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The effects of music, musicality, and mental focus on subjective and physiological stress levels following an acute stressor

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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.

DeepL and ChatGPT were used to translate individual words and improve text passages.

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Abstract

Objectives: Stress is associated with a variety of negative impacts on well-being. Music listening has been identified as a cost-effective and ecological method for stress-reduction, influenced by factors such as musicality or mental focus during listening. This study aimed to explore the effects of music listening on subjective and physiological stress reduction following an acute stressor. Furthermore, the role of mental focus as a mediator of the relationship between musicality and stress reduction was examined.

Methods: In a laboratory setting, 45 healthy female participants were randomly assigned to either a music listening or a silence condition after exposure to the Trier Social Stress Test (TSST). Musicality was assessed using a German version of the Goldsmiths Musical Sophistication Index (Gold-MSI), and mental focus during music listening was measured using a single-item Visual Analogue Scale (VAS). Subjective stress (VAS) and physiological stress (heart rate, HR) were collected before and after the audio intervention.

Results: No significant differences were found between the music listening and silence conditions in terms of subjective and physiological stress reduction. Mediation analyses showed no significant mediating effect of mental focus on the association between musicality and stress reduction. Explorative analyses revealed a significant correlation between mental focus during music listening and subjective stress reduction. All findings need to be interpreted with caution due to the small sample size.

Conclusion: While the study did not find significant stress-reducing effects of music listening compared to silence, the observed correlation between mental focus and subjective stress reduction suggests potential benefits.

Key words: music listening, stress reduction, heart rate, subjective stress, physiological stress, musicality, musical sophistication, focus, mental focus, TSST, Trier Social Stress Test, acute stressor

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Introduction

Stress is a ubiquitous phenomenon with significant impacts on both psychological and physiological well-being. Given the variety of health problems associated with stress, the development of cost-effective and ecological stress-reduction strategies is crucial. In an array of promising studies, music listening has been shown to alleviate physiological and subjective stress levels. However, contradictory findings exist, and the mechanisms through which music exerts this potential stress-reducing effects remain underexplored. This thesis aims to investigate whether listening to music leads to a significant stress reduction following an acute stressor in a sample of healthy female participants. Furthermore, it will examine the role of musicality and mental focus in the relationship between music and stress. The findings of this study can contribute to a deeper understanding of the use of music for stress reduction and lead to the development of targeted therapeutic interventions.

Theoretical background

Stress

Definitions and Key Components

Despite the ever-present nature of the concept of stress, a clear and universally accepted definition has not yet been established. Stress occurs when environmental demands are perceived as overwhelming or exceeding an individual's ability to cope, presenting a threat to their well-being (Lazarus & Folkman, 1984). The term stress as we know it today has been proposed by Hans Selye, who is known as the “father of stress research” (Tan & Yip, 2018). He first brought the term into medical terminology to describe the “response of the body to any demand, whether it is caused by, or results in, pleasant or unpleasant conditions” (Selye, 1976, p. 74).

To facilitate understanding, stressors have been categorized into two primary groups: psychological (emotional) stressors and physical (systemic) stressors. Physical stressors cause disruptions to physiological balance by overwhelming specific homeostatic mechanisms, as seen in cases of hemorrhage or infection. Psychological stressors are perceived as threats to an individual’s current or expected state, such as social conflict or the inability to meet internal needs (Dayas et al., 2001).

As this thesis examines stress reactions following an acute stressor, a conceptual differentiation of acute and chronic stress is relevant. Acute stress is provoked by episodic events that have relatively clear beginnings and endings, leading to a more “short-term stress” (Hammen et al., 2009). At first exposure, most stressful events will act as an immediate threat and elicit an acute stress response, which will facilitate coping with the stressful situation.

Chronic stress, on the other hand, will occur if the stressful situation is sustained over a prolonged time or repeats itself, leading to an array of physical and psychological issues (Rohleder, 2019). The harmful impacts of stress on the human body will be described in a later chapter.

Hans Selye emphasized that prolonged exposure to stress, chronic stress, would adversely affect overall health. Using a rat model, he observed a consistent three-stage pattern of physiological stress in 1936. He termed this model the *general adaption syndrome* (GAS), and later renamed it the *stress response*. According to the GAS, after being confronted with a threatening situation, the body readies itself for fight or flight in the first stage, the alarm reaction stage. This transitions into the resistance stage, where the body gears up for prolonged combat against the stressor. During this second phase, the immune response escalates. The body adjusts to the specific stressor, and the initial alarm reaction has worn off. Finally, in the exhaustion stage, the system becomes exhausted, and its ability to resist the stressor declines (Robinson, 2018). No matter what kind of stressor the rats were exposed to, they showed a consistent response pattern. This pattern involved a reduction in the size of immune system organs, the development of ulcers in the gastrointestinal tract, and the enlargement of the adrenal glands (Lovallo, 2015).

Even with the negative connotation of stress in everyday language, a modest amount of stress can be favorable in testing scenarios. Selye defined this type of stress as “Eustress”, which can arguably be a driving force for self-improvement (O’Sullivan, 2011). He hypothesized that repeated exposure to moderate stressors could enhance the organisms ability to endure more prolonged and severe exposure to the same stressor (Lovallo, 2015). Furthermore, research has shown that both immediate and delayed retrieval of learning material can be enhanced by a moderate level of stress (Hupbach & Fieman, 2012).

While drawing attention to the negative effects of stress on the body, Selye’s model focuses solely on physical responses to a stressor. It overlooks that individuals may react differently to the same stressor due to varying appraisals, interpretations, and available coping mechanisms. These psychological factors influence how stress is perceived and managed.

The Transactional Stress Model

The extent to which situations are perceived as stressful is determined by personal appraisal. The dynamic interplay between individuals and their environment is emphasized in the *transactional model of stress and coping* by Lazarus and Folkman (1984). When an individual is confronted with a potentially stressful stimulus, appraisal processes are activated. First, primary appraisal aids to classify the situation as being benign, irrelevant, or stressful.

Benign and irrelevant situations can be ignored, while stressful situations call for specific actions. Stressful situations can be rated as either challenging or threatening. During the phase of secondary appraisal, the individual's ability to respond to, and cope with, the stressful situation is evaluated. If this evaluation results in the judgment that one does not possess the necessary strategies and resources to cope with the situation, threat is perceived. When the situation changes or new information becomes available, it will be reevaluated, and the perception of the stressor can change. This third step is called reappraisal (Putwain et al., 2021).

Coping strategies to manage stress can be categorized as adaptive and maladaptive. Adaptive strategies are functional, offering both short-term and long-term stress relief. In contrast, maladaptive strategies are dysfunctional and may provide only temporary relief (Zeidner & Saklofske, 1996). Furthermore, coping mechanisms can be classified as emotion-focused or problem-focused. Emotion-focused coping aims to minimize the distress associated with the situation. Examples for these strategies include seeking social support or positively reinterpreting the events. In contrast, problem-focused coping is characterized by efforts to modify the situation at its origin, for example by generating options to solve the problem (Lazarus & Folkman, 1984). In the stress and coping literature, emotion-focused coping strategies are generally considered maladaptive (Baker & Berenbaum, 2007).

The Physiological Stress Response

When a stressor is perceived as threatening and the individual believes they lack the resources to cope, the physiological stress response is triggered (Lazarus & Folkman, 1984). This response involves an interaction of endocrine, immune, and nervous systems, and consists of two main components: the sympathetic-adreno-medullar axis (SAM axis), and the hypothalamic-pituitary-adrenal axis (HPA axis) (Chu et al., 2024).

The SAM axis, part of the sympathetic nervous system (SNS), acts as the faster pathway in the stress response. Upon encountering stress, signals are sent to the adrenal medulla, prompting the release of adrenaline and noradrenaline. These hormones equip the body to respond with a fight-or-flight reaction by causing vasoconstriction, elevated heart rate (HR), and increased blood pressure (Kaiser & Jaillardon, 2023; Chu et al., 2024). Additionally, activation of the SAM axis leads to heightened arousal, vigilance, and focused attention (Chu et al., 2024).

In contrast, the HPA axis functions as a slower pathway. It begins with the release of corticotropin-releasing hormone (CRH) from the hypothalamus into the circulation. This CRH then triggers the anterior pituitary gland to release adrenocorticotropic hormone (ACTH).

ACTH subsequently prompts the adrenal cortex to produce glucocorticoid hormones, leading to the release of the stress hormone cortisol (Chu et al., 2024).

The HPA axis takes longer to activate than the SAM axis, as it primarily works through hormones (Kaiser & Jaillardon, 2023). Although both systems work cooperatively and/or sequentially in managing stress responses, they exert opposite effects on most visceral organ targets (Godoy et al., 2018). The rapid activation of the SAM axis is associated with short-lasting stress responses, whereas the HPA axis activation can lead to both short- and long-term effects (Tank & Lee, 2015). While the short-term stress response is regarded as a beneficial and adaptive process, chronic stress can result in various negative health outcomes (Kaiser & Jaillardon, 2023).

Stress and Health

Prolonged exposure to stressors can lead to dysregulation of the HPA axis, resulting in continuously elevated cortisol levels (McEwen, 2008). This hormonal imbalance contributes to a variety of mental health problems, including depression and anxiety. Furthermore, it elevates the risk for physiological disorders, such as immune dysfunction, metabolic issues, cardiovascular diseases, or cognitive impairment (Ketchesin et al., 2017; McEwen, 2008).

Initial episodes of depression frequently occur after major negative life events (Paykel, 2001). In a study of 13,006 patients with first-time psychiatric admissions in Denmark, higher incidences of recent unemployment, divorces and suicides by relatives compared to age- and gender-matched controls have been revealed (Kessing et al., 2003). Furthermore, stressful life events often precede anxiety disorders (Schneiderman et al., 2005), with anxiety frequently developing before depression (Breslau et al., 1995). Prospective studies have shown that patients with anxiety are more likely to develop depression following stressful life events (Brown et al., 1986).

Chronically stressful situations have been linked to higher alcohol consumption (Linsky et al., 1985). Other consequences of stress include increase in smoking, substance abuse, sleep problems and accidents, leading to adverse health outcomes (Schneiderman et al., 2005). Individuals showing larger than normal reactions to stressors are at higher risk for cardiovascular disease and premature death (Lovallo, 2015). The increased risk of cardiovascular disease is caused by stress triggering acute cardiac events, as well as increasing the risk of developing atherosclerosis (Hjemdahl et al., 2012). Individuals experiencing psychological conditions related to stress have a higher incidence of coronary artery disease, stroke, and hypertension (Chu et al., 2024).

Music and Stress

Stress can be managed in various ways, with music listening being a common method (Baltazar et al., 2019; Dibben & Williamson, 2007; Haake, 2011). Music has been utilized as an intervention for stress reduction through various methods, including music activities like singing or making music, music listening tailored to specific patient groups, and live music therapy conducted by professional music therapists (De Witte et al., 2020). Historically, music has been linked to physical reactions, dating back to ancient Assyrian and Greek cultures, where music was even used during the Olympic Games to improve athletes' performance (Cervellin & Lippi, 2011). Due to its broad accessibility through streaming services, music listening has garnered significant interest as an economical, non-invasive, and highly accepted intervention for managing stress and related health issues in both healthy individuals and clinical patients (Lai & Li, 2011).

Modern research supports the idea that music can aid in stress regulation through various mechanisms. People listen to music for various reasons, with one of the primary motivations being mood regulation (Greasley & Lamont, 2011; Thayer et al., 1994; Lonsdale & North, 2011). Music helps individuals manage their emotions (Chamorro-Premuzic & Furnham, 2007) and promote relaxation (Greasley & Lamont, 2011), which can lead to stress reduction (Fallon et al., 2020). Young people, in particular, often turn to music to help them relax and cope with stress, frequently having a collection of favorite tunes for such occasions (Labbé et al., 2007). The versatility of music in serving different needs makes it more effective than other leisure activities for emotional management (Lonsdale & North, 2011). It can be seen as a diversion strategy, distracting individuals from stress and negative thoughts, thereby aiding in stress recovery (Bernatzky et al., 2011; Chanda & Levitin, 2013). In short-term music interventions for acute stress reduction, the beneficial function of music to distract people from aversive states has been supported (Linnemann et al., 2015). Furthermore, music can provide emotional comfort, and promote a sense of belonging (De Witte et al., 2020). Music lifts the spirit and enhances overall well-being, encouraging individuals to live more fully and happily (Alagha & Ipradjian, 2017).

Recent neuroscientific studies have shown that music listening activates several brain structures involved in emotion and stress regulation. Music-evoked emotions are linked to activity in core emotion networks, particularly the hippocampus and the amygdala, which play crucial roles in regulating the HPA axis (Tsigos & Chrousos, 2002). Listening to music can down-regulate the HPA axis, leading to reduced autonomic nervous system (ANS) activity, with decreased heart rate and lower blood pressure (Linnemann et al., 2015). Additionally, music influences the pituitary gland, which releases endorphins that promote calmness, reduce pain, and improve sleep quality (Malakoutikhah et al., 2020). Overall, music is able to decrease physiological arousal and facilitate health outcomes by influencing neurochemical systems (Chanda & Levitin, 2013). A review of 400 studies concluded that music has a positive impact on the neurochemicals associated with four distinct brain systems: the reward system, the immune system, the social system, and the stress system (Chanda & Levitin, 2013).

Due to its close connection with emotions and potential to act as a cognitive distractor, music listening can serve as an effective intervention for alleviating stress (Radstaak et al., 2014; Sandstrom & Russo, 2010; Thoma et al., 2013). Numerous studies have examined the impact of music listening on stress levels, providing insights into both physiological and psychological benefits. Some of these studies focus on everyday stress and high-stress occupations without inducing experimental stress. For instance, a negative association between classical music consumption and stress levels in daily life has been observed (Alagha & Ipradjian, 2017). Furthermore, music has demonstrated stress-reducing effects among pregnant women (Chang et al., 2015) and nurses (Lai & Li, 2011). Using an electronic diary device, Linnemann et al. (2018) found that participants reported lower stress-levels when they had recently listened to music or were currently listening to music.

Music listening has been shown to decrease cortisol levels (Khalfa et al., 2003) and HR (Scheufele, 2000), both after stress induction and in daily life (Linnemann et al., 2015; Chanda & Levitin, 2013). It also facilitates faster ANS recovery following exposure to a stressor (Chafin et al., 2004; Thoma et al., 2013). Observations of electrodermal activity (EDA), a marker of the physiological stress response, revealed significant reductions in EDA measures after listening to music following the Trier Social Stress Test (TSST) (Fallon et al., 2020). Laboratory studies have also documented significant reductions in subjective stress (Khalfa et al., 2003; Groarke & Hogan, 2019) and self-reported anxiety (Lai & Li, 2011) through music listening. A meta-analysis including 104 randomized controlled trials (RCT) found that interventions involving music can significantly reduce both physiological and psychological stress (De Witte et al., 2020). A subsequent systematic review and meta-analysis by the same group of researchers found a significant effect of music therapy on stress-related outcomes in medical settings (De Witte et al., 2022).

Despite the substantial body of research supporting the stress-reducing effect of music listening compared to control conditions, findings remain inconsistent. Adiasto et al. (2022)

conducted a meta-analysis which concluded that definitive conclusions regarding the effects of music listening on short-term stress recovery in healthy individuals cannot yet be drawn. Linnemann et al. (2016) found no significant associations between mere music listening and stress reduction in daily life. Similarly, Chafin and colleagues (2004) reported no significant difference in HR recovery after music listening compared to sitting in silence following a three-minute arithmetic task. Several studies observed no effect of music on salivary cortisol levels when music was listened to prior to a stress test (Knight & Rickard, 2001; Thoma et al., 2013). In a comprehensive literature review of 67 investigations (Ellis & Thayer, 2010), 15 studies reported non-significant effects of music on HR changes. Additionally, no differences in HR recovery were found among participants who listened to classical music, heavy metal, self-selected relaxing music or who sat in silence (Labbé et al., 2007). Thoma and colleagues (2013) also noted that subjective stress levels and HR did not differ significantly between the participants who listened to music, the sound of rippling water, or sat in silence before being exposed to the TSST. The previously mentioned meta-analysis by Adiasto et al. (2022) suggests that the effects of listening to music on stress reduction are comparable to those of silence or an auditory control condition. Their analysis contained only laboratory studies where participants merely listened to music, unlike many of the previously referenced papers and the review by de Witte et al. (2022), which incorporated music therapy, which must be performed by a trained music therapist.

One potential reason for the inconsistencies observed in previous experiments is the multitude of factors associated with music listening that influence its efficacy in alleviating stress (Chen et al., 2019). For instance, not all music is equally appropriate for stress reduction. Low-arousal and high-pleasure music has been shown to reduce stress more effectively following a stressor (Sandstrom & Russo, 2010; Jiang et al., 2016). Music with a slower tempo is considered more relaxing than faster music, as indicated by less HR acceleration (Bernardi, 2005; Yamamoto et al., 2007). Ideally, the music should have a tempo below the resting heart rate (60-80 beats per minute), pleasing harmonies, predictable dynamics, and a regular rhythm, as these properties cause the body to tune in to the slower beat of the music (Merker et al., 2009). While it is commonly believed that instrumental music promotes better stress recovery than music with lyrics (De Witte et al., 2020), studies have argued that the comforting effects of the lyrics might reinforce the positive effects of music on stress reduction (Adiasto et al., 2022; Koelsch et al., 2011).

Furthermore, musical pieces that individuals choose themselves have been found to have a more significant stress-reducing effect than researcher-selected music (Chennafi et al., 2018; Chanda & Levitin, 2013). The selection of music should be based on participants' music preferences, as studies have revealed that likable music is better for alleviating stress (Jiang et al., 2016; Jiang et al., 2013), by potentially triggering positive memories (Parada-Cabaleiro et al., 2021). It has also been shown that music was linked to stress reduction only when listened to specifically for relaxation purposes (Linnemann et al., 2016; Linnemann et al., 2015). Additionally, the social context of music listening plays a role. For instance, Linnemann et al. (2016) found that listening to music in a social setting can be more effective for stress reduction compared to listening to music alone. This effect is thought to arise because shared music experiences can fulfill important social functions, such as fostering connections and providing emotional support by bonding over musical activities (Boer & Abubakar, 2014).

It is hypothesized that music listening facilitates stress recovery more effectively when listened to before the stressor (Chen et al., 2019; Chennafi et al., 2018). The stress-reducing effect of music may also vary depending on the intensity of the stressor. In a meta-analysis, Pelletier (2004) suggested that music might be effective in reducing stress primarily in the context of mild stressors rather than strong ones. This suggestion was supported by an experimental study, which found that listening to music before a strong socio-evaluative stressor did not effectively reduce stress (Thoma et al., 2013).

When examining the psychological and physiological responses to music, it is essential to consider individual differences in personality traits (Chanda & Levitin, 2013). While relaxing music can alleviate stress levels, the effects are influenced by various factors, including the type of stress, the type of music intervention, and prior musical experience (Pelletier, 2004). The potential impact of *musicality*, which is closely related to experience with music, on the stress-reducing effects of music will be explored in the next chapter.

Musicality and Stress

While the term *musicality* is commonly used in everyday language, literature has yet to reach a consensus on its definition. Research on musicality spans over two centuries and can be divided into three distinct phases, each characterized by different approaches to understanding and measuring musicality (Gembris, 1997). The first phase, from 1800 to 1920, is marked by a phenomenological approach. The second phase, beginning in the 1920s and continuing to the present, is characterized by a psychometric approach. The most recent phase, emerging in the 1980s and extending to today, focuses on musical meaning.

A promising definition stems from Müllensiefen et al. (2014), who define the term *musical sophistication* as "a psychometric construct that can refer to musical skills, expertise, achievements, and related behaviours across a range of facets that are measured on different subscales” (p.2). According to this definition, individuals exhibiting high levels of musical sophistication display “a) higher frequencies of exerting musical skills or behaviours, b) greater ease, accuracy or effect of musical behaviours when executed, and c) a greater and more varied repertoire of musical behaviour patterns.” (p.2). The term musical sophistication has been used less frequently in research, making it less burdened with biases compared to more commonly used terms like musical talent (Hilsenroth et al., 2005; Müllensiefen et al., 2014). As it accurately represents what is often meant by musicality in everyday language, the term musicality will be used when referring to musical sophistication in this thesis.

Most scientific instruments used to study musicality focus on the ability to play an instrument. However, this approach overlooks the skills necessary for engaging with music in ways other than playing an instrument (Levitin, 2012). As the title of the paper “The Musicality of Non-Musicians: An Index for Assessing Musical Sophistication in the General Population” by Müllensiefen et al. (2014) suggests, musicality is a concept that is also evident in non-musicians. The authors developed the Goldsmiths Musical Sophistication Index (Gold-MSI), a questionnaire based on the previously defined concept of musical sophistication (Müllensiefen et al., 2014). The instrument measures a wide range of individual differences in the general population, with less emphasis on highly specialized populations such as professional musicians (Müllensiefen et al., 2014). The Gold-MSI has been utilized to assess the level of musicality of the study participants for this thesis and will be explained in more detail in the chapter *Methods*.

Comparing the activated brain structures of musicians and non-musicians during music listening, PET-studies have revealed that music activates the right (non-dominant) hemisphere in non-musicians, whereas musicians listen by using the left (dominant) hemisphere (Halpern, 1999). The right hemisphere is considered the more intuitive part of the brain, while the left hemisphere is thought to be the more rational side (Cervellin & Lippi, 2011). Timbre and melody of the music are perceived by the right hemisphere, the left hemisphere analyzes more “mathematical” aspects of music such as rhythm and pitch (Halpern, 1999; Pallesen et al., 2005). However, the notion of a strict division between an “analytical left hemisphere“ and an “intuitive right hemisphere“ is now considered outdated. Modern neuroscience recognizes that both hemispheres are interconnected and involved in most cognitive tasks, including musical processing. Furthermore, individuals with longer musical training have demonstrated to display a better capability to experience and perceive the emotional impact of music (Castro & Lima, 2014; Lima & Castro, 2011; Rawlings & Leow, 2008).

Regarding the associations between musicality and stress reduction through music, the influence of music on physiological reactions has found to be enhanced among participants with musical training (Knight & Rickard, 2001). In an experiment including music-majors and non-music majors, the musically trained participants showed a lower state anxiety score after listening to low-arousal music than untrained individuals (Smith & Morris, 1977). In her meta-analysis, Pelletier (2004) proposed that individuals with musical experience tend to be more responsive to music-assisted relaxation techniques, possibly because of greater engagement, understanding and comfort level with the music. In contrast, no significant effects of musical training on stress reduction have been found in other studies (Laohawattanakun et al., 2011; Knight & Rickard, 2001; Bernardi, 2005). After stress was experimentally induced using the TSST, the efficacy of music listening for reducing stress was not influenced by the length of musical training (Jiang et al., 2016).

Musicality, Mental Focus and Stress

As outlined above, the relationship between music listening and stress might be modulated by individual differences in musicality. To further investigate this interaction, it is essential to explore the specific constructs contributing to the facilitation of the stress-reducing effect of music by musicality. Musical training has been associated with advantages in cognitive abilities (Schellenberg, 2005; Talamini et al., 2017), with childhood music lessons showing positive association with various cognitive abilities in both childhood and adulthood (Lad et al., 2022). Consistent with these findings, musicians have demonstrated improved sustained attention (Carey et al., 2015). Interviews with orchestral musicians regarding their way of listening to music have revealed that professional musicians tend to listen to music in a more reflective, conscious and attentive manner (Reitan, 2013). In the previously mentioned study investigating differences in hemispheric activation during music listening between musicians and non-musicians, the authors hypothesized that musicians might engage in more focused and analytical listening, potentially involving different neural processes compared to non-musicians (Halpern, 1999). The tendency towards emotional or attentive music listening is influenced by factors such as music preferences, prior experience, and musical expertise (Leipold & Loepthien, 2021). These observations suggest a potential link between participants' level of musicality and their ability to maintain focus during music listening.

In an experimental study, Jäncke et al. (2018) reported that the same musical piece could trigger different neural responses based on the listener's direction of attention. After listening to a piece by Mozart, changes in HR and heart rate variability (HRV) were stronger in the attentive condition compared to passive listening. Significant, but minor correlations between attentive music listening and relaxation have been found in a study investigating differences between emotional and attentive music listening (Leipold & Loepthien, 2021). Jiang et al. (2016) propose that attentive music listening may have stronger effects on stress reduction than passive listening. However, no studies have been found exploring the relationship between *mental focus* during music listening and stress reduction following an acute stressor. In this context, mental focus is defined as the degree to which one concentrates on the music rather than being distracted by outside stimuli or mind wandering.

Research Gap and Relevance

Results regarding the influence of music listening on stress reduction are contradictory. While numerous studies have demonstrated the stress-reducing effects of music on subjective stress levels and physiological stress measures (Khalfa et al., 2003; Scheufele, 2000; Chanda & Levitin, 2013; Chafin et al., 2004; Thoma et al., 2013; Fallon et al., 2020; Groarke & Hogan, 2019; De Witte et al., 2020; De Witte et al., 2022), other research revealed no significant impact (Linnemann et al., 2016; Chafin et al., 2004; Knight & Rickard, 2001; Thoma et al., 2013; Labbé et al., 2007; Adiasto et al., 2022). Much of the existing literature focuses on music therapy and clinical populations, while the effects of mere music listening on stress responses of healthy individuals remain underexplored (Adiasto et al., 2022). Discrepancies between subjective and physiological stress levels following music exposure have been reported (Thoma et al., 2013; Linnemann et al., 2015), therefore both aspects will be investigated in this thesis. With stress being a ubiquitous phenomenon with the potential of causing a range of negative health outcomes (Ketchesin et al., 2017; McEwen, 2008), the development of efficient, accessible and cost-effective measures for stress-reduction is becoming increasingly important (Adiasto et al., 2022; Malakoutikhah et al., 2020). Music, easily accessible through streaming services, could serve as an effective and cheap method of reducing stress in everyday life. Consequently, the first aim of this study was to further investigate the association between mere music listening and stress reduction following the TSST in healthy individuals.

The effects of music listening on stress are hypothesized to be influenced by various factors, including prior musical experience. Musically experienced individuals are believed to benefit more from music-assisted relaxation techniques (Pelletier, 2004). Positive associations have been observed between musical training and reduction of anxiety scores through music (Smith & Morris, 1977). Conversely, other studies found no significant effects of musical training on stress reduction (Laohawattanakun et al., 2011; Knight & Rickard, 2001; Bernardi, 2005). These studies focus on solely on musical experience, with no research conducted on other aspects of musicality and their effect on stress reduction through music listening. Addressing this research gap, this thesis aims to explore the effects of musicality as a broader construct, beyond merely the ability to play instruments, on stress reduction in response to music.

Musicality is positively associated with advantages in cognitive abilities (Schellenberg, 2005; Talamini et al., 2017), with musicians demonstrating improved sustained attention (Carey et al., 2015) and more attentive music listening (Reitan, 2013). The tendency towards attentive music listening is influenced by factors such as musical expertise (Leipold & Loepthien, 2021), suggesting a link between musicality and the ability to maintain focus on the music during music listening. Furthermore, it has been proposed that attentive music listening may have stronger stress-reducing effects than passive listening (Jiang et al., 2016). However, the effect of musicality, as a broader construct, on mental focus during music listening, or the potential mediating role of mental focus in the relationship between musicality and stress reduction following the TSST, have not been investigated. Thus, the last aim of this thesis was to explore the potential of mental focus as a mediator of the association between musicality and stress reduction through music listening.

Research Questions and Hypotheses

Research Questions

Derived from the presented research gaps, two research questions will be investigated in this thesis. Sub-questions and sub-hypotheses of the second research question follow the paths of the mediation:

RQ1: Do individuals who listen to relaxing music after experiencing an acute stressful event show a greater reduction in subjective stress and heart rate than individuals who sit in silence?

RQ2: Is the relationship between the degree of musicality and the reduction in subjective stress and heart rate after listening to relaxing music following an acute stressful event mediated by mental focus?

> **RQ2.1**: Does musicality influence subjective and physiological stress reduction through music listening following an acute stressor?
>
> **RQ2.2**: Does musicality influence mental focus during music listening?

Hypotheses

H1: Individuals who listen to relaxing music following an acute stressful event will exhibit a greater decrease in subjective stress (VAS) levels than individuals who sit in silence.

H2: Individuals who listen to relaxing music following an acute stressful event will exhibit a greater decrease in heart rate (HR) than individuals who sit in silence.

H3: Musicality is associated with a greater stress reduction after listening to relaxing music following an acute stressor.

> **H3.1** Participants with higher scores of musicality (Gold-MSI) show a greater reduction in subjective stress (VAS) after listening to relaxing music following an acute stressor.
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> **H3.2** Participants with higher scores of musicality (Gold-MSI) show a greater decrease in physiological stress (HR) after listening to relaxing music following an acute stressor.

H4: Participants with higher scores of musicality (Gold-MSI) show higher scores of mental focus (VAS).

H5: Mental focus mediates the association between musicality and the stress reduction after listening to relaxing music following an acute stressor. .

> **H5.1** The association between higher scores of *musicality* (Gold-MSI) and greater decrease in subjective stress (VAS) through music listening is mediated by higher scores of mental focus (VAS).
>
> **H5.2** The association between higher scores of musicality (Gold-MSI) and a lower increase in physiological stress (HR) through music listening is mediated by higher scores of mental focus (VAS).

Methods

Study Design

Data for this master's thesis was gathered as part of the project "Effects of music listening on stress and skin barrier recovery" by the department of Clinical and Health Psychology of the University of Vienna, established by Dr. Jasminka Majdandžić and Univ.-Prof. Dr. Urs Markus Nater in 2019. This overarching project addresses two main research questions: examining the impact of music listening on stress responses induced by an acute stressor and investigating the effects of music and stress on the recovery of skin barrier injuries.

After successfully completing the strict recruitment process (details provided in the next section), participants received a link via e-mail to fill out online questionnaires on

Unipark. These questionnaires addressed a variety of variables relevant for the study, including constructs related to stress, such as chronic stress perceived in everyday life, state and trait anxiety or childhood neglect. Furthermore, the Big-Five personality traits and potential psychiatric or somatic symptoms were evaluated via the online-questionnaire. Related to the topic of music, other questionnaires asked about strategies for music-related mood-regulation used by the participants, music empathizing, and their music preference. The degree of musicality, a construct highly relevant for this thesis, was assessed through the Gold-MSI, which will be described in further detail in the *Materials* section.

Participants were randomly assigned to one of the three conditions of the RCT. During the 30-minute intervention phase, individuals either listened to relaxing music (experimental group), an audiobook (active control group), or silence (passive control group). Playlists for the experimental group were pre-assembled and validated through a pilot study, and participants were asked to choose between five playlists (ambient, guitar, jazz, lo-fi, lounge) in the beginning of the study. In the active control group, individuals could choose one of five proposed topics to listen to during the 30 minutes (biology, cosmology, history, physics, philosophy).

To assess the amount of stress perceived by the participants, a variety of stress measures were taken throughout the study. Subjective stress levels were assessed through self-report, while physiological stress was measured via HR, EDA, salivary cortisol and alpha-amylase. Stress was measured at eight time points during the experiment. To assess the effects of music on the recovery of skin barrier impairments, recovery of the skin barrier was operationalized by trans epidermal water loss (TEWL) of the skin. Other questionnaires were handed out to the participants at various time points, assessing their mood, anxiety, and ratings of the audio stimulus among others.

Sample

Previous studies and meta-analyses have documented medium effect sizes for the impact of music interventions on the reduction of psychological and physiological stress. Based on these findings, a power analysis for independent t-tests (using G*Power) to address the first research question indicated a required sample size of N = 102 (Faul et al., 2009). Regarding the mediation model in the second research question, empirical estimates based on effect sizes of paths a and b have been used to determine the necessary sample size (Fritz & MacKinnon, 2007). However, previous research on the effect of musicality on mental focus as well as the influence of mental focus during music listening on stress reduction did not report effect sizes. To ensure a robust power analysis, a conventional medium effect size has been used for both paths as suggested by Cohen (2009), resulting in a target sample size of $N = 78$ for the mediation analyses (Fritz & MacKinnon, 2007).

Participants for the study were recruited via printed flyers, a mailing list compiled for research purposes, and social media platforms, primarily Facebook groups. The main exclusion criteria were disclosed on the shared flyer, and eligibility was determined through a detailed telephone screening. Upon successfully completing the experiment, participants received a compensation of 45€.

To avoid interferences from extranous variables, strict exclusion criteria were established in accordance with guidelines for assessing alpha-amylase and salivary cortisol in experimental settings (Strahler et al., 2017). The study included only participants assigned female at birth, aged 18 to 35. Given the fluctuations in HPA axis activity throughout the female menstrual cycle (Magiakou et al., 1997), only women with a regular menstrual cycle who were not using hormonal contraception or other medication potentially affecting hormones were included. Pregnant or breastfeeding women were excluded. Since cortisol responses to an acute stressor can be influenced by the menstrual cycle phase (Montero-López et al., 2018), all females were tested within the follicular phase to ensure a more homogenous sample.

Regular consumption of cigarettes, drugs or alcohol led to an exclusion, as an excessive use of these substances is associated with a dysregulated HPA axis and potential alterations of the stress response (Lovallo, 2006). Additionally, participants were required to have a body mass index (BMI) between 18 and 25, as HPA axis hyperactivation has been observed in both overweight and underweight individuals (Fricke & Voderholzer, 2023; Werdermann et al., 2021).

Only healthy females with no history of chronic somatic illnesses, such as metabolic diseases, allergies, or thyroid abnormalities, were included. Diagnosed mental illnesses, such as depression, psychosis, anxiety, or eating disorders within the last five years, as well as the intake of psychopharmaceuticals in the 14 days prior to the experiment, also led to an exclusion.

To ensure comprehension of the questionnaires and experiment instructions, participants needed to be fluent in German. Individuals with previous experiences with the TSST were excluded to avoid biases during the stress test. Music-related exclusion criteria included hearing impairments, chronic tinnitus, music-related studies or professions, and absolute hearing.

Materials

Musicality

The German version of the Goldsmiths Musical Sophistication Index (Gold-MSI; Müllensiefen et al., 2014) was employed to differentiate between individuals with varying degrees of musicality. Schaal et al. (2014) translated and validated the original questionnaire to German. Participants complete the questionnaire online via Unipark prior to the laboratory study. The Gold-MSI comprises 39 music-related items, with participants responding to 31 statements using a 7-point-Likert-scale, ranging from “do not agree at all” to “fully agree”. The remaining 8 items refer to active music making and listening, with responses given by choosing one of many numerical values. The items can be divided into five subscales (active engagement, musical training, perceptual abilities, emotions, singing abilities) and a global scale (general musical sophistication). This global scale, consisting of the 18 items with the highest factor loadings, will be used as a measure of musicality in this thesis. One item lacking relevance to our research questions was excluded from the study. Prior to the analysis, eight out of the remaining 38 items have been reverse-coded, as higher numbers indicated a lower degree of musicality in the original coding. Example items from the global scale include “I am able to hit the right notes when I sing along to a recording” or “I spend a lot of my free time doing music-related activities”.

In a German sample, the German version of the Gold-MSI displayed high reliabilities in the five sub-factors as well as the global scale, indicated by Cronbach α between .72 and .91 (Schaal et al., 2014). In the sample used for this thesis, calculations of internal consistency of the global factor revealed a low internal consistency with a Cronbach α of .50.

Mental Focus

The degree of participants’ focus during music listening was evaluated using one question from the questionnaire “Bewertung_Audiostimulus”, which was administered directly after the music listening session. The question was “Worauf haben Sie sich beim Hören der Musik fokussiert?” which translates to “What did you focus on while listening to the music?”. Participants selected from five predetermined response options, ranging from complete focus on the music (1) to distraction by other stimuli or mind wandering (5).

Subjective Stress

Subjective stress levels were evaluated using a visual analogue scale (VAS). Participants were instructed to indicate their current perceived stress level by marking a 100 mm line with the negative pole labeled “not at all” and the positive pole labeled “very strongly”. The distance from the first pole to the participants’ mark was measured to determine their subjective stress level, ranging from 0 to 100. The VAS is as effective as longer questionnaires, such as the Perceived Stress Scales (PSS; Cohen et al., 1983), in detecting differences in stress levels between groups (Lesage et al., 2012). As previously mentioned, participants reported their stress levels at eight time points throughout the study. For my analyses, only the subjective stress levels directly before (T4) and after the audio session (T5) were considered. Changes in the participants stress levels were obtained by calculating the difference in perceived subjective stress ratings before and after the audio intervention (T4-T5). A greater stress reduction through the audio intervention is indicated by a greater change score.

Physiological Stress

Initially, physiological stress levels were intended to be evaluated by measuring the participants' HRV using "Movisens" sensors connected to a chest strap. HRV, defined as the variation in time intervals between successive heartbeats, is considered an indicator of the heart's ability to adapt to physiological and environmental changes (Rajendra Acharya et al., 2006). HRV is responsive to changes in the activity of the ANS, specifically alterations in the SNS and the parasympathetic nervous system (PNS), associated with stress (Kim et al., 2018). HRV was found to be a more suitable metric than HR for assessing the participant's physiological stress levels (Peabody et al., 2023).

Due to issues with the sensors, we were faced with difficulties regarding the extraction of HRV in our data analysis. Excluding participants with missing HRV values would have resulted in a smaller sample size, reducing the probability of detecting effects. Consequently, HR was used to assess physiological stress levels instead of HRV. A strong physiological stress response is accompanied by HR acceleration (Lovallo, 2015), making HR a suitable measure for physiological stress. Changes in participants' physiological stress levels were obtained by calculating the difference between two five-minute windows: mean HR during the last five minutes before the audio intervention (music / silence) and mean HR during the last five minutes of the audio intervention (HR before – HR after). A larger difference indicates greater stress reduction through the audio intervention.

Trier Social Stress Test (TSST)

The TSST is an acute stress procedure developed by Kirschbaum et al. (1993) to induce moderate psychological stress in laboratory settings. It significantly increases physiological stress indicators such as HR, cortisol levels, growth hormone (GH) and ACTH, as well as subjective stress levels (Kirschbaum et al., 1993; Allen et al., 2017; McRae et al., 2006).

The TSST contains two five-minute parts: a mock job interview and a mental arithmetic task (Kirschbaum et al., 1993). When entering the test room, participants were met by a panel composed of a male student (active stressor) and a female student (passive stressor) from our study team, both dressed in white lab coats. The active stressor was trained to give all instructions to the participants, while the passive stressor remained silent and showed a neutral facial expression, providing no form of social feedback. During the instruction phase, participants were asked to prepare a free speech highlighting their personal characteristics and strengths that make them a suitable candidate for a hypothetical job. To further increase stress, participants were falsely informed that their speech would be videotaped and evaluated by behavioral analysts. After receiving the instructions, participants were given three minutes to prepare the speech, a modification from the original TSST, which allowed ten minutes of preparation (Kirschbaum et al., 1993). They were permitted to take notes but were not allowed to use them during their speech.

After the preparation time was over, participants were asked to stand on a marked position directly in front of the panel. After the experimenter left the room and the passive stressor pretended to turn on the camera, they were instructed to start their speech. Throughout the five-minute monologue, the panel remained neutral, offering no form of social feedback, such as smiling or nodding. If a participant was silent for more than 20 seconds, they were encouraged to continue speaking.

After the speech, participants received instructions for the mental arithmetic task. They were asked to count down from the number 1043 in steps of 17 in our study, whereas the original TSST required counting down from 1022 in steps of 13 (Kirschbaum et al., 1993). As in the speech task, no form of social feedback was provided. If they made mistakes in their calculation, participants were instructed to start over. Additionally, the active stressor sometimes asked them to count faster or look directly into the camera to further increase stress levels. After five minutes of counting, the experimenter escorted the participant out of the test room.

Audio Intervention

The two conditions of the audio intervention relevant for this thesis are the music listening condition and the silence condition. Participants were randomly assigned to either the experimental condition (music listening) or the control condition (silence). At the beginning of the study, participants were asked chose one of five playlists (ambient, guitar, jazz, lo-fi, or lounge music) that had been validated in a pre-study. All musical pieces were non-lyrical, with tempos not exceeding 80 bpm. During the 30-minute audio intervention, the participants sat in a lounge chair and were advised to remain calm, without falling asleep. The music was played through headphones, and participants chose a comfortable volume before the audio intervention began. To maintain comparability between the two conditions and shield them from traffic noise, participants in the silence condition also sat in the lounge chair with headphones on for 30 minutes.

Procedure

The study included a variety of steps and measures, however, only the steps relevant for the analysis of my research questions will be described below. After participants contacted the recruitment team via email, a telephone screening was conducted to ensure they met the strict inclusion and exclusion criteria. Eligible participants were scheduled for a test date during the follicular phase of their menstrual cycle. Following the telephone interview, they received a link to the online survey tool *Unipark* and were asked to complete a range of questionnaires before their test session, including the Gold-MSI used to assess musicality. Two days before their session, participants received an email with a checklist of important information and a reminder to complete the outstanding self-report questionnaires if necessary.

The laboratory study began at 12:45 and lasted for about four hours. Four members of the study group were present for every session: One experimenter, one assistant for the TEWL measurements, and two people for the TSST panel. Upon arrival, the 30-minute acclimatization period began. The participants signed informed consent, and the *Movisens* cheststrap for the HR measures was attached. Participants in the music condition selected their preferred playlist for the 30-minute audio intervention and were instructed to set markers for HR analysis by tapping a wrist sensor twice. After baseline stress measurements, participants were brought to another room for the TSST (see *Materials* for a detailed description).

Back in the initial test room, skin barrier integrity and subsequent skin impairment were measured using the tape stripping procedure, which took approximately 20 minutes. Following these skin measurements, the first subjective stress measures relevant for my thesis (T4) were taken. Physiological stress-levels before the audio condition were gathered through the mean HR in the last five minutes before the audio condition. The audio intervention then began (see *Materials* for a detailed description), with the experimenter dimming the lights and leaving the room.

Immediately after the audio condition, the second relevant subjective stress measures (T5) were obtained while the participant remained in the lounge chair. Participants in the music condition also completed the “Bewertung Audiostimulus” questionnaire, to assess their degree of mental focus during music listening. Post-audio condition physiological stress was gathered through the mean HR in the last five minutes of the audio intervention.

Subsequently, three more TEWL and stress measurements were collected in the span of 90 minutes. In total, five TEWL and eight stress measurements were taken throughout the study, with only the subjective and physiological stress levels before and after the audio condition being relevant for my thesis. Furthermore, the degree of mental focus obtained after music listening, as well as musicality that was assessed via the online self-report questionnaire prior to the test session, were utilized for investigating the hypotheses. After removing all sensors, participants completed the form for monetary compensation, received information about the study, and were given the opportunity to ask questions during the final debriefing phase.

Statistical Analysis

The variables and hypotheses of this thesis were analyzed using IBM SPSS Statistics (Version 29.0). Hypotheses 1 and 2 were tested through independent samples t-test, with the audio condition (music vs. silence) as the independent variable, and subjective stress reduction (VAS) and physiological stress reduction (HR) as dependent variables. A boxplot analysis to detect outliers revealed four extreme outliers. Analyses excluding these outliers yielded no statistically different results, hence the outliers were retained in the sample to maintain the integrity of the data.

Hypotheses 3 to 5 were tested through two mediation analyses using the SPSS PROCESS-macro (Hayes, 2018). These mediation analyses employed the bootstrapping method, a robust procedure not greatly affected by violations of preconditions. Sum scores of the global musical sophistication scale of the Gold-MSI (Müllensiefen et al., 2014) were used as the independent variable. Scores from the single item measuring mental focus (VAS) served as a potential mediating variable. Differences in subjective stress ratings between T4 (before music) and T5 (after music) acted as the dependent variable for the first mediation analysis. For the second mediation analysis, differences in HR from the last five minutes before music to the last five minutes of the music served as the dependent variable, while the independent variable and the potential mediator stayed the same.

Initially, an extreme case analysis was planned as an exploratory approach to identify trends in the data for the two mediation models of the second research question. However, due to the low variance in the data, this approach was deemed impractical, as a sufficient number of extreme values could not be identified. Therefore, exploratory correlations for all paths of the mediation models were calculated to better understand the relationships between the variables.

Results

Descriptive Statistics

Sample Description

As of June 2024, data from 45 participants was available for analysis. Due to issues with the sensor, HR data was missing for three test subjects. However, as their ratings for subjective stress and mental focus were still usable for the analyses of other hypotheses, these three participants were not excluded entirely. Consequently, the final sample size remained at $N = 45$. For the mediation analyses, only data from participants in the music condition was relevant, resulting in a smaller sample size of $N = 22$. Of these, one participant was considered only for subjective stress ratings due to the mentioned HR sensor issues.

The participants' age ranged from 18 to 33, with a relatively young mean age of 24.42 ($SD = 4.14$). The majority of these 45 healthy, female individuals were from Austria (68.8%), have completed their A-levels (97.8%) and attended University at the time of testing (80%). For a detailed description of demographic characteristics see Table 1.

Table 1

Sample description (N = 45)

Sociodemographic characteristics	*Absolute values (n)*	*Relative values (%)*
Sex		
Female	45	100%
Nationality		
Austria	31	68.8%
Germany	8	17.8%
Hong Kong	1	2.2%
Colombia	1	2.2%
Luxembourg	1	2.2%
Serbia	1	2.2%
Ukraine	1	2.2%
Russia	1	2.2%
Education		
A-levels (Abitur/Matura)	44	97.8%
Secondary school	1	2.2%

Vocational Training		
University	36	80%
No vocational training	6	13.3%
Apprenticeship	1	2.2%
University of applied sciences	1	2.2%
Other vocational training	1	2.2%
Employment		
In training	16	35.6%
Less than part-time	13	28.9%
At least part-time	10	22.2%
Unemployed	5	11.1%
Fulltime	1	2.2%

Subjective Stress Levels

Subjective stress levels were assessed using a VAS with a range of 0 to 100, where higher scores represent greater perceived stress. To determine the reduction in subjective stress through the audio intervention, the difference between perceived stress levels before (T4) and after music listening or sitting in silence (T5) was calculated. A higher reduction in subjective stress following music listening or sitting in silence after the TSST is indicated by higher values in the change scores. Negative change scores indicate an increase in subjective stress levels from before to after the audio intervention. In this sample, the change scores ranged from -66 to 38, with the mean being 3.44 (SD = 18.99). Change scores of subjective stress were not normally distributed, as indicated by a significant result of the Shapiro-Wilk-Test ($p < .05$). The histogram for the distribution of change scores between T4 and T5 (Figure 1) revealed a left-skewed distribution, meaning that more participants showed a greater subjective stress reduction.

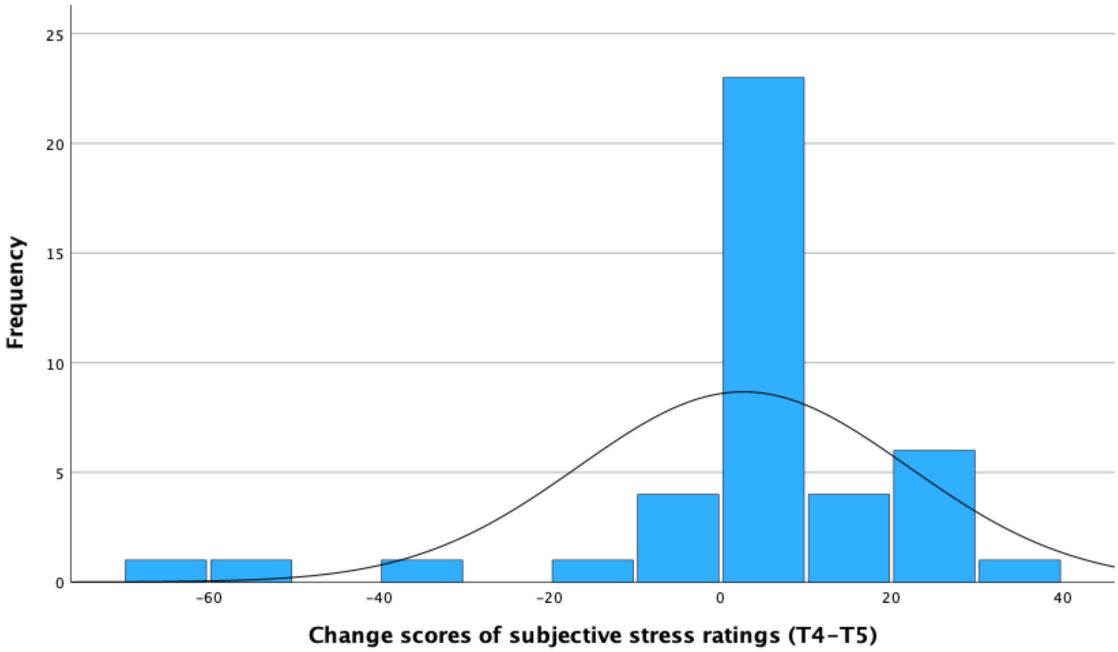

Figure 1. Distribution of change scores for subjective stress ratings. The distribution of the difference in subjective stress levels between T4 and T5 is demonstrated by the blue bars. The normal distribution curve is portrayed by the line.

Physiological Stress Levels

Physiological stress levels were assessed through the mean HR of two five-minute windows. To determine the reduction in physiological stress through the audio intervention, the difference between mean HR in the last 5 minutes before the audio intervention and mean HR in the last five minutes of the audio intervention was calculated. A higher reduction in physiological stress through the audio intervention following the TSST is indicated by higher values in the obtained change scores. Negative change scores represent an increase in physiological stress levels from before to after the audio intervention. For HR, the change scores in this sample ranged from -39 to 33, with the mean being -7.94 (SD = 11.01). As for the subjective stress levels, changes scores of HR were not normally distributed, indicated by a significant Shapiro-Wilk-Test ($p < .05$). The distribution of change scores for physiological stress levels between before and after the audio intervention are illustrated in Figure 2.

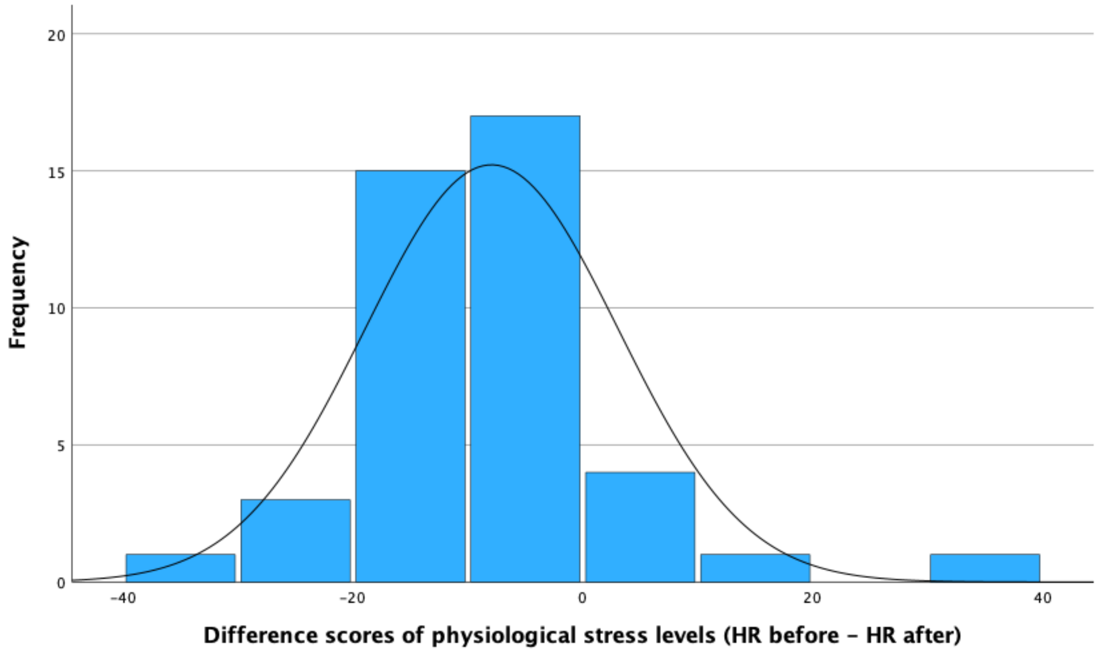

Figure 2. Distribution of difference scores for physiological stress ratings. The distribution of the difference scores of HR before and after the audio intervention is portrayed by the blue bars. The normal distribution curve is illustrated by the line.

Musicality

To generate a sum score for musicality, the participants' responses to the 18 items belonging to the global musical sophistication scale of the Gold-MSI (Müllensiefen et al., 2014) were added up. Possible answers ranged from 1 to 7, leading to a total possible sum score ranging from 18 and 126, with higher values representing higher musicality. In this sample of individuals in the music condition, sum scores ranged from 56 to 90, with a mean of 69.36 (SD = 10.31). Scores were normally distributed, as indicated by a non-significant Shapiro-Wilk-Test (p = .06). In a representative norm sample of 147.633 individuals, a mean value of 81.58 (SD = 20.67) was found for the global musical sophistication scale (Müllensiefen et al., 2014). Therefore, the mean musicality scores in this sample were below the average in comparison to a norm sample. The distribution of musicality is illustrated in Figure 3.

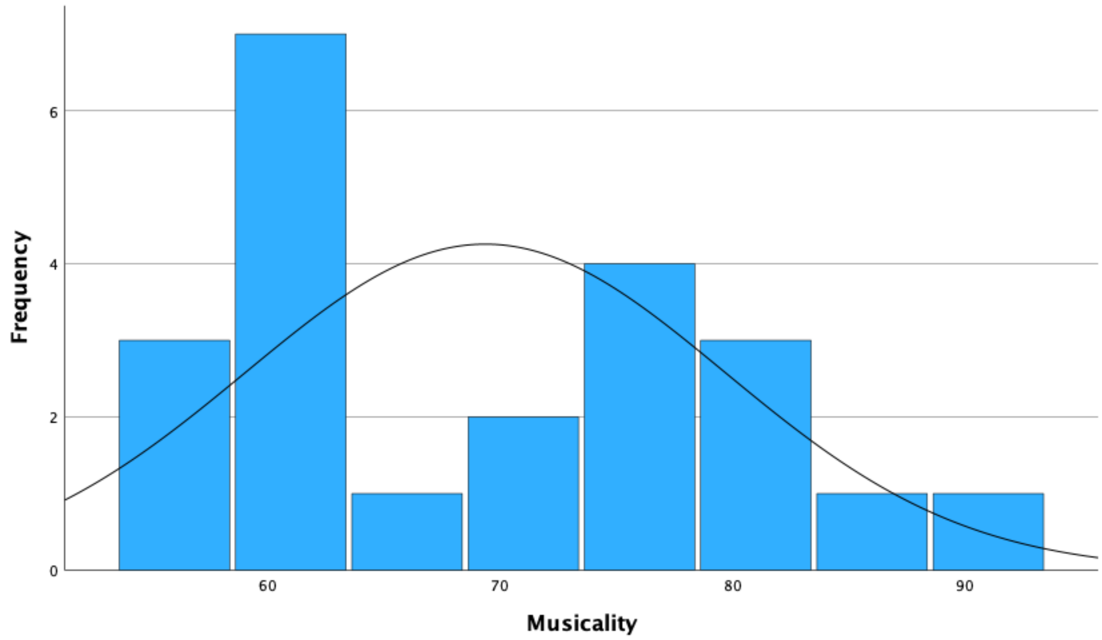

Figure 3. Distribution of musicality scores. The distribution of sum scores of the global musical sophistication scale (Müllensiefen et al., 2014) is illustrated by the blue bars. The normal distribution curve is portrayed by the line.

Mental Focus

To obtain their level of mental focus during music listening, participants in the music condition were asked to rate their degree of focus retrospectively on a VAS ranging from 1 to 5, with higher values portraying a higher degree of mental focus. In this sample, the values ranged from 1 to 5, with a mean of 3.27 (*SD* = 1.24). Scores for mental focus were not normally distributed, as indicated by a significant result of the Shapiro-Wilk-Test ($p < .05$).

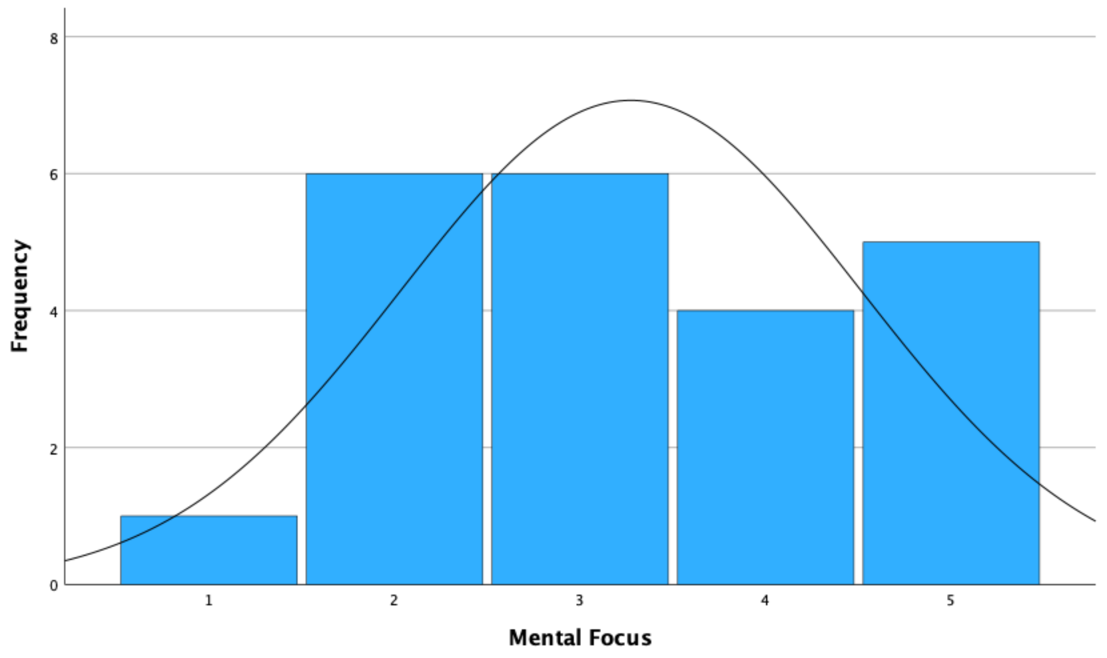

Figure 4. Distribution of scores for mental focus. The distribution of scores of the VAS for mental focus is illustrated by the blue bars. The normal distribution curve is portrayed by the line.

Stress Manipulation Check

Paired t-tests for physiological and self-reported stress were conducted to ensure that the TSST induced a sufficient stress reaction in the study participants. Regarding subjective stress levels, there was a significant increase in stress levels from baseline (M = 11.98, SD = 14.08) to self-reported stress directly following the acute stressor (M = 52.09, SD = 36.09), $t(43) = -7.06$, $p < .001$. This indicates that the TSST successfully elevated subjective stress levels, with a large effect of Cohens d = 1.07 (Cohen, 1992).

Similarly, the mean HR was found to be significantly higher directly after the TSST (M = 103.79, SD = 18.23) compared to the baseline measurement (M = 82.60, SD = 13.16), $t(41) = -7.10$, $p < .001$. This demonstrates that physiological stress was also successfully induced by the TSST, with a large effect size of Cohens d = 1.10 (Cohen, 1992).

Subjective Stress Reduction through Audio Intervention

To test the hypothesis that listening to music following an acute stressor results in a greater decrease in subjective stress compared to sitting in silence (H1), an independent t-test was planned. The independent variable was the audio condition (music listening vs. silence), and the change in subjective stress scores (VAS) was the dependent variable. For the first hypothesis, data from N = 22 individuals in the music group and N = 23 participants in the silence condition were analyzed. The reduction of perceived stress after the TSST due to the audio intervention was calculated by subtracting the VAS scores directly after music listening or sitting in silence (T5) from the scores before the intervention (T4). Higher change scores indicate a greater reduction in subjective stress, with negative values suggesting an increase in stress after the audio intervention compared to the stress level after the TSST. Participants in the music condition reported change scores (T4-T5) ranging from -59 to 38, with a mean score of $M = 3.09$ ($SD = 19.81$). In the silence condition, change scores ranged from -66 to 27, with a mean score of $M = 3.78$ ($SD = 18.61$). The Levene-Test for homogeneity of variances was non-significant ($p = .78$), indicating equal variances between the music and silence groups. The Shapiro-Wilk-Test ($p < .001$) indicated that neither group followed a normal distribution. Due to this violation of the normality precondition, a parametric t-test could not be conducted. Instead, the Mann-Whitney U-Test, a non-parametric alternative, was used to compare the subjective stress reduction of participants listening to music and sitting in silence following the TSST. On average, participants in the silence condition reported a slightly greater stress reduction ($M = 3.78$) than those in the music condition ($M = 3.09$). However, the Mann-Whitney U-Test indicated that this difference was not statistically significant, U ($N_{music} = 22$, $N_{silence} = 23$) = 241, $z = -.27$, $p = .78$. The differences in change scores for perceived stress between the two groups are illustrated in Figure 5.

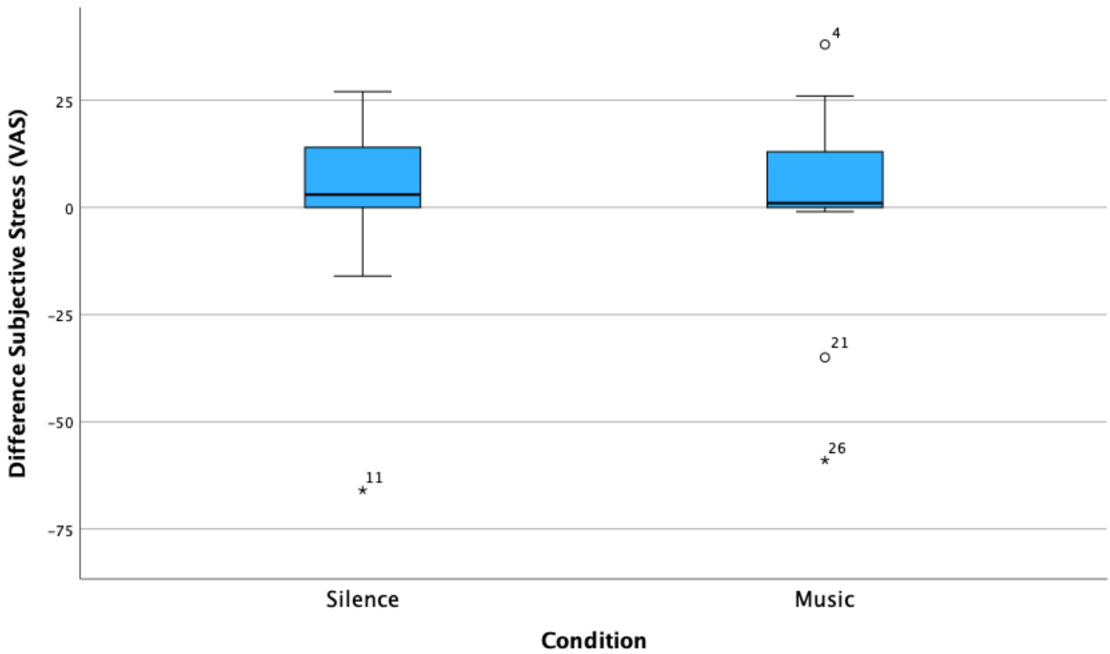

Figure 5. Boxplots depicting the differences in change scores (T4-T5) of subjective stress levels (VAS) between participants in the music condition and individuals in the silence condition. The circles mark slight outliers, extreme outliers are marked by an asterisk.

Physiological Stress Reduction through Audio Intervention

To assess the hypothesis that listening to music following an acute stressor results in a greater decrease in physiological stress compared to sitting in silence (H2), an independent t-test was conducted. The audio condition (music listening vs. silence) was set as the independent variable, while the change in physiological stress scores (HR) served as the dependent variable. For this hypothesis, data was analyzed from $N = 21$ individuals in the music group and $N = 21$ participants in the silence group. To measure the reduction of physiological stress following the TSST through the audio condition, the mean HR from the last 5 minutes of the audio intervention (HR after audio) was subtracted from the mean HR of the last 5 minutes before the audio condition (HR before audio). A greater reduction in physiological stress through the audio condition is indicated by higher change scores, negative values suggest an increase in stress from before to after the audio intervention. Participants in the music condition reported change scores (HR before audio - HR after audio) ranging from -21 to 10, with a mean score of $M = -7.76$ ($SD = 6.81$). In the silence condition, change scores ranged from -39 to 33, with a mean score of $M = -8.12$ ($SD = 14.22$). As indicated by a non-significant result of the Levene-Test for homogeneity of variances ($p = .12$), variances are equal between both groups. The Shapiro-Wilk-Test revealed non-significant results for the music group ($p = .19$) as well as the silence condition ($p = .06$), indicating a normal distribution of the data. Both groups displayed a stress increase through the audio condition, as indicated by the negative change scores for the audio condition ($M = -7.76$) and the silence condition ($M = -8.12$). The independent t-test revealed no significant differences in mean HR changes through the audio condition between the groups ($t(41) = -.10$, $p = .46$). The differences in change scores for physiological stress, measured through mean HR, between the two groups are illustrated in Figure 6.

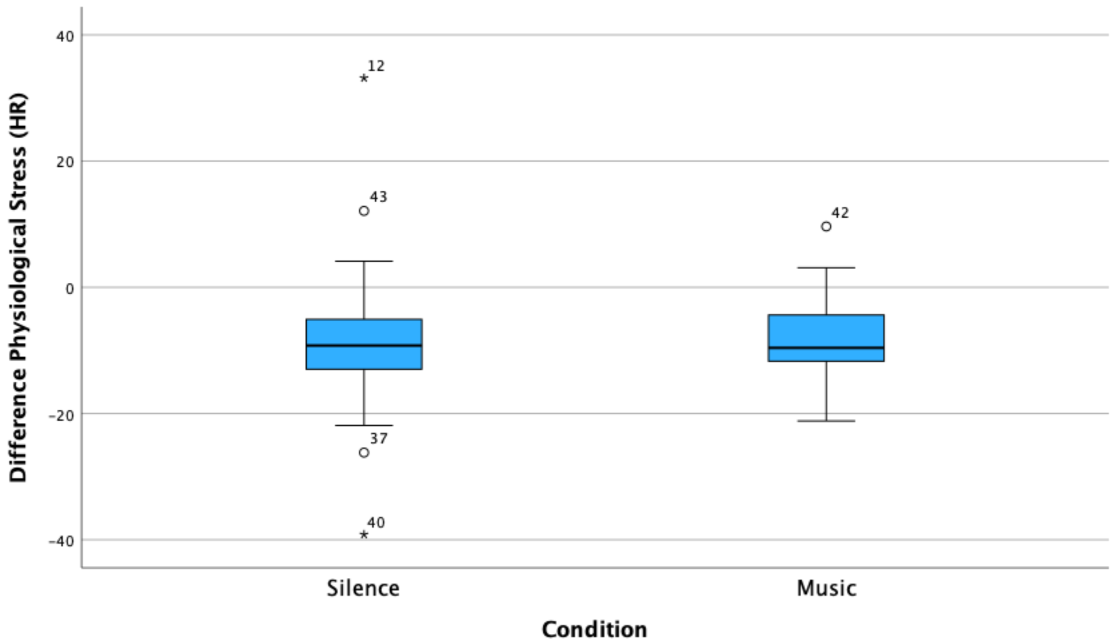

Figure 6. Boxplots depicting the differences in change scores (before audio-after audio) of physiological stress levels (HR) between participants in the music condition and individuals in the silence condition. The circles mark slight outliers, extreme outliers are marked by an asterisk.

Musicality, Mental Focus and Stress

The second research question (H3 to H5) examined the relationship between musicality and stress reduction in the music condition, with mental focus as a potential mediator. The hypotheses were tested using two mediation analyses with the SPSS PROCESS macro (Hayes, 2018). The statistical preconditions for the mediation model include independence of measurements, normality of residuals, homoscedasticity, and linearity. Mediation analysis using the PROCESS macro employs a bootstrapping (resampling) method, making the procedure relatively robust to violations of data distribution assumptions (Field, 2018). While the bootstrapping approach compensates for violations of homoscedasticity and normality of residuals (Hayes, 2018), the precondition regarding independence of measurements was fulfilled due to the nature of the study design. Since mediation approaches are based on linear regression, the included variables should demonstrate linearity. The precondition of linearity was investigated through visual inspection of scatterplots of all variables relevant for the mediation models. LOESS-smoothing (locally estimated scatterplot smoothing) was applied to add fit lines to the scatterplot. Most fit lines in both mediation analyses appeared non-linear, indicating a violation of the linearity assumption. Despite this violation, the analysis was continued, accepting the consequent loss in statistical power.

A positive association between musicality and both subjective and physiological stress reduction was expected (H3). Musicality was anticipated to be positively associated with mental focus (H4), and mental focus was expected to mediate the relationship between musicality and stress reduction (H5). As only participants in the music condition were examined for the mediation models, data was analyzed from N = 21 individuals. The relationships are displayed in Figure 7 and 8 using standardized regression coefficients. Detailed statistical parameters for each path of the mediation analyses are provided in Table 2 and 3.

A significant total effect of musicality on subjective stress reduction (H3.1) was not found, $B = .63$, $p = .15$. Similarly, no total effect of musicality on physiological stress reduction (H3.2) was detected, $B = -.12$, $p = .46$. Earlier researchers (Baron & Kenny, 1986) advocated the causal steps approach, which suggested that mediation analyses should only be performed if a significant total effect is present. However, according to the current consensus among statisticians, a significant total effect is no longer necessary to demonstrate mediation (Zhao et al., 2010). Consequently, the calculations were continued despite the lack of a significant total effect.

No significant effect of musicality on mental focus has been revealed (H4), $B = .02$, $p = .56$. Mental focus was not significantly associated with subjective, $B = 6.16$, $p = .22$, or physiological stress reduction, $B = 1.04$, $p = .41$. Consequently, indirect effects of mental focus on subjective, $B = .09$, 95% CI [-.19, .61], or physiological stress reduction, $B = .03$, 95% CI [-.03, .17], could not be detected as indicated by the confidence intervals containing the number 0. Therefore, the expected role of mental focus as a mediator on the relationship between musicality and stress reduction through music listening following the TSST could not be found (H5).

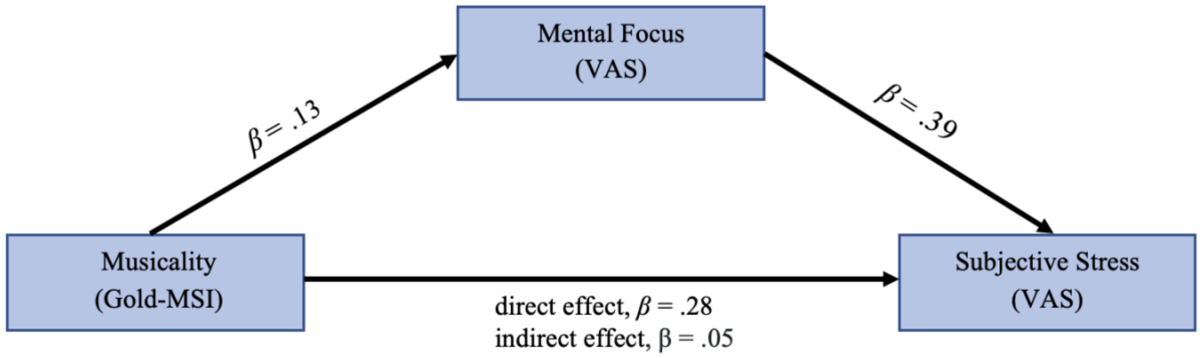

Figure 7. Mediating role of mental focus on the relationship between musicality and subjective stress reduction. N = 21, bootstrapped based on 5000 samples. The numbers represent standardized regression coefficients.

Table 2

Model paths with corresponding statistical values for the mediation of the relationship between musicality (Gold-MSI) and subjective stress reduction (VAS) through mental focus (VAS)

model paths	*B*	*SE*	β	*t*	*p*
a: musicality → mental focus	.02 [-.04, .07]	.03	.13	0.60	.56
b: mental focus → subjective stress	6.16 [-.40, 16.32]	4.86	.39	1.27	.22
c: musicality → subjective stress (without considering the mediator)	.63 [-.24, .1.50]	.42	.33	1.51	.15
direct effect c`: musicality → subjective stress (considering the mediator)	.54 [-.27, 1.35]	.39	.28	1.39	.18
indirect effect ab: musicality → mental focus → subjective stress	.09 [-.19, .61][a]	.20[a]	.05[a]	-	-

Note. N = 21; *B* = unstandardized regression coefficient; square brackets: 95% confidence intervals; *SE* = standard error; *β* = standardized regression coefficient.

[a] = bootstrapping based on 5000 samples.

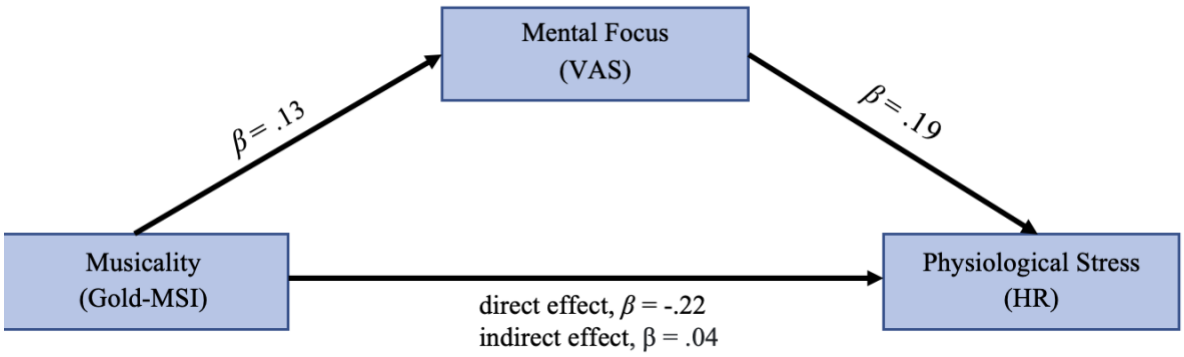

Figure 8. Mediating role of mental focus on the relationship between musicality and physiological stress reduction. N = 21, bootstrapped based on 5000 samples. The numbers represent standardized path coefficients.

Table 3

Model paths with corresponding statistical values for the mediation of the relationship between musicality (Gold-MSI) and physiological stress reduction (HR) through mental focus (VAS)

model paths	*B*	*SE*	β	*t*	*p*
a: musicality → mental focus	.02	.03	.13	0,60	.56
	[-.04, .07]				
b: mental focus → physiological stress	1.04	1.25	.19	0,84	.41
	[-1.58, 3.66]				
c: musicality → physiological stress	-.12	.16	-.18	-0,76	.46
(without considering the mediator)	[-.45, .21]				
direct effect	-.15	.14	-.22	-1.03	.32
c`: musicality → physiological stress	[-.45, .15]				
(considering the mediator)					
indirect effect	.03	.05[a]	.04[a]	-	-
ab: musicality → mental focus →	[-.03, .17][a]				
physiological stress					

Note. N = 21; *B* = unstandardized regression coefficient; square brackets: 95% confidence intervals; *SE* = standard error; *β* = standardized regression coefficient.

[a] = bootstrapping based on 5000 samples.

Exploratory Analyses

The mediation analyses of the second research question yielded insignificant results for all paths, likely due to the extremely small sample size of 21 participants in the music condition, compared to the target sample size of N = 78 to detect medium effects with a power of .80. Furthermore, data variance was low in most variables. Due to these limitations, an exploratory approach was chosen by calculating correlations for all paths of the mediation models. This approach provides a clearer understanding of the relationships and patterns between the variables in the mediation models, despite the limitations imposed by the small sample size and low variance in the data. Due to the non-normal distribution of the variables mental focus, musicality and subjective stress, Spearman's correlations were calculated instead of Pearson product-moment correlations. With the data of $N = 21$ individuals, the targeted sample size of $N = 21$ for correlations to detect medium effects with a power of .80 was reached (Faul et al., 2009).

Musicality and Stress

Two Spearman's rank correlations were computed to examine the expected positive relationship between musicality and both subjective and physiological stress reduction in the music condition (H3). The analysis did not reveal significant correlations between musicality and subjective stress reduction ($r(20) = .26$, $p = .13$) or between musicality and physiological stress reduction ($r(20) = -.14$, $p = .27$). The distributions of musicality scores and changes in subjective and physiological stress due to music listening are depicted in Figures 9 and 10. The regression line is shown in black, with the coefficient of determination for these linear regressions being $r^2 = .11$ for subjective stress and $r^2 = .03$ for physiological stress. The regression lines are depicted for illustration purposes, as the correlation analyses yielded non-significant results.

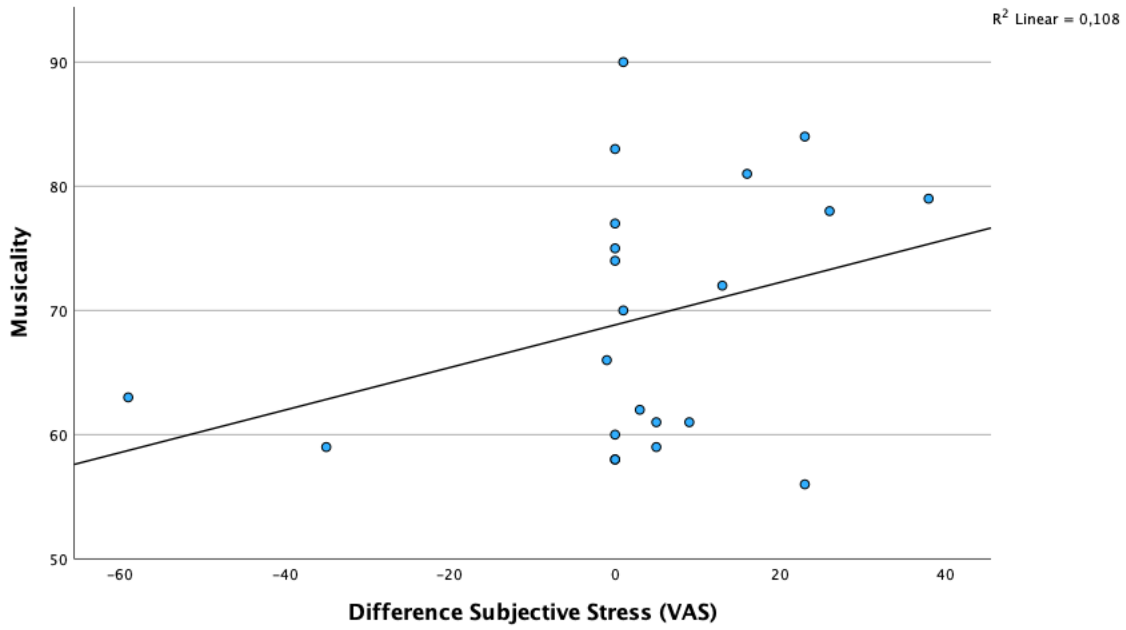

Figure 9. Scatterplot of the correlation between musicality and subjective stress reduction (VAS) in the music listening condition.

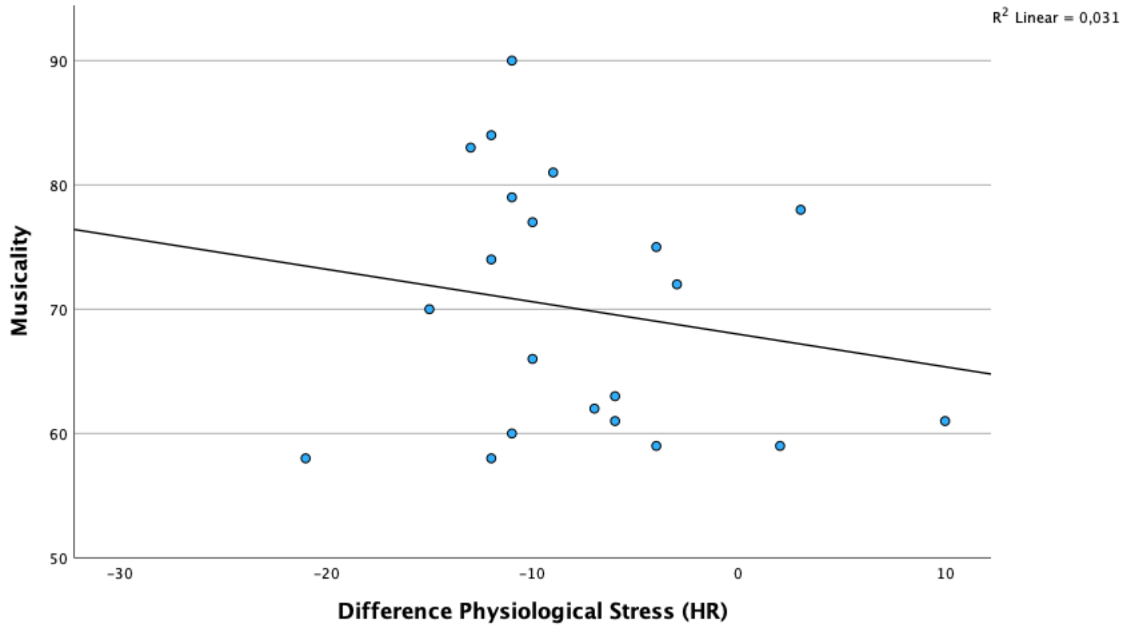

Figure 9. Scatterplot of the correlation between musicality and physiological stress reduction (HR) in the music listening condition.

Musicality and Mental Focus

Another Spearman's rank correlation was conducted to examine the anticipated positive relationship between musicality and mental focus during music listening (H4). Again, no significant correlation was found between musicality and mental focus (r(20) = .09, *p* = .35). The distribution of musicality scores and levels of mental focus during music listening is portrayed in Figure 11. The regression line is shown in black, with the coefficient of determination being r^2= .02. The regression line is depicted for illustration purposes, as the correlation analysis yielded a non-significant result.

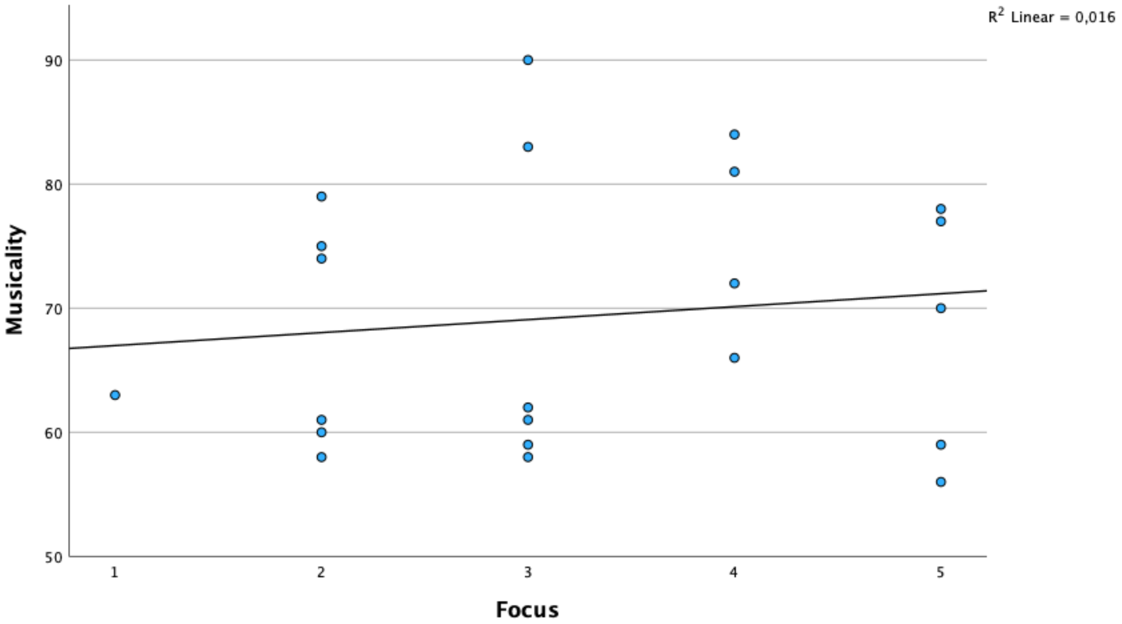

Figure 10. Scatterplot of the correlation between musicality and mental focus during music listening.

Mental Focus and Stress

To examine the relationships between mental focus during music listening and subjective and physiological stress reduction, two last Spearman's rank correlations were conducted. This analysis aimed to investigate the hypothesized positive relationship between mental focus and both subjective and physiological stress reduction within the music condition. The analysis revealed a non-significant correlation between mental focus and physiological stress reduction (r(20) = .13, *p* = .13). However, a significant positive relationship between mental focus and subjective stress reduction was found (r(20) = .40, *p* = .03). The distributions of levels of mental focus and changes in subjective and physiological stress due to music listening are depicted in Figures 12 and 13. The regression line is shown in black, with the coefficient of determination for these linear regressions being $r^2 = .18$ for subjective stress and $r^2 = .02$ for physiological stress.

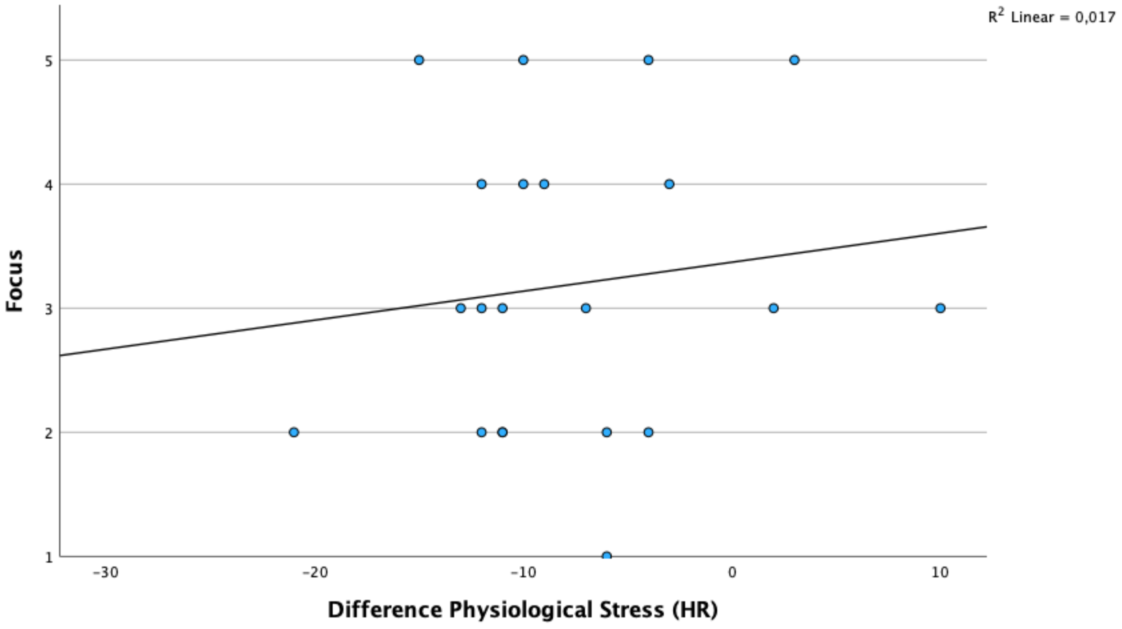

Figure 11. Scatterplot of the correlation between mental focus during music listening and physiological stress reduction (HR).

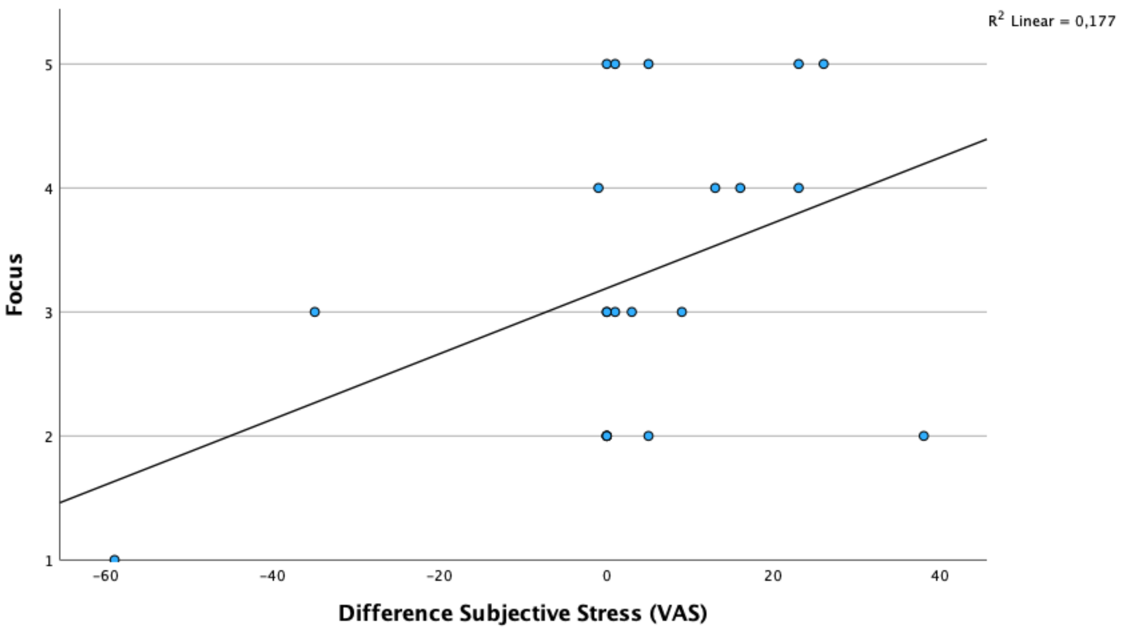

Figure 12. Scatterplot of the correlation between mental focus during music listening and subjective stress reduction (VAS).

Discussion

This thesis aimed to investigate the potential stress-reducing benefits of listening to music. Previous research has documented the positive effects of music listening on stress reduction after experimental stress induction (Fallon et al., 2020; Khalfa et al., 2003; Radstaak et al., 2014). Additionally, an aim was to explore whether individuals with higher levels of musicality experience greater stress reduction through music listening, and to determine the role of mental focus in this relationship. It was hypothesized that listening to music after exposure to an acute stressor would be associated with greater reductions in subjective and physiological stress compared to sitting in silence. Within the music condition, musicality was anticipated to be positively associated with subjective and physiological stress reduction through music following the acute stressor. Furthermore, the study examined the potential mediating role of mental focus in this relationship between musicality and stress reduction through music. This mediation model has been hypothesized based on previous research showing a positive association between musicality and focus during music listening (Carey et al., 2015; Reitan, 2013; Halpern, 1999; Leipold & Loepthien, 2021), as well as beneficial effects of mental focus on stress reduction through music (Jäncke et al., 2018; Leipold & Loepthien, 2021; Jiang et al., 2016). Consequently, it was plausible that participants' level of focus during music listening might account for some of the connection between their level of musicality and the extent of stress reduction experienced through music listening.

Interpretation of Results

Stress Reduction through Audio Intervention

The first research question aimed to investigate the effects of music listening on subjective and physiological stress reduction following an acute stressor. In this study, stress was induced using the TSST (Kirschbaum et al., 1993), a well-established instrument for experimentally inducing stress. As a stress manipulation check, paired t-tests for subjective and physiological stress were conducted to ensure that the TSST induced a sufficient stress reaction in the participants of the study. In line with previous research (Kirschbaum et al., 1993; Allen et al., 2017; McRae et al., 2006), subjective (d = 1.07) as well as physiological (d = 1.10) stress levels were significantly elevated by the TSST in study participants.

No significant effects of music listening on subjective or physiological stress reduction following the TSST were found. In this small sample of N = 45 healthy females, participants listening to relaxing music after being exposed to the TSST did not exhibit a significantly greater subjective stress recovery than individuals sitting in silence. Although the difference in subjective stress reduction did not reach significance, the data revealed a pattern of individuals in the silence condition displaying a slightly greater subjective stress reduction (*M* = 3.78) than those in the music condition (*M* = 3.09). Regarding physiological stress, participants in both conditions showed an increase in subjective stress from before to after the audio condition, with the difference between the groups being non-significant. Thus, H1 and H2, which anticipated a significant effect of music on both subjective and physiological stress reduction, were not supported. These non-significant results contrast with previous studies that reported significant effects of music listening on stress reduction in similar experimental settings (Fallon et al., 2020; Khalfa et al., 2003; Radstaak et al., 2014). Although stress was experimentally induced in a similar manner to these prior studies, no significant reduction of stress due to music listening was observed in the present study.

Before discussing possible reasons for the non-significant outcomes, it is crucial to highlight the limited validity of the results due to the small sample size. A priori power analyses for the planned independent t-tests investigating the first research question revealed a necessary sample size of $N = 102$ to detect medium effects with a power of .80 (Faul et al., 2009). However, the final number of participants was $N = 45$, which amounts to less than half of the targeted sample size. It is plausible that results might have reached significance in a larger sample. Therefore, the non-significant results need to be interpreted with caution due to the sample size.

Prior studies have documented inconsistencies between subjective and physiological measures of stress after music exposure (Thoma et al., 2013; Linnemann et al., 2015). In the present study, subjective reports indicated that participants in both conditions felt a reduction in subjective stress, with a slightly greater stress reduction in the silence condition compared to the music condition, but the difference being non-significant. However, the physiological data revealed an increase in stress following both the music and silence intervention. Despite the lack of significant differences in subjective and physiological stress reduction between the groups, this discrepancy suggests that participants perceived a reduction in stress that was not reflected in their physiological responses.

In order to explore the relationship between subjective and physiological stress, a Spearman correlation was calculated between change scores in subjective (VAS) and physiological stress (HR). The results indicated a very weak negative correlation which was not statistically significant ($r(42) = -.05$, $p = .66$). This suggests that there is no meaningful relationship between the subjective stress reported by participants and their physiological stress responses, aligning with the observed discrepancy between subjective reports of stress reduction and physiological indications of increased stress following the interventions. As the subjective stress levels are self-reported, they can be influenced by factors such as mood or previous personal experiences. The participants' coping strategies or emotional regulation could also influence how they perceive their stress levels. Additionally, while HR is often used as a physiological measure of stress, it primarily reflects general arousal rather than the specific emotional valence of subjective stress ratings, which could further explain the observed discrepancy.

As noted in the meta-analysis by Adiasto et al. (2022), definite conclusions regarding the effects of music listening on short-term stress recovery in healthy individuals cannot yet be drawn. Although the hypotheses in this thesis proposed that music listening would reduce stress more effectively than sitting in silence, the non-significant findings align with previous research suggesting that music listening may not have a substantial stress-reducing effect in everyday life (Linnemann et al., 2016) or experimental settings (Chafin et al., 2004; Knight & Rickard, 2001; Thoma et al., 2013; Labbé et al., 2007) . The results indicate that the impact of music on stress may vary depending on individual differences, such as personality traits (Chanda & Levitin, 2013), or other factors like music characteristics, type, and duration of the music intervention (Pelletier, 2004).

A study by Linnemann et al. (2016) investigating the effects of mere music listening on stress reduction in daily life revealed no significant association. Similarly, a meta-analysis focusing exclusively on studies where participants engaged in passive music listening also failed to reveal any significant impact on stress reduction (Adiasto et al., 2022). Extensive literature, including the review by de Witte et al. (2022), highlights the positive effects of music therapy, administered by trained professionals, on stress reduction in clinical populations. The disparity in findings between these studies and the study used in this thesis may be attributed to the fact the present study adhered to stringent inclusion and exclusion criteria, resulting in a sample composed exclusively of healthy females. Furthermore, the intervention in the study involved passive music listening for 30 minutes, which differs from more interactive forms of music therapy, such as singing, playing instruments, or live music therapy conducted by professional music therapists, investigated in other studies finding an effect on stress reduction (De Witte et al., 2020).

It is plausible that the ability of music to positively impact stress reduction may depend on the social context during listening. Research indicates that music listening serves social functions, such as providing emotional support and bonding with others over musical tastes or activities (Boer & Abubakar, 2014). Listening to music in the presence of others has been revealed to be more effective for stress reduction than listening alone (Linnemann et al., 2016). In the present study, participants in the music condition were isolated in a dark room for 30 minutes, listening to music through headphones. This solitary setting lacked the social context often associated with music listening, which could potentially explain the lack of significant outcomes.

The discrepancy to studies that found significant effects could further be explained by a variety of methodological differences. While music listening was administered following the TSST in the current study, studies demonstrating a positive effect administered music listening before the acute stressor (Thoma et al., 2013; Chen et al., 2019; Chennafi et al., 2018). It is hypothesized that music listening facilitates stress recovery only when listened to before the stressor (Chen et al., 2019), with the “preventive” effect being more effective than the “remedial” effect of music listening after the stressor.

The impact of music on stress reduction might differ based on the intensity of the stressor. Pelletier (2004) proposed that music is more likely to alleviate stress in the context of mild stressors rather than strong stressors. Supporting this hypothesis, listening to music before being exposed to a strong socio-evaluative stressor did not effectively reduce stress in an experimental study (Thoma et al., 2013). The TSST has been developed as an instrument to induce moderate stress (Kirschbaum et al., 1993). Possibly, music listening could not significantly reduce stress following an acute stressor in the current study, as the intensity of the stressor might be too high for music to have a noticeable effect.

Additionally, research indicates that self-selected musical pieces display a greater stress-reducing effect than music chosen by the researchers (Chennafi et al., 2018; Chanda & Levitin, 2013). In the present study, participants did not have complete autonomy in selecting the music played during the 30-minute audio intervention. Instead, they chose one of five playlists curated by the researchers. This lack of participant-selected music may have contributed to the absence of a stress-reducing effect of music.

Furthermore, different results might stem from varying operationalizations of the investigated stress variables. In the current study, subjective stress was assessed through self-reported responses using a single-item VAS. However, this single item might not fully capture the complexity of stress, which often has multiple dimensions, such as intensity or emotional impact. A single-item VAS focuses only on a single aspect of stress, potentially overlooking smaller and more subtle changes in stress levels. Consequently, this might explain why no significant differences in subjective stress levels before and after exposure to audio condition were found. Concerning physiological stress, the emotional states of participants are not fully explained by HR alone (Chennafi et al., 2018). HRV would have been a more precise predictor for evaluating stress than HR (Chennafi et al., 2018), since beat-to-beat changes in HR better reflect the underlying dynamics of the ANS than mean HR (Ellis & Thayer, 2010), which was utilized in this study.

Another aspect to consider is the time between exposure to the acute stressor and the onset of music listening (Adiasto et al., 2022), as it has been proposed that the effects of the TSST on the cardiovascular system might diminish approximately 15 minutes post-exposure (Kirschbaum et al., 1993). In the present study, the baseline measures of skin barrier integrity as well as skin impairment were carried out during the interval between TSST exposure and the audio intervention. Given that this procedure lasted around 20 minutes, it is plausible that the stress induced by the TSST had largely disappeared by the time the audio intervention began. These issues in timing raise the possibility that any potential stress-reducing effect of music listening could not be observed due to the long time interval between the TSST and the start of the audio intervention.

Lastly, it is important to recognize that in our fast-paced world, silence itself may function as an intervention. As our surroundings are characterized by constant stimuli and noise, which can lead to elevated stress levels, a brief period of silence might provide an opportunity for recovery. This could explain why participants in the silence condition reported a slightly greater reduction in subjective stress compared to those in the music condition, even though the results are not statistically significant.

Musicality, Mental Focus and Stress

The second research question aimed to explore the effects of musicality and mental focus on stress reduction through music listening following an acute stressor. Musicality was treated as the independent variable and was hypothesized to be positively associated with reductions in both subjective and physiological stress after music listening. Mental focus was examined as a mediator of this association. Two mediation analyses revealed no significant total effect of musicality on either subjective or physiological stress reduction from before to after music listening. The individual’s level of musicality did not predict the degree of stress reduction experienced though music listening following the TSST. Although neither p-value indicates a significant relationship, the p-value for subjective stress reduction ($p = .15$) is lower compared to physiological stress reduction ($p = .46$), indicating that there might be a trend of an association between musicality and subjective stress reduction compared to physiological stress reduction. Although the expected relationship has been documented in previous research (Smith & Morris, 1977; Pelletier, 2004), several studies have similarly found no significant effect of musical training on stress reduction through music

(Laohawattanakun et al., 2011; Knight & Rickard, 2001; Bernardi, 2005; Jiang et al., 2016), supporting the findings of this thesis. Jiang et al. (2016), using a design similar to the present study, concluded that the efficacy of music listening for reducing stress after the TSST was not influenced by the length of musical training.

Again, it is crucial to highlight the limited validity of the results due to the small sample size. A priori power analyses for the mediation models indicated a necessary sample size of N = 78 to detect medium effects with a power of .80 (Fritz & MacKinnon, 2007). However, only participants in the music condition could be included for investigating the second research question, resulting in a small final number of participants of N = 21. Therefore, all non-significant results from the mediation models should be interpreted with caution, as these findings might have reached significance in a larger sample. Another potential explanation for the non-significant results could be the restricted variance in musicality within the data. No individuals fell below the 25th percentile or above the 75th percentiles of musicality, which might mean that there were not enough cases with varying levels of musicality to adequately explore significant effects. Despite the German version of the Gold-MSI demonstrating high reliabilities (Schaal et al., 2014), calculations of internal consistency in the sample used for this thesis revealed a low Cronbach's Alpha of .50. This poor reliability indicates that the global scale of the Gold-MSI did not accurately capture the variability in musicality, potentially contributing to the non-significant results.

Past research has predominantly focused on the impact of musical training on stress reduction. In contrast, this thesis conceptualized musicality as a broader construct, operationalized by the Gold-MSI. This broader operationalization includes a wide range of musical behaviors and abilities that go beyond mere musical training. It is plausible that the specific effects of musical training, rather than the broader aspects of musicality examined in this thesis, are crucial for stress reduction through music listening. This could explain why the total effect of musicality on stress reduction in the present study was non-significant, as the specific impact of musical training on stress reduction may have been diluted by the broader construct of musicality. Furthermore, other factors not explored in the mediation models might have influenced the relationship between musicality and stress reduction. One potential influential factor is music preference, which is known to influence the effect of musical training on stress reduction (Jiang et al., 2016). Individuals with musical training may experience greater stress reduction when their musical preferences align with the music that is being listened to.

The analysis revealed a non-significant relationship between musicality and mental focus, indicating that participants' level of musicality did not predict their degree of mental focus during music listening. Given the small sample size and limited variance in musicality, no final conclusion should be drawn from this result. No prior studies have directly explored this association between musicality and mental focus during music listening. The hypothesized positive association was based on previous research showing that musicians exhibit improved sustained attention (Carey et al., 2015) and engage in music listening in a more reflective, conscious and attentive manner (Reitan, 2013). The absence of participants with exceptionally high levels of musicality in the sample, paired with the exclusion of professional musicians from the study, may explain the lack of significant findings.

Lastly, neither the analysis of the relationship between mental focus and subjective stress reduction, nor the analysis of the relationship between mental focus and physiological stress reduction yielded significant results. This finding contrasts with previous research suggesting that attentive music listening may have stronger effects on stress reduction than passive listening (Jiang et al., 2016; Leipold & Loepthien, 2021). In line with the total effect of musicality on stress reduction through music, the p-value for subjective stress reduction ($p = .22$) was lower compared to physiological stress reduction ($p = .41$). This observation indicates a potential pattern of an association between mental focus and subjective stress reduction, in contrast to physiological stress reduction. However, this assumption is speculative, due to the lack of statistical significance of both p-values. Based on the non-significant results of paths a and b, no significant indirect effect of mental focus on subjective and physiological stress reduction were revealed in the analysis. It is plausible that individuals with higher musicality tend to analyze the listened music more deeply, which could hinder their ability to relax and reduce stress. Heightened musicality may lead individuals to focus more on the technical aspects of music rather than experiencing it solely for relaxation purposes, hindering the potential stress-reducing effect.

While the mediation analyses of the second research question yielded insignificant results for all paths, these results may occur due to the extremely small sample size of $N = 21$ in the music condition and the limited data variance. Correlations were calculated for all paths of the mediation models to provide a clearer understanding of the relationships and patterns between the variables in the mediation models.

Two Spearman's rank correlations examining the expected positive relationship between musicality and both subjective and physiological stress reduction in the music condition were conducted. While the correlations between musicality and both subjective stress reduction (p = .13) and physiological stress reduction (p = .27) were found to be non-significant, it is worth noting the patterns observed in the data. The positive correlation coefficient of .26 for subjective stress reduction suggests a weak positive correlation between musicality and perceived stress reduction, despite not reaching statistical significance. The negative correlation coefficient of -.14 for physiological stress reduction indicates that physiological stress reduction decreases when the level of musicality increases and vice versa, while also not statistically significant.

Despite the lack of significance, the correlation analysis between musicality and mental focus (p = .35) indicates a very weak positive association between the two variables. The last correlations aimed to explore the hypothesized positive relationship between mental focus and stress reduction within the music condition. Regarding mental focus and physiological stress reduction, a weak positive association was found, although not significant (p = .13). In contrast, a significant positive correlation was observed between mental focus and subjective stress reduction (p = .03), highlighting the previously observed discrepancies between subjective and physiological stress responses. The significant finding from this study highlights an important relationship between mental focus during music listening and reductions in subjective stress. Specifically, participants who reported higher levels of mental focus on the music also experienced greater decreases in their perceived stress levels. This suggests that increased attention to the music may play a key role in enhancing stress relief. The implication is that when individuals engage more deeply with the music, they might be better able to regulate their stress responses, potentially by diverting their attention from stressors and enhancing emotional processing.

Limitations

The following limitations need to be considered when interpreting the findings of this thesis, as they might have influenced the reliability of the results. As previously mentioned, the final sample sizes for both research questions were substantially smaller than the a priori calculated necessary sample sizes required to detect medium effects with sufficient power. This raises the possibility of obtaining false negative results, which may explain why the original analysis did not yield any significant findings. It is plausible that analyses with larger sample sizes could have produced significant results.

Due to this small sample size, the variance for the investigated variables, especially musicality and mental focus, is limited. As the overarching research project was not specifically designed to test the hypotheses of this thesis, professional musicians were excluded from the study, even though musicality is an essential construct investigated.

Although the utilized Gold-MSI questionnaire is designed to test the musicality of non-musicians and is therefore suitable for investigating the research question, the exclusion of professional musicians could explain why the data displayed no individuals with extremely high levels of musicality (≥ 75th percentile). Additionally, no participant received an extremely low (≤ 25th percentile) score in the Gold-MSI, resulting in limited variance at both ends of the spectrum. To explore the influence of varying levels of musicality on stress reduction and mental focus, a fairly equal distribution of the scores would have been necessary. With no individuals at either extreme of the spectrum, comparing between different levels of musicality is difficult, which could explain the non-significant results for the mediation models.

The inclusion and exclusion criteria for this study were very strict to control for extranous variables, which resulted in a very restricted sub-population of young women without any somatic or mental illnesses. The recruitment process, which mainly involved advertising in Cafés in the university area and Facebook groups of various universities, also led to the sample predominantly consisting of university attendees. Consequently, the findings of this study can only be interpreted within the context of this specific sub-population, resulting in restricted external validity, meaning that the results cannot be generalized to the general population. The generalizability of the results is further limited by the study's nature as a laboratory experiment. Due to this artificial setting, the findings may not apply to the effects of music listening on stress reduction in everyday life.

Another limitation is the long time window between exposure to the acute stressor and the onset of music listening or sitting in silence. Since the research project was not specifically tailored to the relevant constructs of this thesis, measurements of the skin were conducted between the TSST and the audio intervention, lasting for around 20 minutes. Given that effects of the TSST on the cardiovascular system might diminish approximately 15 minutes post-exposure (Kirschbaum et al., 1993), it is likely that stress levels had already significantly decreased before the audio intervention began.

Participants were given a choice between pre-existing playlists of different genres, and were not allowed to select individual pieces of music based on their preferences. Research has highlighted that enjoyable music can be more effective in reducing stress (Jiang et al., 2016; Jiang et al., 2013), by potentially triggering positive memories (Parada-Cabaleiro et al., 2021). The use of pre-selected playlist in the present study means that participants were not necessarily listening to music that aligned with their personal preferences, potentially reducing the stress-reducing benefits of the music for those who did not resonate with the chosen playlist.

Regarding the stress parameters, HR was chosen as the physiological stress marker for this thesis due to too many missing values for HRV. However, HR is not the optimal choice, as the emotional states of participants are not fully captures by HR alone (Chennafi et al., 2018). Mean HR does not adequately reflect the underlying dynamics of the ANS, as it offers a general overview of heart activity, but does not account for the fluctuations and variability in HR that are crucial for understanding the responsiveness and adaptability of the ANS (Ellis & Thayer, 2010). Subjective stress was assessed through self-reported responses using a single item, which might not fully capture the multidimensional nature of perceived stress. These limitations could explain the observed discrepancies between subjective and objective stress reduction.

The statistical precondition of linearity for the mediation models was violated. While mediation models are relatively robust to violations of preconditions due to the applied bootstrapping method, a linear relationship between the observed variables is still essential for accurate representation. In this study, none of the three constructs of the mediation models demonstrated this linear relationship, which could result in the relationships being inaccurately represented in the analysis, potentially resulting in misleading conclusions.

The research project started after shortly before outbreak of the COVID-19 pandemic in 2020, a period marked by worry and uncertainty across the population. Many experienced heightened symptoms of mental health issues such as anxiety and depression during the pandemic, which likely increased overall stress levels in this group, potentially distorting the results. Because of the pandemic restrictions, many test sessions needed to be delayed or cancelled, explaining the relatively small sample size.

Implications and outlook

Besides various theoretical considerations, the findings of this study have practical implications. The significant exploratory correlation between mental focus and subjective stress reduction suggests that increasing mental focus during music listening might enhance its stress-reducing effects. To maximize its benefits, music should be combined with other stress-reduction techniques to enhance focus on the music, such as mindfulness or deep breathing exercises. When using music for stress reduction, it is therefore beneficial to enhance focus by minimizing distractions, for instance, by using headphones and finding a quiet space.

Despite the non-significant results from the mediation model and correlation, the correlation between musicality and subjective stress reduction revealed a weak positive trend with a relatively low p-value ($p = .13$). Even though the relationship did not reach statistical significance, this result suggests that individual differences in musicality might influence how people respond to music as a tool for subjective stress reduction. Therefore, programs for stress reduction could incorporate elements of musical training to potentially enhance the effectiveness of the intervention.

Despite mostly non-significant results and the limitations presented, the study has generated several ideas for future research. First and foremost, future studies should include a larger sample size to increase the likelihood of yielding significant results and to achieve greater variance in the variables studied. Given the strict inclusion and exclusion criteria of this project, future research should involve a more diverse and heterogenous sample. This diversity would enable new pathways, such as the investigation of gender differences or cultural variations regarding the effects of music listening on stress. Including professional musicians in future projects could further enrich the exploration of musicality's impact on stress reduction by involving extreme populations.

Regarding stress markers, future studies should investigate the effects of music on HRV instead of HR. Additional objective measures, such as EDA and cortisol levels, should also be incorporated. The study design should be adjusted to the specific hypotheses being tested. For instance, the tape stripping procedure should be removed from the study to ensure that the effects of the acute stressor have not diminished upon the start of the audio intervention. Furthermore, based on the presented findings of other studies (Thoma et al., 2013; Chen et al., 2019; Chennafi et al., 2018), the audio intervention should be applied before the acute stressor to determine if the preventive effects of music listening are indeed superior to the remedial effects. Additionally, the study could be replicated with different stressors, such as the cold pressor test (CPT), to examine whether the stress-reducing effects of music listening vary depending on the type of stressor.

Although only the global scale for musicality has been utilized for this study, the Gold-MSI includes five distinct subscales: active engagement, musical training, perceptual abilities, emotions, singing abilities. Future research should investigate potential differences among these subscales in their impact on the effects of music listening on stress reduction.

An exploratory analysis revealed a correlation between mental focus on the music and subjective stress reduction. By examining the effects of mental focus in an active control group, such as audiobook listening, future studies could determine whether the beneficial effects of music are due to its specific properties or merely the distraction provided by focusing on a different stimulus. Comparing the effects of mental focus during music listening and audiobook listening on stress reduction could help clarify whether the benefits might be attributable to the distraction, rather than the medium itself.

Since laboratory studies are conducted in artificial environments, the results may not accurately represent the effects of music on stress reduction in everyday life. Future research should explore the effects in more naturalistic settings, such as using ecological momentary assessment (EMA) to ensure the findings are more applicable to the real world and improve their external validity.

While the present study focused solely on relaxing music, future research could incorporate different genres to determine whether the effects on stress reduction depend on the music type. Additionally, examining the differences between self-selected and researcher-selected musical pieces could help identify potential mediating or moderating effects of music preference on the relationship between music listening and stress reduction.

Conclusion

The objective of this thesis was to explore the potential effects of music listening on reducing subjective and physiological stress following an acute stressor. The findings indicated that a 30-minute music intervention did not significantly reduce stress compared to a silence condition. While the differences were not statistically significant, the data suggested different patterns between subjective and physiological stress reduction. Participants in the silence condition reported slightly greater reductions in subjective stress, whereas both groups exhibited increased physiological stress after the audio condition. Additionally, the study explored the interplay between musicality, mental focus, and stress reduction in the music condition through mediation analyses. No significant associations were identified between these variables, but the findings need to be interpreted with caution due to the small sample size and limited variance in the data. However, exploratory analyses highlighted a significant positive correlation between mental focus and subjective stress reduction, indicating that participants with higher mental focus during music listening experienced greater reductions in subjective stress. Given the extensive health problems associated with stress, the development of cost-effective and ecological stress-reduction strategies is essential. Increasing the mental focus on music listening, for example by minimizing distractions, may enhance its stress-reducing effects. Moreover, future research should investigate the advantages of incorporating quiet periods or silent mediation practices in everyday life.

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Figures

Tables

List of Abbreviations

ACTH – adrenocorticotropic hormone

ANS – autonomic nervous system

BMI – body mass index

CPT – cold pressor test

CRH – corticotropin-releasing hormone

EDA – electrodermal activity

EMA – ecological momentary assessment

GAS – general adaption syndrome

GH – growth hormone

Gold-MSI – Goldsmiths Musical Sophistication Index

HR – heart rate

HRV – heart rate variability

HPA axis – hypothalamic pituitary adrenal axis

PNS – parasympathetic nervous system

RCT – randomized controlled trial

SAM axis – sympathetic-adrenal-medullary axis

SNS – sympathetic nervous system

TEWL – trans epidermal water loss

TSST – Trier Social Stress Test

Appendix

Zusammenfassung

Ziele: Stress wird mit einer Vielzahl an negativen Auswirkungen auf das psychische und physische Wohlbefinden in Verbindung gebracht. Musikhören wird als kostengünstige und ökologische Methode zur Stressreduktion angesehen, die von Faktoren wie Musikalität und Fokus während des Hörens beeinflusst wird. Diese Studie verfolgte das Ziel, die Auswirkungen des Musikhörens auf die subjektive und physiologische Stressreduktion nach einem akuten Stressor zu untersuchen. Außerdem wurde die Rolle des Fokus als Mediator der Beziehung zwischen Musikalität und Stressreduktion untersucht.

Methoden: In einer Laborstudie wurden 45 gesunde weibliche Teilnehmerinnen nach dem Zufallsprinzip entweder einer Musikhör- oder einer Stille-Bedingung zugeteilt. Nach Absolvierung des Trier Social Stress Test (TSST) hörte die Musikgruppe 30 Minuten lang Musik, während die Kontrollgruppe in einem stillen Raum saß. Musikalität wurde anhand der deutschen Version des Goldsmiths Musical Sophistication Index (Gold-MSI) erfasst, der Fokus während dem Musikhören wurde anhand einer visuellen Analogskala (VAS) eingeschätzt. Subjektiver Stress (VAS) und physiologischer Stress (Herzfrequenz, HR) wurden vor und nach der Intervention erfasst.

Ergebnisse: Es wurden keine signifikanten Unterschiede zwischen der Musikhör- und Stille-Bedingung hinsichtlich der subjektiven und physiologischen Stressreduktion festgestellt. Mediationsanalysen zeigten keinen signifikanten mediierenden Effekt des Fokus auf den Zusammenhang zwischen Musikalität und Stressreduktion. Explorative Analysen zeigten eine signifikante Korrelation zwischen Fokus während des Musikhörens und subjektiver Stressreduktion. Alle Ergebnisse müssen aufgrund der unzureichenden Stichprobengröße mit Vorsicht interpretiert werden.

Schlussfolgerung: Obwohl die Studie keine signifikanten stressreduzierenden Effekte des Musikhörens im Vergleich zur Stille fand, deutet die beobachtete Korrelation zwischen Fokus und subjektiver Stressreduktion auf mögliche positive Effekte des Musikhörens hin.

Schlüsselwörter: Musikhören, Stressreduktion, Herzfrequenz, subjektiver Stress, physiologischer Stress, Musikalität, musikalische Erfahrenheit, Fokus, mentaler Fokus, TSST, Trier Stress Test, akuter Stressor