das Hören von Musik nach dem TSST keinen Vorteil für die Stresserholung hat. Aufgrund der geringen Stichprobengröße und der damit einhergehenden geringen Power sind die Ergebnisse mit Vorsicht zu interpretieren. Dennoch leistet diese Arbeit einen Beitrag im Forschungsfeld von Musikinterventionen und Stressregeneration unter Berücksichtigung von Absorption und zeigt mögliche zukünftige Forschungsrichtungen auf.

Schlagwörter: Stresserholung, Entspannungsmusik, Absorption, positiver Affekt, Entspannung, Herzratenvariabilität, Musikvergnügen