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The Role of Musical Chills in Stress Management

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1. Introduction

While in the past, music was mostly found in theaters or homes, advances in technology, particularly the development of music streaming services, have made listening to music more accessible than ever (North et al., 2004; O'Hara & Brown, 2006). Today, music is available anytime, anywhere and has become an important part of everyday life for many people (Greasley & Lamont, 2011; North et al., 2004). As reported by the International Federation of the Phonographic Industry (IFPI) the global average time for listening to music is approximately three hours per day (Bayley, 2022).

The question thus arises as to why individuals engage with music to this extent. In general, music serves a variety of purposes, whether it is for pleasure (Dubé & Le Bel, 2003), to pass time, out of habit (North et al., 2004), or to enhance the performance in physical activities (Greasley & Lamont, 2011). Moreover, research shows that individuals primarily value music for the emotions it evokes, thereby underscoring its role in regulating and expressing emotions (Juslin & Västfjäll, 2008). For example, recent studies indicate that music is linked to positive emotion up-regulation, negative emotion down-regulation, and increasing arousal (Cook et al., 2019).

Regarding emotion regulation, the mood management theory of Zillmann (1988) suggests that individuals use entertainment, such as music, to enhance or maintain positive affect. The underlying idea of the theory is that individuals are hedonistically motivated to maximize pleasant moods and minimize unpleasant moods. Specifically for music, research has reported cheerful music to improve negative moods, while calming music has been found to have a relaxing effect that helps to reduce stress. Likewise, a recent study highlights that individuals listen to music in order to manage their negative moods and reduce psychological distress (Garrido et al., 2022).

Considering these positive qualities of listening to music, research has started to focus on understanding the beneficial effects of music on health and well-being, with a particular focus on stress management (Fancourt et al., 2014). Given the profound negative impact stress can have on health and well-being, such as cancer, stroke, cardiovascular diseases and depression (American Psychological Association, 2024; McEwen, 1998), the stress-reducing effects of music have become the most excessively researched area in music research (de Witte et al., 2020). Recent reviews highlight the positive effect of music on cortisol levels in both clinical and non-clinical populations, concluding that music can have stress-regulating effects at the hormonal level (Chanda & Levitin, 2013; de Witte et al., 2020; Fancourt et al., 2014; Kreutz et al., 2012).

In addition to its emotion-regulating function, music serves as a medium for expressing emotions (Gabrielsson, 2001; Witvliet & Vrana, 2007) that can also elicit physiological responses in listeners (Gabrielsson, 2011; Gomez & Danuser, 2007; Juslin et al., 2011). Among these responses, musical chills stand out as strong psychophysiological responses to music involving sensations such as shivers down the spine or goosebumps (Blood & Zatorre, 2001). The phenomenon of chills has attracted researchers‘ interest as chills are strong aesthetic experiences that are perceived as highly pleasurable (de Fleurian & Pearce, 2021).

Despite the growing interest in the general stress-reducing properties of music, there is a lack of research exploring the potential contribution of strong psychophysiological responses to music, particularly chills, to the stress-reducing effect of music. Conclusively, the present master's thesis aims to address this gap in the literature by investigating the impact of musical chills in stress management. Therefore, the phenomenon of musical chills will be explained before diving into the concept of stress to establish the connection between music, chills and stress. Finally, the research question and hypotheses will be presented, followed by the methodology, results and discussion.

2. Musical Chills

Chills have been reported to be clear discrete events that can be elicited by aesthetic stimuli (Blood & Zatorre, 2001), among which music has been recognized as an especially effective stimulus to induce chills (Goldstein, 1980). Chills are defined as temporary, pleasant reactions associated with sudden changes in mood or emotion (de Fleurian & Pearce, 2021) and are associated with physiological responses, such as piloerection, also known as goosebumps (Blood & Zatorre, 2001). The physiological responses can last from less than a second to more than ten seconds, with longer reactions usually involving one or more waves of shivers (Huron & Margulis, 2010). Likewise, participants frequently describe chills as sensations of tingling, a sudden rush of cold, or shivers down the spine (e.g. Blood & Zatorre, 2001; Huron & Margulis, 2010; Koelsch, 2010).

The study of chills can be traced back to Maslow's (1964) research of aesthetic peak experiences and was subsequently investigated by Goldstein (1980), who conducted one of the first scientific studies into the experience of chills. He demonstrated that chills frequently originate at the upper spine and subsequently disseminate to other regions of the body and suggested that chills do not always require piloerection. Although later some studies found that chills and goosebumps always occur together (Huron & Margulis, 2010; Panksepp, 1995), most have supported Goldstein's (1980) view (Craig, 2005; Gabrielsson, 2011; Nusbaum & Silvia, 2011). A possible explanation has been provided by Sumpf et al. (2015), suggesting that piloerection may require a certain intensity of chills to become detectable.

In addition to the discrepancies regarding the necessity of piloerection, there were also many disagreements about the terminology of the experience of chills. Various terms have been proposed by researchers for the chills phenomenon, including thrills (Goldstein, 1980), frissons (Huron, 2006; Huron & Margulis, 2010), skin orgasms (Panksepp, 1995) and chills (Bannister, 2020; de Fleurian & Pearce, 2021; Levinson, 2006; McCrae, 2007). To follow the recommendations of de Fleurian and Pearce (2021), here the term chills will be used, which has become the most widely used term in recent literature and is consistent with the terminology presented in the questionnaire utilized in the present study (see Methodology).

Further, it is important to distinguish between musical chills and strong experiences with music (SEMs), since they are comparable but nevertheless distinct phenomena. Gabrielsson (2011) defined SEMs as very intense emotional reactions to music that involve cognitive, emotional, and existential processes. Due to their subjective nature, SEMs can differ greatly among individuals (Gabrielsson, 2011). In contrast, chills may occur during SEMs, but appear to be more physiological and more narrowly focused on the body's reaction to emotional arousal triggered by music (Gabrielsson, 2011; Huron & Margulis, 2010). Moreover musical chills are often brief and occur in response to specific musical stimuli, such as harmonic changes or unexpected shifts in melody (Huron & Margulis, 2010).

As musical chills occur to specific stimuli, they are highly reproducible through specific pieces of music for individuals with the capacity to experience chills, which makes musical chills an interesting subject of study (Blood & Zatorre, 2001). In the existing literature, the number of people who report the ability to experience musical chills varies from 66% (Grewe et al., 2009) to 92% (Nusbaum & Silvia, 2011). Although a systematic review points out that only the results of studies based on a representative sample of the population should be used for prevalence calculations (de Fleurian & Pearce, 2021). The authors therefore suggest that the upper limit of individuals with the ability to experience chills can be set at 90% (de Fleurian & Pearce, 2021).

2.1. Elicitors of Musical Chills

According to de Fleurian and Pearce (2021) understanding chill-inducing factors is necessary to assess the psychological mechanisms underlying chills, as well as develop a theoretical framework for understanding their functioning (de Fleurian & Pearce, 2021). For example, research has shown that musical chills are independent of age, gender and music education (Grewe et al., 2007). Moreover, studies conducted by Panksepp (1995) provided a strong foundation for much of the empirical research related to musical chills. The author showed that a crescendo, that is, a gradual increase in volume over a certain period of time, may elicit chills (Panksepp, 1995).

First, other musical elicitors have been identified to induce chills like build-ups and climaxes (Auricchio, 2017; Bannister, 2020), as well as harmonic shifts, structural changes and the alternation between the orchestra and solo instruments (Auricchio, 2017; Bannister, 2020; Bannister & Eerola, 2018; Guhn et al., 2007). Additionally, one study reported that slow movements in music frequently elicit chills (Guhn et al., 2007).

Second, acoustic changes have been demonstrated to elicit musical chills. Including a sudden increase in volume (Auricchio, 2017; Guhn et al., 2007; Mori & Iwanaga, 2017), frequent peaks in loudness (Bannister, 2020; Bannister & Eerola, 2018; Grewe et al., 2007; Guhn et al., 2007) and expansion of the frequency range (Guhn et al., 2007).

Third, emotions evoked by music have been reported as potentially chill-inducing, whereby both positively and negatively valenced music have been associated with the experience of chills (Grewe et al., 2011; Mori & Iwanaga, 2017; Panksepp, 1995). However, studies suggest that the perceived emotional intensity (Bannister & Eerola, 2018; Rickard, 2004) and importance of the music to oneself (Bannister, 2020; Goldstein, 1980) may act as stronger predictors of chills than valence alone.

Finally, other factors that have been reported to influence the experience of chills are for example the Big-Five personality factor Openness to Experience, which is considered one of the strongest predictors of musical chills (Bannister, 2020; Nusbaum & Silvia, 2011; Sumpf et al., 2015) and familiarity with the music, which is often seen as a strong influence on aesthetic experiences (Verhaeghen, 2018). Familiarity can increase musical chills by either enhancing the perceived meaning of the music or creating a tension between what is schematically expected, like typical structural patterns, and what is concretely expected (Huron, 2006). This can create unexpected moments in familiar music, even if the music itself is very familiar, which can trigger musical chills that, as previously mentioned, can be caused by unexpected musical or acoustic changes (de Fleurian & Pearce, 2021; Verhaeghen, 2018).

In summary, various musical, acoustic, emotional, and individual factors contribute to the elicitation of musical chills, raising the question of how these experiences can affect the body.

2.2. Chills and the CNS

At the central nervous system (CNS) level, research has found a link between chills and attention-related as well as pleasure-related processes. More specifically, a decreased blood flow in the amygdala, the left hippocampus, and the posterior cortex during the experience of chills has been reported (Blood & Zatorre, 2001), which is a hemodynamic pattern characteristic of euphoric or pleasurable experiences (Koelsch, 2010). In addition, increased activity in the thalamus and anterior cingulate has been reported (Blood & Zatorre, 2001), which are regions associated with heightened attention (Koelsch, 2010).

Further, a positive correlation between dopamine release and frequency of chills, as well as between dopamine release, intensity of chills and degree of pleasure has been found (Salimpoor et al., 2011). Regarding dopamine, studies identified two distinct areas of the dopaminergic reward system in the brain that are involved in the experience of chills. The caudate nucleus, which is activated right before the emotional peak, and the nucleus accumbens, which is activated after the peak (Blood & Zatorre, 2001; Salimpoor et al., 2011).

Moreover, the connectivity between auditory areas and emotional and reward-processing systems has been suggested as a predictor of musical chills (Salimpoor & Zatorre, 2013), thus highlighting that chills are not only associated with the activation of only single, modular reward-processing regions, but rather with a network of regions involved in the processing of rewards and emotions, interacting with auditory-motor activity (Harrison & Loui, 2014). Harrison and Loui (2014) thus suggest that chills can help to connect sensory and emotional experiences within the CNS, particularly involving regions responsible for emotion, attention, and motor-auditory integration, which emphasizes the involvement of the brain's reward circuitry in the experience of musical chills.

2.3. Chills and the ANS

Regarding the autonomic nervous system (ANS), the experience of chills has been associated with a variety of physiological responses (de Fleurian & Pearce, 2021). For instance, increases in skin conductance response (Benedek & Kaernbach, 2011; Grewe et al., 2009; Mori & Iwanaga, 2017) and in heart rate (Benedek & Kaernbach, 2011; Blood & Zatorre, 2001; Grewe et al., 2009; Guhn et al., 2007; Salimpoor et al., 2011) have been found. Furthermore, respiration has been reported to become more rapid and deeper when experiencing chills (Benedek & Kaernbach, 2011; Blood & Zatorre, 2001; Grewe et al., 2007).

Interestingly, some studies did not find any effects in skin conductance (Blood & Zatorre, 2001), heart rate (Mori & Iwanaga, 2017; Rickard, 2004) or respiration depth or rate (Mori & Iwanaga, 2017). A possible explanation for these contradicting results could be the uncertain temporal sequence of the physiological responses associated with chills, as alterations in physiological arousal may occur either prior to, during, or subsequent to the occurrence of chills (de Fleurian & Pearce, 2021).

The given disagreement in the findings on the physiology of musical chills makes it difficult to investigate the phenomenon on the grounds of physiological correlates. Nevertheless, it can be summarized that musical chills are associated with various physiological changes, even if these have not always been consistently observed (e.g., Mori & Iwanaga, 2017). In this regard, the experience of musical chills is directly related to ANS activity, thus indicating similarities to the human body's physiological reactions to stress. However, the experience of chills is perceived as positive (Blood & Zatorre, 2001; Goldstein, 1980), whereas stress, if chronic, is associated with discomfort and long-term negative impact on the body (American Psychological Association, 2024; Nater et al., 2011). Given that both stress and chills involve physiological reactions to emotional stimuli, this raises the question of whether chills could contribute to or moderate the stress-reducing effects of music. Hence, to investigate the potential moderating role of chills, it is essential to first understand the physiological mechanisms of stress.

3. Stress

One of the first definitions of stress defined stress as a general activation reaction to internal or external stimuli, which can be either perceived as a positive challenge or a negative threat (Selye, 1956). Today, stress is recognized as a complex interplay of various factors (Nater, 2018), such as environmental influences or the type and nature of stressors, as well as personal factors such as the appraisal of the stressor and available resources for coping (Nater et al., 2011).

Building on this understanding of stress as intertwined with appraisal, the transactional stress model (Lazarus & Folkman, 1984) provides a framework for examining the way people perceive and respond to distressing situations. According to Lazarus and Folkman (1984), stress occurs when a situation is perceived as challenging and hard to cope with, which means that any situation can be a stressor and elicit a stress response. The stress response can vary between individuals (McEwen, 1998) and is influenced by the perceived stress reactivity, a disposition characterized by variations in physiological and psychological reactions to stress (Schlotz et al., 2011). Perceived stress reactivity is considered to be relatively stable over time and across different situations. However, it can be altered by the frequency and intensity of stress exposure, as well as by how individuals appraise these experiences (Schlotz et al., 2011).

To elaborate further, a stress response can be seen as a neurochemical reaction to the loss of homeostatic balance (Chanda & Levitin, 2013; McEwen, 1998). While the acute stress response is a natural process and necessary for survival, prolonged or extreme exposure to stressors can lead to chronic stress, which negatively affects our health and well-being (McEwen, 1998). When an adverse combination of environmental challenges and individual characteristics over a long period of time causes chronic stress (Nater et al., 2011), regulatory systems and coping strategies can help individuals to adapt to those challenges and restore their homeostatic balance (McEwen, 1998).

During a stress response, the two most important stress systems in the body, the ANS and the hypothalamic-pituitary-adrenal (HPA) axis become activated and interact directly with each other and the immune system (Chanda & Levitin, 2013). The activity of the ANS can be observed through biomarkers, such as heart rate variability (HRV) and electrodermal activity (EDA), which allow a relatively precise interpretation of sympathetic and parasympathetic activity (Thomas et al., 2019). Another relevant biomarker for stress is the hormone cortisol, which reflects the activity of the HPA axis (Hellhammer et al., 2009).

To maintain the organism's homeostasis in stressful situations the interaction between the HPA axis and the ANS regulates physiological responses, including endocrine and cardiovascular activation and psychological processes, such as emotional processing (Tsigos, 2002). However, chronic stress can impact both stress systems negatively. For instance, prolonged activation, as seen in chronic stress, has the potential to alter the adaptive response of the HPA axis, leading to maladaptive functioning and lasting dysregulation of the HPA axis (Herman, 2013).

Given that chronic stress is a known risk factor for problems such as stroke, cardiovascular diseases, depression, and anxiety disorders, coping with chronic stress is important to protect physical and mental health in the long term (American Psychological Association, 2024; McEwen, 1998). To avoid these negative effects, many people use tranquilizers for stress management, which unfortunately have the potential for dependence and abuse (Bandelow et al., 2015; de Witte et al., 2020). Accordingly, stress research has progressed in recent decades and has increasingly focused on finding non-pharmacological methods, like art and music, for reducing and preventing stress (de Witte et al., 2022).

Here, it is important to distinguish between music therapy and music-based interventions. While trained music therapists play an important role in music therapy, music-based interventions can be applied without therapists to support mental or physical wellbeing. This includes, for example, the attempt to improve everyday lives of patients with chronic illnesses through music interventions or listening to music to reduce stress (Wuttke-Linnemann et al., 2020). Thus, music-based interventions that can be used in everyday life without a therapist serve as a low-risk, cost-effective method of improving mental and physical health (de Witte et al., 2020).

4. Music, Chills and Stress

Whether in a clinical setting or in everyday life, music has been found to reduce stress and contribute to general well-being (de Witte et al., 2022). Specifically, music listening has been proposed to reduce both psychological and physiological markers of stress (de Witte et al., 2020; Fancourt et al., 2014). For instance, music has been found to significantly lower cortisol levels, mean arterial pressure, and heart rate (Burrai et al., 2020; Koelsch et al., 2016; Kreutz et al., 2012). Similarly, Linnemann et al. (2015) showed that the simple act of listening to music can effectively reduce subjective stress levels and concentrations of cortisol in the body.

To explain the benefits of music on stress, Thoma et al. (2012) have proposed a mediation model, suggesting that the effects of music are characterized by their ability to reduce biopsychological stress. Similarly, Chanda and Levitin (2013) have linked listening to music with the potential to modulate HPA axis and ANS activity, indicating that the stress systems play a mediating role between health and music. Moreover, listening to music has been associated with the downregulation of the HPA axis (Kreutz et al., 2012). Complementary to this, research found that listening to music after a stressor had a positive influence on the HPA axis (Khalfa et al., 2003), and listening to music before a stressor had a positive effect on ANS activity (Thoma et al., 2013).

Further, recent research suggests that frequency-modulated music may positively influence the ANS (Feneberg et al., 2020). For example, a frequency modulation study has demonstrated that higher frequencies of classical music were more effective in supporting autonomic recovery than non-modulated versions (Nakajima et al., 2016). Similarly, Akimoto et al. (2018) found that piano music tuned from 440 Hz to 444 Hz improved the HRV and reduced negative mood. In addition, a clinical intervention called Audio-visuelle-Wahrnehmungsförderung (AVWF) showed potential improvement of biological stress markers such as HRV and cortisol levels (Olbrich et al., 2015; Olbrich & Näher, 2017), which is also currently being investigated in an ongoing study by Feneberg et al. (2020).

To summarize, the existing literature shows that listening to music can have a positive impact on the body's stress systems and help to alleviate stress (e.g., Chanda & Levitin, 2013; Thoma et al., 2013). However, there is a gap in the literature as to how exactly musical chills are involved in stress-related processes.

4.1. Potential role of musical chills in stress reduction

A key consideration with musical chills is that chills are not just fleeting sensations but are rather linked to strong emotional and physiological processes (de Fleurian & Pearce, 2021) that could affect our well-being by enhancing the stress-reducing effects of music. Since an important feature of musical stimulation of the ANS is eliciting emotions and modulating affective states, research suggests a link between emotional responses and stress (Kreutz et al., 2012). Likewise, Panksepp and Bernatzky (2002) argue that music-induced activations affect neuronal networks of the human brain that are associated with endocrine systems and homeostatic changes in these systems. Specifically for chills, it has been shown that intense chill-inducing music can activate brain regions with structural and functional significance for the HPA axis (Blood & Zatorre, 2001). In this context, music that elicits emotional arousal has been associated with reductions in HPA axis-related markers such as salivary cortisol levels (Fukui & Toyoshima, 2013).

Further, the aforementioned changes in mesolimbic dopaminergic neurotransmission due to chills and their association with reward-related processes (Blood & Zatorre, 2001; Salimpoor et al., 2011) could promote stress management, since stress negatively affects both dopamine concentrations and the functioning of dopaminergic neurons within the mesolimbic system (Baik, 2020). Likewise, the connectivity between auditory areas and reward centers

(Salimpoor & Zatorre, 2013; Harrison & Loui, 2014) suggests that chills could help to integrate sensory impressions and emotional processing in the brain, which contributes to the regulation of intense emotions and thus facilitates stress management.

As already stated above, physiological correlates of musical chills are not clearly interpretable, as findings are often inconsistent, with conflicting effects or lack of replication across studies (de Fleurian & Pearce, 2021). However, chills are mostly associated with increases in skin conductance response (Benedek & Kaernbach, 2011; Grewe et al., 2011; Guhn et al., 2007; Mori & Iwanaga, 2017; Salimpoor et al., 2011) and heart rate (Benedek & Kaernbach, 2011; Blood & Zatorre, 2001; Guhn et al., 2007; Salimpoor et al., 2011; Sumpf et al., 2015), which are both biomarkers of stress.

These findings, together with the aforementioned studies that show that chills are associated with the activation of brain structures related to emotion regulation, pleasure, attention and reward (e.g., Blood & Zatorre, 2001; Salimpoor et al., 2011), suggest that the processes involved in chills and stress could be intertwined. Accordingly, the following section will examine which processes associated with musical chills may be relevant for stress management.

4.1.1. Pleasure and Reward

Acute stress has been reported to increase individuals' reward sensitivity, which helps them to cope with stressors by activating corresponding reward-related neural connections. In contrast, chronic stress has been shown to impair reward sensitivity, which is closely related to stress-related depression (Baik, 2020; McEwen, 1998). To counteract the resulting loss of pleasure or lack of motivation, music that is perceived as pleasant can increase positive emotional valence and perceived happiness, resulting in stress reduction (Jiang et al., 2016; Witvliet & Vrana, 2007). Similarly, Jain et al. (2025) emphasize the potential of chills as an effective approach towards eliciting and enhancing positive affect, suggesting that the experience of chills can influence reward learning in anhedonic individuals. Given that previous research has found a correlation between the experience of chills and the subjective pleasantness of music (Grewe et al., 2007), the question arises whether music that induces highly pleasurable chills could enhance the stress-reducing effect of music.

Additionally, Baik (2020) hypothesized that the modulation of the dopaminergic reward system may be required to monitor and select optimal processes for coping with aversive events, and therefore stress. Listening to music can lead to a release of dopamine in CNS pathways, which can subsequently activate the opioid system in so-called hedonic hotspots, which are regions of the brain associated with pleasure (Berridge & Kringelbach, 2008). Opioid activity has also been shown to be intertwined with the HPA axis (Zhang et al., 2008), suggesting that pleasant music may have a stress-reducing effect (Berridge & Kringelbach, 2008). Consequently, dopamine activity in the mesolimbic reward system is associated with intense music pleasure, indicating a strong link to musical chills, which are perceived as highly pleasurable (Blood & Zatorre, 2001; Koelsch, 2010) and are associated with dopamine release (Salimpoor et al., 2011).

4.1.2. Distraction

One additional way in which musical chills might influence coping with stress is through distraction. As a distractor, music has the potential to reduce stress levels by shifting attention from a stressful event towards something positive (Chanda & Levitin, 2013; de Witte et al., 2020). Likewise, research has proposed that this attention-shifting effect can reduce rumination and negative affect, thus enhancing stress recovery (Adiasto et al., 2023). Regarding chills, Tihanyi (2016) suggested that chills might be able to enhance these effects of music by directly drawing attention towards the chills experience and distracting from stress-inducing thoughts. In particular, the author hypothesized that awareness is directed towards the physiological reactions evoked by chills, which could promote somatic interoceptive awareness. Given that somatic interoceptive awareness plays a role in psychosomatic health and has been associated with both ANS functioning and stress reactivity (Kanbara & Fukunaga, 2016), it is plausible that chills might contribute to stress reduction through this pathway.

4.1.3. Mindfulness

One other concept that might contribute to the stress-reducing effect of musical chills is mindfulness, which can be defined as the ability to observe thoughts and feelings in the present moment without judgment and is believed to have a variety of positive health effects (Ballantyne et al., 2021). In the context of stress research, mindfulness has been associated with lower stress levels and enhanced stress recovery (Sharma & Rush, 2014). Studies, which investigated the relationship between mindfulness and aesthetic experiences, found that individuals with higher levels of mindfulness were more likely to have aesthetic experiences, including chills (Diaz, 2013; Harrison & Clark, 2016). Conversely, Tihanyi (2016) proposed that the experience of chills may promote mindfulness, as the underlying physiological responses of chills may act as an anchor that directs awareness to the present moment, thereby promoting a mindful state. Although this reciprocal effect of mindfulness and chills has not been directly investigated, the available research (e.g., Tihanyi, 2016) supports the plausibility that the focus on the present moment and heightened body awareness associated with chills could promote mindfulness. This suggests that mindfulness may indeed increase the likelihood of chills, while chills may simultaneously promote mindful awareness, potentially highlighting the stress-reducing effect of chills.

5. Research Question and Hypotheses

This master's thesis seeks to contribute to the growing body of knowledge on the beneficial effects of music on health and well-being, with a specific focus on the experience of musical chills and stress management. Understanding the effect of chills could provide valuable insights for improving the potential of music for better management and alleviation of stress. As research has associated chills with stress-managing factors, such as dopamine release, reward sensitivity, and enhanced interoceptive awareness (Blood & Zatorre, 2001; Salimpoor et al., 2011; Tihanyi, 2016), I hypothesize that participants who report more chill experiences during music-listening interventions will show a greater improvement in subjective chronic stress levels (H1) and a greater decrease in perceived stress reactivity (H2) over time compared to participants who report fewer or no chill experiences.

To investigate whether individuals who respond more strongly to music and experience chills benefit more from certain music interventions, I hypothesize that the ability to experience chills moderates the relationship between different types of music interventions and stress reduction (H3). The moderation analysis makes it possible to investigate how different types of music interventions affect stress management and whether the ability to experience chills moderates the effectiveness of these interventions.

6. Methods

This master's thesis was conducted using data from the study Music-Listening Interventions in Reducing Pain (MINTREP; Feneberg et al., 2020) of the Music and Health Laboratory of the Faculty of Psychology of the University of Vienna. MINTREP has been an ongoing study since 2016, which investigates how effectively different music listening interventions can reduce pain and stress over a long period of time and which biopsychological mechanisms are involved. After two interruptions due to the laboratory changing from Marburg, Germany to Vienna, Austria and later the Covid-19 pandemic, the study was resumed in February 2024.

In order to avoid plagiarism, it should be noted that the MINTREP study is a long-term study involving many students. Therefore, there may be methodological overlaps between the master's theses, in particular with current theses like those of Roman Böswirth and Nina Pylypiw.

6.1. Study Design

The MINTREP study employs a double-blind, randomized, controlled trial design with three types of music interventions, conducted as a within-subject study. The three conditions comprise frequency-modulated researcher-selected music, unmodulated researcher-selected music, and unmodulated self-selected music (Feneberg et al., 2020). The same study design was applied to this thesis, maintaining the framework of the double-blind, randomized, controlled study, which assessed the frequency of chills (independent variable for H1 and H2), the ability to experience chills (independent variable for H3), chronic stress (dependent variable for H1 and H3) and perceived stress reactivity (dependent variable for H2).

This thesis examined a data subset of the MINTREP study, which is a longitudinal study where participants attended a baseline measurement followed by 10 music intervention sessions over three consecutive weeks. After the music intervention period, each participant underwent a post-intervention measurement, followed by a follow-up measurement one month later. Further, group assignments of the participants were also drawn from the MINTREP study for the purpose of this thesis and were included in the analyses of the hypotheses.

6.2. Study Population

The planned sample size for the MINTREP study is N = 90, with 30 participants allocated to each type of music intervention. As the recruitment process is still ongoing, of the planned 90 participants, 34 individuals have already participated in the MINTREP study to date from which 27 individuals have completed all 13 appointments of the study and will be included in the analyses.

The participants were randomly assigned to the groups in order to guarantee that all participants, regardless of the assigned music intervention, had similar expectations of the treatment outcome. Prior to the aforementioned interruption of the study, participants that attended all 13 sessions received a monetary compensation of 80 €. Once the study was resumed in 2024, the compensation was adjusted for inflation and increased to 120 €.

6.2.1. Exclusion Criteria

Participants between the ages of 18 and 35 years were included in the study. Further, inclusion criteria required participants to have a body mass index between 18.5 and 30, as well as the ability to speak and read in German fluently. Additionally, participants needed to have enough time to attend the laboratory twelve times within three weeks (baseline appointment, 10 music interventions and post appointment) and once more four weeks later for the follow-up appointment. Moreover, participants were excluded if they had perfect pitch, were studying or working in a music-related field or suffered from a hearing impairment (e.g. chronic/acute tinnitus, hearing loss).

Participants were excluded if screened positive for premenstrual syndrome, depression, or other mental disorders, like anxiety, eating disorders, problematic alcohol consumption or substance abuse, psychosis, schizophrenia, or bipolar disorder. Further, self-reported conditions, such as cardiovascular disease, artery occlusive disease, hyper-/hypotension, diabetes, extreme visual impairment, chronic pain condition and Raynaud syndrome, as well as the inability to withhold from smoking for more than 2.5 hours resulted in the exclusion from the study. Other exclusion criteria included an irregular menstrual cycle, the usage of hormonal contraception, current pregnancy or breastfeeding, regular use of pain medication and/or psychotropic drugs, and inability to self-identify as a man or woman. These exclusion criteria were applied to minimize possible risks associated with participation in the study (Feneberg et al., 2020) and to reduce the potential for bias in the results, given that the primary and secondary outcomes of the study were found to be influenced by a number of health conditions and lifestyle factors, such as smoking (Barutcu et al., 2005) or drinking alcohol (Zale et al., 2015).

6.2.2. Randomization and Blinding

If eligible for the study, participants were randomly assigned to one of the three types of music interventions. A block randomization stratified by gender was performed beforehand by an independent researcher using the blockrand package (Snow, 2015) in the statistical program R (v3.4.2; R Core Team, 2017). Subsequently, 90 computer-generated notes were created, each indicating the participant's gender and assigned experimental condition. The notes were stored in a secure location within the laboratory in sealed envelopes. For each new participant included in the study, the consecutive envelope was selected to ensure proper randomization. In order to comply with double blinding, the envelopes with the group allocation were only allowed to be opened by researchers who were not responsible for instructing and engaging with the participants during the treatment sessions. Furthermore, the participants were unaware of whether the music they were listening to had been frequency modulated or not.

6.3. Materials

The MINTREP study collects a wide range of primary, secondary and tertiary variables (see Figure 1), which are mentioned for replication purposes but will not be discussed in detail as they are outside the scope of this thesis. However, the four variables, chronic stress, stress reactivity, frequency of chills (in music related perceptions) and the ability to experience chills (in music preferences), which are highlighted in Figure 1, are directly relevant to testing the hypotheses and will now be discussed in detail.

6.3.1. Frequency of Chills

The independent variable of H1 and H2, which is frequency of chills, was measured after each of the 10 music listening sessions using the questionnaire “Music-related perceptions”, which was developed by Feneberg et al. (2020). The questionnaire included questions on music-induced emotions and memories, perceived valence and arousal of the music, and sleep.

However, there was one item in the questionnaire, which assessed the frequency of chills on a visual analogue scale (VAS) with the instruction “Please indicate how often you experienced chills while listening to music today”. The VAS is a subjective paper-and-pencil method whereby participants are instructed to indicate the frequency of their perceived chills by placing a mark on a 100mm line, which represents a scale from not at all to almost always.

Measures Primary outcomes		Online survey	BL	ML1	ML2	ML3	ML4	ML5	ML6	ML7	ML8	ML9	ML10	Post	FU
				Appointments Intervention period											
Pain	Pain tolerance[1] (seconds)		x	x		x			x				x	x	x
	Pain intensity[1] (VAS)		x	x		x			x				x	x	x
Secondary outcomes															
Subjective stress	Momentary stress[2] (VAS)		x	x	x	x	x	x	x	x	x	x	x	x	x
	Chronic Stress (SSCS)	**x**												**x**	**x**
	Chronic Stress (TICS)	x													
	Stress reactivity (PSRS)	**x**												**x**	**x**
Biological stress markers	HRV indices[3]		x	x		x			x				x	x	x
	EDA		x	x		x			x				x	x	x
	Hair cortisol		x												x
Tertiary variables															
Momentary mood[4]	MDMQ-short		x	x	x	x	x	x	x	x	x	x	x	x	x
Music-related perceptions				**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**		
Musical engagement **between sessions**				x	x	x	x	x	x	x	x	x	x	x	x
Music preferences	**MPQ-R**	**x**													
Cognitive style of music listening	ME-MS	x													
Mood regulation via music	B-MMR	x												x	x
Emotion regulation	ERQ	x												x	x
Fatigue	MFI-20	x												x	x
Sleep Quality	PSQI	x												x	x
Personality	BFI-10	x													
Social support	BSSS	x													
Depression	BDI-II	x	x											x	x
Mental health	PHQ-D	x													
Premenstrual syndrome	PMS questionnaire	x													
Menstrual cylce		x													
Hair characteristics			x												x

Figure 1

Measures of the MINTREP Study

Note. HRV indices: resting state at baseline, post- and follow-up; continuous measurement throughout music listening sessions; VAS, visual analogue scale; SSCS, Screening Scale for Chronic Stress; TICS, Trier Inventory of Chronic Stress; PSRS, Perceived Stress Reactivity Scale; HRV, heart rate variability; EDA, electrodermal activity; MDMQ-short, short-scale of the Multidimensional Mood Questionnaire; MPQ-R, Music Preference Questionnaire, revised version; ME-MS, Music Empathizing-Systemizing Inventory; B-MMR, Brief Music in Mood Regulation Scale; ERQ, Emotion Regulation Questionnaire; MFI-20, Multidimensional Fatigue Inventory; PSQI, Pittsburgh Sleep Quality Inventory; BFI-10, Big-Five-Inventory-10; BSSS, Social Support Scale; BDI-II, Beck's Depression Inventory II; PHQ-D, German version of the Patient Health Questionnaire; PMS questionnaire, Premenstrual Syndrome Questionnaire. From Efficacy, Treatment Characteristics, and Biopsychological Mechanisms of Music-Listening Interventions in Reducing Pain (MINTREP): Study Protocol of a Three-Armed Pilot Randomized Controlled Trial by A. C. Feneberg et al., 2020, Frontiers in Psychiatry, 11, https://doi.org/10.3389/fpsyt.2020.518316

6.3.2. Chronic Stress

To address the dependent variable chronic stress of H1 and H3 of the master thesis, participants completed the German-language instrument, Screening Scale for Chronic Stress (SSCS; Schulz et al., 2004), at the baseline, post and follow-up appointments. The SSCS is a short version of the Trier Inventory for Chronic Stress (TICS) and is an instrument for measuring general chronic stress independent of specific demands and situations in the last three months. While the TICS conceptualizes chronic stress across five dimensions, including chronic worry, work-related and social overload, excessive demands and lack of social recognition and relaxation, the SSCS aggregates the variable into two factors, namely *high demands* and *lack of social recognition and relaxation*, which has been identified by a principal axis factor analysis with oblimin rotation.

The SSCS comprises twelve items, such as “In the last three months, there have been times when I was overwhelmed by worries” which are answered on a five-point Likert scale from 0 = never to 4 = very often. Schulz et al. (2004) reported the psychometric properties of the SSCS as satisfactory, which is reflected by a high Cronbach's α ($\alpha = 0.91$) and reliability of $r = 0.887$. Furthermore, correlations with both construct-related and non-construct-related tests demonstrated good construct validity.

6.3.3. Perceived Stress Reactivity

The dependent variable perceived stress reactivity for testing H2 of this thesis was measured by the German translation of the Perceived Stress Reactivity Scale (PSRS; Schlotz et al., 2011), which was assessed at the baseline, post, and follow-up sessions. The PSRS is a questionnaire that comprises 23 items on 5 subscales that map the overall perceived stress reactivity scale. The authors operationalized perceived stress reactivity as the subjectively perceived typical intensity of an individual's reaction in different potentially stressful everyday situations on six scales. Therefore, various stress reactions were captured, including reactions to work overload, social conflict, social evaluation, failure, anticipatory stress and persistent stress.

By aggregating the subscales a total score can be calculated. Schlotz et al. (2011) reported adequate internal consistency ($0.71 \leq \alpha \leq 0.91$) and sufficient retest reliability coefficients over 7 months ($0.63 \leq r_{tt} \leq 0.84$).

6.3.4. Ability to Experience Chills

To test H3, the ability to experience chills was assessed using the German Music Preference Questionnaire-Revised (MPQ-R; Nater et al., 2005) in the pre-screening before the baseline session. The MPQ-R measures various aspects of music listening and music preferences. In addition to preferences for different music genres such as pop, rock and hip hop, the MPQ-R comprises open questions about favorite music and artists or groups, as well as an approximate indication of the time spent listening to music per day. Further reasons for listening to music, the personal importance of music, and the frequency and intensity of musical chills are also included in the questionnaire. To operationalize the ability to experience chills, the item "Please indicate how often you experience chills when listening to music" of the MPQ-R was assessed and included in the analyses as a moderator variable.

6.4. Procedure

The recruitment of the participants started in Marburg, Germany in 2016 and was carried out through advertisements on public bulletin boards, social media, and announcements in university lectures. In 2024, the study was advertised with a new flyer (see Appendix B) titled Music for Stress Management: A Music-Based Intervention Study, which was created by the author of this thesis and invited interested individuals to email their contact information. Once contact was established via email, an appointment was scheduled for the initial screening over the telephone. The study followed a two-step screening approach to identify and exclude individuals who met the exclusion criteria. After the telephone interview, which gathered demographic and health-related information, positively screened participants were asked to fill out various online questionnaires in order to account for further detailed inclusion and exclusion criteria.

6.4.1. Screening Interview

The telephone interview started with a general explanation of the study, then potential participants were asked whether they were able to attend 12 appointments (baseline, 10 music listening sessions, and the post-session) in the laboratory over the next three weeks as well as a follow-up session 4 weeks after the post-measurement. If the potential participant was available for all 13 appointments, the interviewer proceeded with the screening questions.

Following the telephone interview, participants who met the inclusion criteria received an appointment for the baseline measurements, as well as an email with detailed study information and the consent form for participation, informing participants that they could withdraw from the study at any time without providing a reason. Regarding the detailed study information, the following instructions were included for all subsequent appointments:

- No intake of any analgesic medication on the days of study appointments.
- No use of body lotion or other fatty agents on the chest area before appointments to minimize artifacts in electrocardiogram (ECG) recordings.
- No drinking of alcoholic and/or energizing beverages or food, no smoking, and no excessive exercising or relaxation techniques (e.g., meditation, yoga) for at least 1 hour prior to study appointments.
- Wearing comfortable clothing during appointments. In case of wearing a brassiere, it should be one without a metal underwire to avoid distortion of the ECG data.

Then, participants were instructed to fill out the informed consent in order to get the link to the online questionnaires, which had to be completed up to two days before the baseline appointment.

6.4.2. Baseline

Baseline appointments, as well as all subsequent appointments were conducted within the premises of the University of Vienna, specifically the Music and Health Lab located at Liebiggasse 5, 1010 Vienna. The laboratory of the MINTREP study consists of two rooms. In the first room all measurements for the baseline, post and follow-up appointments took place, while the second room was reserved for the music interventions. All appointments were scheduled exclusively between 12:00 p.m. and 06:00 p.m. in accordance with research findings indicating the influence of chronobiological rhythms on the outcome variables, specifically the perception of pain and stress parameters (Hagenauer et al., 2017; Sammito et al., 2016).

The baseline appointment measured initial biomarkers of stress and pain, as well as some secondary and tertiary variables (see Figure 1). At the end of the baseline appointment, all the music intervention appointments (M1-M10) and the post-session and follow-up session were scheduled with the participants.

6.4.3. Music Listening Interventions (M1-M10)

After the baseline appointment, the intervention period started, where the participants attended 10 sessions of music listening interventions (M1-M10) over a three-week period.

Additionally, the sessions M1, M3, M6 and M10 involved a cold pressor test (CPT) and the measurement of biological stress markers.

Depending on the type of music intervention (frequency-modulated researcher-selected music, non-modulated researcher-selected music and non-modulated self-selected music), participants listened to different music for 60 minutes. In the self-selected condition, participants were instructed to bring their own music, which was catalogued at every session by the researcher. However, the researcher-selected music conditions consisted of six different albums, which were played during M1 to M10 (Table 1). The music was consistent in both the modulated and unmodulated conditions, with the only distinction being the presence of frequency modulation in one condition and its absence in the other. In the frequency-modulation condition the music got gradually more strongly modulated in later sessions.

Table 1

Overview of the music in researcher-selected conditions

ML session	Title of Album	Artist
1	Well-balanced	Oliver Shanti
2	AVWF–Classics I	AVWF®
3	QE2; Earth Moving	Mike Oldfield
4	Violine Volume I	AVWF®
5	The Beatles; The Beatles	Munich Symphonic Sound Orchestra; Classic Dream Orchestra
6	same as Session 1	
7	same as Session 4	
8	same as Session 5	
9	same as Session 3	
10	Guitar I	AVWF®

Note. ML session = Music listening session

From Efficacy, Treatment Characteristics, and Biopsychological Mechanisms of Music-Listening Interventions in Reducing Pain (MINTREP): Study Protocol of a Three-Armed Pilot Randomized Controlled Trial by A. C. Feneberg et al., 2020, Frontiers in Psychiatry, 10, https://doi.org/10.3389/fpsyt.2020.518316

6.4.4. Post- and Follow-Up Session

Following the music intervention period, a post-session was conducted to evaluate the immediate effects. The same variables as those measured at the baseline session were collected. Subsequently, three to four weeks after the post appointment, participants attended a follow-up session, which had the purpose of assessing potential long-term effects of the music listening interventions and measured the same variables as baseline and post-appointment.

After the follow-up appointment all participants were provided with a debriefing via e-mail. Furthermore, they were invited to identify the condition they suspected they had been administered in order to ensure that the blinding process had been successful.

7. Analysis

7.1. Sample

The power analysis for this thesis was conducted with G*Power, with a medium effect size of Cohen's f = 0.25, a power of 80% and an alpha level of 0.05 for a repeated measures analysis of variance (ANOVA) with three measurements (baseline, post-session, follow-up) and three groups, resulting in a total sample size of 30 participants for H1 and H2. For H3 the power analysis yielded 77 participants. Therefore, all 27 participants who fully completed the study were included in the analysis. Consequently, the results related to H3 must be considered preliminary, as the required sample size was not achieved.

Participants' ages ranged from 20 to 33 with a mean age of 24. 63% of the participants were female, and all 27 participants were students. Both chronic stress levels and perceived stress reactivity were higher than in the normative samples (Table 2), whereas the mean chills frequency across all participants was M = 7.25 on a scale of 0 to 100, with Min = 0 and Max = 31.75, indicating that participants experienced overall very few chills during the music intervention sessions (see Figure 2).

Table 2

Assessed Stress Levels with Regard to the Normative Sample

	Variable	Min	Max	Mean	t value	Normative Sample
Stress	SSCS	12	40	22.7	t = 60	t = 50
	PSRS	29	57	39.81	/	20-25

Note. SSCS = screening scale for chronic stress values; PSRS = perceived stress reactivity scale values; Min = minimum value in the sample; Max = maximum value in the sample; Mean = arithmetic mean in the sample. For chronic stress (SSCS), the associated t-value (t = 60) is also given, whereby the value in the normative sample is t = 50. The mean range for perceived stress reactivity (PSRS) is 20 to 25 in the normative sample, whereas in the present study PSRS = 39.81.

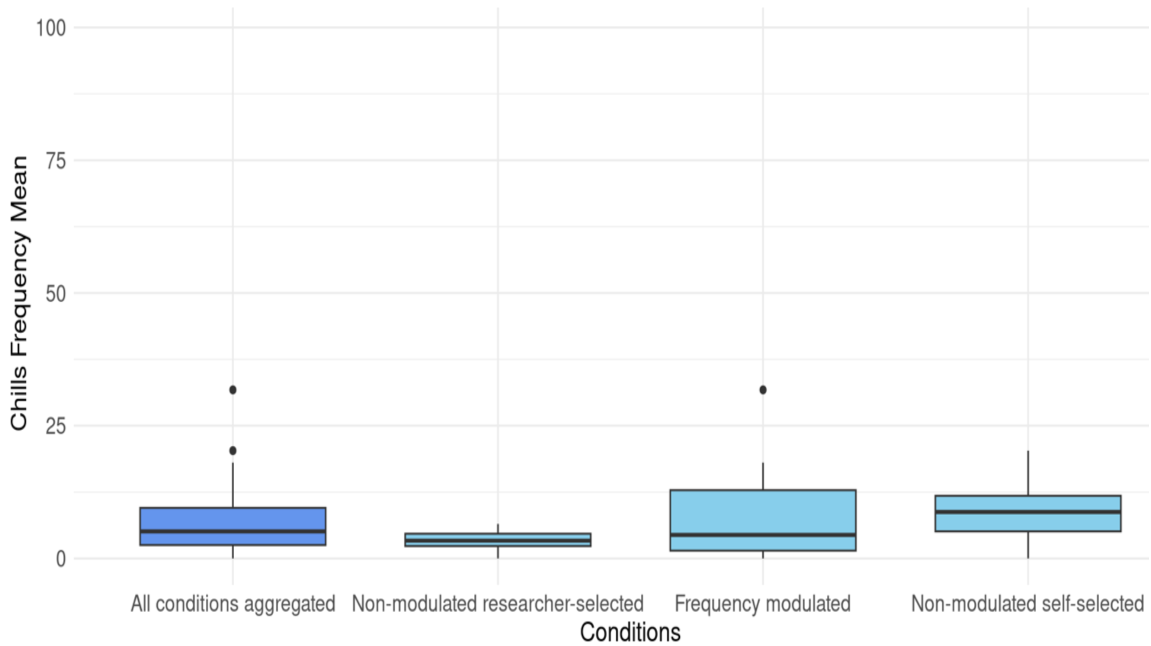

Figure 2

Boxplot of Chills Frequency Mean

Note. The figure displays a boxplot of the mean chills frequency across the different music intervention conditions. The x-axis displays the three music intervention conditions, along with an aggregated category representing all participants across all conditions. The y-axis represents the visual analog scale (VAS) scores ranging from 0 to 100, indicating the frequency of chills experienced by participants, suggesting that the mean chills frequency was very low across all conditions.

7.2. Statistical Analysis

First, to investigate whether chronic stress levels were influenced by the frequency of musical chills (H1), a repeated-measures ANOVA was conducted with the baseline, post and follow-up timepoints as the within-subjects factor Time and type of music intervention as the between-subjects factor Group. Chills frequency was included as a continuous variable to examine its effect on the change in chronic stress levels, represented by SSCS values, over time.

Beforehand, the normal distribution of SSCS values was determined using the Shapiro-Wilk test (baseline: $W = 0.93$, $p = .075$; post: $W = 0.95$, $p = .263$; follow-up: $W = 0.95$, $p = .192$), as well as distribution plots (see Figure 3), which indicated no significant deviations from normality. Further, homogeneity of variances was assessed using Levene's test at all three time points ($F(2, 78) = 0.093$, $p = .911$), indicating no significant violation of the homogeneity assumption. In addition, the Mauchly test for sphericity was performed and was not significant ($W = 0.83$, $p = .138$), therefore no correction was needed.

The repeated-measures ANOVA was then performed and allowed for the assessment of the main effects Time, Chills and Group, as well as their interactions Time*Chills and Time*Group, including the three-way interaction between Time*Chills*Group.

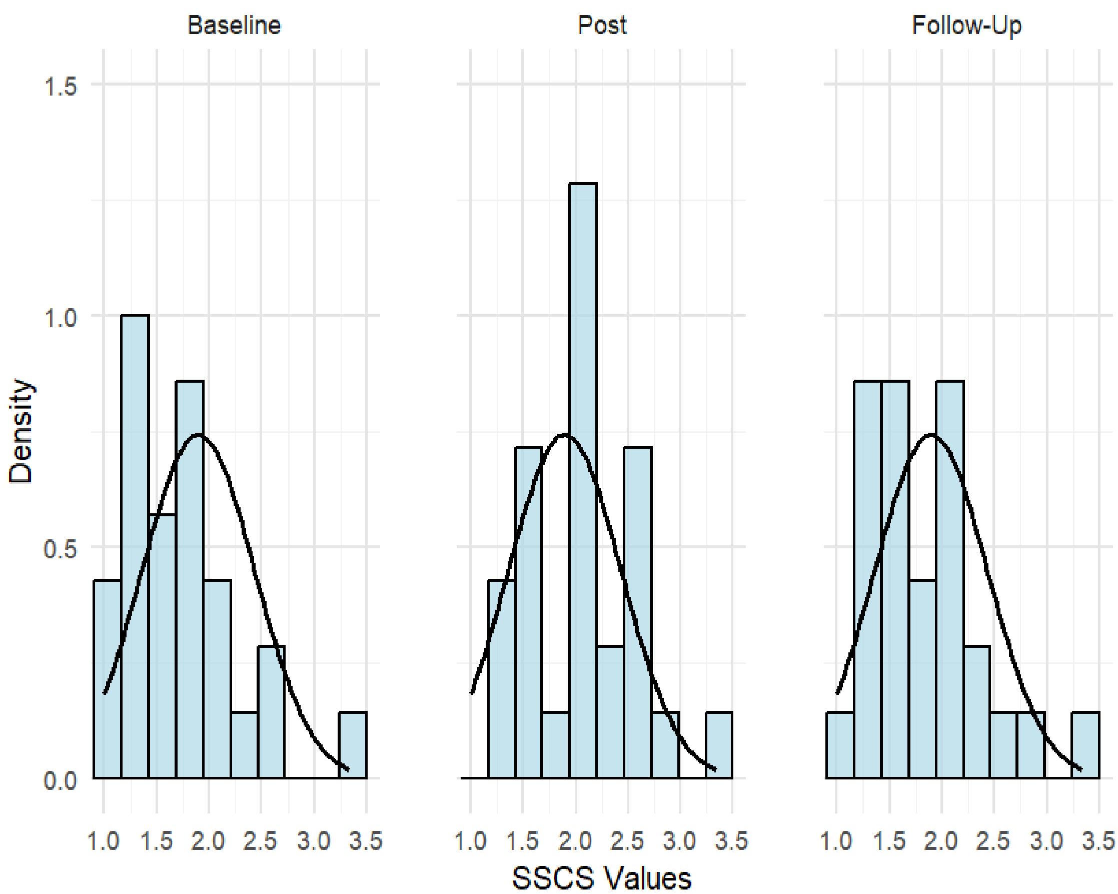

Figure 3

Distribution Plots of SSCS Values

Note. The histograms show the distribution of the values for chronic stress (SSCS) at three different points in time: baseline, post and follow-up. The black curves represent estimates of the normal distribution based on the mean and standard deviation at the respective time points.

Second, a similar approach was used to test whether perceived stress reactivity levels were influenced by the frequency of musical chills (H2). However, the assumption of normal distribution for the PSRS values was violated (baseline: W = 0.93, p = .120; post: W = 0.92, p = .049; follow-up: W = 0.90, p = .016; see Figure 4). Therefore, the non-parametric Friedman test was conducted to identify significant differences in the PSRS values across the three time points. If a significant change in the PSRS values was found, post-hoc tests were planned to test whether the chills frequency had a significant influence on the changes.

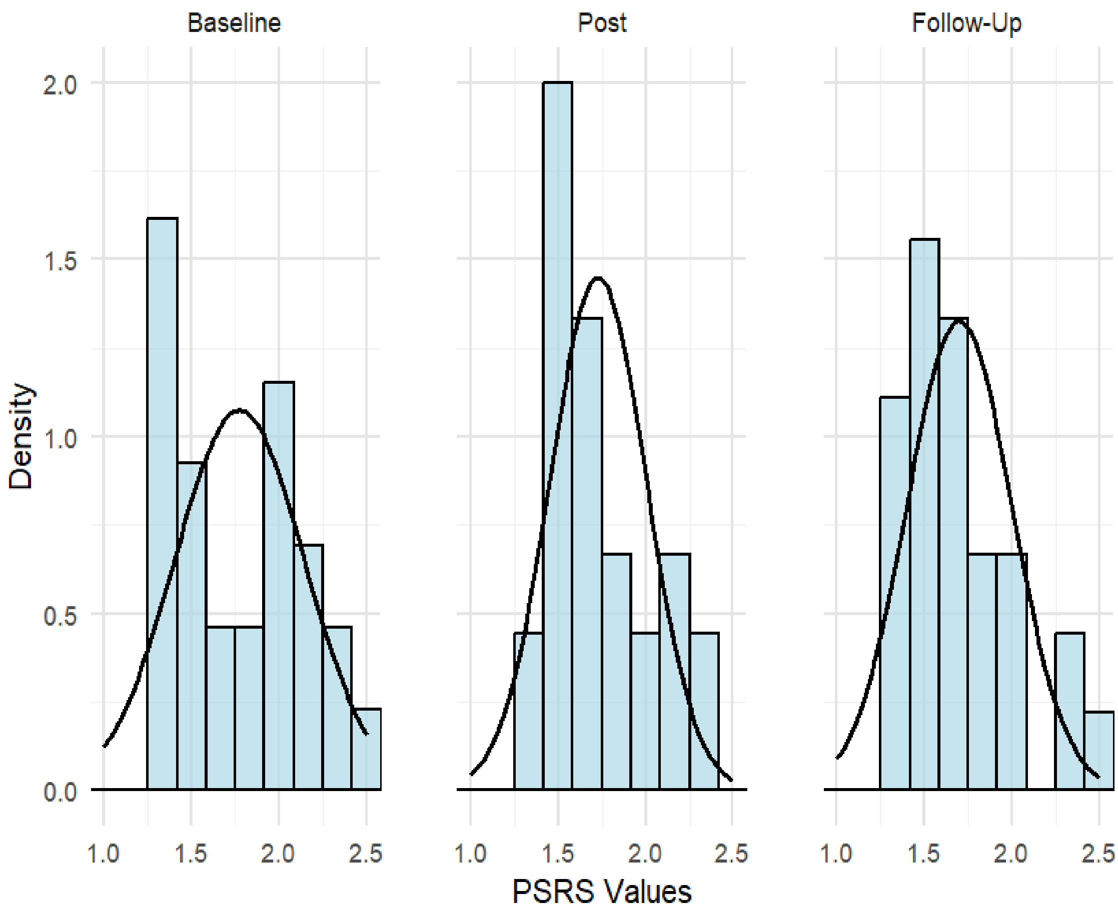

Figure 4

Distribution Plots of PSRS Values

Note. The histograms show the distribution of the values for perceived stress reactivity (PSRS) at three different points in time: baseline, post and follow-up. The black curves represent estimates of the normal distribution based on the mean and standard deviation at the respective time points.

Third, a moderation analysis was conducted to examine whether the ability to experience chills moderates the relationship between music intervention type and chronic stress reduction (H3). Chronic stress reduction was calculated as the difference between baseline and post SSCS values. Given the considerably smaller sample size ($n = 27$, instead of the calculated $n = 77$), a bootstrap analysis with 1000 repetitions was carried out to ensure the reliability of the results despite the small sample. Bootstrapping provided robust estimates of standard errors by repeatedly sampling the data and estimating the desired parameters. The distribution of the residuals ($W = 0.98$, $p = .826$; see Figure 5) did not deviate significantly from normality, meeting the model's normality assumptions. Additionally, the Breusch-Pagan test (BP(3) = 5.548, p = .136) indicated no significant heteroscedasticity, confirming the assumption of homoscedasticity (see Figure 6).

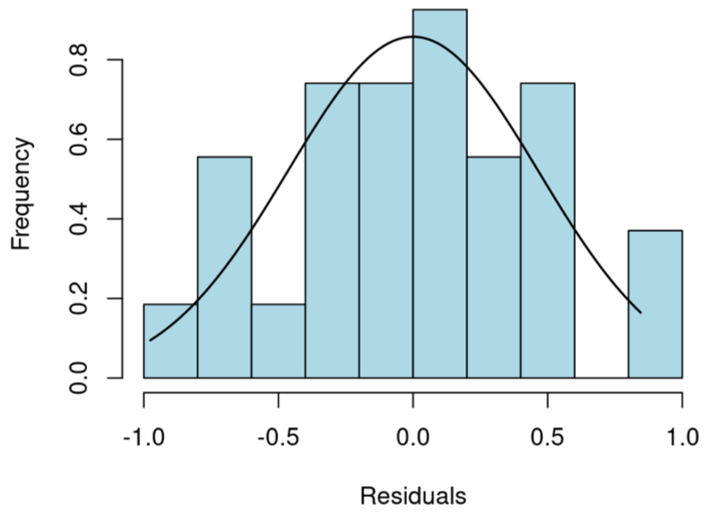

Figure 5

Distribution Plot of Residuals

Note. The histogram shows the distribution of the residuals of the regression model with the normal distribution curve applied. The residuals appear to be approximately normally distributed, with no extreme skewness or outliers, which supports the assumption that the model is normally distributed.

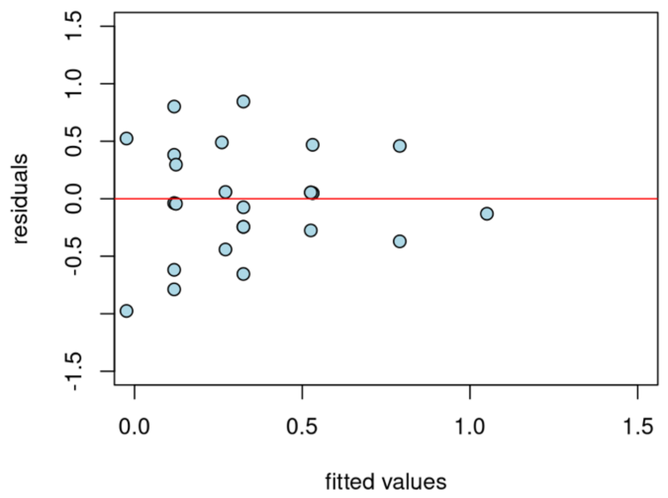

Figure 6

Scatterplot of Residuals vs. Fitted Values

Note. The residuals appear to be randomly scattered around zero, with no clear pattern, funnel shape or systematic trend, indicating that the assumption of homoscedasticity is met.

8. Results

8.1. Hypothesis 1

The main effect of Time on SSCS scores of the repeated-measures ANOVA (F(2, 46) = 4.0655, p = .024, η_p^2 = 0.150 , see Figure 7) was significant, indicating that the chronic stress values of the participants did varied significantly across the three time points (see Figure 8). The interaction Chills*Time was not significant (F(2, 46) = 0.216, p = .806, η_p^2 = 0.009), just as the interaction effect Group*Time (F(2, 46) = 2.447, p = .098, η_p^2 = 0.096), indicating that neither the frequency of chills nor the different types of music interventions influenced the chronic stress values significantly. Finally, the three-way interactions between Time*Chills*Group were also not significant (F(2, 46) = 0.857, p = .431, η_p^2 = 0.036).

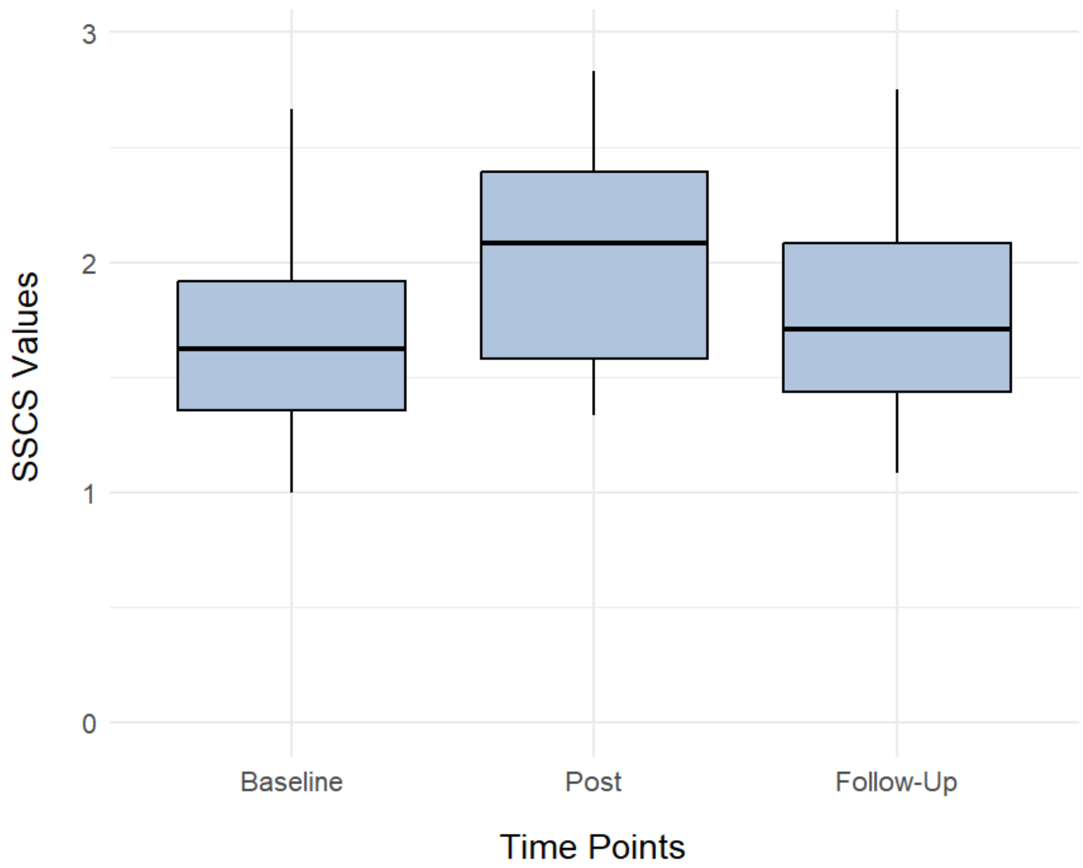

Figure 7

Boxplot of Chronic Stress at Baseline, Post and Follow-Up

Note. The figure shows the distribution of Screening Scale of Chronic Stress (SSCS) values across the three time points. The boxplots indicate that SSCS values remained relatively stable over time, contradicting the statistical analysis that found a significant effect of time on chronic stress levels.

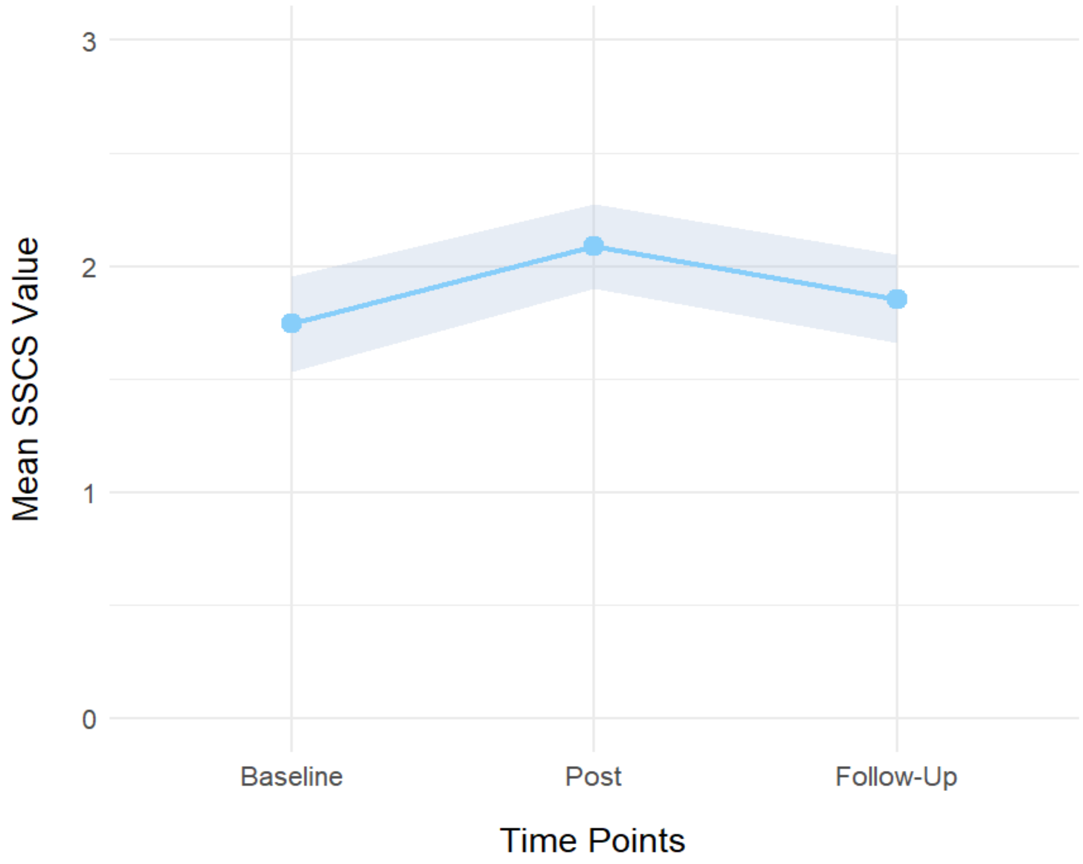

Figure 8

Chronic Stress Over Time

Note. The figure shows the mean values of chronic stress (SSCS) for the baseline, post and follow-up measurements. The y-axis represents the mean SSCS values, while the x-axis indicates the time points. The blue line shows the mean SSCS score of all participants, while the shaded area displays the 95% confidence interval (CI). Although the CIs overlap, the statistical analysis identified a significant effect of time, indicating that chronic stress levels changed significantly across the timepoints.

8.2. Hypothesis 2

As displayed in Figure 9, the results of the Friedman test showed that there were no statistically significant differences in PSRS values across the baseline, post, and follow-up time points ($\chi^2(2) = 1.596$, $p = .450$, Kendall's $W = 0.030$). This suggests that perceived stress reactivity remained stable across the three time points (see Figure 10), which is why no further post-hoc analyses were conducted.

In the present dataset, the PSRS value for one participant was missing at baseline. In order to ensure the complete dataset could be used for analysis, mean imputation was performed. This method was chosen because only a single value was missing, and the potential distortion of the results was therefore considered minimal. Additionally, the results with and without imputation ($\chi^2(2) = 1.26$, $p = .533$, Kendall's $W = 0.023$) were compared and no significant differences were found.

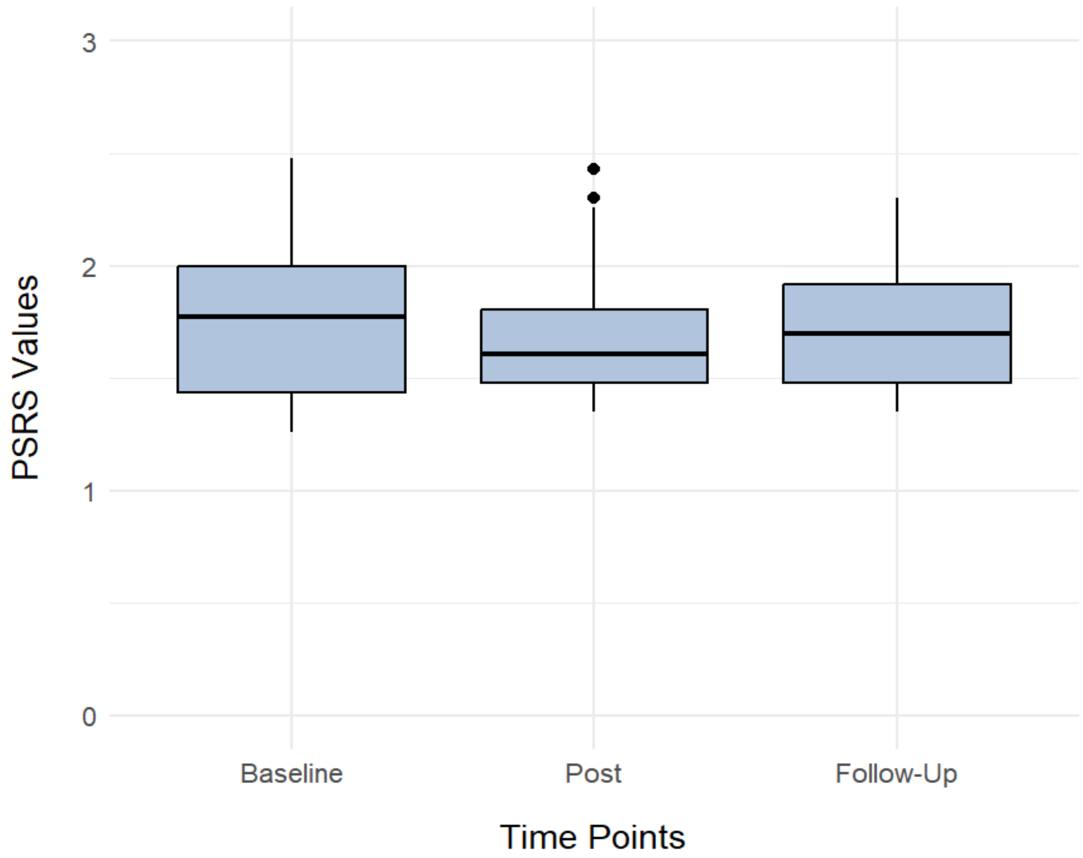

Figure 9

Boxplot of Perceived Stress Reactivity at Baseline, Post and Follow-Up

Note. The figure shows the distribution of the Perceived Stress Reactivity Scale (PSRS) values at three measurement points for the participants. The boxplots show that PSRS scores remained relatively stable over time, with no significant changes in the median or overall distribution, which is consistent with the non-significant results of the statistical analysis.

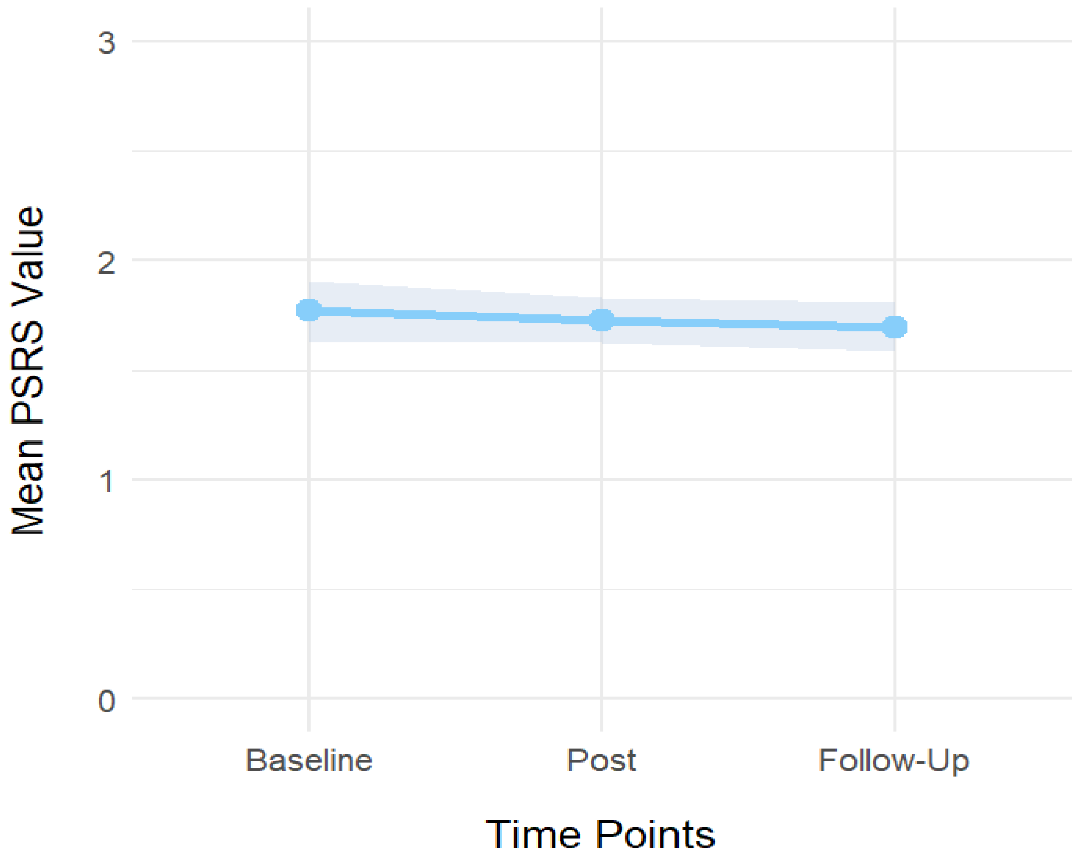

Figure 10

Perceived Stress Reactivity Over Time

Note. The figure displays the mean Perceived Stress Reactivity Scale (PSRS) values across, post, and follow-up time points. The y-axis represents the mean PSRS value, while the x-axis indicates the time points. The blue line connects the mean PSRS values at each time point, and the shaded area illustrates the 95% confidence interval, suggesting that perceived stress reactivity remained stable across the three measurement points.

8.3. Hypothesis 3

The bootstrap analysis provided confidence intervals (CI) for the estimated effects. In the non-modulated researcher-selected music condition (0), the results showed that stress levels did not change significantly ($t(6) = -2.147$, $p = .075$; 95%-CI = [0.776; 2.798]). Likewise, no significant changes were found in the frequency-modulated researcher-selected music condition (1; $t(8) = -0.641$, $p = .539$; 95%-CI = [-0.123; 1.274]) and the non-modulated self-selected music condition (2; $t(7) = -0.652$, $p = .535$; 95%-CI = [-1.347; 2.971]). Furthermore, the interaction effect between music condition and chills was not significant ($t(23) = 0.445$, $p = .661$; 95%-CI = [-0.289; 0.320]), indicating that the ability to experience chills did not moderate the impact of music interventions on stress reduction. However, the 95%-CI = [-0.624; -0.052] showed a significant negative effect of the ability to experience chills frequently on stress reduction. Therefore, an exploratory simple regression analysis was conducted with chills as a predictor of stress reduction. This analysis revealed a significant negative association ($t(25) = -2.273$, $p = .032$, Cohen's $d = -0.91$), which indicates that individuals who experience chills more frequently tend to show greater reductions in stress levels, independent of the music condition (see Figure 11).

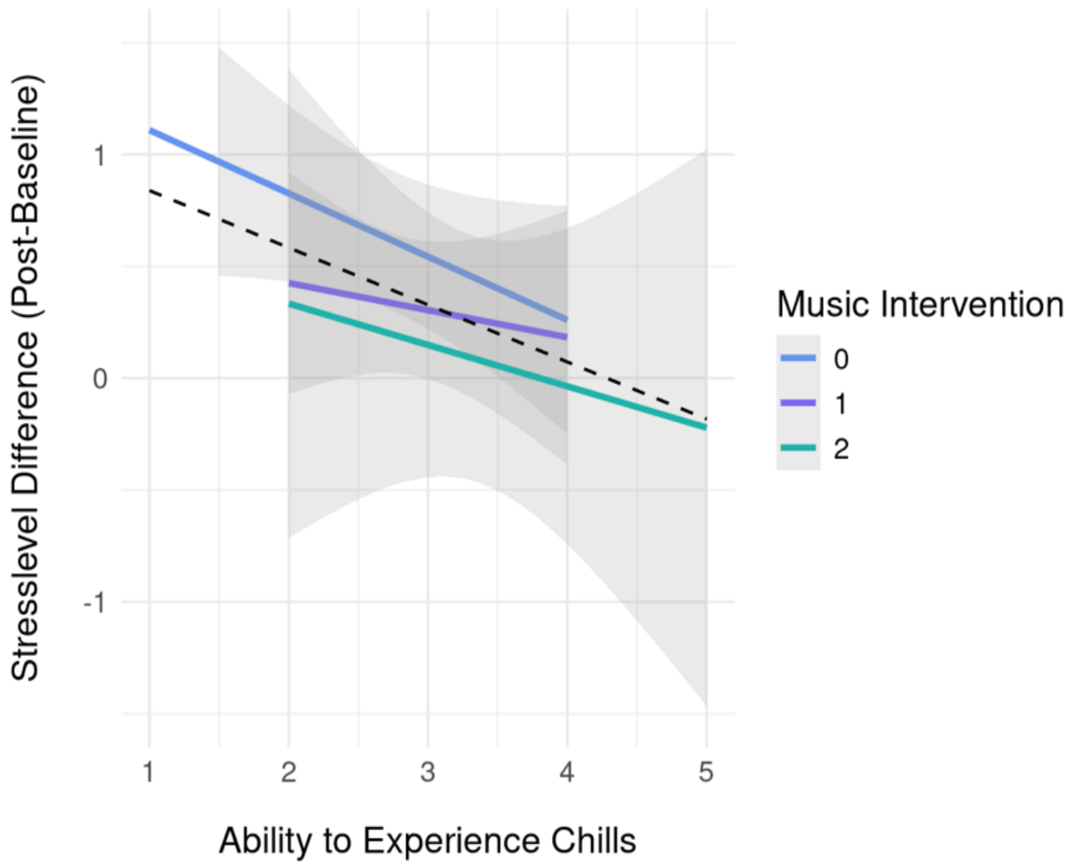

Figure 11

Effect of the Ability to Experience Chills on Stress Across Music Conditions

Note. This figure illustrates the relationship between the ability to experience chills and the changes in stress levels across the three music intervention conditions. Positive stress level values indicate an increase in stress, whereas negative values represent a decrease in stress from baseline to post. The colored lines represent the linear regression estimates for each condition (0 = non-modulated researcher-selected music, 1 = frequency-modulated researcher-selected music, 2 = non-modulated self-selected music), while the shaded areas around the lines indicate 95% confidence intervals. The regression slopes suggest that the ability to experience chills did not moderate the relationship between music condition and stress level changes, as the trends across conditions are largely parallel and the confidence intervals overlap. A significant main effect of chills frequency on stress reduction was observed, indicating that individuals who experience chills more frequently tend to show greater reductions in stress levels, independent of the music condition, which can be seen by the black dashed line representing the overall regression trend across all conditions.

9. Discussion

In clinical and everyday settings, music has been shown to reduce stress and anxiety and contribute to overall well-being (de Witte et al., 2022). The aim of the present study was to investigate whether strong emotional and physiological processes elicited by music, such as the experience of musical chills, can contribute to stress management.

9.1. Chronic Stress

Contrary to hypothesis H1, the interaction effect between chills and time was not significant, which indicates that the experience of chills is not associated with a greater reduction of SSCS values over time. Similarly, the interaction between group and time did not show a significant effect, indicating that the type of music intervention did not systematically reduce SSCS values either. However, a significant main effect of time was observed, indicating that chronic stress levels changed across the three timepoints. Interestingly, visualizations (see Figure 7 and Figure 8) did not reveal a strong or consistent pattern of change. Therefore, the effect might be due to high interindividual variability, which may be explained by individual differences in response to music (Juslin & Västfjäll, 2008). Despite the lack of a clear visual trend, however, the significant main effect of time indicates that music interventions had an effect on chronic stress independent of chills frequency and intervention type.

In contrast to H1, the analysis of H3 showed that SSCS values did not change significantly over time. However, this discrepancy between H1 and H3 may reflect differences in statistical power rather than contradictory effects, as the moderation analysis in H3 was likely underpowered to detect interaction effects (see Limitations). Otherwise a similar pattern was found for hypothesis H3. Thus, neither the music interventions nor the acute chills frequency during the intervention had a significant effect on SSCS values and no moderation effect of chills was found. Therefore, H3 which examined whether the ability to experience more chills moderated the relationship between different types of music interventions and reduction of SSCS values was rejected.

Additionally, an interesting finding was observed, namely that individuals who reported experiencing chills more frequently in general showed a significantly greater reduction in chronic stress than participants who reported experiencing chills less often. This exploratory finding stands in contrast to the results observed in H1, wherein the frequency of chills during the intervention did not influence stress reduction. One possible explanation for this contradiction could be that people who generally experience chills more frequently are more sensitive to emotional responses to music, which might enhance music's effectiveness in stress management, independent of the intervention. This aligns with previous research showing that the tendency to experience chills is strongly associated with the Big-Five personality trait Openness to Experience (Bannister, 2020; Nusbaum & Silvia, 2011). Since Openness to Experience has been linked to greater emotional engagement with aesthetic stimuli (Nusbaum & Silvia, 2011), it is possible that individuals high in this trait derive stronger emotional and psychological benefits from music, which may explain their greater stress reduction. Alternatively, it is possible that the number of chills reported during the intervention period was simply too low to have an observable effect on stress (see Limitations).

9.2. Perceived Stress Reactivity

Hypothesis H2 proposed that participants with a higher frequency of chills experiences would exhibit a greater decrease in PSRS values over time. However, PSRS values remained stable across the three time points, and no significant interaction with chills frequency was found. Consequently, H2 got rejected, indicating that experiencing chills more often does not improve the perceived stress reactivity.

Another possible explanation for the non-significant result derives from the fact that perceived stress reactivity is considered a relatively stable personality trait that cannot be easily changed by short-term interventions (Schlotz et al., 2011). While music has been shown to modulate acute stress responses (Thoma et al., 2013), there is a lack of research regarding the long-term effects of music on PSRS values. As Schlotz et al. (2011) have reported, the intensity of stress exposure and its appraisal have the capacity to modify perceived stress reactivity. Nevertheless, it is possible that the intervention period of three weeks and the subsequent follow-up session after one month might have been too short to find significant effects.

9.3. Limitations

When interpreting the results, some methodological and content-related limitations must be considered, as they can affect the validity of the study. First, the non-significant results may be due to the small sample size ($n = 27$), which was lower than the originally calculated sample sizes (H1 and H2: $n = 30$; H3: $n = 77$). This limitation reduces the statistical power, making it more difficult to find an effect. Additionally, the sample consisted exclusively of students who had higher stress levels compared to the normative samples, which could limit the generalizability of the results to other population groups.

Second, a methodological limitation is the low number of chills experiences reported during the intervention period (M = 5.74 on a scale of 0 to 100). This might have confounded the potential effects of chills on stress reduction, as a higher frequency of chills might be required to observe significant effects.

Third, the questionnaires on the chills experiences were based on subjective self-reports. Although self-report questionnaires are an established method for measuring subjective experiences, they can be subject to bias, for example through retrospective memory or individual differences in interpretation. However, while some physiological markers have been explored for recording chills, findings were inconsistent, as it is not clear whether they occur before, during or after chills. This uncertainty makes it difficult to directly link physiological markers to chills, which is why self-report instruments remain the most commonly used method in practice (de Fleurian & Pearce, 2021).

9.4. Practical Implications

The present thesis provides first insights into how the experience of musical chills may be associated with stress management. Although the direct effect of chills during the intervention on stress reduction was not significant, the finding that individuals with a generally higher chill frequency showed a greater reduction in chronic stress values suggests a potential benefit of chill-inducing music.

These findings could be utilized in the design of future music-based interventions by specifically selecting pieces of music that have been shown to trigger chills. Individualized music selection could therefore be an effective strategy to increase the stress-reducing effect of music.

9.5. Prospects for Future Research

Future research should focus on further investigating the potential influence of musical chills on stress reduction while addressing the limitations of this thesis. Future longitudinal studies could investigate whether repeated exposure to music that is actually chill-inducing has an effect on stress management over time. Additionally, extending the research beyond laboratory conditions and incorporating everyday experiences of listening to music could strengthen external validity and provide insights into whether and how chills could be involved in everyday stress regulation.

Further, most existing studies rely on retrospective questionnaires, making objective assessments of chills and their effects on stress reduction a critical area for further research. While physiological changes during chills have been observed (e.g., Benedek & Kaernbach, 2011; Blood & Zatorre, 2001; Salimpoor et al., 2011), empirical inconsistencies remain (e.g., Mori & Iwanaga, 2017), which prevents the establishment of reliable physiological markers for chills. Future research should therefore focus on developing and validating physiological measures of chills, possibly through studies that look more closely at physiological correlates before, during, and after chills.

It is important to note that the present thesis was conducted using data from the MINTREP study, which means that the conditions for investigating the phenomenon of chills were not fully optimized, as reflected in the low number of reported chills. Therefore, several recommendations for future research can be made.

9.5.1. Mock Study

First, using certain pieces of music that reliably elicit chills could help increase the frequency of chills. Music that is particularly effective in triggering chills, like music that contains harmonic changes (Auricchio, 2017; Bannister, 2020; Bannister & Eerola, 2018; Guhn et al., 2007) or acoustic changes such as sudden increases in volume (Auricchio, 2017; Guhn et al., 2007; Mori & Iwanaga, 2017), should be selected. Additionally, emotional factors, including emotional intensity (Bannister & Eerola, 2018; Rickard, 2004) and the personal meaning of the music (Bannister, 2020; Goldstein, 1980), should be assessed as they play a role in the experience of chills.

Second, the targeted selection of participants who are particularly responsive to musical stimuli could be considered an inclusion criterion. Given that the Big-Five personality factor Openness to Experience has been reported as one of the best predictors to trigger chills (Bannister, 2020; Nusbaum & Silvia, 2011; Sumpf et al., 2015), future studies could focus on individuals with high Openness to Experience scores to maximize the occurrence of chills.

Third, to differentiate between the general stress-reducing effects of music and the specific effects of chills, a control group should be included. This group would listen to music unlikely to induce chills, helping to isolate the effect of chills in stress reduction. Without such a comparison, it remains unclear whether any stress-reducing effects observed are due to chills themselves or merely general music listening effects.

10. Conclusion

The present study investigated the potential role of musical chills in stress management. While no significant effects of reported chills during the music interventions on stress were found, individuals with a generally higher tendency to experience chills showed a greater reduction in chronic stress. This suggests that individual differences in susceptibility to musical chills may influence the effectiveness of music-based stress management.

The findings indicate that musical chills could enhance the stress-reducing effects of music, making them a potentially valuable component of music-based interventions. Designing interventions that specifically aim to elicit chills may improve their efficacy, while simply listening to chill-inducing music in everyday life could serve as an easily accessible self-help tool for stress regulation and well-being.

Further research is needed to determine the extent to which chills contribute to stress regulation. Future studies should carefully select music pieces with a high likelihood of inducing chills and incorporate physiological markers for more objective assessments. Additionally, research should explore how targeted chill-inducing music can optimize music interventions and which individual factors influence its effectiveness.

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12. List of Figures

13. List of Tables

14. List of Abbreviations

ANOVA	Anaysis of Variance
ANS	Autonomic Nervous System
APA	American Psychological Association
AVWF	Audio-Visuelle-Wahrnehmungsförderung
BDI-II	Beck’s Depression Inventory II
B-MMR	Brief Music in Mood Regulation Scale
BFI-10	Big-Five-Inventory-10
BSSS	Social Support Scale
CNS	Central Nervous System
CPT	Cold Pressor Test
ECG	Electrocardiogram
EDA	Electrodermal Activity
ERQ	Emotion Regulation Questionnaire
HPA axis	Hypothalamic-Pituitary-Adrenal Axis
HRV	Heart Rate Variability
IFPI	International Federation of the Phonographic Industry
MDMQ-short	short Multidimensional Mood Questionnaire
ME-MS	Music Empathizing-Systemizing Inventory
MFI-20	Multidimensional Fatigue Inventory
MINTREP	Music-Listening Interventions in Reducing Pain
ML session	Music Listening Session
MPQ-R	Music Preference Questionnaire revised
PHQ-D	Patient Health Questionnaire German Version
PMS questionnaire	Premenstrual Syndrome Questionnaire
PSQI	Pittsburgh Sleep Quality Inventory
PSRS	Perceived Stress Reactivity Scale
SEMs	Strong Experiences with Music
SSCS	Screening Scale for Chronic Stress
TICS	Trier Inventory of Chronic Stress
VAS	Visual Analogue Scale

15. Appendix

15.1. A: Abstracts

15.1.1. Abstract (English)

Music is widely recognized for its ability to regulate emotions and reduce stress. One phenomenon when listening to music is the experience of chills, defined as intense emotional and physiological responses to music that are often accompanied by shivers. While music-based interventions have been shown to reduce stress, there is a lack of research regarding the role of musical chills in stress regulation. This thesis investigates whether individuals who frequently experience chills benefit more from music-based stress interventions. To investigate the relationship between chills and stress reduction, this thesis used data from the Music-Listening Interventions in Reducing Pain (MINTREP) study, a double-blind, randomized, controlled trial. This thesis measured chronic stress levels and perceived stress reactivity in participants (n = 27) undergoing different music intervention conditions. Results indicated that the frequency of chills during music-listening sessions did not significantly predict reductions in chronic stress or perceived stress reactivity. However, an exploratory analysis showed that individuals with a higher general tendency to experience chills exhibited greater reductions in chronic stress over time, which suggests that sensitivity to music-induced emotions may influence the effectiveness of music interventions in stress management. These findings highlight individual differences in music responsiveness and suggest that musical chills could contribute to the optimization of stress-reducing interventions. Future research should explore the role of targeted chill-inducing music and personality traits in enhancing music-based intervention for stress management.

15.1.2. Abstract (German)

Musik ist weithin für ihre Fähigkeit bekannt, Emotionen zu regulieren und Stress abzubauen. Ein Phänomen beim Hören von Musik ist das Erleben von Chills, definiert als intensive emotionale und physiologische Reaktionen auf Musik, die oft von Gänsehaut begleitet werden. Während für musikbasierte Interventionen gezeigt werden konnte, dass sie Stress reduzieren können, fehlt es an Forschung zur Rolle von Chills bei der Stressregulation. In dieser Arbeit wird untersucht, ob Personen, die häufig Chills erleben, mehr von musikbasierten Stressinterventionen profitieren. Um den Zusammenhang zwischen Chills und Stressabbau zu untersuchen, wurden in dieser Arbeit Daten aus der MINTREP-Studie (Music-Listening Interventions in Reducing Pain), einer randomisierten, kontrollierten Doppelblindstudie, verwendet. Es wurden das chronische Stressniveau und die wahrgenommene Stressreaktivität bei Teilnehmern (n = 27) in drei verschiedenen Musikinterventionsbedingungen gemessen. Die Ergebnisse zeigten, dass die Häufigkeit von Chills während des Musikhörens keinen signifikanten Einfluss auf die Verringerung von chronischem Stress oder wahrgenommener Stressreaktivität hatte. Eine explorative Analyse zeigte jedoch, dass Personen mit einer höheren allgemeinen Tendenz zum Erleben von Chills im Laufe der Zeit eine stärkere Verringerung von chronischem Stress zeigten, was darauf hindeutet, dass die Sensibilität für musikinduzierte Emotionen die Wirksamkeit von Musikinterventionen bei der Stressbewältigung beeinflussen könnte. Diese Ergebnisse verdeutlichen die individuellen Unterschiede in der Empfänglichkeit für Musik und legen nahe, dass Chills zur Optimierung stressreduzierender Interventionen beitragen könnten. Zukünftige Forschungen sollten die Rolle von gezielter Chills-induzierender Musik und Persönlichkeitsmerkmalen bei der Verbesserung musikbasierter Interventionen zur Stressbewältigung untersuchen.

15.2. B: Recruitment Flyer