MASTERARBEIT | MASTER'S THESIS

Titel | Title

How liking and focus impact the effectiveness of audio interventions in stress reduction

verfasst von | submitted by

Daniela Liebhart BA BSc

angestrebter akademischer Grad | in partial fulfilment of the requirements for the degree of

Master of Science (MSc)

Wien | Vienna, 2024

Studienkennzahl lt. Studienblatt | Degree programme code as it appears on the student record sheet:	UA 066 840
Studienrichtung lt. Studienblatt | Degree programme as it appears on the student record sheet:	Masterstudium Psychologie
Betreut von | Supervisor:	Univ.-Prof. Dr. Urs Markus Nater
Mitbetreut von | Co-Supervisor:	Dr. Jasminka Majdandzic

Declaration on cooperation with other master's students

This master's 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 Jasminka Majdandžić.

Abstract

Background: With stress contributing to both physical and psychological health problems, music listening has emerged as a promising intervention to help reduce it. While the precise mechanisms by which music exerts stress-reducing effects are unclear, reward and distraction could constitute potential mechanisms. This master's thesis investigates the effects of music listening on stress, focusing specifically on music liking and mental focus. The study examined physiological indicators and subjective evaluations of stress following an acute stressor. Additionally, stress reduction was compared between participants in the music condition and those in an active control condition (audiobook).

Methods: A total of 41 women participated in this laboratory study, during which they underwent a 30-minute audio intervention. After completing the Trier Social Stress Test (TSST), participants in the music condition (n = 20) could choose from five researcher-selected playlists, while those in the audiobook condition (n = 21) could select from five researcher-selected audiobooks. Liking and mental focus were assessed via a post-intervention questionnaire, physiological stress was measured through electrodermal activity (EDA), and subjective stress levels were indicated on a Visual Analogue Scale (VAS).

Conclusion: The findings revealed no significant association between the degree of liking or the level of focus and stress reduction. Although physiological and subjective stress reduction was descriptively greater in the music condition than in the audiobook condition, there was no statistically significant difference. Due to the study's limited sample size and the lack of variability in liking and mental focus, these results should be interpreted with caution.

Keywords: music intervention, relaxing music, music characteristics, music preference, reward system, stress reduction, physiological stress, subjective stress, TSST

Contents

Introduction

Stress is something we experience on the daily (e.g., Linnemann et al., 2015; McEwen & Stellar, 1993; Yehuda, 2011), whether it be at home, school, work, or in our relationships (Yehuda, 2011). Particularly in the modern technological world, stress is often seen as a given by-product of one's life (Yehuda, 2011). However, stress is broadly acknowledged as a considerable factor contributing to adverse health outcomes. Elevated stress levels have been closely linked to numerous physical and psychological issues, including chronic pain, cardiovascular disease, depression, anxiety, addiction and generally a heightened susceptibility to illness (De Witte et al., 2020; Groarke et al., 2020). The increasing prevalence of stress is a cause for great concern (Groarke et al., 2020). Understandably, the interest in developing affordable interventions to reduce stress is significant (De Witte et al., 2020).

Stress definition

"Stress is defined as a state in which homeostasis is actually threatened or perceived to be so" (Chrousos, 2009, p.374). *Homeostasis* concerns the maintenance of balance and holding a person's internal environment constant (Lovallo, 2015; Sterling & Eyer, 1988). Every organism must sustain this dynamic balance which is continually disrupted by internal or external stressors. Stressors include a wide range of potentially harmful physical or emotional forces (Chrousos, 2009). While physical stressors can be heat, cold, infection, etc., psychological stressors are things that challenge a person due to the person's thoughts and interpretations (e.g., walking alone at night, failing a class) (Lovallo, 2015).

Allostasis is the ability to attain stability amid change (Sterling & Eyer, 1988). Unlike homeostatic systems, which regulate parameters such as body temperature, and blood oxygen withing narrow limits, allostatic systems operate within broader margins. These adaptive systems allow us to adjust to various physical states (e.g., asleep, awake, working out) and manage factors like noise, hunger, temperature extremes and danger (McEwen, 1998). However, an adaptation to stress can result in *allostatic load* which refers to the wearing off caused by chronic over- or underactivity of allostatic systems (McEwen, 1998). Both acute stress ("fight" or flight" response) and chronic stress (accumulation of daily stressors) can lead to lasting repercussions (Chu et al., 2024; McEwen, 1998).

The Transactional Model of Stress and Coping

Lazarus and Folkman (1984) created the *Transactional Model of Stress and Coping* and defined psychological stress as “a relationship between the person and the environment that is appraised by the person as taxing or exceeding his or her resources and endangering his or her well-being” (Lazarus & Folkman, 1984, p.21). They wanted to emphasize the importance of a person’s *appraisal* of the environment, since while some environmental pressures create stress in a considerable portion of society, individual and group differences in reaction intensity and type remain consistently evident.

When a person faces a stimulus, he or she initially assesses whether it is something potentially harmful (primary appraisal). There are three possible results coming from the primary appraisal: It is either seen as (1) not relevant (hence nothing can be lost or gained from it), (2) benign-positive (e.g., joy, happiness), or as (3) stressful (e.g., a threat, challenge). When the stimulus is appraised as stressful, a person engages in a secondary appraisal to evaluate his or her available coping strategies and resources (Lazarus & Folkman, 1984). Coping refers to a range of conscious techniques used to regulate emotions, behaviors, and physical responses in challenging situations (Miranda et al., 2012). Broadly, coping strategies can be divided into emotion-focused and problem-focused coping. Emotion-focused coping (e.g., avoiding, minimizing) tends to happen when individuals assess that threatening environmental conditions cannot be changed. In contrast, problem-focused coping (e.g., finding a different solution) is more likely when these conditions are viewed as capable of modification (Lazarus & Folkman, 1984).

Physiological stress response

The stress response is controlled by the stress system which is located both in the central nervous system and in peripheral organs. The stress system maintains a fundamental circadian activity and additionally reacts to stressors when needed. Proper basal activity, along with a well-regulated response to stressors in terms of intensity and timing, is crucial for well-being, performance, and healthy social interactions. However, improper baseline activity or stress responses (too strong, too weak, or prolonged) can negatively affect development and growth, potentially contributing to various cardiovascular, endocrine, metabolic, behavioral, allergic, and autoimmune disorders (Chrousos, 2009). The stress response is regulated by a complex interaction among the nervous, endocrine, and immune apparatuses, involving the sympathetic-adreno-medullary (SAM) axis, the HPA axis, and the immune system. This response equips the body to manage internal or external challenges posed by stressors (Chu et al., 2024). The stress response has two aspects: a fast response via the SAM axis and a slow response via the HPA axis. The SAM axis enables a much faster response than the HPA axis, since it works through direct nervous stimulation of the adrenal medulla and not through the slower hormonal mechanisms (Kreutz et al., 2012).

The SAM system triggers an amplified release of epinephrine and norepinephrine from the adrenal medulla into the circulatory system and an augmented release of norepinephrine from the sympathetic nervous system (SNS), raising norepinephrine levels in the brain. This causes, among other things, increased heart rate, blood pressure, skeletal muscle blood flow but also heightened alertness, arousal, and focused attention (Chu et al., 2024).

The HPA axis encompasses both brain and peripheral structures, including the hypothalamus, pituitary gland, and adrenal cortex. Activation of this axis begins when the hypothalamus releases corticotropin-releasing factor (CRF) which in turn triggers the pituitary to secrete adrenocorticotropic hormone (ACTH) and beta (ß)-endorphin into the bloodstream. The ACTH stimulates the adrenal cortex to produce and release cortisol, along with smaller amounts of testosterone (Chu et al., 2024; Kreutz et al., 2012).

Music and stress

”Music listening is a universal human experience” (Feneberg et al., 2023, p.1), and people of any age often engage in music listening (Groarke & Hogan, 2018). From inducing excitement to promoting relaxation, the impact that music has on us is versatile (Nater et al., 2006; Ooishi et al., 2017) and has been explored across various research domains such as physiological studies, brain imaging, and endocrinology (Ooishi et al., 2017).

The regulation of affect is frequently viewed as the main function of music listening (Groarke et al., 2020). Affect is considered to entail multiple components such as emotions, mood, and stress. It comprises both the aspect of arousal (high/low) as well as of valence (positive/negative). For example, tension, worry, anxiety, and stress can be classified as high-arousal negative affective states (Groarke et al., 2020). To establish an optimal status, people may intentionally use music to either up- or downregulate their arousal-related states (Feneberg et al., 2023; Nater et al., 2005). Therefore, music listening is frequently seen as an intentional coping strategy for managing stress (Miranda et al., 2012). It is hypothesized that music has the potential to mitigate both the physiological and psychological reactions to stress (e.g., De Witte et al., 2020). Findings from observational, experimental, and animal studies suggest a strong connection between emotions and physical health. While emotions can positively impact an individual's subjective wellbeing, research has demonstrated that emotions trigger bodily responses that can affect physical health (e.g., alterations in dopamine, serotonin, oxytocin, endorphin, and cortisol levels) (Västfjäll et al., 2012). "Music perception potentially elicits emotions, thus giving rise to the modulation of emotional effector systems such as the subjective feeling system, the autonomic nervous system, the hormonal, and the immune system" (Koelsch, 2011, p.1).

Potential underlying mechanisms of the stress-reducing impact of music

While research in music neuroscience has started to shed light on how the brain processes musical stimuli (as outlined below), the precise mechanisms remain a topic of ongoing debate (LaGasse & Thaut, 2012).

Reward & pleasure

All organisms participate in motivated behaviors aimed at survival (e.g., consuming food**)**. Reward is a complex concept that involves motivation (wanting or craving), prediction, actions which are goal-directed, learning through reinforcement, and feelings of pleasure (Chanda & Levitin, 2013). A reward can be seen as something that generates a sense of pleasure and since it is something positive, we tend to repeat the actions that lead to this enjoyable result (Zatorre & Salimpoor, 2013). While music lacks the obvious survival advantages of food or sex and does not have the addictive qualities of drugs, people still devote a great amount of time listening to music and rate it as one of the most pleasurable activities (Chanda & Levitin, 2013).

A well-recognized neurotransmitter in the reward system is dopamine (Dutcher & Creswell, 2018). In animals, the mesolimbic reward system reinforces essential behaviors like eating, mating, and caring for offspring. In humans, dopamine release in the mesolimbic regions also supports behaviors linked to eating, sex, and love. However, as species evolve, added factors can become important for survival. For example, getting a certain amount of money has become a predictor of successful survival in human societies. Unsurprisingly, acquiring money is highly rewarding and activates the mesolimbic areas, which shows that humans can recognize the value of abstract items that lack an inherent reward. Similarly, many people derive pleasure from stimuli that hold conceptual meaning, such as music, even if they aren't directly tied to survival (Zatorre & Salimpoor, 2013).

To investigate the neural processes that underlie highly pleasurable responses to music, Blood and Zatorre (2001) undertook a positron emission tomography (PET) experiment. Since music preferences are highly personal, each participant chose a piece of music that evoked highly pleasant emotional reactions (and each of those selected songs were used as another participant’s control). They found that music engages neural systems related to emotion and reward, similar to those activated by biologically essential stimuli like food, sex, or artificially stimulated by drugs. They also proposed that music’s activation of the reward system likely enhances pleasure by both engaging reward pathways and reducing activity in brain regions linked to negative emotions (e.g., amygdala). Indeed, in the functional magnetic resonance imaging (fMRI) study of Koelsch et al. (2006) they discovered that unpleasant (permanently dissonant) music increased the blood-oxygen-level dependent (BOLD) signals in the amygdala, parahippocampal gyrus, hippocampus, and temporal poles, which are regions that have been connected to the processing of negative emotions and fear. Conversely, there was also decreased BOLD signals from the mentioned areas when pleasant (consonant) music was played. Menon and Levitin (2005) inspected study participants’ brain activity in response to classical music using fMRI. They found a strong functional connectivity between various brain regions involved in reward and affect. Listening to music triggered notable activation in a network of subcortical structures, including the nucleus accumbens, the ventral tegmental area, and the hypothalamus.

Enjoyable music does not only trigger the release of dopamine but also enhances serotonin release, which is associated with good mood (Yehuda, 2011) and feelings of contentment from anticipated outcomes (Evers & Suhr, 2000). Evers and Suhr (2000) examined the changes of the neurotransmitter serotonin during the perception of pleasant and unpleasant music. They found that serotonin levels in platelets dropped when individuals listened to unpleasant music compared to pleasant music. This decrease was strongly associated with how listeners subjectively rated the music's pleasantness or unpleasantness, based on a standardized score. The authors suggested that subjective emotional responses are crucial for understanding physiological reactions to stimuli.

The review of Dutcher and Creswell (2018) concluded that activating the reward system may lessen physiological and behavioral stress responses in animal but also in human studies. There is indication that dopamine directly contributes to the regulation of stress, since in the study of Sullivan and Dufresne (2006) rats displayed heightened physiological stress responses after receiving a dopamine antagonist which inhibited the neurotransmitter sequence of the reward system.

Distraction & attention

Studies have shown that music which is played before or during surgical procedures can significantly reduce stress (Koelsch & Stegemann, 2012). This could stem from music's ability to occupy emotional, perceptual, and cognitive processes. These processes generate feelings of pleasure and reward but also use up attentional resources (Koelsch & Stegemann, 2012). Music can function as a distractor, redirecting attention away from a stressful situation towards something more enjoyable, thus lowering stress levels (De Witte et al., 2020; MacDonald et al., 2012).

A majority of studies that observe the neural networks of music listening do not have certain instructions on how participants should process the musical stimuli (Jäncke et al., 2018). Jäncke et al. (2018) wanted to deliberately manipulate the individuals' attention during music listening. In the group "attentive listening", people were instructed to pay attention to the music, while in the group "passive listening" they should focus on a played film excerpt. They detected that depending on the focus of attention, the same piece of music can elicit very different neural responses.

The influence of differing acoustic features of calming and exciting music is noticeable even when music is playing in the background and listeners are not actively focusing on it. This kind of listening is called *incidental* and continues automatically, even during early stages of sleep, when most external stimuli are filtered out. It is an adaptive mechanism for monitoring the environment for potential threats. Some of these acoustic features are more powerful than others, with simpler, low-level features getting processed almost automatically (Reybrouck et al., 2021). However, the review of Reybrouck et al. (2021) highlighted that neural activity in the brain's reward circuit plays a crucial role in the *conscious* experience of listening to music. Neuroimaging studies show clear distinctions between different types of listening, from incidental but also skilled listening (e.g., listening to music as a musician) to aesthetic listening (perceiving music as an aesthetic experience). Reybrouck et al. (2021) describes a musical aesthetic experience as a deeply immersive state where the listener fully engages with the music. In this state, a person is not just hearing the music but is actively focusing on how it sounds, feels, and resonates emotionally. These different types of listening (incidental, skilled, aesthetic) are reflected in progressively stronger connections between key brain networks involved in perception, cognition, attention, and reward. Specifically, there is increased connectivity between the mesolimbic and orbitofrontal reward circuits, the auditory cortex, and the prefrontal cortex during aesthetic listening.

Music interventions

To enhance a speedy stress recovery, various interventions have been suggested. Among these, music listening has been a popular and frequently employed strategy (De La Torre-Luque et al., 2017). The two meta-analyses of De Witte et al. (2020) made use of 104 randomized controlled trials (RCTs) and concluded that music interventions significantly reduced both psychological (d = .545) and physiological (d = .380) signs of stress. The meta-analytic review of Pelletier (2004) demonstrated an overall large mean effect size (d = .67) which indicated that music, in combination with relaxation procedures significantly reduces the stress-induced arousal. However, Pelletier (2004) also noted that determining the impact of music on relaxation remains challenging due to the multitude of relaxation methods coupled with diverse musical selections, varying stress types and stress levels, and differences in measurements. According to the findings of the systematic review of Fancourt et al. (2014), sixteen out of twenty studies found that relaxing music decreased the physiological parameters heart rate, respiration rate, and blood pressure.

Factors impacting the stress reducing effects of music listening

Gender

First, the physiological and psychological reaction to stress appears to differ between women and men, causing significant gender differences in stress parameters (De Witte et al., 2020). Moreover, men and women exhibit variations in their emotional responses to music as well as in their preferences in music (Nater et al., 2006). Nater et al. (2006) detected that in comparison to men, women are hypersensitive to unpleasant and arousing music stimuli and Pelletier (2004) found that especially females and adolescents had the greatest benefits from listening to music.

Music characteristics

Not every musical piece is suitable for promoting relaxation and reducing stress (Jiang et al., 2016). It is suggested that particular attributes of music possibly influence the stress-reducing impact of music interventions. Music tempo emerges as a significant factor in moderating music-related relaxation and arousal (De Witte et al., 2020; Ooishi et al., 2017).

Especially a slow tempo between 60 to 80 beats per minute (bpm) is often linked with a reduced heart rate and greater relaxation (De Witte et al., 2020) while a fast tempo is associated with increased sympathetic nerve activity (Ooishi et al., 2017). Slow music has also been shown to lower the levels of norepinephrine, a neurotransmitter involved in regulating arousal (Yehuda, 2011). Music that has a simple rhythm, a slow tempo and includes just a few instruments appears to be more relaxing (Wang, 2014). In the study of Gomez and Danuser (2007), music that was fast and staccato elicited quicker breathing, an increased heart rate, and skin conductance which further supports the argument that rhythmic elements primarily influence the physiological reactions to music. Moreover, music that is instrumental appears to be more calming than music with lyrics. Rather than soothing, lyrics can be more distracting or even activating (De Witte et al., 2020). The valence and arousal level of music also impact listener's physiological responses. Music with a high arousal level has been associated with amplified skin conductance level (SCL) and an increased heart rate compared to low-arousal music. Additionally, music with positive valence has been linked to higher heart rates than music with negative valence (Sandstrom & Russo, 2010).

Individual factors

Yehuda (2011) stated that it is overly simplistic to presume that individuals have uniform responses to calming music. Variables such as preference, familiarity, mood, and musical background impact the reactions. In the research of Stratton and Zalonowski (1984), the type of music was not as powerful as music preference in inducing relaxation. In the study of Jiang et al. (2016) music preference also impacted the decrease in stress levels. They concluded that music preference is an essential component that should be considered when music is utilized for stress reduction. In the study of De La Torre-Luque et al. (2017), listening to preferred relaxing music after the Trier Social Stress Test (TSST) resulted in adaptions in valence and arousal, meaning that the participants reported lower levels of negative affect, anxiety, and depression, and increased levels of positive affect in comparison to the control group (silence). It appears that music preference but also being familiar with the played music correlates with perceived relaxation (Wang, 2014). However, there are conflicting findings: Iwanaga and Moroki (1999) stated that calming characteristics of music have a greater impact on the reduction of stress and anxiety than music preference. In the study of Sandstrom and Russo (2010) the degree of liking the provided musical excerpts did also not significantly correlate with participants' subjective stress levels. Their study results illustrated that particularly low-arousal, positively valenced music is most successful in promoting physiological and subjective recovery after a stressor. In this regard, I would also like to raise the topic of who is selecting the music:

Researcher selected vs. self-selected music. There is research that supports the notion that study participants should be able to select their own preferred music, since it heightens the stress reduction (De Witte et al., 2020). Study participants have even mentioned that they prefer a silence-condition over a music condition that is prescribed (Yehuda, 2011). However, being able to self-select does not particularly mean that participants have to bring their own music (De Witte et al., 2020). As noted in the two meta-analyses of De Witte et al. (2020) a difficulty arises with the term *self-selected music* since researchers often use it when they mean that participants bring their own favorite music but also when participants were able to select music that was pre-selected from the research team. It is suggested that self-selected music is also more effective than researcher-selected music due to the locus of control and therefore, a greater sense of control and self-efficacy (Hekmat & Hertel, 1993). However, according to the meta-analysis of Pelletier (2004) researcher-selected music had a greater stress-reducing effect than self-selected music.

Research gap and relevance

Stress is often a daily occurrence in our lives and influences not only our well-being but also our health (De La Torre-Luque et al., 2017). Stress is commonly perceived as a major factor in disease development, and increasing clinical evidence suggests significant influences of stress on the cardiovascular and immune system (McEwen & Stellar, 1993). Over the past decade, there has been a notable surge in the development and application of music interventions aimed at alleviating stress in various settings and supporting mental and physical health by establishing a space that promotes relaxation (De Witte et al., 2020). Given that music is very popular (Feneberg et al., 2023; Linnemann et al., 2015) and music interventions are low-cost, cause no side effects and are easy to implement (Chanda & Levitin, 2013; De La Torre-Luque et al., 2017; De Witte et al., 2020; Feneberg et al., 2023; Gillen et al., 2008; Song et al., 2023; Thoma et al., 2013), its calming effects hold considerable importance in both preventing and addressing stress-related issues (De Witte et al., 2020). However existing literature frequently appears to be inconsistent on the stress-reducing effects of music listening (Adiasto et al., 2023; Linnemann et al., 2015; Thoma et al., 2013). This discrepancy could stem from the great variability in research on music listening and stress (Adiasto et al., 2023) which highlights the necessity for additional research to find the most effective music interventions (De Witte et al., 2020). Since studies examining the stress-reducing effects of music predominantly utilize music that is either provided by the researchers (focusing mostly on calming musical attributes) or by the study participants (focusing mostly on individual music preference) (De Witte et al., 2020; Pelletier, 2004), this thesis aims to “combine” these approaches by letting study participants chose from five researcher-selected playlists and asking them to rate how much they liked it after listening. While unpleasant music is linked to increased activity in brain areas that are associated with the process of fear and negative emotions (e.g., Blood & Zatorre, 2001; Koelsch et al., 2006), pleasurable music is connected to the activation of the reward system (Blood & Zatorre, 2001; Dutcher & Creswell, 2018; Zatorre & Salimpoor, 2013) which potentially directly reduces a person’s stress response (Dutcher & Creswell, 2018; Sullivan & Dufresne, 2006). This suggests that the degree of liking the music excerpts should impact the extent of stress reduction. Hence, the first goal of this study was to investigate the impact of liking the provided music on physiological and psychological stress reduction after an acute stressor. Insights from this study could be helpful in developing better fitted music interventions for managing stress effectively.

It has also been proposed that music can reduce stress levels by distracting us from distressing thoughts and experiences and bringing our attention to something more pleasurable (e.g., De Witte et al., 2020; Koelsch & Stegemann, 2012; MacDonald et al., 2012). Jäncke et al. (2018) demonstrated that depending on whether individuals attentively or passively listened to music, differing neural pathways were activated. Particularly since music is rarely the focus of attention in daily life (Greasley & Lamont, 2011; Greb et al., 2018) and typically supports rather than overtakes an activity that it is paired with (Sloboda, 2010), it would be interesting to see whether more/less focus on music has an impact on stress reduction. Jiang et al. (2016) suggested that passive music listening, in comparison to attentive music listening could have a weaker stress reducing effect. However, so far, there has been no experimental study investigating the mental focus of study participants during a music intervention and its influence on stress reduction, therefore, this constitutes as the second objective of this study.

Reybrouck et al. (2021) underlined that the activation of the brain’s reward system through music appears when a person consciously listens to it and that neuroimaging research supports the notion, that there are qualitative differences between varying types of music listening (from incidental to aesthetic listening). While this is speculative, the third aim of this research is to investigate whether there is an interaction between liking and mental focus.

Particularly, whether a person's degree of liking the music excerpts only affects the extent of stress mitigation if the person listens attentively.

Finally, there is an overreliance on silent control groups in studies examining the effects of music listening and an active control group (e.g., audiobook, white noise) could pave the way for a better comparison and understanding (Groarke et al., 2020). Particularly since most reviewed studies lack proper control conditions to match arousal, emotional qualities, attention, or mood it raises the possibility that the effects observed might not be specific to music but could result from any stimulus offering similar engagement (Chanda & Levitin, 2013; Thoma et al., 2013). Therefore, the last objective of this thesis was to compare the music condition with the audiobook condition and see whether there are significant differences in stress reduction.

Research questions and hypotheses

Based on the illustrated findings and research gaps, the research questions and hypotheses are the following:

Q1: Does liking the audio intervention affect the decrease in physiological and subjective stress levels following an acute stressor with individuals who like the audio intervention more showing a bigger decrease in physiological and subjective stress levels?

H1: Higher liking of the music is associated with a bigger decrease in electrodermal activity (EDA).

H2: Higher liking of the music is associated with a bigger decrease in subjective stress levels.

H3: Higher liking of the audiobook is associated with a bigger decrease in EDA.

H4: Higher liking of the audiobook is associated with a bigger decrease in subjective stress levels.

Q2: Does the extent to which participants focus on the audio during the audio intervention affect the decrease in physiological and subjective stress levels following an acute stressor, with individuals focusing more strongly on the audio showing a bigger decrease in physiological and subjective stress levels?

H1: Greater mental focus on the music is associated with a bigger decrease in EDA.

H2: Greater mental focus on the music is associated with a bigger decrease in subjective stress levels.

H3: Greater mental focus on the audiobook is associated with a bigger decrease in EDA.

H4: Greater mental focus on the audiobook is associated with a bigger decrease in subjective stress levels.

Q3: Does the interaction between liking and mental focus affect the decrease in physiological and subjective stress levels following an acute stressor?

H1: The interaction between liking and mental focus affects the decrease in EDA.

H2: The interaction between liking and mental focus affects the decrease in subjective stress level.

It was hypothesized that liking only has an impact on stress reduction if the mental focus on the audio excerpt was high.

Q4: Does audio condition (music or audiobook) affect the decrease in physiological and subjective stress levels following an acute stressor?

H1: EDA decrease is greater in the music condition compared to the audiobook condition.

H2: Subjective stress level decrease is greater in the music condition compared to the audiobook condition.

Methods

This master's thesis comprises data gathered in the overarching project "Muskiba: Effects of music listening on stress and skin barrier recovery" at the Clinical and Health Psychology department of the University of Vienna. Data used in this study was gathered between January 2020 and May 2024.

Study design

This laboratory study was conducted as a randomized controlled trial (RCT), wherein participants were allocated to one of three listening conditions (music/audiobook/silence) which served as independent variables. Study participants were able to select a playlist of their choice in the music and in the audiobook condition.

A key part of the research project was to investigate the impact of relaxing music on stress, therefore, various stress measures served as dependent variables. Next to EDA and subjective stress ratings (which were both used for this master's thesis), physiological stress measures like heart rate, heart rate variability, cortisol levels and salivary alpha-amylase were collected. Stress parameters that were not continuously measured (subjective stress levels via a questionnaire and alpha amylase & cortisol via saliva samples) were gathered eight times throughout the laboratory assessment.

Since the main goal of the research was to examine the effect of music listening on skin barrier recovery after mechanical disruption and whether it was mediated by stress, trans-epidermal water loss (TEWL) measurements were taken. The mechanical disruption of the skin was established via a tape stripping procedure in which adhesive tape was repeatedly removed (max. of 50 stripes) from the previously marked area on the participant's inner forearm.

Prior to the lab appointment, participants had to fill out questionnaires regarding several trait variables online. While some focused on personality traits (the Big-Five personality traits, trait anxiety, self-esteem), others examined stress (e.g. perceived stress reactivity, chronic stress), health (e.g. depression, premenstrual syndrome), coping, resilience and emotion regulation. There were also several questionnaires concerning music, investigating, for example, music preference, cognitive style of music listening and music reward sensitivity.

During the lab appointment, participants also had to fill out questionnaires. Next to the questionnaire which required participants to evaluate the played audio (which was used for this master's thesis), affective states, such as positive affect, current mood, anxiety, primary and secondary appraisal and perceived control were assessed.

Participants

The recruitment of participants was predominantly conducted online via various social media platforms (e.g., Facebook, Instagram) and the mailing list of the University of Vienna. Additionally, flyers were distributed. For partaking in our study (and completing), participants received monetary compensation of 45 euros. Individuals could express their interest by writing an email to the given email address. Prior to inviting them to a lab appointment, a telephone interview was arranged and screened potential participants concerning the inclusion and exclusion criteria.

Criteria for Inclusion and Exclusion

Due to the measurement of salivary cortisol and alpha-amylase multiple factors that are known to impact those measures (Strahler et al., 2017) needed to be considered. As highlighted by Kirschbaum et al. (1999) there are gender differences in the HPA axis response following a stressor. Women appear to not only react to stress more sensitively but also to music (Nater et al., 2006). Given those differences, we only included women in our study. Therefore, the study included women aged 18 to 35, with a body mass index between 17 and 30, who were fluent in German. Participants were required to have a regular menstrual cycle since the testing was scheduled to occur during the participant's follicular phase to control for hormonal changes. Consequently, hormonal medication or contraception, pregnancy or breastfeeding led to exclusion.

Additional health criteria excluded individuals with specific conditions, such as heart diseases, lung and respiratory diseases, metabolic diseases, digestive tract diseases, liver diseases, infectious diseases (e.g., HIV), thyroid diseases, autoimmune diseases, skeletal and muscle diseases, blood diseases, hearing impairment (e.g., hearing loss, tinnitus), blindness or severe visual impairment, chronic or acute infectious skin diseases, hypersensitivity reactions, allergies, neurological diseases, and mental disorders (e.g., major depression, anxiety disorder, eating disorder, schizophrenia, psychosis).

Individuals were also excluded if they had been in a tropical region in the past six months, underwent surgery in the past eight weeks, or received a vaccination in the past two weeks. Since habitual cigarette smokers exhibit higher cortisol levels (Kirschbaum et al., 1992) only non-smokers or non-habitual smokers could participate. Moreover, people were excluded if they exhibited regular problematic alcohol consumption or took specific medications, including psychotropic drugs (due to the effects on the HPA axis or ANS). Finally, individuals with absolute pitch, a career in music, or prior experience with stress tests like the Trier Social Stress Test (TSST) were excluded from participating in the study.

Materials

Audio intervention

In the music condition participants could select between *ambient, guitar, jazz, lofi*, and *lounge music* (although they were only labeled with numbers from 1 to 5 and did not include the name of the genre). The playlists themselves have been edited by the research team and include only nonlyrical music that appeared calm, pleasant, and relaxing, with a tempo not exceeding 80 beats per minute. A prestudy with 70 women had been conducted to ensure that the music was perceived as relaxing.

In the audiobook condition, participants could listen to pre-selected audiobooks that should be non-arousing. They could select between the topics of *biology, history, cosmology, philosophy* and *physics.*

In the silent condition (not used in this master's thesis) participants were lying in silence but also wore the headphones that were used for the music and audiobook condition.

Liking

Directly after the audio intervention, participants' liking of the audio excerpt (music or audiobook) was assessed via the statement "Die Musik/Das Hörbuch hat mir gefallen." (I liked the music/audiobook) which was part of the questionnaires "Bewertung_Musikstimulus" and "Bewertung_Hörbuchstimulus", respectively. Participants needed to indicate their level of liking on a five-point Likert scale ranging from 1= "gar nicht" (not at all) to 5= "sehr" (very) after listening to the audio.

Mental focus

As with the item for liking, mental focus was measured directly after participants listened to the audio intervention. Whether the participants were preoccupied with other things (e.g., daydreaming, memories) or focused (predominantly) on the audio excerpts was also assessed in the questionnaires "Bewertung_Musikstimulus" and "Bewertung_Hörbuchstimulus", respectively, with the item "Worauf haben Sie sich beim Hören der Musik/des Hörbuchs konzentriert?" (What did you focus on while listening to the music/audiobook?). Possible answers on the five-point Likert scale ranged from 1 = "Ich habe mich beim Musikhören/Hörbuchhören gedanklich (fast) nur mit anderen Dingen als der gehörten Musik/dem gehörten Hörbuch beschäftigt (z.B. mit Erinnerungen, Zukunftsplänen, Tagträumen, etc.)" (While listening to music/audiobook, my thoughts were (almost) entirely focused on things other than the music/audiobook itself (e.g., memories, future plans, daydreams, etc.) to 5 = "Ich habe mich beim Musikhören/Hörbuchhören gedanklich (fast) nur auf die Musik/das Hörbuch konzentriert" (While listening to music/audiobook, I focused my thoughts (almost) entirely on the music/audiobook.)

Physiological stress levels

Participants' physiological stress level was captured throughout the assessment with electrodermal activity (EDA) via a *movisens* EDA sensor (EdaMove4, movisens GmbH, Karlsruhe, Germany). EDA displays the variances in the electrical properties of the skin which is caused by the activity of sweat glands (Horvers et al., 2021). Since the sweat glands are entirely controlled by the sympathetic nervous system, skin conductance illustrates physiological or psychological arousal or a stress response (Bradt et al., 2013; Cacioppo et al., 2000; van den Bosch et al., 2013). Van den Bosch et al. (2013) also stated that in music emotion research, emotional arousal is often measured through physiological parameters like heart rate, EDA, respiration, and body temperature. Of these measures, EDA is typically preferred due to its high sensitivity and the fact that it is solely controlled by the sympathetic nervous system.

In the systematic review of Horvers et al. (2021), the *mean EDA* of a study participant is the feature most frequently used to measure physiological arousal. The mean EDA refers to the average EDA measured within a certain period of time. To evaluate the impact of the audio intervention on stress reduction, delta scores were calculated. Therefore, the disparity between the mean EDA of the five-minute measuring window before listening to the audio excerpt and the mean EDA of the five-minute measuring window during listening to the audio excerpt (the last 5 minutes of the 30-minute audio intervention) was calculated ($\Delta_{PhysStress}= PhysStress_{pre\text{-}audio} - PhysStress_{during\text{-}audio}$).

Subjective stress levels

Participants indicated their perceived stress level on a Visual Analogue Scale (VAS) ranging from 0 to 100 to the question “Wie sehr fühlen Sie sich gestresst?” (How stressed do you feel?). The VAS is a widely used and satisfactory measurement for perceived stress (Lesage et al., 2012). As with the measurement of physiological stress levels, delta scores were calculated, meaning the disparity between the VAS measured prior to the audio intervention and the VAS administered immediately after the audio intervention ($\Delta_{SubjStress}= SubjStress_{pre\text{-}audio} - SubjStress_{post\text{-}audio}$). Therefore, the higher the $\Delta_{SubjStress}$-score the greater the stress-reduction.

Trier Social Stress Test

To be able to study stress in laboratory settings, it is necessary to apply standardized stress tests that reliably induce stress (Skoluda et al., 2015). A widely used tool to induce stress in laboratory settings is the TSST. It employs a range of tasks that involve speech preparation, speaking in public and arithmetic testing (Groarke et al., 2020). According to Kirschbaum et al. (1993) the salivary cortisol levels double or even quadruple in individuals participating in the TSST. Individual variations in the cortisol increase caused by the TSST are likely to derive from factors, such as genetics, gender, and nicotine consumption, but not from personality traits (Kirschbaum et al., 1993).

Procedure

When someone wanted to participate in our study, fulfilled the inclusion and exclusion criteria and filled out the online questionnaires, they came to a scheduled laboratory assessment. To mitigate variation in hormone levels due to the time points in the day, the study always started in the afternoon, around 13:00 and lasted around four hours in total. Before the scheduled appointment, participants were instructed to abstain from intense physical exercise for 24 hours, from consuming alcohol or caffeinated beverages for 48 hours, and from tooth brushing or eating for at least an hour. After the arrival of the study participants at the lab, they received a brief overview of the procedure and the informed consent form. Moreover, they were instructed on how to take saliva samples, had the area for the tape stripping procedure marked, received a chest strap for measuring the heart rate/heart rate variability and EDA sensors on the non-dominant hand and selected, if applicable, their preferred music playlist or audiobook.

Following a 30-minute adaptation period, participants gave their initial saliva sample and completed the following questionnaires (T1): Multidimensional Mood Questionnaire, The Types of Positive Affect Scale and Visual Analogue Scales concerning stress. These questionnaires were repeatedly handed out at various time points (8 times) throughout the experiment. Every time participants filled them out, they also provided a saliva sample (8 times). This set of measurements will further be referred to as T1 through T8 measurements.

The TSST started by bringing the study participant into another room where two "interviewers" in white coats were already seated at a table with a visible video recorder. The interviewers/committee always consisted of a male (active stressor) and a female (passive stressor) person. The passive stressor did not speak or talk to the study participant, only the active stressor did and also only gave instructions. Participants were instructed that they had time to prepare for a mock job interview. However, they should only prepare to present personal qualities since the interviewers supposedly already have the information about their past work experience and education. After the preparation time (3 minutes) they provided another saliva sample, received the questionnaires mentioned before (T2) and additionally filled out the questionnaire concerning primary and secondary appraisal. They had to give a speech for their chosen job application and then do an arithmetic task (counting backwards starting from 2,043 by continuously subtracting 17 and starting over in case of mistakes) in front of the committee. Each task lasted five minutes, however the participants were not aware of this set time duration. Moreover, the interviewers kept a neutral facial expression throughout the tasks and did not give any form of verbal or nonverbal feedback besides the instructions. Before going back to the previous room, they provided a saliva sample, filled out the usual questionnaires (T3) and an additional questionnaire which asked to retrospectively evaluate their stress level caused by the TSST.

After returning to the initial test room the baseline TEWL measurement, the tape-stripping procedure and the first TEWL measurement after impairment occurred (~30 minutes). This was followed by the fourth round of repeated measurements (T4) and the 30-minute audio intervention.

For the audio intervention, participants were lying on a deck chair and listened to their selected music playlist or audiobook (depending on their group allocation) on over-ear headphones. The lights were turned off and the experimenter left the test room. Right after the 30 minutes, they had the fifth measurement (T5) with an additional questionnaire for evaluating the music/audiobook/silence.

Following this, a TEWL measurement was taken, and participants spent about 30 minutes reading provided magazines. Then, another set of measurements took place (T6). This sequence was repeated two more times and therefore included T7 and the final T8 measurements. At the end of the study, all measuring devices were removed, and participants could ask questions and got debriefed. They further filled out a form with their bank details so we could transfer the financial compensation for their study participation.

For this thesis only the physiological (EDA) and subjective stress levels (VAS) from before and during (EDA)/after (VAS) the audio intervention were used, together with the questionnaire that served the purpose of evaluating the auditory stimuli (liking and mental focus) directly after the audio intervention.

Statistical Analysis

The proposed hypotheses were analyzed in the statistics program IBM SPSS Statistics (Version 29.0). To answer the first two research questions (H1 – H8) several linear multiple regression analyses were conducted.

For the hypotheses concerning EDA (H1, H3, H5, H7), liking of music/audiobook and focus on music/audiobook served as independent variables, differences in EDA between T4 and during listening to the audio excerpt were the dependent variable.

For the hypotheses concerning subjective stress levels (H2, H4, H6, H8) liking of music/audiobook and focus on music/audiobook served as independent variables, differences in subjective stress ratings between T4 and T5 (after audio listening) constituted the dependent variable.

For the research question concerning the interaction between liking and mental focus (H9, H10) moderation analyses with the PROCESS Macro of Hayes (2018) were executed, since statistically the effects of a moderation are equal to an interaction (Hayes, 2018). Liking of music/audiobook served as the independent variable, focus on music/audiobook was entered as the moderator and differences in EDA between T4 and during listening to the audio excerpt (H9) or respectively, differences in subjective stress ratings between T4 and T5 (H10) were the dependent variable.

For H11 and H12 t-tests for independent samples were used. For H11, listening condition (music or audiobook) was the independent variable and differences in EDA between T4 and during listening to the audio excerpt were the dependent variable.

The listening condition (music or audiobook) also served as the independent variable in H12, with the dependent variable being the differences in subjective stress ratings between T4 and T5 (after listening to the audio excerpt).

To estimate sample sizes that allow finding results of significance, G*Power was used. Based on the meta-analyses of De Witte et al. (2020) and Pelletier (2004), medium effect size of $f2= 0.15$ was assumed. With two predictors (liking, focus) and a power of .80, an alpha level of .05 and the statistical model of linear multiple regression, the minimum sample size for the analyses constituted of 68 participants. The moderation analyses with the PROCESS macro rely on bootstrapping and are considered as very robust (Hayes, 2018).

For H11 and H12, assuming small to medium effect sizes ($d = .50$), a power of .80, an alpha level of .05 and the statistical model of differences between two independent means (independent t-test), the minimum sample size for the analyses was 102 participants.

Results

Descriptive statistics

Sample description

The final sample considered for analyses consisted of $N = 41$ women (20 music condition, 21 audiobook condition). Participants' ages ranged from 20 to 34 years with a mean age of 24.88 ($SD = 3.82$). Since most participants were Austrians (65.9%), had completed their A-levels (90.2%) and attended university (75.6%), this sample can be considered as quite homogeneous. For a more detailed overview of participants' demographic variables see Table 1.

Table 1
Sample description (N = 41)

		Absolute values (n)	*Relative values (%)*
Sex			
	Female	41	100,0%
Nationality			
	Austria	27	65,9%
	Germany	5	12,2%
	Hungary	2	4,9%
	Croatia	2	4,9%
	Italy	2	4,9%
	Switzerland	1	2,4%
	France	1	2,4%
	Chile	1	2,4%
School education			
	A-levels	37	90,2%
	Other school-leaving qualifications	2	4,9%
	Advanced technical college	1	2,4%
	Secondary school	1	2,4%
Vocational education			
	University	31	75,6%
	No vocational education	5	12,2%
	Apprenticeship	2	4,9%
	Other vocational education	2	4,9%
	University of applied sciences	1	2,4%
Employment			
	No, in education	15	36,6%
	Yes, less than part-time	11	26,8%
	Yes, at least part-time	8	19,5%
	No, unemployed	4	9,8%
	Yes, full-time	3	7,3%

Liking

Directly after participants listened to either music (n = 20) or audiobook (n = 21) (depending on their assigned audio condition) they retrospectively rated how much they liked the audio from 1= ”gar nicht” (not at all) to 5= “sehr” (very).

Music

As visible in Figure 1 the distribution of music liking is very left skewed with a mean value of 4.45 (SD = 0.69). As tested by Shapiro-Wilk-test, item ratings were not normally distributed (p = .001).

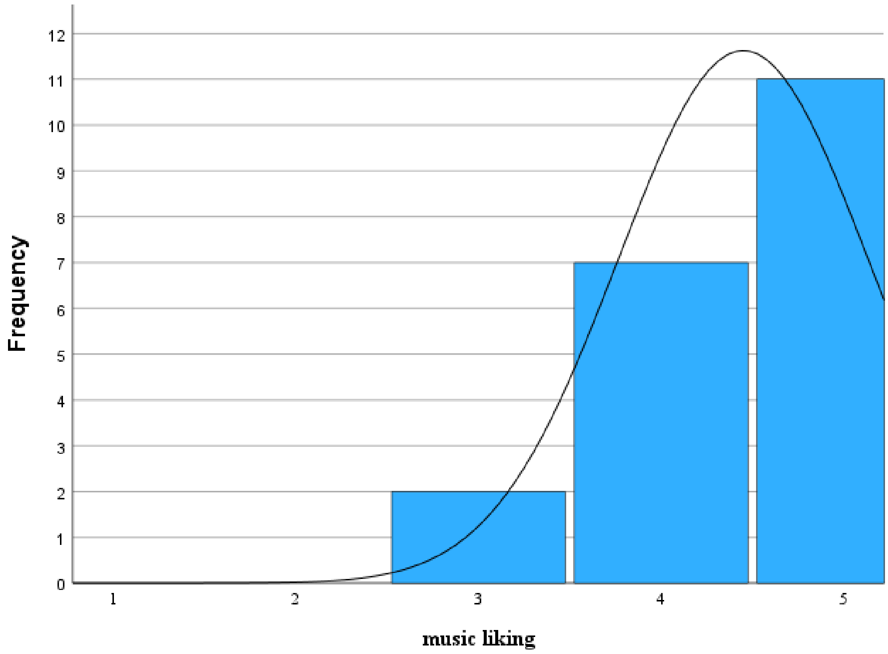

Figure 1. Distribution of liking music scores. Blue bars display the distribution of music liking. The black line illustrates the normal distribution curve.

Audiobook

In comparison to music listening, participants liked audiobook listening with a mean value of 3.71 (SD = 0.85). Equally to the music listening condition, ratings were not normally distributed as assessed by Shapiro-Wilk- test, p = .006, and left skewed (see Figure 2).

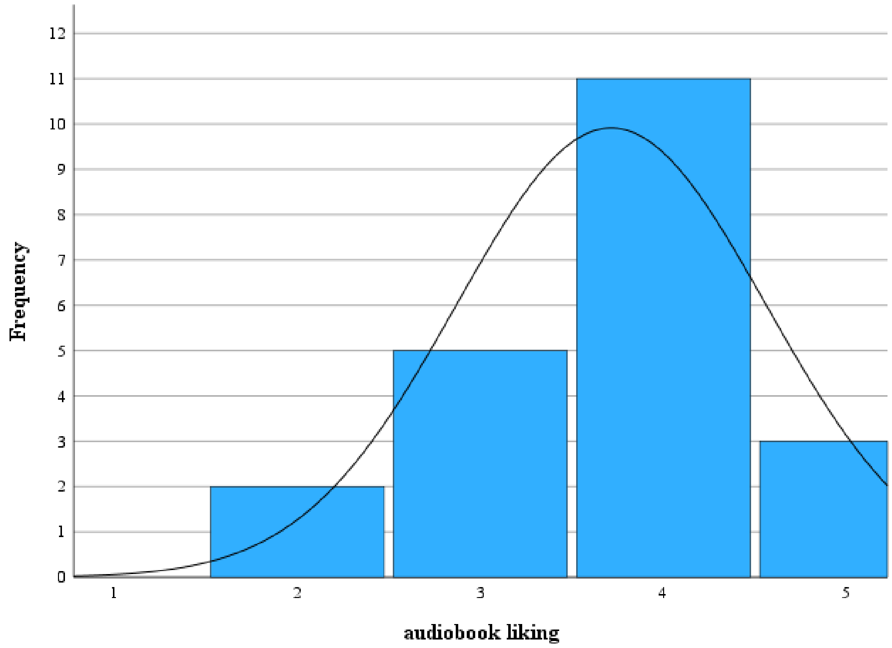

Figure 2. Distribution of liking audiobook scores. Blue bars display the distribution of audiobook liking. The black line illustrates the normal distribution curve.

Mental focus

After listening to the audio excerpt, participants also indicated how much they focused on the audio and whether they were preoccupied with other things (e.g., daydreaming, memories). Participants were able to choose from five answer options, with the first one being the least focused on the audio, up to the fifth option, which indicated the highest focus on the played audio.

Music

Due to two missing values, 18 instead of 20 participants could be considered. The mean value was 2.89 (SD = 1.08) and the ratings were right skewed (see Figure 3). Scores were not normally distributed, as tested by Shapiro-Wilk test, p = .05.

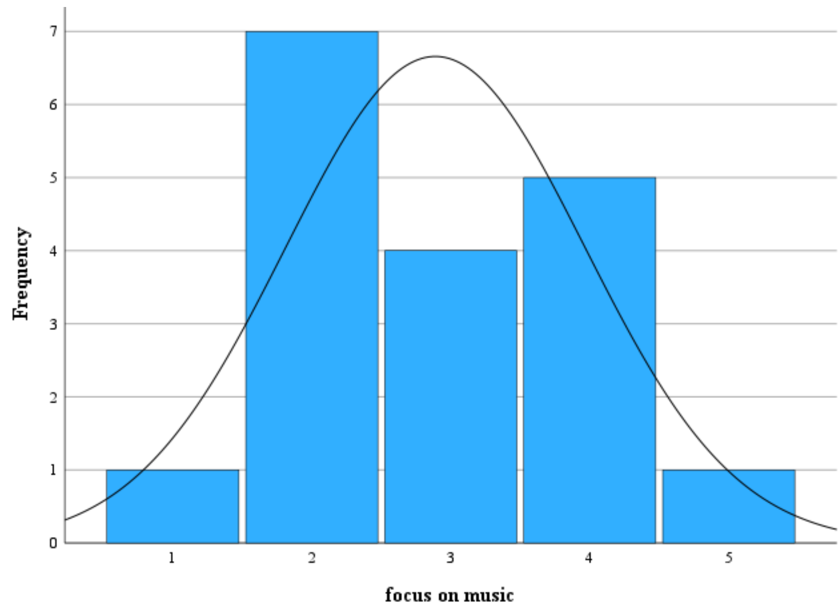

Figure 3. Distribution of music focus scores. Blue bars display the distribution of focus on music. The black line illustrates the normal distribution curve.

Audiobook

The mean value of the 21 participants was 2.86 (SD = 0.85). The distribution of the data is left skewed and not normally distributed, as assessed by Shapiro-Wilk test, $p = .01$ (see Figure 4).

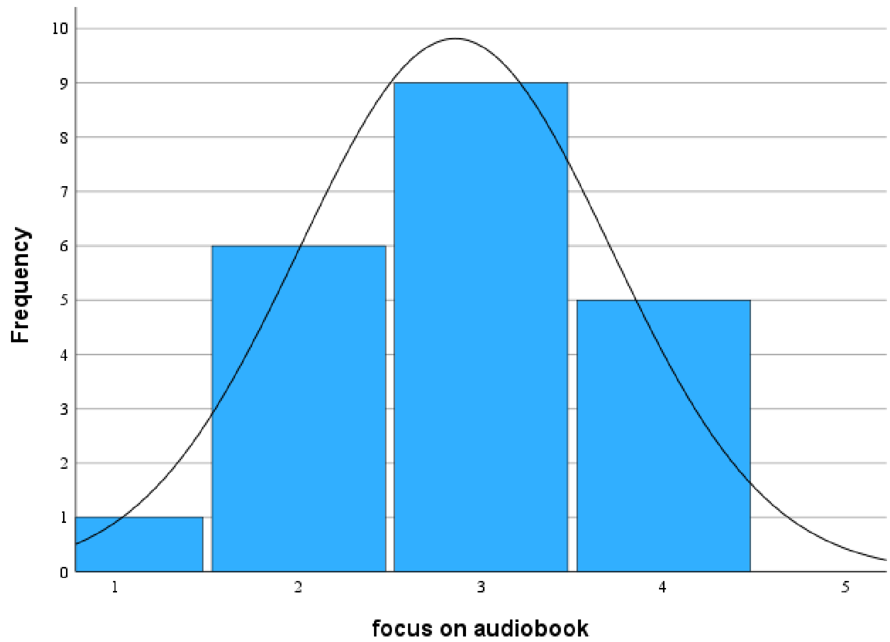

Figure 4. Distribution of audiobook focus scores. Blue bars display the distribution of focus on audiobook. The black line illustrates the normal distribution curve.

Stress

Physiological stress was measured via EDA with the mean EDA of five-minute measuring windows representing EDA values for T4 (before listening to the audio excerpt) and during listening to the audio excerpt (the last 5 minutes of the 30-minute audio intervention). To assess the change in EDA the difference between those two time points was used (T4 - $T_{\text{during music}}$). Higher score changes represent greater differences between EDA before listening to the audio excerpt and during listening to the audio excerpt, displaying greater reduction in physiological arousal which can be described as physiological stress. Negative values indicate higher EDA during listening to the audio excerpt compared to T4 (before listening to the audio excerpt).

Music

Change scores for EDA ranged in this sample (n = 20) from -5.82 to 15.95 with a mean of 5.95 (SD = 5.68). As assessed by Shapiro-Wilk test, scores were normally distributed (p = .57). Figure 5 displays the distribution of EDA score changes between before music listening and during music listening.

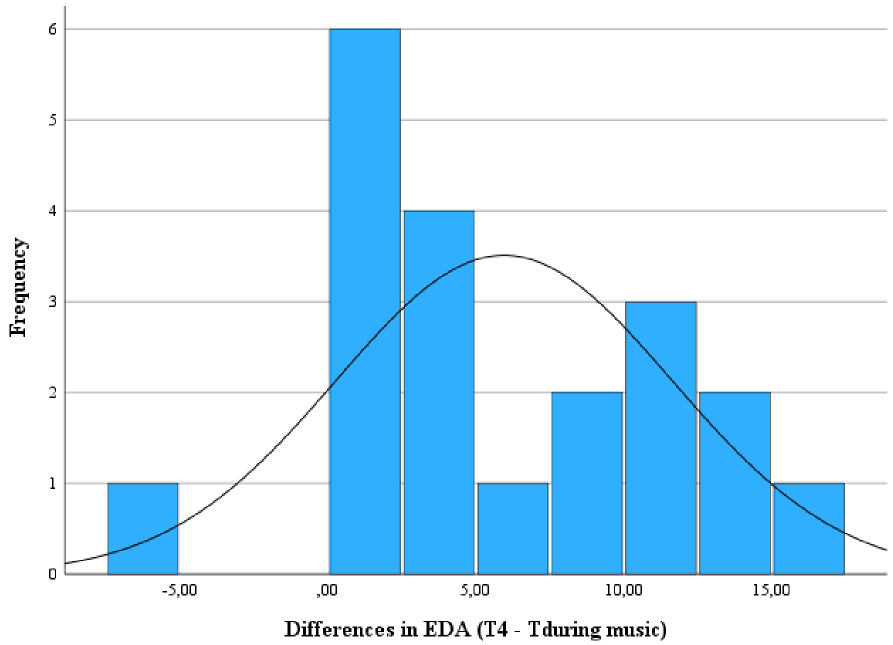

Figure 5. Distribution of changes in physiological stress ratings (music). Blue bars display the distribution of changes in EDA from T4 to $T_{\text{during music}}$. The black line illustrates the normal distribution curve.

Audiobook

Change scores for EDA ranged in this sample (n = 21) from -6.49 to 17.11 with a mean of 4.13 (SD = 4.98). As assessed by Shapiro-Wilk test, scores were normally distributed (p = .52). Figure 6 displays the distribution of EDA score changes between before audiobook listening and during audiobook listening.

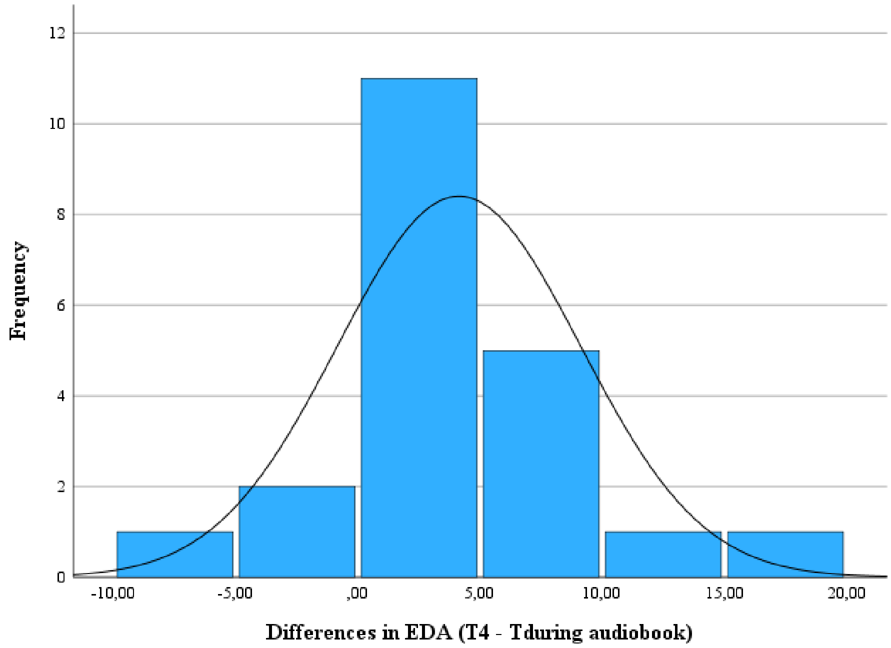

Figure 6. Distribution of changes in physiological stress ratings (audiobook). Blue bars display the distribution of changes in EDA from T4 to $T_{during\ audiobook}$. The black line illustrates the normal distribution curve.

However, since the boxplot detected one outlier (see Figure 7), it was excluded from the data set and all analyses which included EDA measures. Change scores in this sample (n = 20) ranged from -6.49 to 11.37 with a mean of 3.48 (SD = 4.10). As calculated by the Shapiro-Wilk test, the data was normally distributed, p = .83 (see Figure 8).

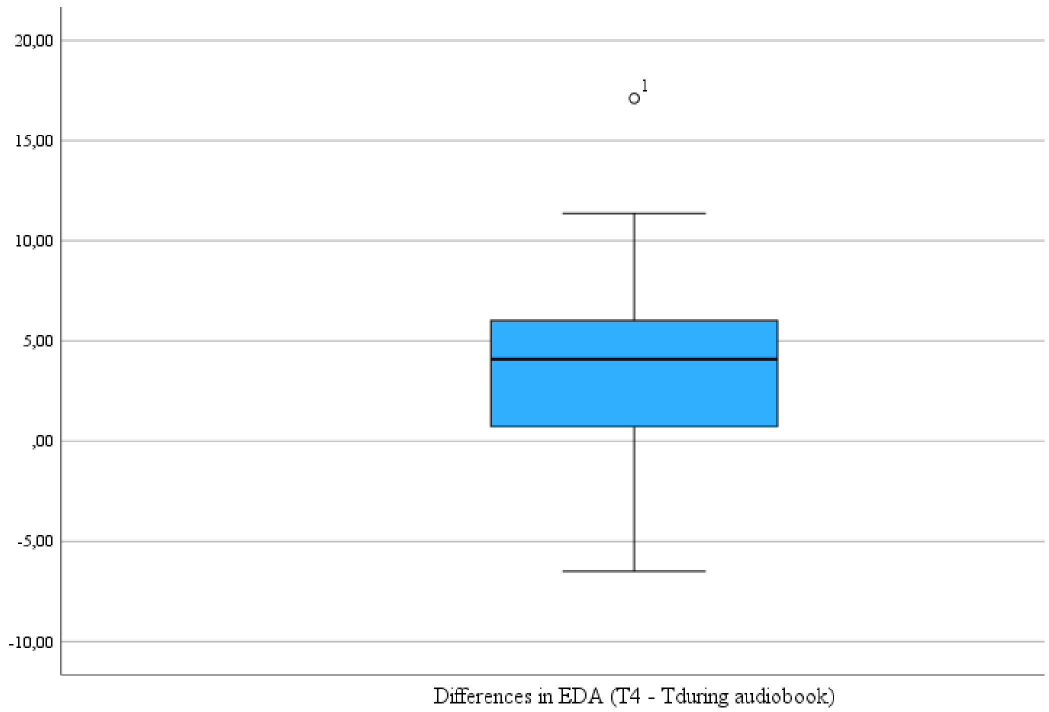

Figure 7. Boxplot of the distribution of changes in physiological stress ratings (audiobook) including the marked outlier.

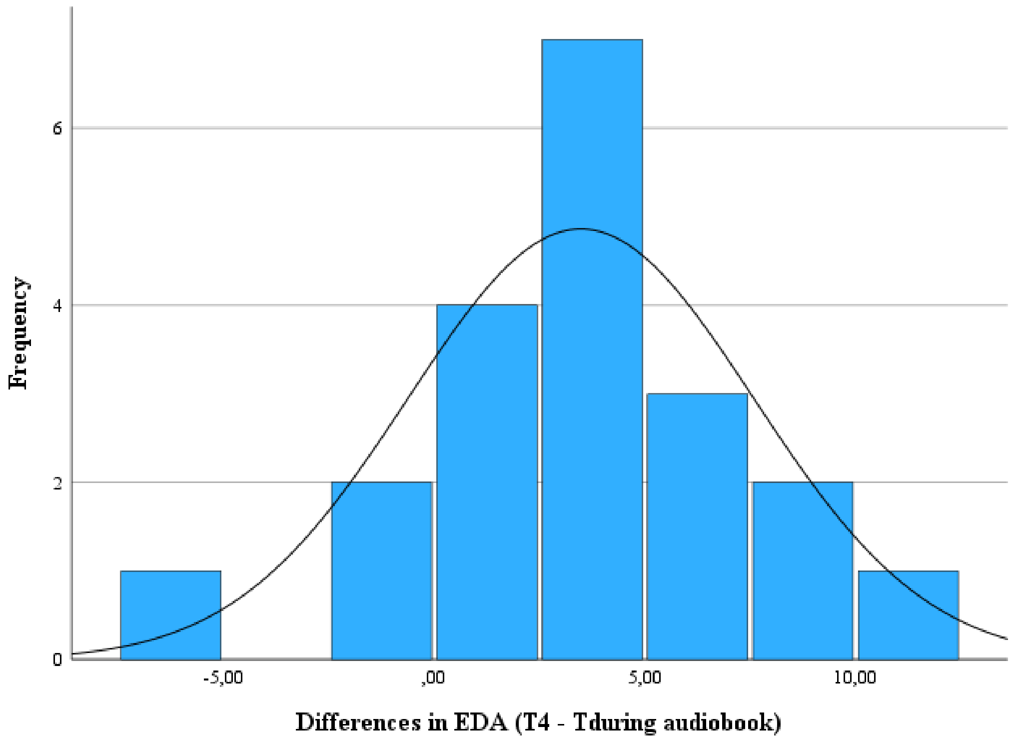

Figure 8. Distribution of changes in physiological stress ratings (audiobook) after exclusion of an outlier. Blue bars display the distribution of changes in EDA from T4 to $T_{during\ audiobook}$. The black line illustrates the normal distribution curve.

Subjective stress levels were measured using a VAS ranging from 0 = ”gar nicht” (not at all) to 100 = “sehr stark” (very strongly). To see whether there was a change in subjective stress rating from T4 (before listening to the audio excerpt) to T5 (after listening to the audio excerpt), the difference between those two time markers was calculated (T4 minus T5). A higher value indicates a greater change between T4 and T5 and therefore a lower subjective stress level after listening to the audio excerpt. Negative change scores indicate a higher subjective stress level at T5 (after listening to the audio excerpt) compared to T4 (before listening to the audio excerpt).

Music

Figure 9 displays the distribution of changes in the subjective stress scores between T4 and T5 for the music condition. Change scores in this sample (n = 20) ranged from -59 to 38 with a mean of 3.35 (SD = 20.81). As calculated by the Shapiro-Wilk test, the data was not normally distributed, p = .002 and left skewed.

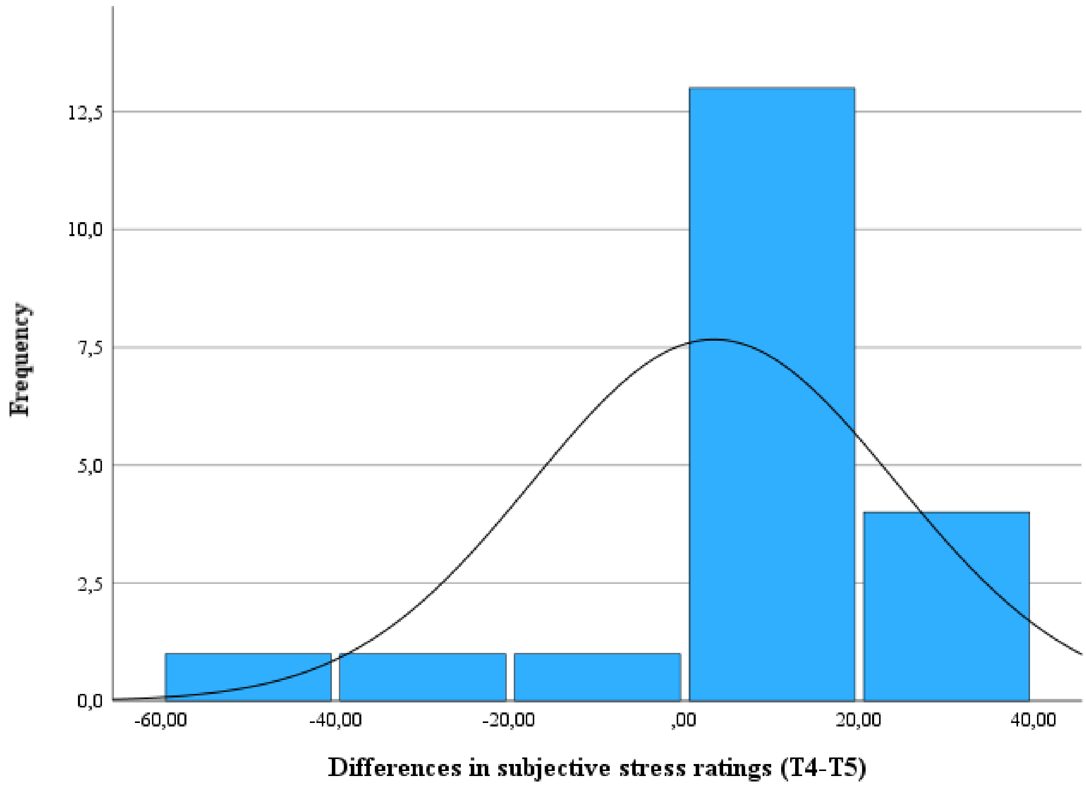

Figure 9. Distribution of changes in subjective stress ratings (music). Blue bars display the distribution of changes in subjective stress scores from T4 to T5. The black line illustrates the normal distribution curve.

However, since the boxplot detected three outliers (see Figure 10), these were excluded from the data set and all analyses which included subjective stress levels. Change scores in this sample (n = 17) ranged from -1 to 26 with a mean of 7.24 (SD = 9.40). As calculated by the Shapiro-Wilk test, the data was not normally distributed, p = .002 and right skewed (see Figure 11).

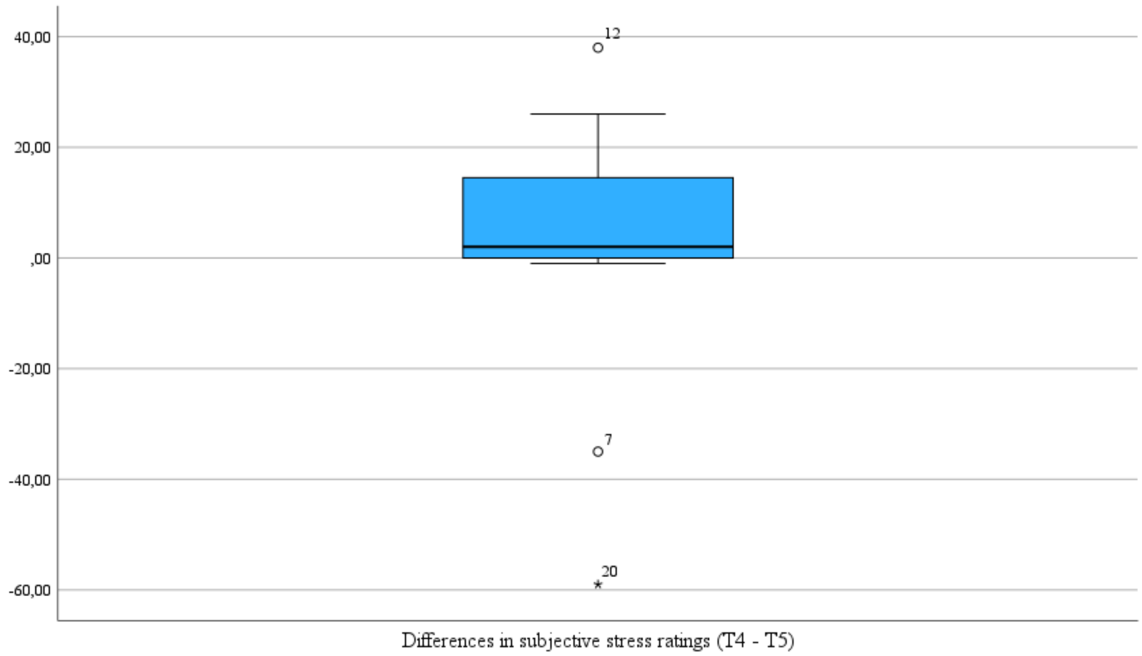

Figure 10. Boxplot of the distribution of changes in subjective stress ratings (music) including marked outliers.

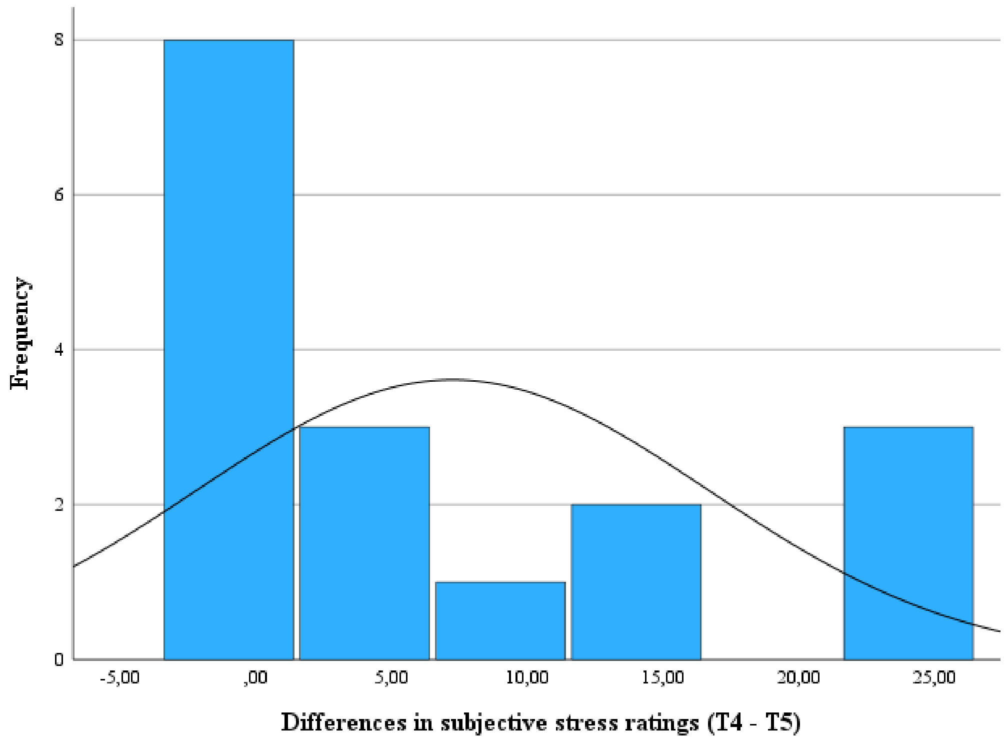

Figure 11. Distribution of changes in subjective stress ratings (music) after exclusion of outliers. Blue bars display the distribution of changes in subjective stress scores from T4 to T5. The black line illustrates the normal distribution curve.

Audiobook

Figure 12 displays the distribution of changes in the subjective stress scores between T4 and T5 for the audiobook condition. Change scores in this sample (n = 21) ranged from -16 to 47 with a mean of 9.19 (SD = 15.58). As calculated by the Shapiro-Wilk test, the data was not normally distributed, $p = .003$ and right skewed.

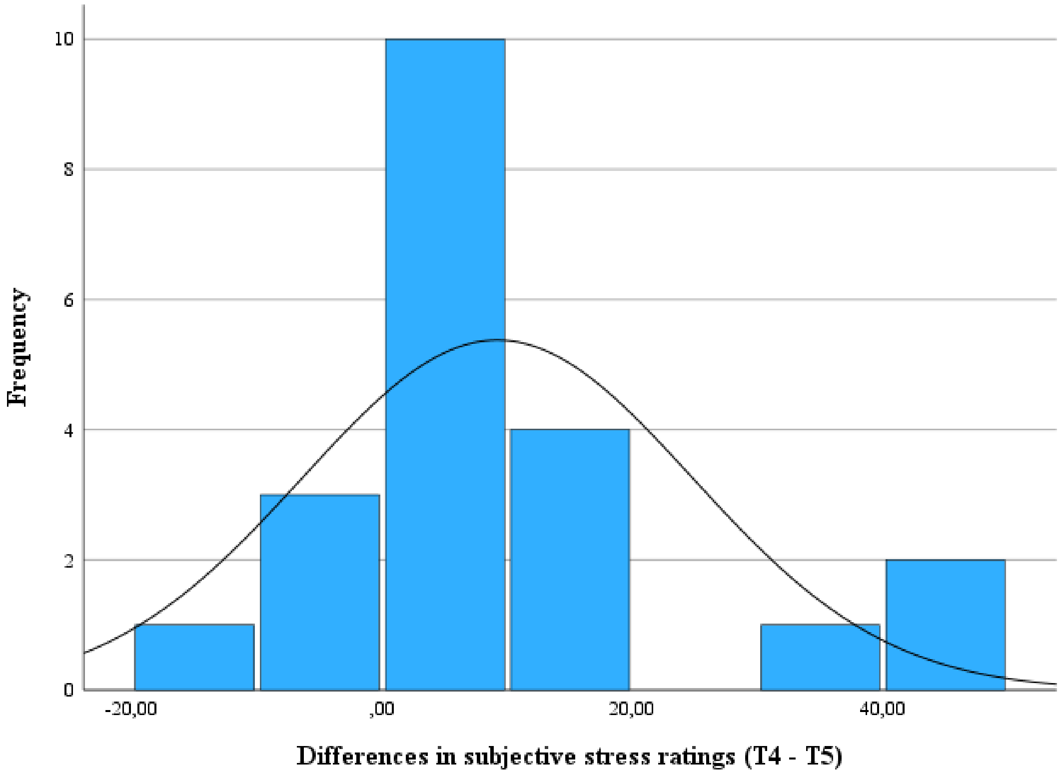

Figure 12. Distribution of changes in subjective stress ratings (audiobook). Blue bars display the distribution of changes in subjective stress scores from T4 to T5. The black line illustrates the normal distribution curve.

The boxplot detected four outliers (see Figure 13), these were excluded from the data set and all analyses which included subjective stress levels. Change scores in this sample (n = 17) ranged from -5 to 19 with a mean of 4.88 (SD = 6.02). As calculated by the Shapiro-Wilk test, the data appeared to have a normal distribution, p = .67 (see Figure 14).

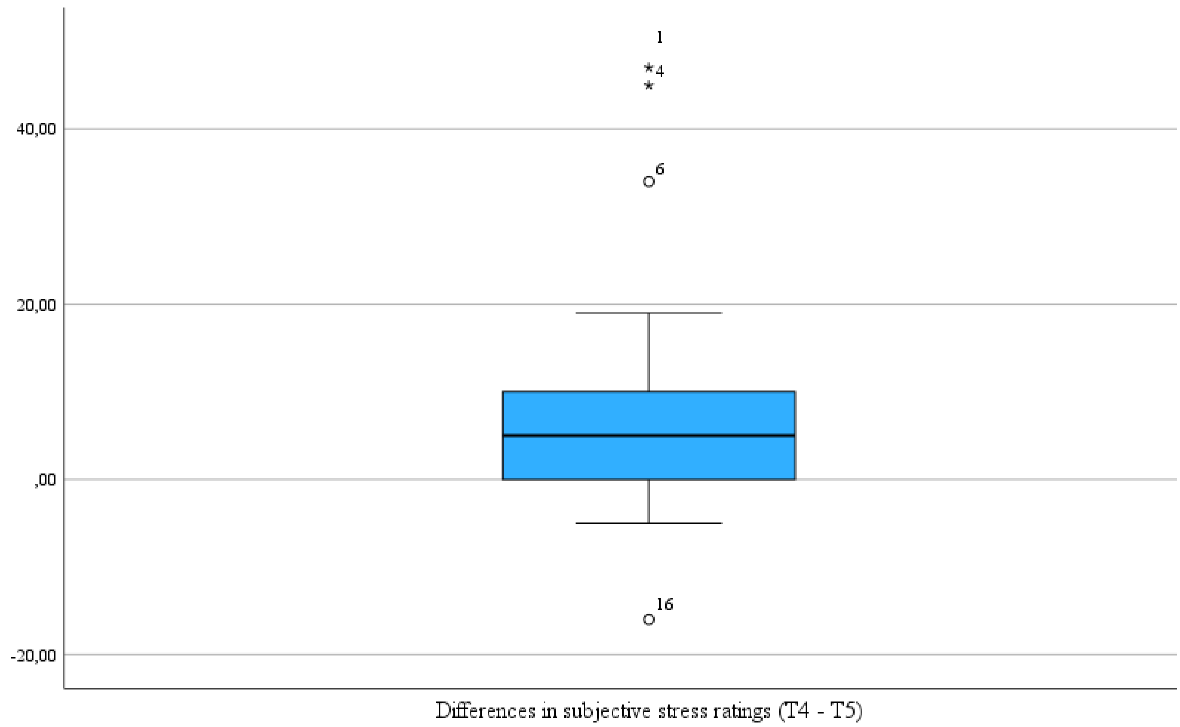

Figure 13. Boxplot of the distribution of changes in subjective stress ratings (audiobook) including marked outliers.

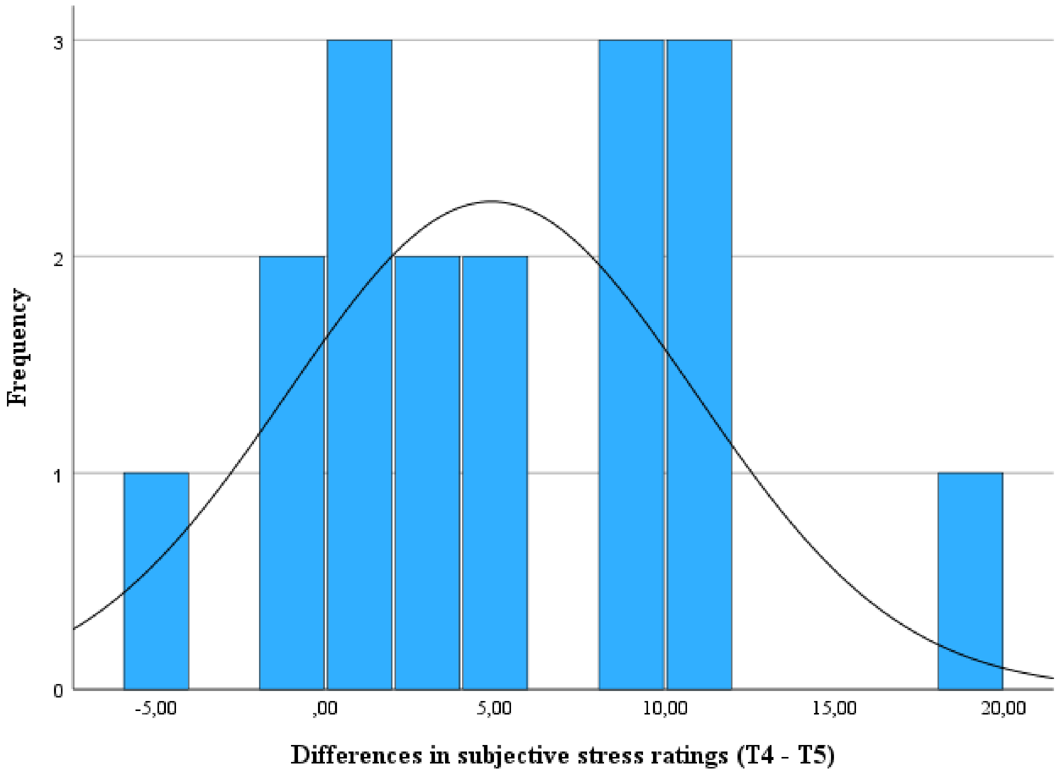

Figure 14. Distribution of changes in subjective stress ratings (audiobook) after exclusion of outliers. Blue bars display the distribution of changes in subjective stress scores from T4 to T5. The black line illustrates the normal distribution curve.

Hypothesis testing

Liking and mental focus

The first two research questions were tested by performing multiple linear regression analyses. The preconditions for multiple linear regression analyses were all met after following recommended cut-offs for leverage values and Cook's distance and removing identified outliers.

The first research question focused on whether the degree of liking the audio intervention (music or audiobook) impacts the physiological (EDA) and subjective (VAS) stress levels following an acute stressor. Higher liking of either music or audiobook was expected to be associated with a bigger decrease in EDA and subjective stress levels.

Similarly, the second research question concentrates on whether the level of mental focus on the audio intervention (music or audiobook) impacts the physiological and subjective stress levels following an acute stressor. Higher focus on either music or audiobook was expected to be associated with a bigger decrease in physiological and subjective stress levels.

Physiological stress reduction

A multiple linear regression was used to predict a study participant's physiological stress reduction after an acute stressor using her scores in liking music and focusing on music. The model did not significantly explain the variance in physiological stress reduction, $F(2, 15) = 1.93$, $p = .184$, $R^2 = .23$, $R^2_{adjusted} = .11$.

Liking music ($B = -0.49$, $t(15) = -1.70$, $p = .112$, 95% CI [-12.25, 1.45]) and focus on music ($B = 0.49$, $t(15) = 1.73$, $p = .108$, 95% CI [-0.63, 5.66]) were not statistically significant predictors of physiological stress reduction after the TSST.

Equally, a multiple linear regression was used to predict a study participant's physiological stress reduction after an acute stressor using her scores in liking the audiobook and focusing on the audiobook. The model did also not significantly explain the variance in physiological stress reduction, $F(2, 19) = 0.012$, $p = .988$, $R^2 = .001$, $R^2_{adjusted} = -.12$.

Liking audiobook ($B = 0.02$, $t(19) = 0.05$, $p = .959$, 95% CI [-2.72, 2.86]) and focus on audiobook ($B = -0.04$, $t(19) = -0.15$, $p = .881$, 95% CI [-2.96, 2.56]) were not statistically significant predictors of physiological stress reduction.

Subjective stress reduction

A multiple linear regression was used to predict a study participant's subjective stress reduction after an acute stressor using her scores in liking music and focusing on music. The model did not significantly explain the variance in subjective stress reduction, $F(2, 14) = 0.85$, $p = .452$, $R^2 = .12$, $R^2_{adjusted} = -.02$.

Liking music ($B = 0.21$, $t(14) = 0.62$, $p = .548$, 95% CI [-9.94, 17.83]) and focus on music ($B = 0.19$, $t(14) = 0.56$, $p = .584$, 95% CI [-4.75, 8.06]) were not statistically significant predictors of subjective stress reduction.

Equally, a multiple linear regression was used to predict a study participant's subjective stress reduction after an acute stressor using her scores in liking the audiobook and focusing on the audiobook. The model did also not significantly explain the variance in subjective stress reduction, $F(2, 14) = 0.186$, $p = .833$, $R^2 = .03$, $R^2_{adjusted} = -.132$.

Liking audiobook ($B = 0.14$, $t(14) = 0.51$, $p = .621$, 95% CI [-4.25, 6.83]) and focus on audiobook ($B = -0.09$, $t(14) = -0.32$, $p = .755$, 95% CI [-5.06, 3.76]) were not statistically significant predictors of subjective stress reduction after an acute stressor.

Interaction between liking and mental focus

The third research question investigated the interaction between liking and mental focus and whether it impacts the decrease in physiological and subjective stress levels after an acute stressor. Moderation analyses were used since statistically speaking, the effect of the moderating variable is equal to an interaction (Hayes, 2018).

The preconditions are similar to those applicable in a multiple linear regression, however, since the PROCESS macro (Hayes, 2018) uses bootstrapping, it is a robust procedure that generally does not make any distributional assumptions regarding the sample.

Physiological stress reduction

As described, a moderation analysis was applied to determine whether the interaction between liking and focus significantly predicts physiological stress reduction (measured via EDA). This was neither the case in the music condition, $F(3,12) = 0.831$, $p = .5024$ nor in the audiobook condition, $F(3,16) = 0.01$, $p = .999$.

Subjective stress reduction

Equally, a moderation analysis was applied to determine whether the interaction between liking and focus significantly predicts subjective stress reduction (measured via VAS). There were no significant findings for the music condition, $F(3,11) = 0.824$, $p = .5076$, or the audiobook condition, $F(3,11) = 0.2388$, $p = .8675$.

Music vs. audiobook condition

The fourth and final research question examined whether the audio condition (music or audiobook) has an impact on the decrease in physiological and subjective stress levels following an acute stressor (TSST). EDA and subjective stress levels decrease were expected to be greater in the music condition. To answer this, an independent t-test was applied.

The preconditions for the independent t-test (e.g., independence of the observations, no outliers) were mostly met. In cases where homogeneity of variances was not given, the Welch t-test was used (which is highlighted). The data for each group were normally distributed, only the subjective stress ratings (VAS) in the music condition were not normally distributed. However, studies have demonstrated (e.g. Wilcox, 2012) that the independent t-test is robust against violations of the assumption of normal distribution.

Physiological stress reduction

There were 20 participants in the music condition and 20 participants in the audiobook condition (an outlier was removed as described in *Descriptive statistics*). As tested with the Levene test, variances were equal in each group, $p = .051$. EDA differences from before listening to the audio excerpt to during listening to the audio excerpt were higher in participants who listened to music ($M = 5.95$, $SD = 5.68$) than an audiobook ($M = 3.48$, $SD = 4.10$) (A visualization of the data distribution can be seen in Figure 15). Mean EDA differences were 2.47 µS (95% CI [-0.71, 5.64]) higher for the music listening group. However, there was no statistically significant difference between the EDA differences of the music condition and the audiobook condition, $t(38) = 1.58$, $p = .12$.

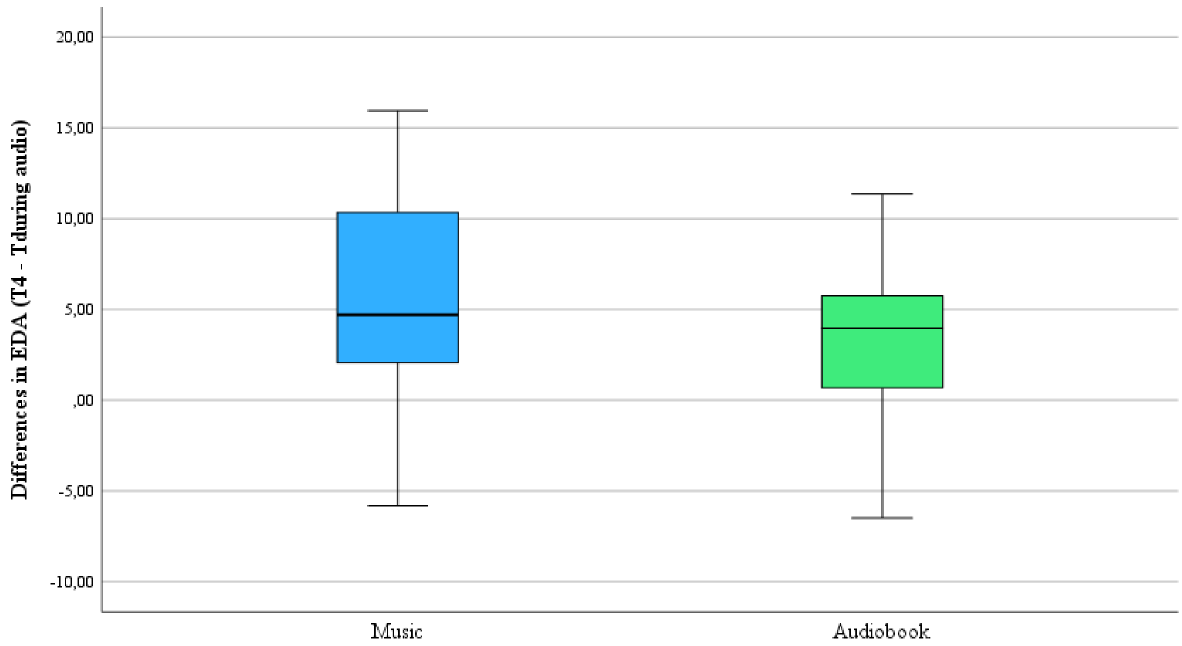

Figure 15. Boxplots of the differences in physiological stress levels measured through EDA (T4-$T_{during\ audio}$) in the audio conditions.

Subjective stress reduction

There were 17 participants in the music condition and 17 participants in the audiobook condition (because outliers were already excluded as described in *Descriptive statistics*). Subjective stress level differences from pre-audio to post-audio (T4 – T5) were higher in participants who listened to music (M = 7.24, SD = 9.39) than an audiobook (M = 4.88, SD = 6.02) (A visualization of the data distribution can be seen in Figure 16). Mean subjective stress level differences were 2.35 units (95% CI [-3.20, 7.90]) higher for the music listening group. The Welch test is used for interpretation since the Levene test demonstrated that the variances were not equal in each group, p = .043. There was no statistically significant difference between the subjective stress level differences of the music condition and the audiobook condition, t(27.25) = 0.87, p = .196.

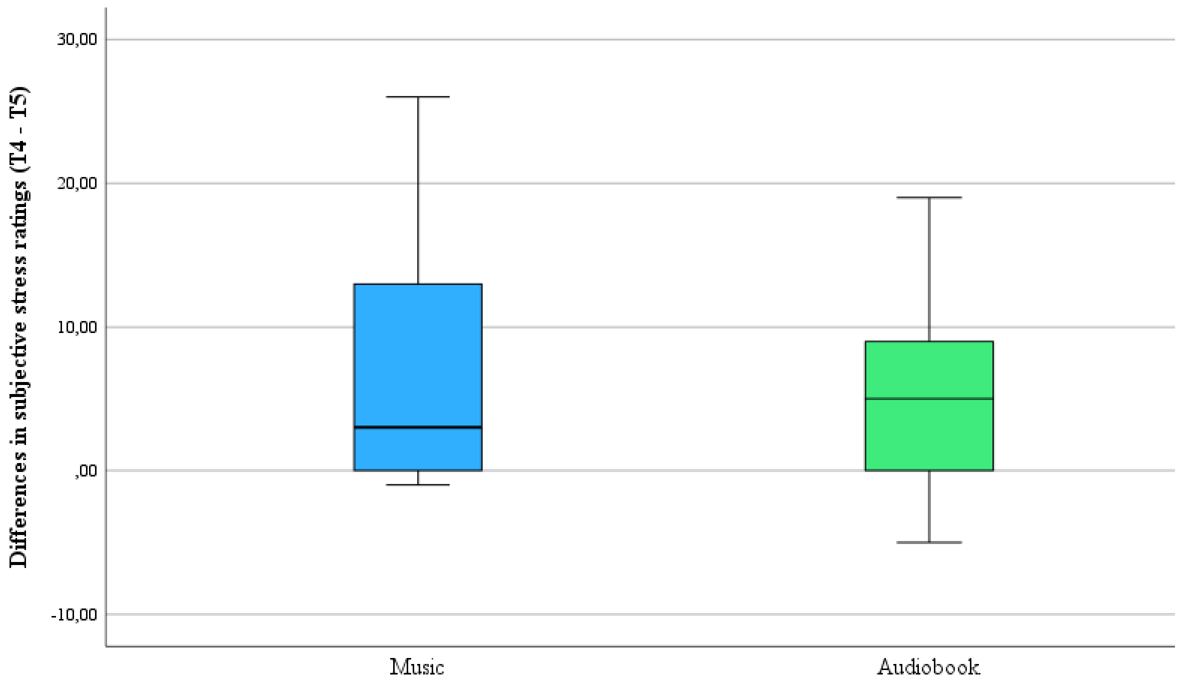

Figure 16. Boxplots of the differences in subjective stress ratings (T4-T5) in the audio conditions.

Discussion

The aim of this study was to examine whether liking the audio intervention and mental focus during listening to the audio excerpt affect the decrease in physiological and subjective stress levels following an acute laboratory stressor (TSST). Additionally, it was investigated whether the stress-reducing benefits of music listening stem from its inherent qualities or from the calming effects of auditory stimuli (Thoma et al., 2013). To test that, the music condition was compared to an active control condition (audiobook) that could offer comparable benefits to music in terms of arousal level, attentional involvement, and emotional engagement (Chanda & Levitin, 2013).

Interpretation of results

Liking

For the first research question, no significant association was found between liking the audio intervention (neither for music nor audiobook) and reductions in physiological and subjective stress levels. Therefore, in this sample, differences in how much a participant liked the music/audiobook did not significantly affect the decrease in stress levels (objective and subjective). This result does not support H1-H4 in which higher liking was expected to be associated with a greater decrease in physiological and subjective stress levels. This finding is also not in line with previous research indicating that music preference plays an important role in the reduction of stress (e.g., De La Torre-Luque et al., 2017; Jiang et al., 2016; Stratton & Zalanowski, 1984).

The insufficient impact of participants' degree of liking the music intervention might be explained by the music selection procedure. While providing participants with selected music excerpts made it possible to control the musical properties, the participants have not heard the music before, and their chosen playlist might not be comparable with music they would typically *prefer* to listen (Iwanaga & Moroki, 1999). Even when individuals indicate that they liked the provided music to a high degree, it does not imply that they would choose this type of music (e.g., instrumental, slow tempo) normally (Stratton & Zalanowski, 1984). Consequently, the degree of liking a music excerpt might simply not be comparable to a person's music preference.

Being familiar with a musical piece plays a key role in triggering chills/the shiver reactions which are linked to profound emotions. This highlights the strong connection between familiar music and intense emotional experiences (Grewe et al., 2007). The PET experiment of Blood and Zatorre (2001) also pointed out that their study participants' music selection (which should be highly pleasurable) frequently induced chills. As chills intensity grew, increased cerebral blood flow was measured particularly in the left ventral striatum and dorsomedial midbrain while reduced blood flow was detected in the amygdala and the ventral medial prefrontal cortex. These brain areas are equally found to be active in stimuli that induce euphoria (e.g., food, sex, and drugs). Therefore, it is possible that since the study participants in this thesis were not familiar with the music excerpts and potentially did not experience deep emotions and chills, the level of perceived pleasure was not high enough to activate a reward response and in turn impact physiological and subjective stress reduction.

In the study of Sandstrom and Russo (2010) liking the musical pieces did also not significantly correlate with individuals' subjective stress ratings. However, the authors mention that there was a lack of variability in the liking scores. Besides the fact that this current study is underpowered, and the sample size is too small to detect small- to medium-sized effects, there was also very little variability in the indicated liking scores which could further impede significant findings. Jiang et al. (2016) measured music preference on a 7-point Likert scale, while Sandstrom and Russo (2010) utilized a 4-point Likert scale. This restriction in the range might have additionally contributed to the non-significant findings in their research but also in this current study.

Mental focus

For the second research question, the association between mental focus on the audio excerpt and the decrease in physiological and subjective stress levels was not significant in either the music or audiobook condition. Hence, differences in how focused a study participant was on the audio excerpt did not significantly affect the decrease in EDA and subjective stress levels. This finding also contradicts H5-H8 in which greater mental focus on the music/audiobook was associated with a greater stress reduction.

Distraction is considered an effective self-regulation technique for improving mood (Schäfer et al., 2020) and it has been shown that people's anxiety levels tend to decrease when they are distracted by other stimuli (e.g., visual cues) (Lu et al., 2021). Since the effects of music are often attributed to music’s ability to distract us (Chanda & Levitin, 2013), it was thought that increased focus on the music (and diversion from stressful or negative thoughts after the TSST) is associated with a greater stress reduction. However, there are no past studies that particularly investigated mental focus during a music-based stress intervention.

While we should interpret this non-significant result with caution due to the small sample size, it could give us an interesting insight: Studies consistently show that people typically listen to music while doing personal tasks (like housework or cooking), engaging in leisure activities (such as exercising or socializing), or traveling (driving or walking) (Greb et al., 2018). Hence, in everyday situations it is relatively rare for music listening to occur without any accompanying activity (Greb et al., 2018; Jäncke et al., 2018). The main focus also remains on the non-musical task, as its objectives still need to be accomplished. Even when music is used as a distraction, the listener must maintain enough attention and control to successfully finish the given task at hand (Sloboda, 2010).

The EMA study of Juslin et al., (2008) investigated the emotional responses to music in daily life and concluded that even during passive listening, music remains impactful. In 64% of the times participants listened to music, they stated that it impacted their mood (e.g., calmed down, brought joy). Particularly the reason for listening to music (e.g., wanting to relax) played a crucial role in which specific emotion (e.g., calmness) got triggered.

While in their study it was not specifically inspected whether they used music in stressful circumstances or in an attempt to reduce stress, the ambulatory assessment of Linnemann et al. (2015) examined the stress-relieving impact of listening to music in everyday life. They also found that when “relaxation” was the indicated listening purpose, the levels of subjective stress and salivary cortisol were the lowest. These findings could indicate that for music to help us relax and reduce stress, our focus on it does not necessarily need to be high but that potentially other factors, such as listening motives, play a greater role.

Liking and mental focus

H9 and H10 (RQ 3), which proposed that the interaction between liking and mental focus affects the decrease in EDA (H9) and subjective stress levels (H10) can also be rejected. It was hypothesized that liking might only have a significant impact on stress reduction if mental focus was high since a person needs to have their attention on the musical stimuli to have an aesthetic experience (Hodges, 2016). However, as commented previously regarding music liking, it could be that even if the study participants indicated a high level of liking the provided music, it might not be equivalent to their individual music preference. Therefore, focused attention could still be a prerequisite for an aesthetic experience, but other needed aspects (for an aesthetic experience), such as experiencing aesthetic emotions, like chills or being moved, or having aesthetic judgements, like evaluating the beauty of music (Reybrouck et al., 2021) might have been missing. Because of this, the reward system might not have been (sufficiently) activated to impact the physiological and subjective stress response. However, no definite conclusions can be drawn from these results due to the underpowered sample and the limited variability in the variable liking and mental focus.

Music vs. audiobook condition

In the fourth and final research question, the participants in the music condition did not have a significantly greater stress reduction (physiological and subjective) than participants in the audiobook condition which contradicts the proposed hypotheses H11 and H12. However, it needs to be highlighted that for testing those hypotheses a minimum sample size of 102 participants would have been required to detect small-to medium-effect sizes. Hence, these non-significant findings should be interpreted with care. Descriptively, there appeared a pattern in which listeners of the music intervention had a greater stress reduction (physiological and subjective) than listeners of the audiobook intervention.

The evidence on the stress-reducing impact of music listening is inconsistent (Linnemann et al., 2015). Research indicates that music listening is more successful than an audio control or silence condition in facilitating recovery of blood pressure, heart rate, mood, and anxiety after an acute stressor but an equivalent number of studies cannot support these results (Adiasto et al., 2023). Moreover, since most existing studies only used one control group with no acoustic stimuli, outcome interpretation is more difficult (Groarke et al., 2020).

These studies do not conclusively determine whether the beneficial impacts of music on regulating emotions stem from the music's intrinsic qualities or variations in participant arousal levels. For instance, in the study of Khalfa et al. (2003), cortisol levels of the silent control group increased during the silent condition. While the study sample was relatively small (n=24) it could suggest that the silent condition itself was perceived as stressful.

Particularly in this thesis there also needs to be considered whether participants were still significantly stressed when the audio intervention started, since after the TSST and before the audio intervention the tape stripping procedure occurred and took about 20-30 minutes. Kirschbaum et al. (1993) pointed out that after 15 minutes the stress which was caused by the TSST has probably subsided completely, which could explain the lacking effect of the different audio interventions.

Describing music interventions thoroughly and transparently presents unique challenges because of the complexity of music stimuli and various factors, such as music selection, how it is delivered, and whether/how it is combined with other interventions (e.g. diaphragmatic breathing) (Robb et al., 2011). Those methodological differences (e.g. varying music selection, stress intensities) could also constitute as a possible explanation for the discrepancies in study findings (Linnemann et al., 2015). Finally, the contradicting research findings on which factors are associated with stress reduction (e.g., arousal level, music preference, familiarity, music training) could also indicate complex relationships between these aspects (Jiang et al., 2016).

Limitations

This study has several limitations that need to be considered. A major limitation is constituted in the small sample size. Due to this, there was not enough statistical power to detect small- to medium-sized effects which limits the interpretation of the (non-significant) findings. Although the comparison between the music and the audiobook condition presented a pattern that stress reduction (physiological and subjective) is greater when participants listen to music instead of an audiobook, it is only a descriptive information since it did not reach significance. However, this could illustrate potentially promising findings for a future bigger sample. The present sample also indicated quite similar ratings concerning the variables liking and mental focus which reduced the variance within those scales and impeded finding disparities in differing levels of liking and mental focus.

As already mentioned, after the stress test, participants underwent a tape stripping procedure and TEWL-measurements that lasted approximately 20 to 30 minutes. Only after this, they listened to either music, an audiobook or sat in silence (depending on their group allocation). Kirschbaum et al. (1993) underlined that after around 15 minutes, the stressing effects of the TSST on the cardiovascular system likely already disappeared. Thus, the limited impact of the different audio conditions may be explained by the lack of sustained stress reaction after the TSST. Future studies should consider implementing a music intervention right after an acute stressor like the TSST to not dilute potential findings.

Similar to other studies, this study obtained subjective stress levels with a single item, however as highlighted by Linnemann et al. (2017), a more thorough inquiry about stress could increase the validity. Since the sound volume is positively linked with level of arousal (Robb et al., 2011), it would have been important to keep the volume of the played audio consistent and not allow study participants to change this setting to their preference at the beginning of the laboratory assessment. This study used laboratory-induced stress (TSST) in a healthy and very specific (in terms of inclusion and exclusion criteria) population which limits the generalizability. Moreover, the final sample appeared to be quite homogeneous as described in *Sample description*.

Classical or nonlyrical music is frequently not the preferred choice for music listeners (e.g., Groarke et al., 2020), therefore it does not represent the typical listening experience and further impedes the generalizability of findings. Additionally, cultural differences should be considered. While the place of a music intervention (Western or non-Western countries) appeared to not have a significant moderating effect in the meta-analyses of De Witte et al. (2020) a trend emerged (p = 0.089) that indicated greater physiological stress reduction in non-Western countries.

Finally, this research project began just before the start of the COVID-19 pandemic in 2020, resulting in numerous unforeseen challenges. Governmental regulations and lockdowns lead to difficulties in the execution of test sessions and delayed the data collection. Testing conditions varied, since some participants, for example, needed to wear face masks and keep a distance, while others did not. These inconsistencies affected not only the test conditions but also the interactions between the participants and the testing team. Moreover, the pandemic constituted exceptional circumstances that affected us all and potentially impacted participants' lives to varying degrees (e.g., stress due to changes caused by the pandemic, social isolation). Therefore, it is possible that the stress responses also varied based on when participants were tested (before, during or after the pandemic).

Implications

Since this study was underpowered, the interpretation of the non-significant findings and their possible implications is limited. Previous studies have often emphasized that particularly slow, soft music, like classical music, is more effective in coping with negative emotion than heavy or hard music. The findings on this notion are inconsistent and it could be that the music type does not impact the level of relaxation and stress reduction (Vidas et al., 2021). The study of Howlin and Rooney (2020) suggests that individuals in pain are more likely to prefer music that is more energetic, danceable, and less instrumental, than what researchers typically select. On the other hand, Vidas et al. (2021) explored the types of music people listen to when managing stress related to Covid-19 and found that the chosen songs frequently had a negative emotional tone and moderate energy levels. The PET study of Blood and Zatorre (2001) could also not determine specific musical features that were consistently linked to pleasurable responses, as the same music could evoke different emotional reactions in different listeners (the same music that caused chills in one participant was used as a control in another participant). The absence of a strong link between the music's characteristics and how effective it was as a coping strategy emphasizes the importance of music self-selection. Through music self-selection it can be expected that listeners are familiar with the songs and that they perceive them as pleasurable which in turn could activate the reward system and lower stress. Moreover, since instrumental and classical music is likely not the favored music choice for most people, allowing study participants to select their own preferred music could increase ecological validity. While most studies on music and stress have been conducted in experimental settings (Linnemann et al., 2017), ecological validity can also be increased by studies in daily settings since listening to music is a frequent activity in people's everyday life.

Although focus on music did not significantly impact stress reduction in our sample, it would be worthwhile to explore how levels of focus or attention affect people listening to highly enjoyable music, both in experimental settings and everyday life. It is possible that a high level of attention is required to experience a musical aesthetic response. However, an aesthetic experience or a high focus may not be required for music to impact mood and facilitate a stress reduction as suggested by Linnemann et al. (2015).

Since a laboratory-induced stressor was applied in a healthy and very narrowly defined population, future studies should be undertaken in varying settings and stressors (e.g., high-workload positions) with different people in terms of gender, age, education, physical and psychological issues, etc., and with a bigger sample size, that enables finding small-to medium-effect sized results. Moreover, while the impact of short-term interventions to reduce stress is relevant, it would also be interesting to investigate whether potential changes can be sustained over an extended period of time.

The presence of numerous studies that fail to detect significant effects of music listening on stress-related biomarkers (e.g., cortisol) (Finn & Fancourt, 2018) indicates that this potential connection requires further examination. Many studies also lack comprehensive descriptions of music interventions, hindering comparisons between studies, generalizability, and practical implications (Robb et al., 2011). Therefore, future studies should put an emphasis on thoroughly describing their courses of action.

Music listening can pose a readily available resource for regulating stress and mood in everyday life (Feneberg et al., 2023). Understanding the influence of different factors related to music listening on decreasing stress could empower individuals to select music more effectively and maximize their stress reduction (Jiang et al., 2016).

Conclusion

The aim of this master's thesis was to investigate the impact of music listening, particularly the influence of music liking and mental focus during listening on physiological and subjective stress parameters following an acute stressor. Additionally, it was inquired whether study participants who listened to calming music experienced greater stress reduction than those in the active control condition (audiobook), which was assumed to provide a similar level of stimulation and engagement.

The statistical analyses provided no significant findings, however descriptively the stress reduction (physiological and subjective) was greater in the music condition than in the audiobook condition. Nevertheless, due to the underpowered sample size and a lack of variability in the collected data, the identified results need to be interpreted with great caution and further research with a bigger sample size is required. Moreover, study designs that allow an increase in ecological validity and generalizability should be applied, so music interventions can be used effectively. Music is an easily accessible tool that can be tailored to individual preferences and enjoyed in various settings. Its potential to reduce stress deems it a valuable aid for both individual and public health.

References

Adiasto, K., Van Hooff, M. L. M., Beckers, D. G. J., & Geurts, S. A. E. (2023). The sound of stress recovery: An exploratory study of self-selected music listening after stress. *BMC Psychology*, *11*(1), 40. https://doi.org/10.1186/s40359-023-01066-w

Blood, A. J., & Zatorre, R. J. (2001). Intensely pleasurable responses to music correlate with activity in brain regions implicated in reward and emotion. *Proceedings of the National Academy of Sciences*, *98*(20), 11818–11823. https://doi.org/10.1073/pnas.191355898

Bradt, J., Dileo, C., & Shim, M. (2013). Music interventions for preoperative anxiety. *The Cochrane Database of Systematic Reviews*, *2013*(6), CD006908. https://doi.org/10.1002/14651858.CD006908.pub2

Chanda, M. L., & Levitin, D. J. (2013). The neurochemistry of music. *Trends in Cognitive Sciences*, *17*(4), 179–193. https://doi.org/10.1016/j.tics.2013.02.007

Chrousos, G. P. (2009). Stress and disorders of the stress system. *Nature Reviews Endocrinology*, *5*(7), 374–381. https://doi.org/10.1038/nrendo.2009.106

Chu, B., Marwaha, K., Sanvictores, T., Awosika, A. O., & Ayers, D. (2024). Physiology, Stress Reaction. In *StatPearls*. StatPearls Publishing. http://www.ncbi.nlm.nih.gov/books/NBK541120/

De La Torre-Luque, A., Díaz-Piedra, C., & Buela-Casal, G. (2017). Effects of preferred relaxing music after acute stress exposure: A randomized controlled trial. *Psychology of Music*, *45*(6), 795–813. https://doi.org/10.1177/0305735617689953

De Witte, M., Spruit, A., Van Hooren, S., Moonen, X., & Stams, G.-J. (2020). Effects of music interventions on stress-related outcomes: A systematic review and two meta-analyses. *Health Psychology Review*, *14*(2), 294–324. https://doi.org/10.1080/17437199.2019.1627897

Dutcher, J. M., & Creswell, J. D. (2018). The role of brain reward pathways in stress resilience and health. *Neuroscience & Biobehavioral Reviews*, *95*, 559–567. https://doi.org/10.1016/j.neubiorev.2018.10.014

Evers, S., & Suhr, B. (2000). Changes of the neurotransmitter serotonin but not of hormones during short time music perception. *European Archives of Psychiatry and Clinical Neuroscience*, *250*(3), 144–147. https://doi.org/10.1007/s004060070031

Fancourt, D., Ockelford, A., & Belai, A. (2014). The psychoneuroimmunological effects of music: A systematic review and a new model. *Brain, Behavior, and Immunity*, *36*, 15–26. https://doi.org/10.1016/j.bbi.2013.10.014

Feneberg, A. C., Stijovic, A., Forbes, P. A. G., Lamm, C., Piperno, G., Pronizius, E., Silani, G., & Nater, U. M. (2023). Perceptions of Stress and Mood Associated With Listening to Music in Daily Life During the COVID-19 Lockdown. *JAMA Network Open*, *6*(1), e2250382. https://doi.org/10.1001/jamanetworkopen.2022.50382

Finn, S., & Fancourt, D. (2018). The biological impact of listening to music in clinical and nonclinical settings: A systematic review. *Progress in Brain Research*, *237*, 173–200. https://doi.org/10.1016/bs.pbr.2018.03.007

Gillen, E., Biley, F., & Allen, D. (2008). Effects of music listening on adult patients' pre-procedural state anxiety in hospital. *International Journal of Evidence-Based Healthcare*, *6*(1), 24–49. https://doi.org/10.1111/j.1744-1609.2007.00097.x

Gomez, P., & Danuser, B. (2007). Relationships between musical structure and psychophysiological measures of emotion. *Emotion*, *7*(2), 377–387. https://doi.org/10.1037/1528-3542.7.2.377

Greasley, A. E., & Lamont, A. (2011). Exploring engagement with music in everyday life using experience sampling methodology. *Musicae Scientiae*, *15*(1), 45–71. https://doi.org/10.1177/1029864910393417

Greb, F., Schlotz, W., & Steffens, J. (2018). Personal and situational influences on the functions of music listening. *Psychology of Music*, *46*(6), 763–794. https://doi.org/10.1177/0305735617724883

Grewe, O., Nagel, F., Kopiez, R., & Altenmüller, E. (2007). Emotions over time: Synchronicity and development of subjective, physiological, and facial affective reactions to music. *Emotion (Washington, D.C.)*, *7*(4), 774–788. https://doi.org/10.1037/1528-3542.7.4.774

Groarke, J. M., & Hogan, M. J. (2018). Development and Psychometric Evaluation of the Adaptive Functions of Music Listening Scale. *Frontiers in Psychology*, *9*. https://doi.org/10.3389/fpsyg.2018.00516

Groarke, J. M., Groarke, A., Hogan, M. J., Costello, L., & Lynch, D. (2020). Does Listening to Music Regulate Negative Affect in a Stressful Situation? Examining the Effects of Self-Selected and Researcher-Selected Music Using Both Silent and Active Controls. *Applied Psychology: Health and Well-Being*, *12*(2), 288–311. https://doi.org/10.1111/aphw.12185

Hayes, A. F. (2018). *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach* (2nd ed.). Guilford Press.

Hekmat, H. M., & Hertel, J. B. (1993). Pain Attenuating Effects of Preferred Versus Non-preferred Music Interventions. *Psychology of Music*, *21*(2), 163–173. https://doi.org/10.1177/030573569302100205

Hodges, D. A. (2016). The Neuroaesthetics of Music. In S. Hallam, I. Cross, & M. H. Thaut (Eds.), *The Oxford Handbook of Music Psychology* (p. 0). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780198722946.013.20

Horvers, A., Tombeng, N., Bosse, T., Lazonder, A. W., & Molenaar, I. (2021). Detecting Emotions through Electrodermal Activity in Learning Contexts: A Systematic Review. *Sensors (Basel, Switzerland)*, *21*(23), 7869. https://doi.org/10.3390/s21237869

Howlin, C., & Rooney, B. (2021). Patients choose music with high energy, danceability, and lyrics in analgesic music listening interventions. *Psychology of Music*, *49*(4), 931–944. https://doi.org/10.1177/0305735620907155

Iwanaga, M., & Moroki, Y. (1999). Subjective and Physiological Responses to Music Stimuli Controlled Over Activity and Preference. *Journal of Music Therapy*, *36*(1), 26–38. https://doi.org/10.1093/jmt/36.1.26

Jäncke, L., Leipold, S., & Burkhard, A. (2018). The neural underpinnings of music listening under different attention conditions. *Neuroreport*, *29*(7), 594–604. https://doi.org/10.1097/WNR.0000000000001019

Jiang, J., Rickson, D., & Jiang, C. (2016). The mechanism of music for reducing psychological stress: Music preference as a mediator. *The Arts in Psychotherapy*, *48*, 62–68. https://doi.org/10.1016/j.aip.2016.02.002

Juslin, P., Liljeström, S., Västfjäll, D., Barradas, G., & Silva, A. (2008). An Experience Sampling Study of Emotional Reactions to Music: Listener, Music, and Situation. *Emotion (Washington, D.C.)*, *8*, 668–683. https://doi.org/10.1037/a0013505

Khalfa, S., Bella, S. D., Roy, M., Peretz, I., & Lupien, S. J. (2003). Effects of Relaxing Music on Salivary Cortisol Level after Psychological Stress. *Annals of the New York Academy of Sciences*, *999*(1), 374–376. https://doi.org/10.1196/annals.1284.045

Kirschbaum, C., Kudielka, B. M., Gaab, J., Schommer, N. C., & Hellhammer, D. H. (1999). Impact of Gender, Menstrual Cycle Phase, and Oral Contraceptives on the Activity of the Hypothalamus-Pituitary-Adrenal Axis: *Psychosomatic Medicine*, *61*(2), 154–162. https://doi.org/10.1097/00006842-199903000-00006

Kirschbaum, C., Pirke, K.-M., & Hellhammer, D. H. (1993). The 'Trier Social Stress Test' – A Tool for Investigating Psychobiological Stress Responses in a Laboratory Setting. *Neuropsychobiology*, *28*(1–2), 76–81. https://doi.org/10.1159/000119004

Kirschbaum, C., Wüst, S., & Strasburger, C. J. (1992). 'Normal' cigarette smoking increases free cortisol in habitual smokers. *Life Sciences*, *50*(6), 435–442. https://doi.org/10.1016/0024-3205(92)90378-3

Kreutz, G., Quiroga Murcia, C., & Bongard, S. (2012). Psychoneuroendocrine Research on Music and Health: An Overview. In R. MacDonald, G. Kreutz, & L. Mitchell (Eds.), *Music, Health, and Wellbeing* (p. 0). Oxford University Press. https://doi.org/10.1093/acprof:oso/9780199586974.003.0030

Koelsch, S. (2011). Toward a Neural Basis of Music Perception – A Review and Updated Model. *Frontiers in Psychology*, *2*, 110. https://doi.org/10.3389/fpsyg.2011.00110

Koelsch, S., Fritz, T., V Cramon, D. Y., Müller, K., & Friederici, A. D. (2006). Investigating emotion with music: An fMRI study. *Human Brain Mapping*, *27*(3), 239–250. https://doi.org/10.1002/hbm.20180

Koelsch, S., & Stegemann, T. (2012). The Brain and Positive Biological Effects in Healthy and Clinical Populations. In R. MacDonald, G. Kreutz, & L. Mitchell (Eds.), *Music, Health, and Wellbeing* (p. 0). Oxford University Press. https://doi.org/10.1093/acprof:oso/9780199586974.003.0029

LaGasse, A. B., & Thaut, M. H. (2012). Music and Rehabilitation: Neurological Approaches. In R. MacDonald, G. Kreutz, & L. Mitchell (Eds.), *Music, Health, and Wellbeing* (p. 0). Oxford University Press. https://doi.org/10.1093/acprof:oso/9780199586974.003.0012

Lazarus, R. S., & Folkman, S. (1984). *Stress, Appraisal, and Coping*. Springer Publishing Company.

Linnemann, A., Ditzen, B., Strahler, J., Doerr, J. M., & Nater, U. M. (2015). Music listening as a means of stress reduction in daily life. *Psychoneuroendocrinology*, *60*, 82–90. https://doi.org/10.1016/j.psyneuen.2015.06.008

Linnemann, A., Strahler, J., & Nater, U. M. (2017). Assessing the Effects of Music Listening on Psychobiological Stress in Daily Life. *Journal of Visualized Experiments: JoVE*, *120*, 54920. https://doi.org/10.3791/54920

Lovallo, W. R. (2015). *Stress & health: Biological and psychological interactions* (Third edition). SAGE Publications, Inc.

Lu, X., Yi, F., & Hu, L. (2021). Music-induced analgesia: An adjunct to pain management. *PSYCHOLOGY OF MUSIC*, *49*(5), 1165–1178. https://doi.org/10.1177/0305735620928585

MacDonald, R., Kreutz, G., Mitchell, L., MacDonald, R., Kreutz, G., & Mitchell, L. (Eds.). (2012). What is Music, Health, and Wellbeing and Why is it Important? In *Music, Health, and Wellbeing* (p. 0). Oxford University Press. https://doi.org/10.1093/acprof:oso/9780199586974.003.0001

McEwen, B. S. (1998). Protective and Damaging Effects of Stress Mediators. *New England Journal of Medicine*, *338*(3), 171–179. https://doi.org/10.1056/NEJM199801153380307

McEwen, B. S., & Stellar, E. (1993). Stress and the Individual: Mechanisms Leading to Disease. *Archives of Internal Medicine*, *153*(18), 2093–2101. https://doi.org/10.1001/archinte.1993.00410180039004

Menon, V., & Levitin, D. J. (2005). The rewards of music listening: Response and physiological connectivity of the mesolimbic system. *NeuroImage*, *28*(1), 175–184. https://doi.org/10.1016/j.neuroimage.2005.05.053

Miranda, D., Gaudreau, P., Debrosse, R., Morizot, J., & Kirmayer, L. J. (2012). Music Listening and Mental Health: Variations on Internalizing Psychopathology. In R. MacDonald, G. Kreutz, & L. Mitchell (Eds.), *Music, Health, and Wellbeing* (p. 0). Oxford University Press. https://doi.org/10.1093/acprof:oso/9780199586974.003.0034

Nater, U. M., Abbruzzese, E., Krebs, M., & Ehlert, U. (2006). Sex differences in emotional and psychophysiological responses to musical stimuli. *International Journal of Psychophysiology*, *62*(2), 300–308. https://doi.org/10.1016/j.ijpsycho.2006.05.011

Nater, U. M., Krebs, M., & Ehlert, U. (2005). Sensation Seeking, Music Preference, and Psychophysiological Reactivity to Music. *Musicae Scientiae*, *9*(2), 239–254. https://doi.org/10.1177/102986490500900205

Ooishi, Y., Mukai, H., Watanabe, K., Kawato, S., & Kashino, M. (2017). Increase in salivary oxytocin and decrease in salivary cortisol after listening to relaxing slow-tempo and exciting fast-tempo music. *PloS One*, *12*(12), e0189075. https://doi.org/10.1371/journal.pone.0189075

Pelletier, C. L. (2004). The Effect of Music on Decreasing Arousal Due to Stress: A Meta-Analysis. *Journal of Music Therapy*, *41*(3), 192–214. https://doi.org/10.1093/jmt/41.3.192

Reybrouck, M., Vuust, P., & Brattico, E. (2021). Neural Correlates of Music Listening: Does the Music Matter? *BRAIN SCIENCES*, *11*(12), 1553. https://doi.org/10.3390/brainsci11121553

Robb, S. L., Burns, D. S., & Carpenter, J. S. (2011). Reporting Guidelines for Music-based Interventions. *Music and Medicine*, *3*(4), 271–279. https://doi.org/10.1177/1943862111420539

Sandstrom, G., & Russo, F. (2010). Music Hath Charms: The Effects of Valence and Arousal on Recovery Following an Acute Stressor. *Music and Medicine*, *2*, 137–143. https://doi.org/10.1177/1943862110371486

Schäfer, K., Saarikallio, S., & Eerola, T. (2020). Music May Reduce Loneliness and Act as Social Surrogate for a Friend: Evidence from an Experimental Listening Study. *Music & Science*, *3*, 205920432093570. https://doi.org/10.1177/2059204320935709

Skoluda, N., Strahler, J., Schlotz, W., Niederberger, L., Marques, S., Fischer, S., Thoma, M. V., Spoerri, C., Ehlert, U., & Nater, U. M. (2015). Intra-individual psychological and physiological responses to acute laboratory stressors of different intensity. *Psychoneuroendocrinology*, *51*, 227–236. https://doi.org/10.1016/j.psyneuen.2014.10.002

Sloboda, J. (2010). Music in everyday life: The role of emotions. In *Handbook of Music and Emotion: Theory, Research, Applications* (pp. 493–514). https://doi.org/10.1093/acprof:oso/9780199230143.003.0018

Song, Y., Mewes, R., Skoluda, N., & Nater, U. M. (2023). How is music listening purpose related to stress recovery? - Two preliminary studies in men and women. *Frontiers in Psychology*, *14*, 1108402. https://doi.org/10.3389/fpsyg.2023.1108402

Sterling, P., & Eyer, J. (1988). Allostasis: A New Paradigm to Explain Arousal Pathology. *Handbook of of Life Stress, Cognition and Health*.

Strahler, J., Skoluda, N., Kappert, M. B., & Nater, U. M. (2017). Simultaneous measurement of salivary cortisol and alpha-amylase: Application and recommendations. *Neuroscience & Biobehavioral Reviews*, *83*, 657–677. https://doi.org/10.1016/j.neubiorev.2017.08.015

Stratton, V. N., & Zalanowski, A. H. (1984). The Relationship Between Music, Degree of Liking, and Self-Reported Relaxation. *Journal of Music Therapy*, *21*(4), 184–192. https://doi.org/10.1093/jmt/21.4.184

Sullivan, R. M., & Dufresne, M. M. (2006). Mesocortical dopamine and HPA axis regulation: Role of laterality and early environment. *Brain Research*, *1076*(1), 49–59. https://doi.org/10.1016/j.brainres.2005.12.100

Thoma, M. V., La Marca, R., Brönnimann, R., Finkel, L., Ehlert, U., & Nater, U. M. (2013). The Effect of Music on the Human Stress Response. *PLoS ONE*, *8*(8), e70156. https://doi.org/10.1371/journal.pone.0070156

Van den Bosch, I., Salimpoor, V. N., & Zatorre, R. J. (2013). Familiarity mediates the relationship between emotional arousal and pleasure during music listening. *Frontiers in Human Neuroscience*, *7*, 534. https://doi.org/10.3389/fnhum.2013.00534

Västfjäll, D., Juslin, P. N., & Hartig, T. (2012). Music, Subjective Wellbeing, and Health: The Role of Everyday Emotions. In R. MacDonald, G. Kreutz, & L. Mitchell (Eds.), *Music, Health, and Wellbeing* (p. 0). Oxford University Press. https://doi.org/10.1093/acprof:oso/9780199586974.003.0027

Vidas, D., Larwood, J. L., Nelson, N. L., & Dingle, G. A. (2021). Music Listening as a Strategy for Managing COVID-19 Stress in First-Year University Students. *Frontiers in Psychology*, *12*. https://doi.org/10.3389/fpsyg.2021.647065

Wang, W.-C. (2014). A study of the type and characteristics of relaxing music for college students. *Proceedings of Meetings on Acoustics*, *21*(1), 035001. https://doi.org/10.1121/1.4902001

Wilcox, R. R. (2012). *Introduction to robust estimation and hypothesis testing* (3rd ed). Academic Press.

Yehuda, N. (2011). Music and Stress. *Journal of Adult Development*, *18*(2), 85–94. https://doi.org/10.1007/s10804-010-9117-4

Zatorre, R. J., & Salimpoor, V. N. (2013). From perception to pleasure: Music and its neural substrates. *Proceedings of the National Academy of Sciences*, *110*, 10430–10437. https://doi.org/10.1073/pnas.1301228110

Figures

Tables

List of abbreviations

ACTH – adrenocorticotropic hormone

ANS – autonomic nervous system

BOLD – blood-oxygen-level-dependent

CRF – corticotropin-releasing factor

EDA – electrodermal activity

fMRI – functional magnetic resonance imaging

HPA-axis – hypothalamic pituitary adrenal axis

PET – positron emission tomography

RCT – randomized controlled trial

SAM-axis – sympathetic-adreno-medullary axis

SCL – skin conductance level

SNS – sympathetic nervous system

TEWL – trans epidermal water loss

TSST – Trier Social Stress Test

VAS – Visual Analogue Scale

Appendix

Zusammenfassung

Hintergrund: Da Stress sowohl zu physischen als auch zu psychologischen Gesundheitsproblemen beiträgt, hat sich das Musikhören als vielversprechende Intervention zur Stressreduktion erwiesen. Während die genauen Mechanismen, durch die Musik stressreduzierende Effekte ausübt, unklar sind, könnten Belohnung und Ablenkung potenzielle Mechanismen darstellen. Diese Masterarbeit untersucht die Auswirkungen des Musikhörens auf Stress, wobei der Schwerpunkt speziell auf dem Gefallen an der Musik und dem mentalen Fokus beim Hören liegt. Die Studie untersuchte physiologische Indikatoren und subjektive Bewertungen von Stress nach einem akuten Stressor. Darüber hinaus wurde die Stressreduktion zwischen Teilnehmerinnen in der Musikbedingung und jenen in einer aktiven Kontrollbedingung (Hörbuch) verglichen.

Methoden: Insgesamt nahmen 41 Frauen an dieser Laborstudie teil, während derer sie eine 30-minütige Audiointervention durchliefen. Nach dem Trier Social Stress Test (TSST) konnten die Teilnehmerinnen in der Musikbedingung ($n = 20$) aus fünf vom Forscherteam ausgewählten Playlists wählen, während die Teilnehmerinnen in der Hörbuchbedingung ($n = 21$) aus fünf vom Forscherteam ausgewählten Hörbüchern auswählen konnten. Das Gefallen der Musik und der mentale Fokus wurden über einen Fragebogen nach der Intervention erfasst, physiologischer Stress wurde durch elektrodermale Aktivität (EDA) gemessen, und subjektive Stressniveaus wurden mittels der Visuellen Analogskala (VAS) angegeben.

Fazit: Die Ergebnisse zeigten keinen signifikanten Zusammenhang zwischen dem Gefallen der Musik oder dem mentalen Fokus und der Stressreduktion. Obwohl die physiologische und subjektive Stressreduktion in der Musikbedingung deskriptiv größer war als in der Hörbuchbedingung, gab es keinen statistisch signifikanten Unterschied. Aufgrund der begrenzten Stichprobengröße und des Mangels an Variabilität in Gefallen und mentalem Fokus sollten diese Ergebnisse mit Vorsicht interpretiert werden.

Schlüsselwörter: Musikintervention, entspannende Musik, Musikeigenschaften, Musikpräferenz, Belohnungssystem, Stressreduktion, physiologischer Stress, subjektiver Stress, TSST