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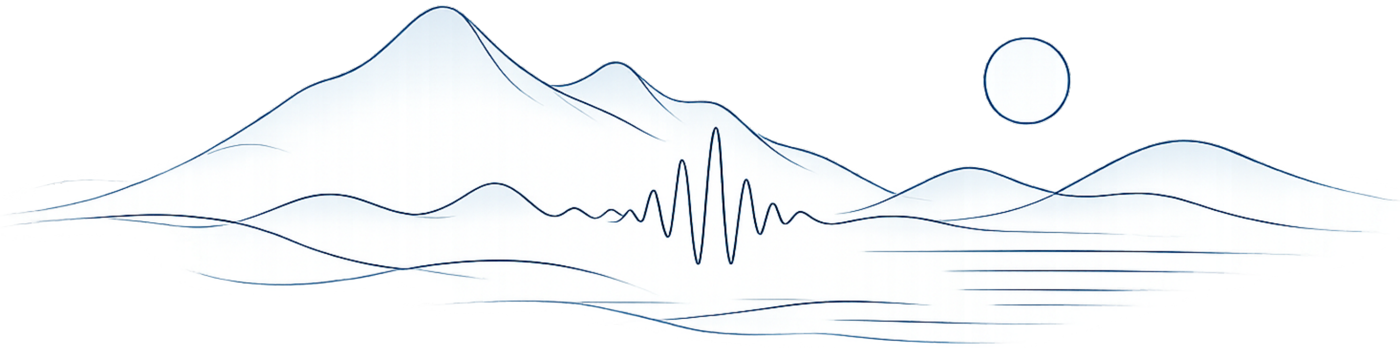

The Impact of Music on Patients' Well-Being in Waiting Rooms

In a Healthcare Environment

Master's thesis in Applied Acoustic

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MASTER'S THESIS 2026:06

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Cover:
Illustrate sound waves transitioning into a harmonious landscape to create a sense of tranquillity (created with AI).

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ABSTRACT

Background. The acoustic environment in healthcare waiting rooms may influence patients' emotional experiences and perceived levels of stress and anxiety before healthcare appointments. Previous research has shown that ambient sound, music, and soundscape perception may affect anxiety, comfort, and the overall healthcare experience. However, there is still limited research comparing different types of sound environments in real waiting room settings.

Aim. The aim of this study was to investigate how different sound environments in healthcare waiting rooms influence patients perceived stress and anxiety levels.

Method. The study was conducted in a real healthcare waiting room at Nötkärnan healthcare center in Gothenburg, Sweden. A quantitative design was applied using a two-part questionnaire based on the State-Trait Anxiety Inventory short form (STAI-6), together with self-reported measures of stress, anxiety, and perception of the sound environment. A total of 205 participants were included and distributed across five sound environments: No Sound, Pink Noise, Classical Music, Nature Sound, and Neutral Music. Statistical analyses included paired T-tests, one-way ANOVA, Tukey HSD post hoc analysis, and descriptive statistics, with Wilcoxon signed-rank tests and a Kruskal-Wallis test conducted as non-parametric robustness checks.

Results. The results showed that the No Sound environment resulted in increased STAI-6 scores post exposure. In contrast, all introduced sound environments showed tendencies toward reduced stress and anxiety levels. Nature Sound produced the largest reduction in STAI-6 scores and, together with Classical Music, showed statistically significant reductions. Pink Noise showed a smaller positive effect, while Neutral Music demonstrated the weakest effect among the introduced sound environments.

Conclusion. The findings indicate that sound environments in healthcare waiting rooms may influence patients' emotional experiences and perceived stress and anxiety levels. In particular, natural sounds appeared to have the strongest potential for contributing to calmer and more restorative healthcare waiting room environments in this study. The study highlights the importance of considering soundscape perspectives and acoustic design as part of future healthcare environments.

Keywords. State anxiety, stress, anxiety, STAI-6, soundscape, healthcare waiting rooms, natural sounds, background music, pink noise, acoustic environment, psychoacoustics.

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Finally, I would like to thank all participants who took the time to take part in the study and thereby made this work possible.

CONTENTS

1 INTRODUCTION

In recent years, the use of sound design (soundscape) in private and public environments has become increasingly common and integrated as a means of shaping the overall architectural atmosphere and enhancing the spatial environment. Furthermore, soundscape is used to evoke specific emotional states to help stabilize and reduce patients' levels of stress and anxiety.

The background music used is often carefully composed to deliberately influence mood, most commonly to evoke feelings of calmness, security, relaxation, and similar states. The effects of sound environments on humans have been studied in a variety of forms and settings, including hospitals and primary healthcare facilities.

Regarding the impact of sound environments on stress and anxiety levels, there is overall some evidence suggesting that background music have attenuating effects on patients, although both music selection and methodology vary considerably across studies [1]. A. Curry emphasizes in her study that music in waiting rooms is more than just background music. Music that influences patients' behaviour, may contribute to an improved healthcare experience and can have a relaxing effect [2]. Similarly, M. Collins et al. highlight that implementing music in waiting rooms can be an effective way to improve the well-being of both patients and healthcare staff [3].

Based on previous studies, classical music is one of the genres most appreciated by patients. It is also one of the music genres, which is most frequently used in several studies to inveterate the impact background music has on patients' state anxiety. However, this may be considered controversial, as classical music was also the genre most associated with experiencing pain among participants who were waiting in the waiting room. [2]. Furthermore, studies indicate that classical music in waiting rooms does not necessarily result in a markedly positive effect on patients' stress and anxiety levels compared to having no background music at all or using another music genre. It is important to match the choice of background music to factors such as tempo, complexity, and how well it integrates with the surrounding environment [4]. In some cases, it may be preferable to adapt the background soundscape and instead use natural sounds [5] or music with a simpler structure [4]. Other studies suggest that waiting rooms with soundscape in general may reduce perceived anxiety, but do not draw specific conclusions regarding which music genres are more or less effective compared to one another [6].

In addition to reducing patients' stress and anxiety levels, background music in waiting rooms is most often associated with reductions in state anxiety. Some studies also indicate that background music can create such a pleasant, comfortable, and calm environment that preoperative anxiety may likewise be reduced [7].

1.1 SCOPE

The scope of this study is to investigate the impact, that different sound environments in a wating room environment, have on patients' stress and anxiety levels before a healthcare appointment. This study will be conducted in a realistic healthcare setting to ensure ecological validity.
The study aims to determine how particularly background music and ambient sounds influence patients' psychological well-being in healthcare waiting areas.

1.1.1 STUDY QUESTIONS

This study seeks to provide practical insights on how to create a more supportive and pleasant waiting room environment by answer the following questions:

- How does the perceived sound environment in waiting rooms affect patients' stress and anxiety levels?

- How do different types of sound environment in waiting rooms influence patients' stress and anxiety levels?

- Which of the used sound environments exposed in waiting rooms has the greatest impact in reducing patients' stress and anxiety levels?

The study is expected to be represented as a further contribution to already existing research within the field of how background music influences patients' stress and anxiety levels in a waiting room setting.

1.2 DELIMITATIONS

This study is limited to the impact of background music in a healthcare centres' waiting room environment. Its focuses on the impact different background music or sound have on patients' stress and anxiety levels prior to a healthcare visit, while excluding the impact of the room acoustic parameters from the investigation.

The background music used for this study limits down to five sound environments, No Music or Sound, Pink Noise, Classical Music, Nature Sound, and Neutral Music.

2 THEORY

To analyse how different acoustic environments influence stress and anxiety in healthcare waiting rooms, a theoretical framework grounded in soundscape research, psychoacoustics, environmental psychology, and stress theory is required. The present chapter introduces the theoretical concepts and previous research relevant to understanding how auditory environments may affect emotional and physiological responses in healthcare settings.

The chapter begins by presenting theories concerning stress and anxiety in healthcare environments, followed by an introduction to the soundscape concept and its relevance within healthcare contexts. Thereafter, psychoacoustics and auditory perception are discussed to explain how humans perceive, interpret, and emotionally respond to sound stimuli. The chapter further explores restorative environments and theories concerning stress recovery and attention restoration. Finally, previous research regarding music and natural sounds in healthcare waiting rooms is reviewed, followed by a presentation of the STAI-6 instrument and self-reported measures used in the study.

2.1 STRESS AND ANXIETY IN HEALTHCARE ENVIRONMENTS

Healthcare environments are often associated with increased levels of stress and anxiety, particularly in situations involving uncertainty, anticipation, and limited control [1], [8]. Waiting rooms may therefore constitute emotionally sensitive environments in which patients experience psychological discomfort prior to consultations, examinations, or treatment. Previous research has shown that environmental conditions, waiting time, and sensory stimuli may influence patients' emotional states and overall healthcare experiences [1], [5].

2.1.1 COGNITIVE APPRAISAL AND STRESS

Lazarus and Folkman [9] describe stress as a process arising through the interaction between the individual and the environment. According to the theory, emotional responses are influenced by cognitive appraisal processes in which individuals evaluate whether situations are relevant to their well-being and whether sufficient coping resources are available.

The theory distinguishes between primary appraisal and secondary appraisal. Primary appraisal concerns whether a situation is interpreted as threatening, stressful, or harmless, whereas secondary appraisal concerns the individual's perceived ability to manage the situation. Lazarus and Folkman further describe coping as the cognitive and behavioural efforts used to manage internal or external demands perceived as stressful [9].

2.1.2 STATE AND TRAIT ANXIETY

Within psychological research, anxiety is commonly categorised into trait anxiety and state anxiety. Trait anxiety refers to relatively stable individual differences in anxiety proneness, whereas state anxiety refers to transient emotional states that vary in intensity and fluctuate over time depending on situational conditions [10].

According to Spielberger and Reheiser [10], state anxiety is characterised by subjective feelings of tension, apprehension, nervousness, and activation of the autonomic nervous system. State anxiety is therefore commonly used to assess temporary emotional responses associated with specific situations or environments.
Previous research has also shown that acoustic conditions in healthcare environments may influence patient comfort and well-being. Busch-Vishniac et al. [11] reported that hospital noise levels frequently exceed recommended guidelines and identified associations between elevated noise exposure, stress, sleep disturbance, and reduced comfort among patients and healthcare staff.

2.2 SOUNDSCAPES IN HEALTHCARE ENVIRONMENTS

Traditionally, research concerning acoustic environments has primarily focused on measurable acoustic parameters such as sound pressure levels, reverberation, and noise exposure. Contemporary soundscape research, however, emphasizes that acoustic environments should also be understood through human perception and contextual experience [12]-[17].

2.2.1 SOUNDSCAPE DEFINITION

According to ISO 12913-1 [18], soundscape is defined as:

> *"The acoustic environment as perceived or experienced and/or understood by a person or people, in context".*

The soundscape concept emphasizes that acoustic environments should be understood through human perception and contextual experience rather than only through physical acoustic measurements [12], [13], [18]. Research concerning hospital soundscapes has similarly shown that patients and healthcare staff perceive acoustic environments in relation to contextual, emotional, and social factors rather than only through sound levels [19].

Schafer [20] introduced the soundscape concept as a way of understanding acoustic environments as experiential phenomena rather than merely collections of sounds. Later soundscape research further incorporated psychoacoustics, environmental psychology, and perceptual evaluation methods into the field [12], [13].

2.2.2 SOUNDSCAPE PERCEPTION AND CONTEXTUAL FACTORS

A central principle within soundscape research is that auditory perception is influenced by contextual factors. Human responses to sound environments depend not only on physical sound characteristics, but also on psychological, social, and situational conditions [13], [15]. Within healthcare environments, patients are often exposed to multiple auditory stimuli, including speech, medical equipment, alarms, ventilation systems, and background music [11]. Previous research concerning healthcare waiting environments has reported associations between ambient acoustic conditions, perceived comfort, and patient experience [8], [1].

Axelsson, Nilsson, and Berglund [21] proposed that soundscape perception can largely be described through the dimensions of pleasantness and eventfulness. Pleasantness refers to how positively or negatively an acoustic environment is perceived, whereas eventfulness refers to the perceived level of activity or stimulation within the environment. Within this framework, pleasant and low-eventful sound environments are commonly associated with calmness and relaxation, whereas highly eventful environments are associated with increased stimulation.

2.3 Psychoacoustics and sound perception

Psychoacoustics concerns how humans perceive, interpret, and respond to sound. The focus is therefore not only on the physical properties of sound, but also on the subjective experience of auditory stimuli [17], [22]. Auditory perception is influenced not only by acoustic characteristics such as frequency, intensity, and temporal variation, but also by psychological, emotional, and contextual factors [15], [17].

Genuit and Fiebig [17] describe that human hearing differs from conventional acoustic measurement because the auditory system interprets sound in relation to perception, attention, and context. This means that an acoustic environment cannot be fully understood only through physical measurements such as sound pressure level. Fastl and Zwicker [22] further describe that auditory perception is influenced by characteristics such as loudness, frequency content, temporal variation, and the structure of sound signals. These psychoacoustic aspects are relevant when comparing different waiting room sound environments, since music, natural sounds, and hospital noise may differ not only in sound level, but also in how they are perceived by listeners.

Within soundscape research, human perception of the acoustic environment is considered central [12]-[17]. Axelsson, Nilsson, and Berglund [21] showed that soundscape perception can largely be described through the dimensions of pleasantness and eventfulness. These dimensions are relevant for understanding why different sound environments may be experienced as calming, stimulating, pleasant, or unpleasant. The perception of sound is therefore both subjective and context dependent [13], [15]. In healthcare waiting rooms, where patients may experience uncertainty and anticipatory stress, the perceived character of the sound environment may be relevant for understanding stress, anxiety, and comfort [1], [10].

2.4 Stress, anxiety and restorative environments

Research within environmental psychology has shown that environmental conditions may influence both psychological and physiological responses related to stress and recovery [14], [16]. Restoration research concerns how certain environments may support recovery from stress, mental fatigue, and attentional demands.

2.4.1 ATTENTION RESTORATION THEORY

Attention restoration theory describes restoration as a process through which directed attention may recover after mental fatigue [23]. Kaplan [23] explains that environments containing restorative qualities may support recovery by reducing demands on directed attention and promoting psychological restoration.

Natural environments and natural stimuli have frequently been discussed within restoration research because they are considered capable of engaging attention in a less demanding and more effortless way [14], [23]. Within environmental psychology and soundscape research, restorative environments are therefore often associated with reduced stress, improved well-being, and recovery from mental fatigue [14].

2.4.2 STRESS RECOVERY THEORY AND BIOPHILIA

Ulrich [24] describes stress recovery as a process involving affective and physiological responses to environmental stimuli. According to Stress Recovery Theory, exposure to natural environments may contribute to reduced physiological stress responses and more positive emotional states. Ulrich [25] further demonstrated that surgical patients exposed to natural views recovered faster and required less analgesic medication compared to patients exposed to urban wall views.

Related perspectives have also been presented through the biophilia hypothesis, which describes humans as having an inherent tendency to respond positively to natural environments and natural stimuli [26]. Within environmental psychology and soundscape research, natural sounds such as water, wind, and birdsong have therefore frequently been associated with restorative and calming qualities [14], [16], [26].
Previous soundscape research has also shown that environments dominated by natural sounds are often perceived as more pleasant than environments dominated by technological sounds [21]. Research concerning stress recovery and restorative soundscapes has therefore increasingly examined how natural acoustic environments may contribute to reduced stress and improved well-being [14], [24].

2.5 MUSIC AND NATURAL SOUNDS IN WAITING ROOM

Previous research has investigated how music and natural sounds may influence emotional responses, stress, and patient experiences within healthcare environments [1], [4], [6]. Waiting rooms have received particular attention because patients often experience uncertainty, anticipation, and elevated anxiety prior to consultations or treatment [8], [6].

2.5.1 MUSIC INTERVENTIONS IN HEALTHCARE ENVIRONMENTS

Music interventions in healthcare settings have frequently been associated with reduced anxiety and improved emotional comfort [1], [4], [6]. Lai and Amaladoss [1] describe how background music in waiting rooms may influence emotional states, perceived waiting time, and overall patient experience.
Lundberg et al. [6] conducted a systematic review and meta-analysis concerning waiting room ambience and reported that environmental interventions, including

music, were associated with reduced stress and anxiety among patients undergoing medical treatment.
Research has also examined physiological stress responses related to music listening. Thoma et al. [27] investigated psychobiological stress responses and reported that music listening influenced autonomic recovery following stress exposure. Nilsson [28] further reported lower cortisol levels among cardiac surgery patients who listened to calming music during postoperative rest compared to control groups.

Several studies have additionally discussed how musical characteristics such as tempo, familiarity, volume, and genre may influence emotional responses to music [1], [4]. Previous research therefore suggests that responses to music may vary depending on both listener-related and contextual factors.

2.5.2 NATURAL SOUNDS AND RESTORATIVE SOUNDSCAPES

Natural sounds have frequently been discussed within restoration and soundscape research because they are commonly associated with pleasant and restorative environments [14], [16]. Research concerning restorative soundscapes has often focused on sounds such as birdsong, flowing water, and wind in vegetation [14].

Alvarsson, Wiens, and Nilsson [27] investigated physiological stress recovery during exposure to natural sounds and environmental noise. Their results showed faster physiological recovery during exposure to natural sounds compared to noise exposure.
Previous soundscape research has also shown that environments dominated by natural sounds are generally perceived as more pleasant than environments dominated by technological sounds [21]. Within healthcare environments, natural sounds have therefore increasingly been discussed as potentially supportive acoustic elements in restorative healthcare design [14], [24].

2.5.3 CONTEXTUAL AND INDIVIDUAL FACTORS

Previous research has shown that emotional responses to music and sound environments may vary depending on contextual and individual factors [1], [4], [13], [15]. Research concerning music listening has further shown that music may serve functions related to mood regulation, arousal regulation, emotional processing, and self-awareness [29].

Yeoh and Spence [4] further describe that background music in healthcare waiting rooms may produce both positive and negative responses depending on factors such as music selection, playback level, and listener preference. Soundscape research similarly emphasises that acoustic environments are experienced in relation to contextual and perceptual factors rather than solely through physical sound characteristics [12], [13].

2.6 STAI-6 AND SELF-REPORTED MEASURES

Self-reported questionnaires are commonly used within psychological and healthcare research to measure subjective emotional states such as anxiety, stress, and psychological well-being [10], [30]. These instruments allow individuals to rate their own experiences using standardized questions and response scales. Since anxiety is considered a subjective emotional state, self-reported measures are regarded as suitable for assessing how individuals experience anxiety in specific situations [10].

One of the most widely used instruments for measuring anxiety is the State-Trait Anxiety Inventory (STAI), developed by Spielberger et al. [31]. The instrument distinguishes between temporary state anxiety and more stable trait anxiety [10], [31]. The original STAI consists of 40 items divided into two separate 20-item scales measuring state anxiety and trait anxiety respectively [31], [32]. The state scale measures how a person feels "right now", whereas the trait scale measures how a person generally feels [32].

Spielberger and Reheiser [10] describe state anxiety as a temporary emotional condition characterised by feelings of tension, apprehension, nervousness, and increased autonomic activity. This makes state anxiety relevant in studies where temporary emotional responses are examined in relation to specific situations or environmental conditions.

To enable shorter and more time-efficient assessments, Marteau and Bekker [30] developed a shortened six-item version of the state scale, commonly referred to as STAI-6. The shortened version was designed to maintain acceptable validity and reliability while reducing the time required for assessment and has been shown to correlate well with the full version of the STAI [30].

Self-reported measures are frequently used within healthcare and environmental psychology research because emotional responses to environmental conditions are subjective and context dependent [13], [15]. When questionnaires consist of multiple items intended to measure the same construct, internal consistency is commonly assessed using reliability measures such as Cronbach's alpha [33].

3 METHOD

This study is a questionnaire-based study conducted in a waiting room in a realistic environment at Nötkärnan healthcare center in Masthugget, Gothenburg, see Figure 1.

Figure 1. Nötkärnan health care centers' waiting room.

For this type of study, a quantitative study with a two-part questionnaire and a within-subjects design, is a powerful way to measure the direct effect, "a pre and post effect" [34]. To minimise non-responder the questionnaire was designed with a high degree of standardisation and a clear structure [35].
This is very important in a realistic healthcare environment, where the participants that choose to contribute to the study are real patients visiting the healthcare center for their own needs. They may otherwise not have the time or energy to complete the questionnaire.
Therefore, the questionnaire was short and had a simple design to follow. Each part consisted of a shortened 6-item State Trait Anxiety Inventory (STAI-6) along with a couple statements about stress and anxiety levels.
In addition, the first part of the questionnaire also included questions to collect general participants information, such as age and gender, while the second part contained a few multiple-choice questions regarding the overall perception of the waiting room environment (See Appendix A for the full questionnaire).

Sample size was calculated using the software G*power, by specifying the statistical power, the effect size, α-level and the number of tails.

The required sample size for this study was 41, based on a statistical power of 80%, an estimated effect size of 0.45, which is similar to effect sizes reported in previous research [4], an α-level of 0.05 and a two-tailed test.

3.1 PROCEDURE

The participants for the study were the patients visiting the healthcare center.
Before entering the healthcare center and the waiting room, everyone was asked to participate in the study and complete a two-part questionnaire. Those who consented to participate was handed the first part of the questionnaire to complete before entering the healthcare center.
After finishing the first part, participants were given the second part of the questionnaire, along with instructions to complete it in the waiting room after sitting there for 5–10 minutes while waiting for their appointment.
To prevent the participants' responses on the second part from being influenced by how they answer the first part, they were required to submit the first part before receiving the second part of the questionnaire.

To ensure that the first part was properly organised together with the corresponding second part after it was collected, each questionnaire was numbered and colour coded. The colour coding was used to prevent the questionnaire from being mixed up. Each colour corresponded to the appropriate sound environment presented that day.

3.2 SETUP

To provide sufficient coverage and an even distribution of sound energy in the waiting room, three Sonos ERA100 loudspeakers were installed, one in "each corner". Figure 2 shows the floor plan of the waiting room, with loudspeaker placements indicated by red markers. The loudspeakers were mounted at a height above the floor corresponded to a sited ear level. For even better sound distribution, wall mounting would have been preferable.

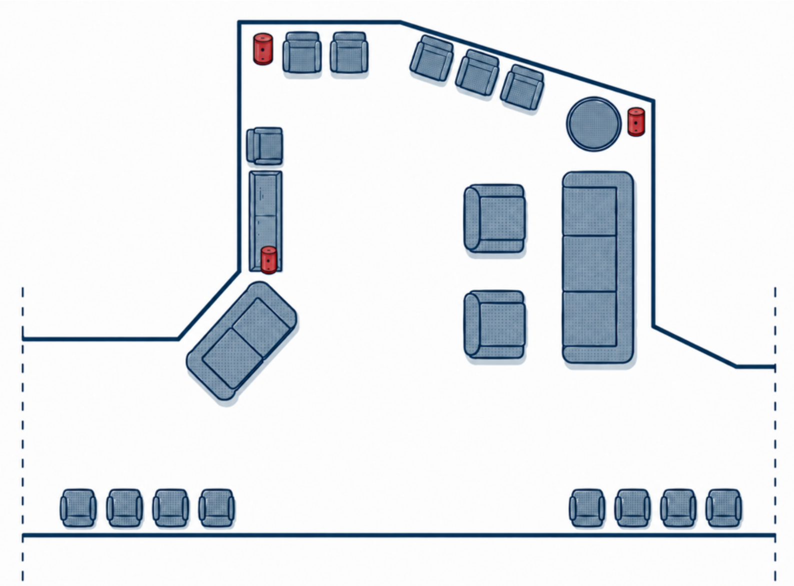

Figure 2. Layout of the waiting room, with loudspeaker locations indicated by red dots. (Created with AI).

The loudspeaker was connected to the WIFI to synchronise with one another.
Each loudspeaker was also configured so that the manual control buttons on the units were disabled. The systems' settings could only be controlled via my Sonos account. This was done to prevent unauthorised persons to accessing the controls, for example adjusting the volume or turning the speakers off.
In addition, the maximum volume was also set to a limit of 35% of the system's full capacity to minimise the risk of excessive sound levels due to accidental adjustments. This limit was also considered appropriate for the acoustic environment of the waiting room.

The sound system was connected to a media player, a computer or phone either, through an aux cable or via WIFI, see connection illustration in Figure 3.

Figure 3. Illustration of the sound system setup, with a computer connected to a loudspeaker through an aux cable and connected to a phone via WIFI. (Created with AI).

Furthermore, to achieve an optimal auditory experience and perception of the perceived sound in the waiting room, it is important to acknowledge the room acoustics properties of the space. As this is already well established and lies outside the scope of this study, the room acoustic conditions of the conducted waiting room were not modified.

3.3 Sounds Environment

The music and sound material used in the experiment were selected in collaboration with the former Sound Architects Division at AFRY, now operating under the company Ljudkontoret.

Each playlist was carefully composed so that all tracks shared a similar energy level and were designed to emphasise a specific atmosphere. The playlists were played in the waiting room as a separate sound environment on different days. In total, five sound environments were used, as listed below in no particular order.

- Sound environment 1: No Sound (baseline)
- Sound environment 2: Pink Noise

- Sound environment 3: Classical Music (Master Piano)
- Sound environment 4: Nature Sound
- Sound environment 5: Neutral Music (Master Puls)

The Classical Music sound environment (Master Piano) consisted of calm classical piano tracks, including works by composers such as Frédéric Chopin and Claude Debussy. The Neutral Music sound environment (Master Pulse) consisted of mainstream style remixes and electronic tracks within genres such as pop, tropical house, deep house, disco, and electronic music. Detailed descriptions and complete track lists for the Classical Music, Nature Sound, and Neutral Music sound environments are provided in Appendices B, C, and D, respectively.

3.4 DATA PROCESSING AND STATISTICAL ANALYSIS

The collected questionnaire data were processed and analysed quantitatively. STAI-6 scores were calculated for each participant pre and post exposure to the assigned sound environment. Positively worded items within the STAI-6 scale, including "calm", "relaxed", and "content", were reverse scored before calculating the total score. The total STAI-6 score was calculated by summing the six item scores and multiplying the sum by 20/6, in accordance with the STAI-6 scoring procedure [31]. The change in STAI-6 score was then calculated as the difference between the post exposure and pre exposure scores.

Descriptive statistics were used to summarise the collected data. Mean values and standard deviations were calculated to describe the average responses and the variation within each sound environment.

To examine whether the differences between the pre and post exposure STAI-6 scores within each sound environment were statistically significant, paired T-tests were conducted. To compare the change scores between the five sound environments, a one-way analysis of variance (ANOVA) was performed. When the ANOVA indicated statistically significant differences, Tukey's Honestly Significant Difference (HSD) post hoc test was applied to identify which sound environments differed significantly from one another [33].

Although the individual STAI-6 items are ordinal, the analyses were performed on the reverse-scored and summed STAI-6 score. To assess the robustness of the parametric analyses, additional non-parametric tests were conducted. Wilcoxon signed-rank tests were used as an alternative to the paired T-tests, and a Kruskal–Wallis test was used as an alternative to the one-way ANOVA.

Equation 1 presents the Tukey HSD calculation used to determine the minimum difference between group means required for statistical significance.

Equation 1. Tukey HSD.

$$HSD = q_{crit} \cdot \sqrt{\frac{MS_{within}}{n}}$$

where:
q_{crit} is the critical value from the studentized range distribution.
MS_{within} is the within-group mean square from the ANOVA.
n is the number of observations per group.

To evaluate the strength of observed differences between sound environments, effect size was calculated using eta squared (η^2). Eta squared describes the proportion of the total variance explained by the differences between groups.

Equation 2. Effect size (η^2).

$$\eta^2 = \frac{SS_{between}}{SS_{Total}}$$

where:
$SS_{between}$ is the variation explained by the differences between groups.
SS_{total} is the total variation in the data.

Standard error (SE) was further used to estimate the uncertainty surrounding mean differences between paired measurements.

Equation 3. Standard error (SE).

$$SE = \frac{SD_{diff}}{\sqrt{n}}$$

where:
SD_{diff} is the standard deviation of the differences between paired measurements.
n is the number of paired observations.

To estimate the uncertainty around the mean difference, 95% confidence intervals were calculated.

Equation 4. Confidence interval (CI).

$$\mathrm{CI}_{95\%} = \bar{\mathrm{d}} \pm \mathrm{t}_{crit} \cdot \frac{SD_{diff}}{\sqrt{n}}$$

where:
$\bar{\mathrm{d}}$ is the mean defiance between pre and post exposure scores.
t_{crit} is the critical t-value.
SD_{diff} is the variation in the differences.
n is the number of participants.

To assess the internal consistency of the STAI-6 questionnaire, Cronbach's alpha (α) was calculated for each sound environment pre and post exposure. Cronbach's alpha is commonly used to evaluate the reliability of questionnaire scales and describes how consistently the questionnaire items measure the same underlying construct [33].

Table 1 presents commonly used interpretation levels for Cronbach's alpha.

Table 1. Interpretation of Cronbach's alpha values.

Alpha [α]	Interpretation
< 0.60	Weak
0.60–0.69	Acceptable
0.70–0.79	Good
0.80-0.89	Great
≥ 0.90	Perfect

Previous research has shown that STAI-6 demonstrates acceptable to good validity and reliability and correlates well with the full version of the State-Trait Anxiety Inventory [31].

4 RESULT

As mentioned in Chapter 3 the study consisted of five different sound environments, No Sound, Pink Noise, Classical Music, Nature Sound, and Neutral Music. Each sound environment included a group of 41 unique participants, with no participant's contribution to more than one sound environment.

In Table 2 below, the general data collected about each group are shown.

Table 2. Participant data across sound environment.

Participant data	No Sound	Pink Noise	Classical Music	Nature Sound	Neutral Music	Total
n_{total}	41	41	41	41	41	205
Age_{total}						
- Range	18-70+	18-70+	20-70+	18-70+	18-70+	18-70+
- $Mean_{range}$	50-59	50-59	60-69	50-59	50-59	50-59
Male						
n_{male}	19	15	18	17	14	83
n_{male} (%)	46.3%	36.6%	43.9%	41.5%	34.1%	40.5%
Age_{male}						
- Range	18-70+	30-70+	20-70+	30-70+	40-70+	18-70+
- $Mean_{range}$	50-59	60-69	60-69	60-69	60-69	60-69
Female						
n_{female}	22	26	23	24	27	122
n_{female} (%)	53.7%	63.4%	56.1%	58.5%	65.9%	59.5%
Age_{female}						
- Range	20-70+	18-70+	20-70+	18-70+	18-70+	18-70+
- $Mean_{range}$	50-59	50-59	60-69	50-59	50-59	50-59

The study included, in total, 205 participants equally divided in each sound environment group. The mean age range is in general 50-59 years across the sound environments, except for the Classical music group, where the mean age range was 60-69 years. Out of all participants, 122 were females and 83 were males. All participants included in Table 2 completed both the before- and the after-questionnaire for respectively sound environment.

4.1 STAI-6

Based on the collected questionnaire data the mean STAI-6 scoring was calculated with the reverse scoring method of the positive items (Calm, Relaxed and Content), for each sound environment, which is shown Table 3.

Table 3. Mean STAI-6 scores pre and post exposure to different sound environments.

Sound Environment	Mean (STAI-6)						
	Calm	Tense	Upset	Relaxed	Content	Worried	Total
No Sound							
- *Pre*	1.80	1.76	1.17	2.20	1.88	1.63	34.80
- *Post*	2.20	1.95	1.49	2.59	1.98	1.63	39.43
Pink Noise							
- *Pre*	1.68	1.68	1.15	1.95	1.78	1.49	32.44
- *Post*	1.56	1.66	1.17	1.68	1.56	1.63	30.89
Classical Music							
- *Pre*	1.59	1.59	1.17	2.12	1.90	1.52	32.93
- *Post*	1.59	1.37	1.17	1.95	1.76	1.44	30.89
Nature Sound							
- *Pre*	2.02	1.83	1.24	2.17	1.98	1.76	36.67
- *Post*	1.71	1.51	1.12	1.83	1.78	1.41	31.22
Neutral Music							
- *Pre*	1.66	1.63	1.10	2.02	1.90	1.51	32.76
- *Post*	1.73	1.78	1.12	1.78	1.73	1.46	32.03

Table 4 presents the standard deviations of STAI-6 scores pre and post exposure for each sound environment.

Table 4. STAI-6 standard deviation pre and post exposure to different sound environments.

Sound Environment	No Sound	Pink Noise	Classical Music	Nature Sound	Neutral Music
Standard Deviation					
- Pre	10.22	10.49	10.70	13.00	10.51
- Post	10.43	10.38	9.72	11.27	10.13
- Total	6.23	6.24	6.19	9.6	5.08

Figure 4 illustrates the mean STAI-6 scores pre and post exposure to the different sound environments. The No Sound condition resulted in an increase in mean STAI-6 scores, whereas all sound environments produced reductions in anxiety levels. The largest reduction was observed for Nature Sound, followed by Classical Music and Pink Noise. Neutral Music showed only a minor decrease. Error bars indicate one standard deviation (SD) above and below the mean.

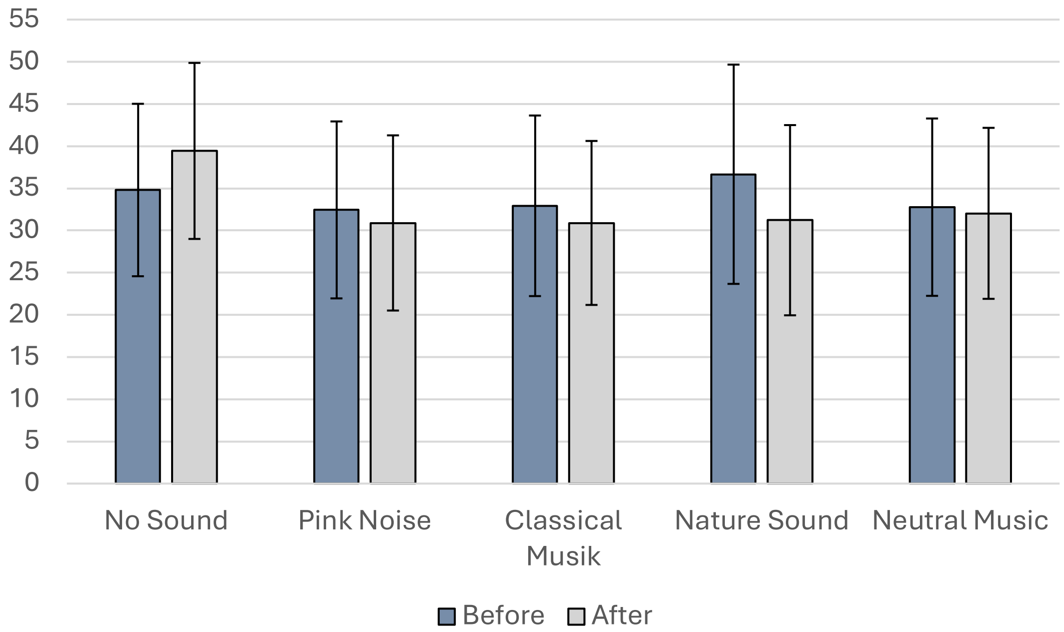

Figure 4. Mean STAI-6 scores pre and post exposure to each sound environment. Error bars represent standard deviation (SD) for each corresponding sound environment.

NO SOUND. For the No Sound environment, the mean STAI-6 score pre exposure was 34.80 (SD = 10.22). Post exposure, the mean increased to 39.43 (SD = 10.43), which indicates a mean change of +4.63 (SD = 6.23).

PINK NOISE. The mean STAI-6 score for the Pink Noise environment, was 32.44 (SD = 10.49) and 30.89 (SD = 10.49), pre and post exposure respectively. This indicates a mean change of -1.56 (SD = 6.24).

CLASSICAL MUSIC. For the Classical Music environment, the mean STAI-6 score decreased from 32.93 (SD = 10.70) pre exposure to 30.89 (SD = 9.72) post exposure. This corresponds to a mean change of -2.03 (SD = 6.19).

NATURE SOUND. In the Nature Sound environment, the mean STAI-6 score decreased from 36.67 (SD = 13.00) to 31.22 (SD = 11.27), which indicates a mean change of -5.45 (SD = 9.60).

NEUTRAL MUSIC. For the Neutral Music environment, the mean STAI-6 score pre exposure was 32.76 (SD = 10.51). Post exposure, the mean decreased to 32.03 (SD = 10.13). This corresponds to a mean change of -0.73 (SD = 5.08).

4.1.1 ASSESSMENT OF NORMALITY

Visual inspection of the histograms and Q-Q plots indicated that the distribution of ΔSTAI-6 scores had a symmetric tendency across all sound environments. As shown in Figure 5 to Figure 14, minor deviations from normality were observed for No Sound, Nature Sound and Neutral Music. However, no substantial deviations from normality or extreme outliers were identified.

No Sound.

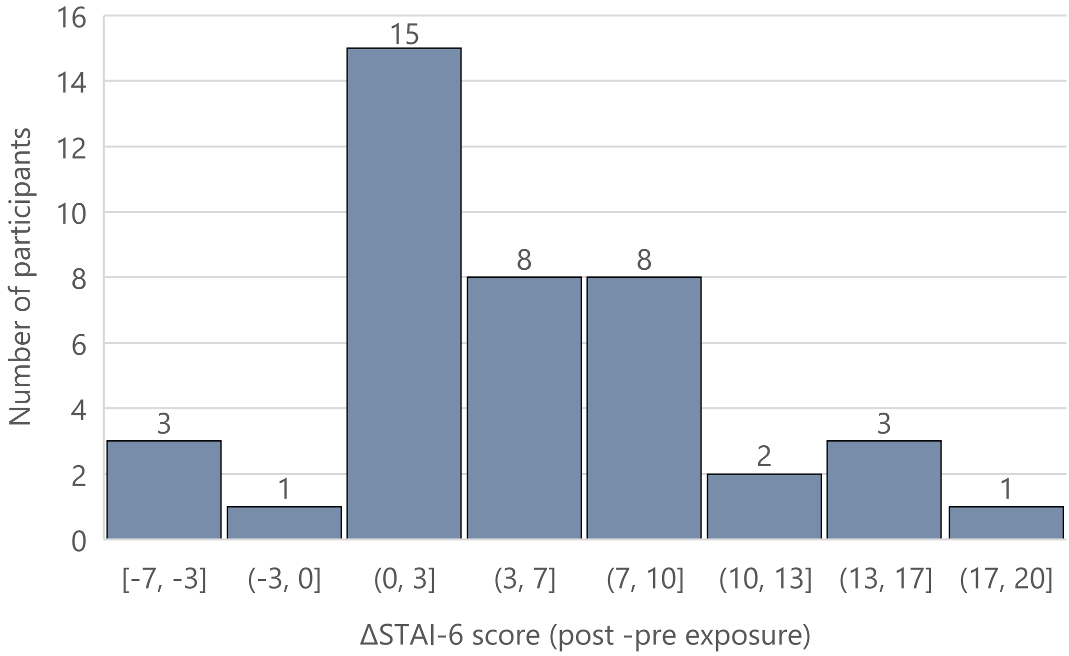

Figure 5. Histogram of ΔSTAI-6 scores post - pre exposure of No Sound environment.

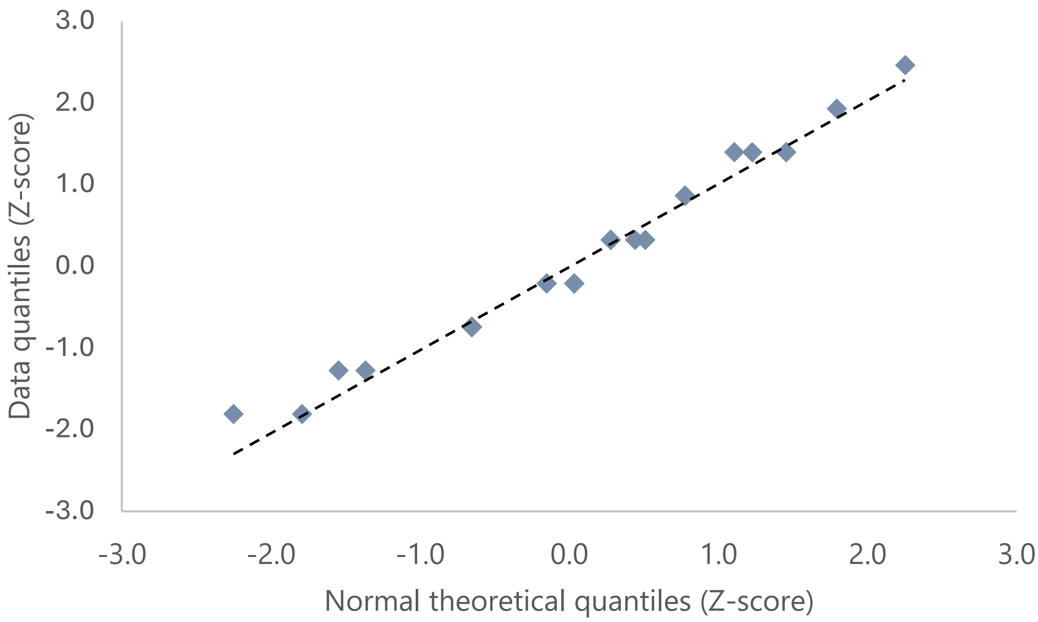

Figure 6. Q-Q plot of ΔSTAI-6 scores post - pre exposure of No Sound environment.

Pink Noise.

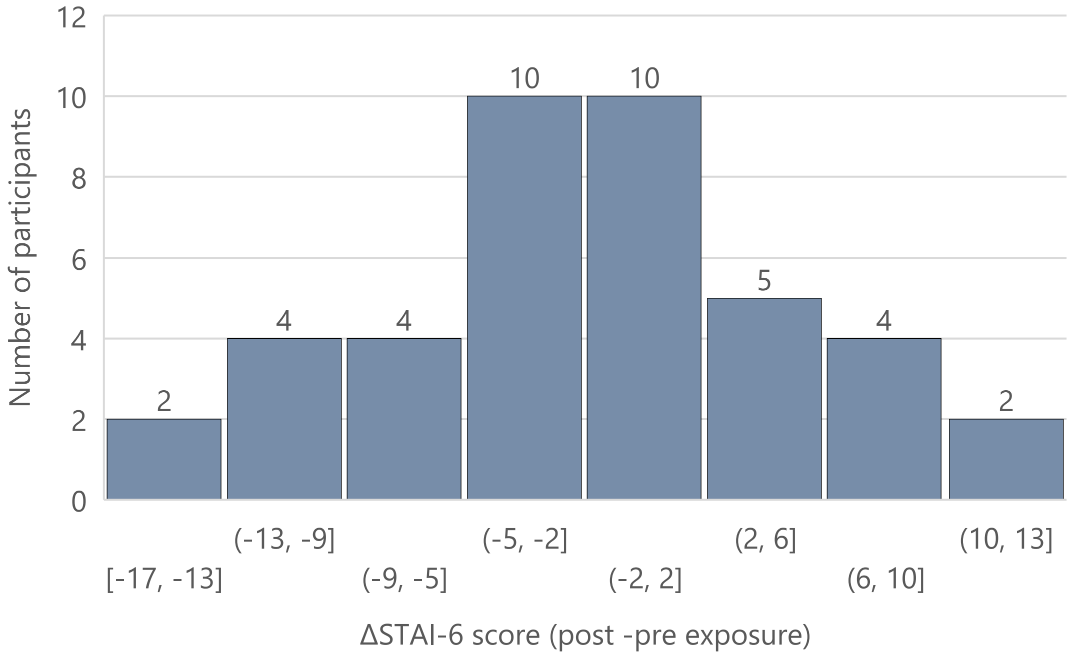

Figure 7. Histogram of ΔSTAI-6 scores post - pre exposure of Pink Noise environment.

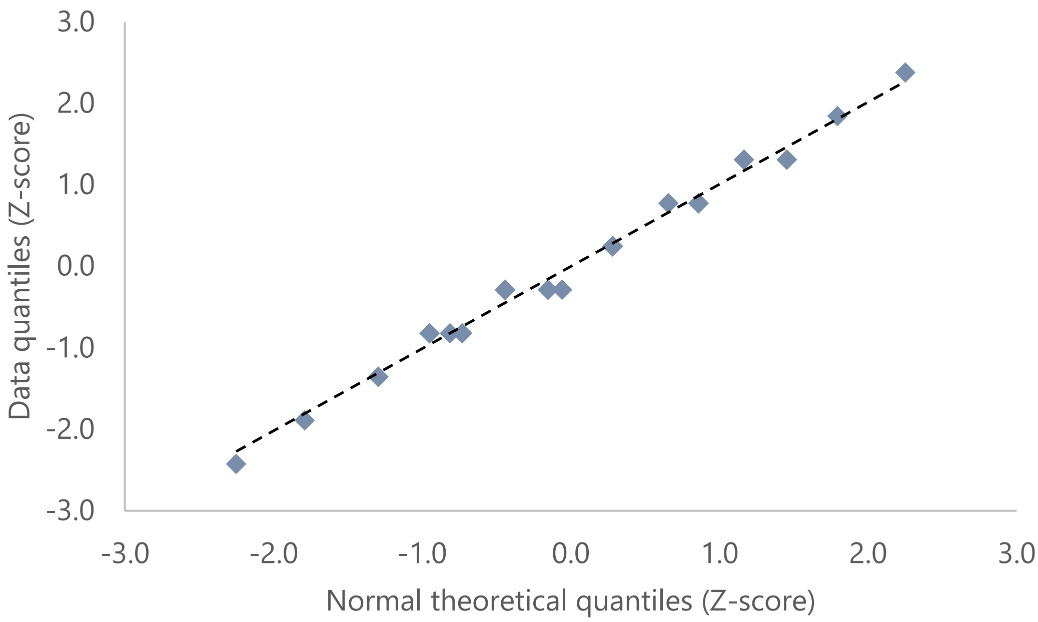

Figure 8. Q-Q plot of ΔSTAI-6 scores post - pre exposure of Pink Noise environment.

Classical Music.

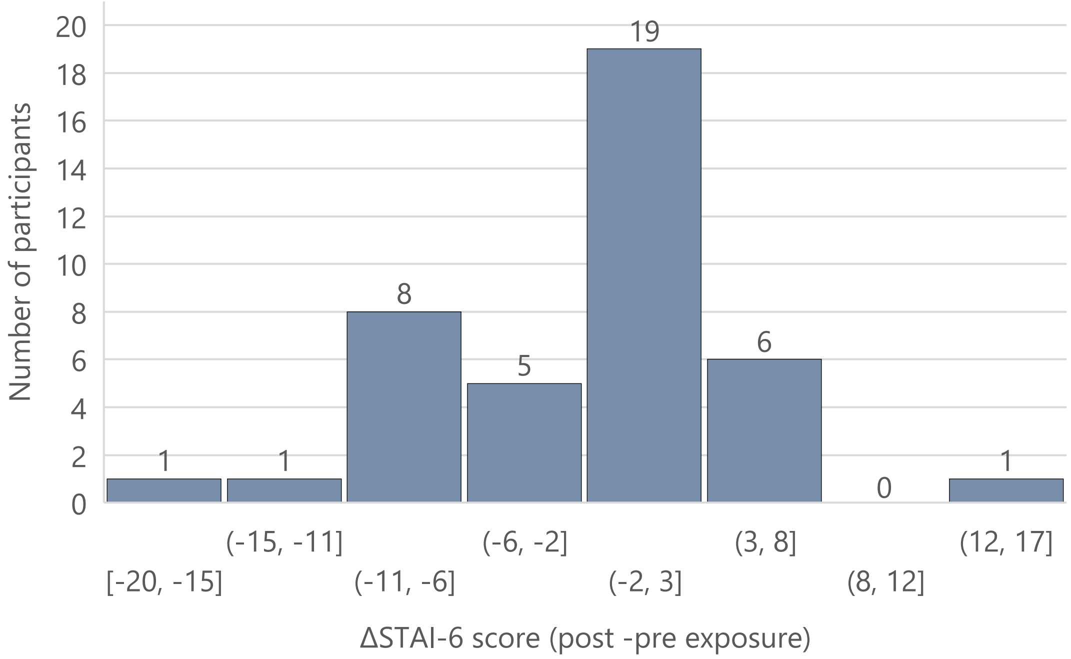

Figure 9. Histogram of ΔSTAI-6 scores post - pre exposure of Classical Music environment.

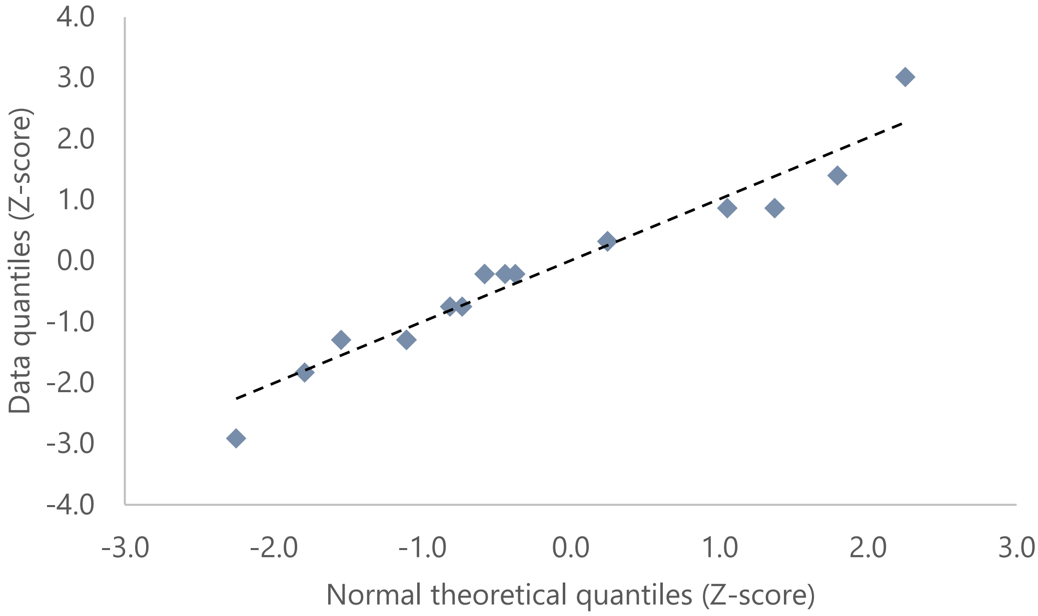

Figure 10. Q-Q plot of ΔSTAI-6 scores post - pre exposure of Classical Music environment.

Nature Sound.

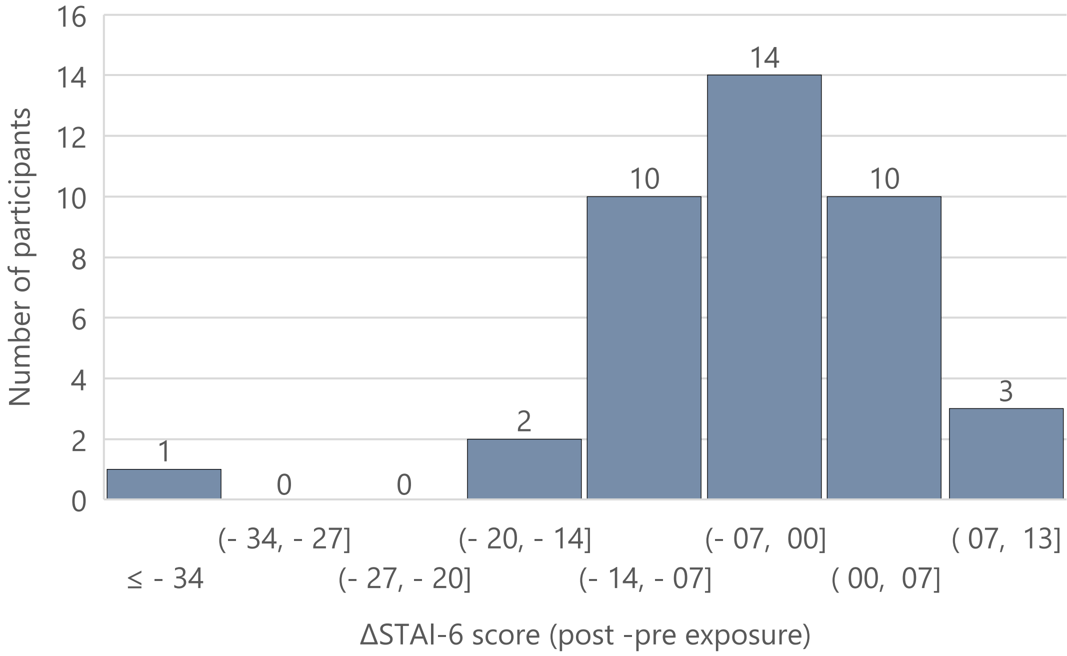

Figure 11. Histogram of ΔSTAI-6 scores post - pre exposure of Nature Sound environment.

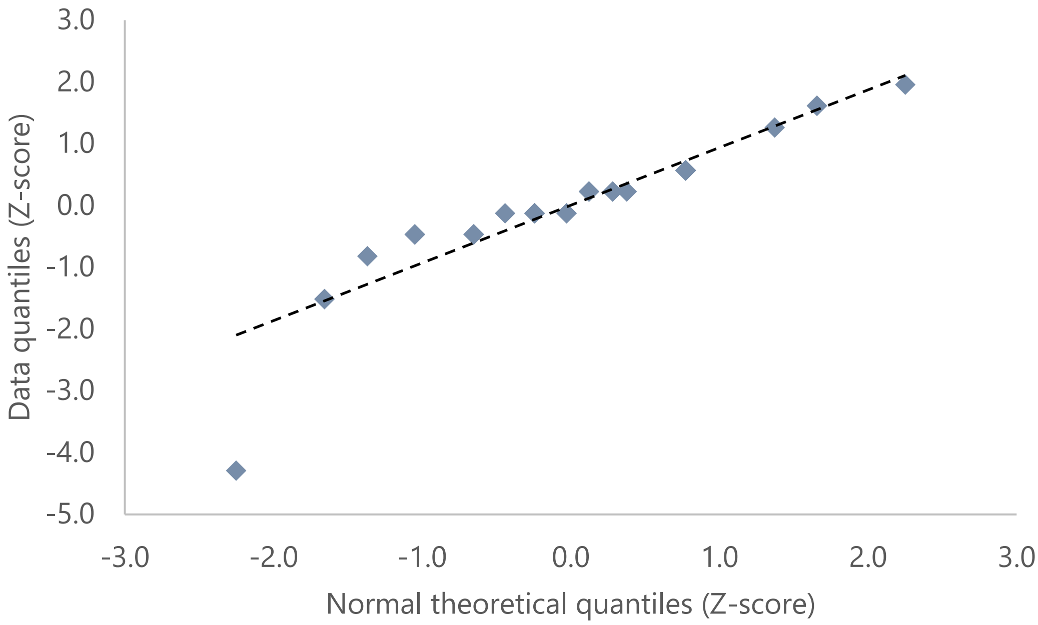

Figure 12. Q-Q plot of ΔSTAI-6 scores post - pre exposure of Nature Sound environment.

Neutral Music.

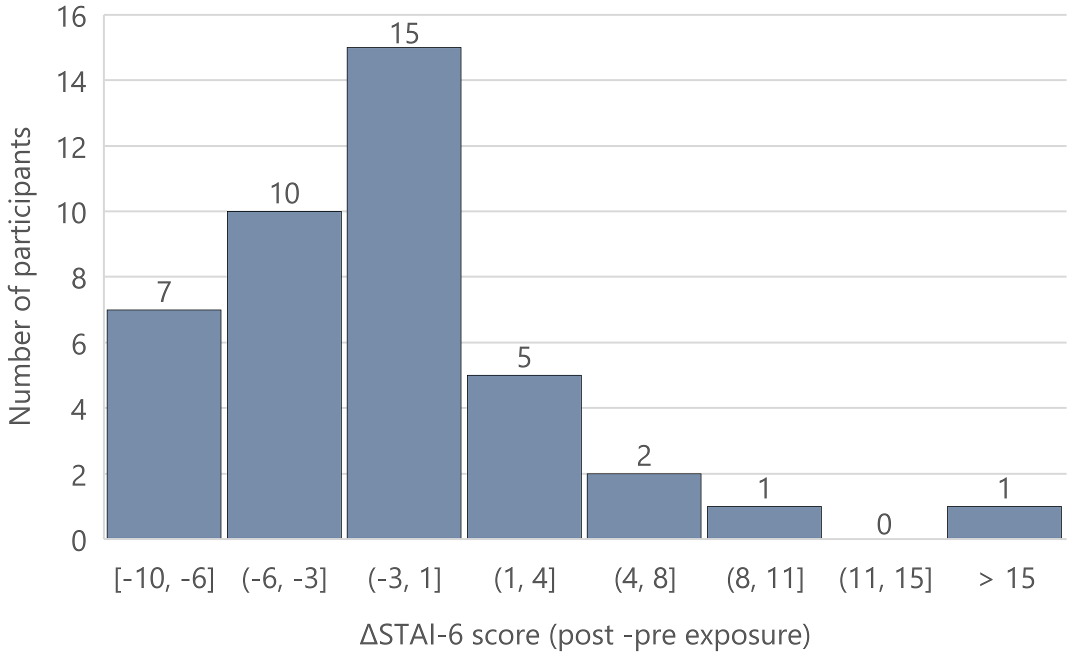

Figure 13. Histogram of ΔSTAI-6 scores post - pre exposure of Neutral Music environment.

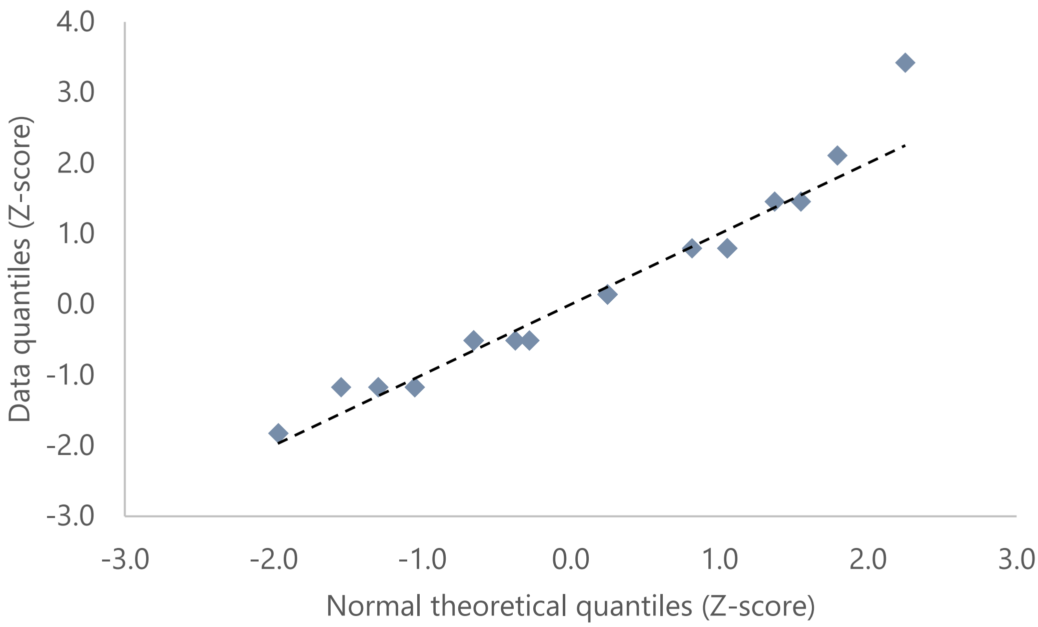

Figure 14. Q-Q plot of ΔSTAI-6 scores post - pre exposure of Neutral Music environment.

4.1.2 PAIRED T-TEST ANALYSE WITHIN EACH SOUND ENVIRONMENT

Table 5 shows the results of the paired T-test, where n is the Sample Size, M is the mean value and Δ is the difference between post and pre exposure score, SD is the Standard Deviation, t is the T-Value, p is the p-value, d is the Cohen's d, and t_{crit} is the critical T-value.

Table 5. Paired T-test (two-tailed) comparing STAI-6 scores pre and post exposure to each sound environment.

Sound Environment	n	M			SD	$t(40)$	p	d	t_{crit}
		Pre	Post	Δ					
No Sound	41	34.80	39.43	4.63	6.23	-4.76	<.001	0.7	2.02
Pink Noise	41	32.44	30.89	-1.54	6.24	1.58	.121	-0.2	2.02
Classical Music	41	32.93	30.89	-2.03	6.19	2.10	.042	-0.3	2.02
Nature Sound	41	36.67	31.22	-5.45	9.60	3.63	<.001	-0.6	2.02
Neutral Music	41	32.76	32.03	-0.73	5.08	0.92	.362	-0.1	2.02

NO SOUND. For the No Sound environment, STAI-6 scores increased substantially between pre (M = 34.80, SD = 10.22) and post (M = 39.43, SD = 10.43) exposure and post exposure to the sound environment. A paired T-test revealed a significant difference, $t(40) = 4.76$, $p <.001$, with a medium to large effect size ($d = 0.7$) and a 95% confidence interval [2.67, 6.60].

PINK NOISE. A slight decrease in the STAI-6 sores was showed between pre (M = 32.44, SD = 10.49) and post (M = 30.89 SD = 10.38) exposure to the Pink Noise environment. A paired T-test revealed no significant difference, $t(40) = 1.58$, $p = .121$, with small effect size ($d = -0.2$) and, a 95% confidence interval [-3.51, 0.43].

CLASSICAL MUSIC. For the Classical Music environment, STAI-6 scores decreased slightly between pre (M = 32.93, SD = 10.70) and post (M = 30.89, SD = 9.72) exposure to the sound environment. A paired T-test revealed a significant difference, $t(40) = -2.10$, $p = .042$, with small effect size ($d = -0.3$) and, a 95% confidence interval [-3.99, -0.08].

NATURE SOUND. A substantial decrease in STAI-6 score was revealed between pre (M = 36.67, SD =13.00) and post (M = 31.22, SD = 11.27) exposure to the Nature Sound environment. A paired T-test showed a significant difference, $t(40) = 3.63$, $p = <.001$, with medium effect size ($d = -0.6$) and, a 95% confidence interval [-8.48, -2.42].

NEUTRAL MUSIC. For the Neutral Music environment, a minimal decrease in STAI-6 scores were showed between pre (M = 32.76, SD = 10.51) and post (M = 32.03, SD = 10.13) exposure. A paired T-test revealed no significant difference, $t(40) = 0.92$, $p = .362$, with medium effect size ($d = -0.1$) and, a 95% confidence interval [-2.34, 0.87].

CRONBACH'S α

To ensure the internal consistency was within an acceptable interval of the STAI-6 scale for each sound environment, the Cronbach's α was calculated, which is shown in Table 6.

Table 6. Cronbach's α pre and post exposure of each sound environment.

Sound Environment	No Sound	Pink Noise	Classical Music	Nature Sound	Neutral Music
Cronbach's α					
- Pre	0.71	0.75	0.76	0.82	0.82
- Post	0.67	0.77	0.72	0.83	0.78

The results in Table 6 illustrate that the internal consistency was in general acceptable across all five sound environments where the majority had an $\alpha > 0.7$. However, a slightly lower reliability was observed in the No Sound environment post exposure with an $\alpha = 0.67$. Although this is still considered to be within an acceptable interval for STAI-6.

4.1.3 ANOVA ANALYSE, ACROSS ALL SOUND ENVIRONMENTS

The results of the one-way factor Anova are presented in Table 7, where *SS* is the Sum of Squares, *df* is the degree of freedom, *MS* is the mean square, *F* is the F-value and *p* is the *p*-value.

Table 7. One way ANOVA analyse examining differences in STAI-6 change across all sound environments.

Source of Variation	SS	df	MS	F	*p*
Between Groups	2171	4	542.8	11.6	<.001
Within Groups	9358	200	46.8		
Total	11529	204			

As shown above the one-way ANOVA, revealed a significant difference in STAI-6 across all five sound environments, $F(4, 200) = 11.60$, $p < .001$. The effect size was further, calculated with Equation 2 to 0.19%, which indicate a large effect.

TUKEY HSD

In addition, to determine which sound environments differed significantly from one another, Tukey HSD post hoc comparisons were conducted.

Table 8 presents the mean difference of STAI-6 scores between each sound environment and indicates whether the difference exceeds the HSD critical value, Equation 1.

Table 8. Tukey HSD post hoc comparison for STAI-6 differences between sound environments.

Comparison	$\Delta M_{STAI\text{-}6}$	Significant ($\alpha = 0.05$)
No Sound – Pink Noise	6.18	Yes
No Sound – Classical Music	6.67	Yes
No Sound – Nature Sound	10.08	Yes
No Sound – Neutral Music	5.37	Yes
Pink Noise – Classical Music	0.49	No
Pink Noise – Nature Sound	3.90	No
Pink Noise – Neutral Music	0.81	No
Classical Music – Nature Sound	3.41	No
Classical Music – Neutral Music	1.30	No
Nature Sound – Neutral Music	4.72	Yes

Illustrated in Table 8 the Tukey HSD post hoc tests showed that the No Sound environment differed significantly from all other sound environments and Nature Sound also differed significantly from Neutral Music. No significant differences were found between Nature Sound and Pink Noise or Classical Music.

4.1.4 NON-PARAMETRIC ROBUSTNESS ANALYSIS

Wilcoxon.
The results from conducted Wilcoxon signed rank analysis for each sound environment are presented in Table 9.

Table 9. Wilcoxon signed-rank test comparing pre and post exposure STAI-6 scores within each sound environment.

Sound Environment	Median		T	*p*	*r*
	Pre	Post			
No Sound	36.67	40.00	33.50	<.001	0.84
Pink Noise	30.00	30.00	177	0.169	0.29
Classic Music	30.00	30.00	59	0.028	0.53
Nature Sound	33.33	26.67	73.50	0.028	0.70
Neutral Music	33.33	30.00	130.50	0.258	0.26

A significant difference between pre and post exposure STAI-6 scores were observed for No Sound ($p < .001$), Classical Music ($p = .028$), and Nature Sound ($p = .028$), meanwhile no significant differences were observed for Pink Noise ($p = .169$) or Neutral Music ($p = .258$).

The median STAI-6 score increased in the No Sound condition, from 36.67 to 40.00. The median remained unchanged for Pink Noise and Classical Music, while decreases were observed for Nature Sound, from 33.33 to 26.67, and Neutral Music, from 33.33 to 30.00.

Kruskal–Wallis.
The result if the Kruskal-Wallis test is presented in Table 10.

Table 10. Kruskal–Wallis test comparing ΔSTAI-6 scores across sound environments.

Source of variation	*H*	*df*	*p*
Between groups	40.61	4	<.001

As precented above the Kruskal-Wallis test showed a significant effect of sound environment on ΔSTAI-6 scores, $H(4) = 40.61$, $p < .001$.

4.2 SELF-REPORTED STRESS AND ANXIETY LEVELS

Distribution of self-reported stress and anxiety level pre and post exposure to respectively sound environment is presented in Figure 15 as a box plot.

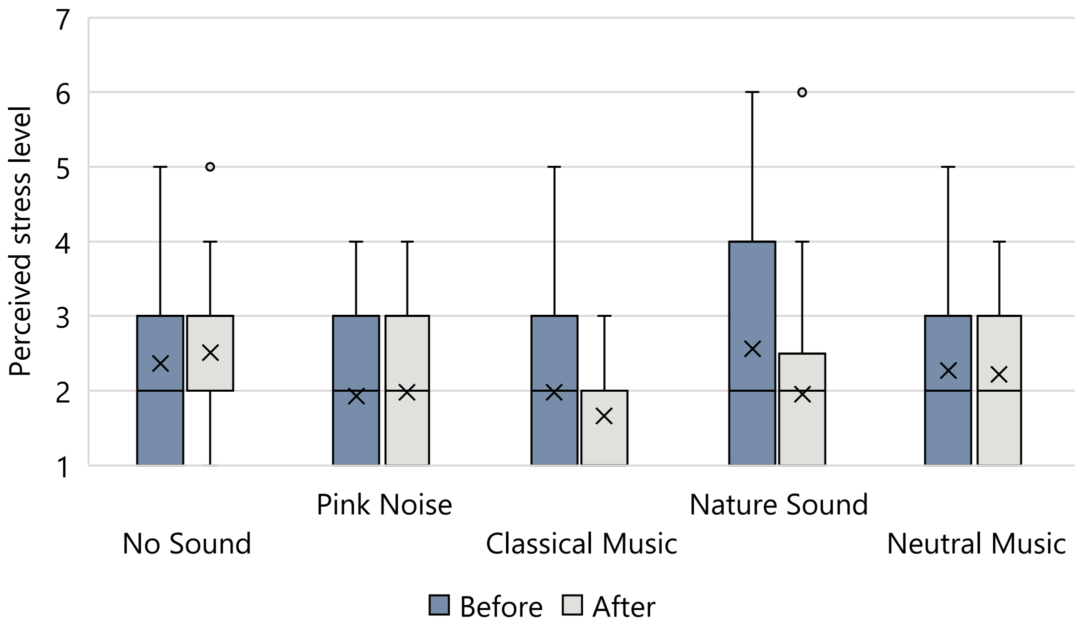

Figure 15. Self-reported stress level before and after entering the waiting room for respective sound environment.

In addition to examine variability in self-reported stress and anxiety levels, the interquartile ranges (IQR) were calculated for each sound environment pre and post exposure. Table 6 summarizes the IQR values as well as the change in dispersion.

Table 11. Interquartile range (IQR) of self-reported stress and anxiety levels pre and post exposure to sound environments.

Sound Environment	IQR		
	Pre	Post	Δ
No Sound	2	1	1
Pink Noise	2	2	0
Classic Music	2	1	1
Nature Sound	3	1.5	1.5
Neutral Music	2	2	0

A decrease in mean stress and anxiety levels post exposure to the sound environment is shown for Classical Music, Nature Sound and Neutral Music. The decrease is most apparent in the Nature Sound environment as shown in Figure 15. Additionally, the median stress and anxiety levels tend to be relatively stable across all sound environments. Table 11 however, shows that the IQR value has decreased for No Sound, Classical Music and Nature Sound. The largest reduction was observed in the Nature Sound environment, with a decrease in IQR of 1.5. Meanwhile Pink Noise and Neutral Music showed no change in IQR.

4.2.1 SELF-REPORTED IMPACT OF EXPOSED SOUND ENVIRONMENT

Figure 16 illustrates the distribution of participants' self-reported impact of exposed sound environments. Negative (increased the levels) responses are shown to the left of zero in red, neutral responses are centred in grey, and positive (decreased the levels) responses to the right of zero in blue.

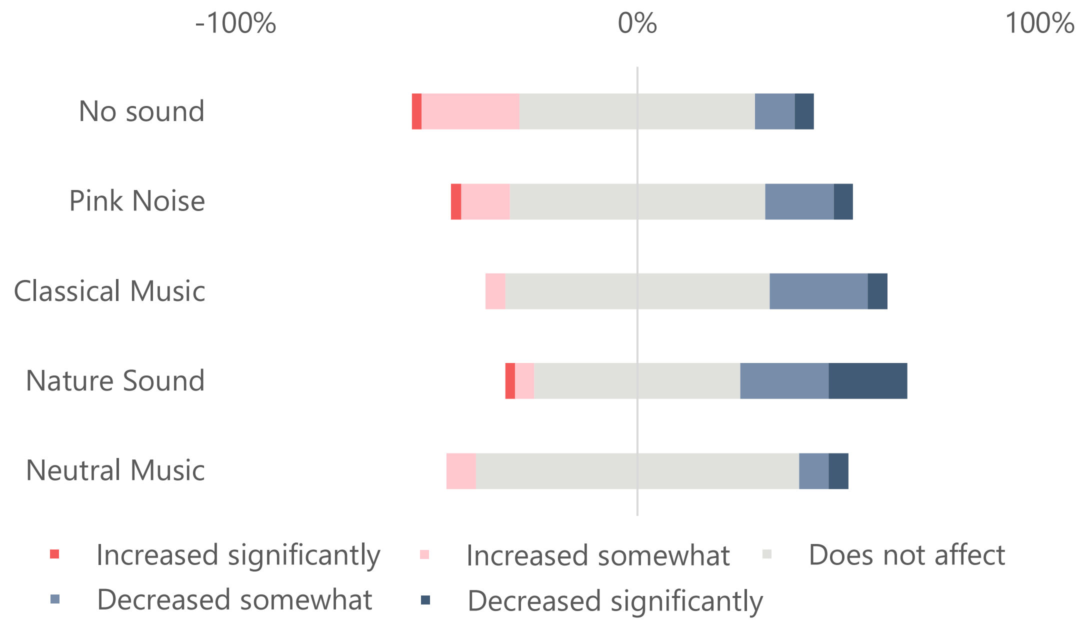

Figure 16. Distribution of self-reported impact on stress/anxiety levels across all sound environments.

As illustrated in the figure above, Nature Sound received the highest proportion of positive responses, closely followed by Classical Music. In contrast to No Sound that received most negative (increasing stress) responses. Both Neutral Music and Pink Noise show to have a more symmetric response proportion between positive and negative values and, with most neutral responses received.

4.3 LIKING OF EACH SOUND ENVIRONMENT

Whereas Figure 17 illustrated the distribution of participants' liking rating to the exposed sound environment in a box plot.

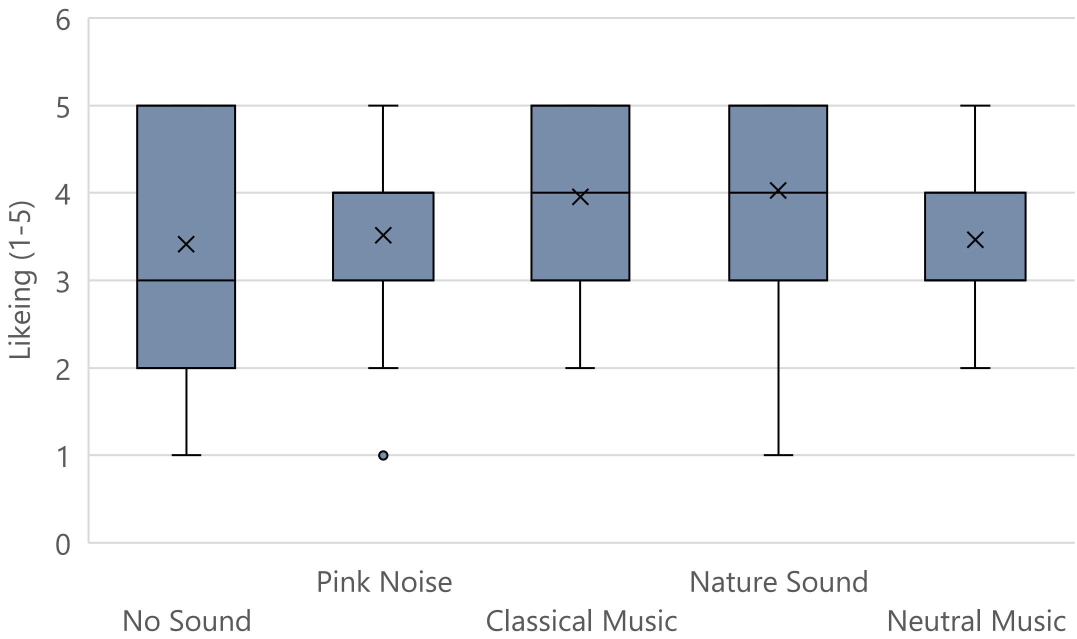

Figure 17. Participants' ratings of liking across all five sound environments.

In addition, Table 12 shows the mean, median, and standard deviation of participants' liking ratings for each sound environment.

Table 12. Means, medians, and standard deviations of participants' liking for each sound environment.

Sound Environment	Mean	Median	SD
No Sound	3.41	3	1.26
Pink Noise	3.51	4	1.12
Classical Music	3.95	4	0.8
Nature Sound	4.02	4	1.01
Neutral Music	3.46	3	1.12

The standard deviation shown in Table 12 was relatively low across all five sound environments. Classical Music (*SD* = 0.80) had the lowest one which indicates grater agreement among the participants compared to No Sound (*SD* = 1.26) which had a higher variability.

As illustrated in Figure 17 together with Table 12, Nature Sound, Classical Music and Pink Noise received a high median rating of 4, which indicates in general a positive outcome meanwhile, No Sound and Neutral Music had a median rating of 3 which in general indicates to a more natural outcome. However, both Nature Sound and Classical Music also received a high mean value around 4, which together with the median correlates to a symmetric distribution of the responses. Nevertheless, had Natural Sound and No Sound similarly correlation between mean value and median rating meanwhile Pink Noise had a slight difference which generally indicates responses includes an outlier.

5 DISCUSSION

The aim of this study was to investigate how different sound environments in healthcare waiting rooms influence patients perceived stress and anxiety levels. The results indicate that the acoustic environment may influence patients’ emotional experiences while waiting for healthcare appointments. Differences were observed between the tested sound environments, where Nature Sound and Classical Music were associated with reduced anxiety levels, while the No Sound environment instead showed increased STAI-6 scores post exposure. Similar patterns were observed in the non-parametric analyses (Wilcoxon signed-rank and Kruskal–Wallis tests) as in the paired T-tests and one-way ANOVA, suggesting that the findings were robust to the choice of statistical method.

One of the most notable findings was that the No Sound environment resulted in increased STAI-6 scores post exposure. In contrast, all introduced sound environments showed tendencies toward reduced stress and anxiety levels. The largest reduction was observed for Nature Sound, which also demonstrated statistically significant results together with Classical Music. These findings suggest that the presence of a carefully designed sound environment may contribute to a calmer waiting room experience compared to having no background sound at all.

The increase in anxiety observed in the No Sound environment may indicate that silence in healthcare waiting rooms is not necessarily experienced as calming. Instead, the absence of masking or restorative auditory stimuli may increase patients’ awareness of waiting and uncertainty before healthcare appointments. This interpretation is consistent with previous soundscape research emphasising that acoustic environments are experienced in relation to psychological and contextual factors rather than solely through physical sound characteristics [12], [13], [15].

The findings are also consistent with previous research within soundscape and restorative environment theory, where acoustic environments may contribute to well-being, restoration, and reduced stress [14]. Natural sounds have previously been associated with pleasant and restorative environments, which corresponds with the results of the present study, where Nature Sound showed the strongest reduction in perceived stress and anxiety [21].

One possible explanation for why Nature Sound produced the strongest effect is that natural sounds may be perceived as more pleasant, familiar, and less cognitively demanding than other sound environments. In waiting rooms, where patients may experience uncertainty and anticipation, this type of sound environment may help shift attention away from stress and contribute to a calmer emotional state.

The findings may also be understood in relation to the biophilia hypothesis, which suggests that humans may have an inherent tendency to respond positively to nature and natural environments [26]. Nature-related sounds may therefore evoke associations with safety, familiarity, and restoration, which could help explain the positive responses observed in the present study.

Classical Music also demonstrated a statistically significant reduction in STAI-6 scores, although the effect was smaller compared to Nature Sound. This finding is partly consistent with previous research suggesting that calm and relaxing music may influence stress-related responses and physiological activation [27], [28]. However, emotional responses to music are often influenced by contextual and individual factors such as familiarity and personal preference [4], [29].

Neutral Music and Pink Noise both showed reductions in STAI-6 scores, although neither result was statistically significant. One possible explanation is that more structured music may become cognitively engaging and therefore less restorative, while neutral sounds such as Pink Noise may lack the emotional or restorative associations connected to natural sounds.

The results also suggest that the perception of sound environments is individual and context dependent. Although Nature Sound and Classical Music generally received the highest appreciation ratings, participants' experiences varied across the different sound environments. This corresponds with previous soundscape research emphasising that personal preferences and contextual factors influence how sound environments are perceived [13], [15], [29].

Although the individual STAI-6 items are based on ordinal response categories, the analyses were conducted on the reverse-scored and summed STAI-6 score. In addition, the non-parametric analyses produced results consistent with those obtained from the paired T-tests and one-way ANOVA, providing additional support for the robustness of the findings.

Overall, the findings illustrate how healthcare sound environments may influence patients' experiences of waiting situations. Rather than functioning only as background conditions, acoustic environments may contribute to emotional responses in healthcare settings, particularly in situations characterised by uncertainty and anticipation.

5.1 FURTHER INVESTIGATION

Future research could further investigate how different musical characteristics, sound levels, and combinations of auditory and visual environmental factors influence emotional responses within healthcare environments. Additional studies including physiological stress measures, larger participant samples, and longer exposure periods may also contribute to a deeper understanding of restorative healthcare soundscapes. Furthermore, future studies could be conducted under more controlled conditions and include acoustic and psychoacoustic measurements of the sound environments. This would make it possible to examine how factors such as sound level, perceived loudness, and other acoustic characteristics influence emotional responses in healthcare waiting rooms.

6 CONCLUSION

The results of this study indicate that the sound environment in healthcare waiting rooms may influence patients' emotional experiences and perceived levels of stress and anxiety. In this study, the No Sound environment was associated with increased STAI-6 scores, while the introduced sound environments generally showed tendencies toward reduced stress and anxiety levels.

The study further demonstrated that different types of sound environments influenced patients in different ways. Nature Sound and Classical Music showed the clearest positive effects and resulted in statistically significant reductions in STAI-6 scores. Nature Sound produced the largest reduction in perceived stress and anxiety and was also the most appreciated sound environment among the participants. Pink Noise showed a smaller reduction, although the result was not statistically significant, while Neutral Music demonstrated the weakest effect among the introduced sound environments.

Based on these findings, Nature Sound appeared to have the strongest restorative potential in the present study, followed by Classical Music. The results therefore suggest that natural sounds may be particularly suitable for creating calmer and more supportive waiting room environments.

The study further indicates that sound environments in healthcare waiting rooms should not only be viewed as background elements, but also as part of the overall healthcare environment and patient experience. A more conscious use of soundscape design may therefore contribute to the development of calmer and more restorative healthcare environments.

APPENDIX A - QUESTIONNAIRE

This study is part of my master's thesis in the Sound and Vibration program. The purpose is to investigate how sound in waiting rooms affects stress and/or anxiety levels. Participation is voluntary, and the survey is anonymous. Only information about gender and age group is collected, and no responses can be linked to you personally. **By completing the survey, you consent to participate.**

PART 1:

What is your age group?

☐ 18-20 ☐ 20-29 ☐ 30-39 ☐ 40-49 ☐ 50-59 ☐ 60-69 ☐ ≥70

Gender?

☐ Male

☐ Female

☐ Other/Don't want to answer

STAI-6 questions

A few statements which people have used to describe themselves are given below. Read each statement and then mark the box that best indicate how you feel right now, at this moment. **There are no right or wrong answers!**

Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

	Not at all	**Somewhat**	**Moderately**	**Very much**
I feel Calm…?	☐	☐	☐	☐
I am tense…?	☐	☐	☐	☐
I feel upset…?	☐	☐	☐	☐
I am relaxed…?	☐	☐	☐	☐
I feel content…?	☐	☐	☐	☐
I am worried…?	☐	☐	☐	☐

What is your current level of stress and/or anxiety before your appointment?

☐ ☐ ☐ ☐ ☐ ☐

Negligible Very high

Is your current stress and/or anxiety level caused by your healthcare appointment?

☐ YES

☐ No

PART 2:

STAI-6 questions
Read each given statement below and, then mark the box that best indicate how you feel right now, at this moment. **There are no right or wrong answers!**
Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

	Not at all	**Somewhat**	**Moderately**	**Very much**
I feel Calm…?	☐	☐	☐	☐
I am tense…?	☐	☐	☐	☐
I feel upset…?	☐	☐	☐	☐
I am relaxed…?	☐	☐	☐	☐
I feel content…?	☐	☐	☐	☐
I am worried…?	☐	☐	☐	☐

What is your current level of stress and/or anxiety level?

☐	☐	☐	☐	☐	☐
Negligible					Very high

How would you rate the impact of the current sound environment on your stress and anxiety levels?

☐	☐	☐	☐	☐
Decreased much		Negligible		Increased much

Do you like the current sound environment in the waiting room?

☐	☐	☐	☐	☐	☐
Don't like it at all					Like it very much

Thank you for taking the time to participate in this study!

APPENDIX B – CLASSICAL MUSIC

The Classical Music sound environment consisted of a playlist of calm piano-based classical music. The playlist primarily featured compositions by Frédéric Chopin and Claude Debussy performed by various pianists. The full track list used for the experiment is provided in Table 13 below.

Table 13. Complete track list for the Classical Music sound environment (Master Piano).

Artist	Track
Frédéric Chopin, Daniel Barenboim	Nocturne No. 2 in E-Flat Major, Op. 9 No. 2
Frédéric Chopin, Janusz Olejniczak	Nocturne in E Minor, Op. 72 No. 1
Frédéric Chopin, Peter Schmalfuss	Nocturne, Op. 15 No. 3
Frédéric Chopin, Vladimir Feltsman	Nocturne in B-Flat Minor, Op. 9 No. 1
Frédéric Chopin, Alexandre Tharaud	24 Préludes, Op. 28: No. 15 (“Raindrop”)
Frédéric Chopin, Mao Fujita	24 Préludes, Op. 28: No. 13 in F-Sharp Major
Frédéric Chopin, Benjamin Grosvenor	Berceuse in D-Flat Major, Op. 57
Frédéric Chopin, Janusz Olejniczak	Prélude in E Minor, Op. 28 No. 4
Frédéric Chopin, Brigitte Engerer	Nocturne in C-Sharp Minor, B. 49
Frédéric Chopin, Nikolai Lugansky	24 Preludes, Op. 28: No. 15
Frédéric Chopin, Elisabeth Leonskaja	Nocturne No. 21 in C Minor
Frédéric Chopin, Alexandre Tharaud	Waltzes, Op. 69, B. 35: No. 1 in A-Flat Major
Frédéric Chopin, Benjamin Grosvenor	Nocturne No. 19 in E Minor, Op. 72 No. 1
Frédéric Chopin, Elisabeth Leonskaja	Nocturne No. 5 in F-Sharp Major
Frédéric Chopin, YUNDI	Nocturne No. 1 in B-Flat Minor
Frédéric Chopin, Elisabeth Leonskaja	Nocturne No. 17 in B Major
Frédéric Chopin, Murray Perahia	12 Études, Op. 10: No. 3 in E Major (“Tristesse”)
Frédéric Chopin, Elisabeth Leonskaja	Nocturne No. 3 in B Major
Frédéric Chopin, Claudio Arrau	Nocturne No. 19 in E Minor, Op. 72 No. 1
Frédéric Chopin, Lang Lang	Nocturne in E-Flat Major, Op. 55
Frédéric Chopin, Vladimir Ashkenazy	Nocturne No. 9 in B Major, Op. 32
Frédéric Chopin, Seong-Jin Cho	Ballade No. 3 in A-Flat Major, Op. 47
Frédéric Chopin, Lang Lang	Nocturne No. 8 in D-Flat Major, Op. 27
Frédéric Chopin, Tamás Vásáry	Étude “Tristesse” in B Major, Op. 10 No. 3
Frédéric Chopin, Elisabeth Leonskaja	Nocturne No. 16 in E-Flat Major
Frédéric Chopin, Alexandre Tharaud	Ballade No. 1 in G Minor, Op. 23
Frédéric Chopin, Eugene Mursky	Polonaise No. 15 in B-Flat Minor (“Adieu”)
Frédéric Chopin, Gabriela Montero	Nocturne No. 8 in D-Flat Major
Frédéric Chopin, Seong-Jin Cho	Ballade No. 4 in F Minor, Op. 52
Frédéric Chopin, Martha Argerich	Andante spianato et Grande polonaise brillante

Frédéric Chopin, Maurizio Pollini	Mazurka in F Minor, Op. Posth. 68
Claude Debussy, Hélène Grimaud	2 Arabesques
Claude Debussy, Seong-Jin Cho	Suite bergamasque
Claude Debussy, Jean-Yves Thibaudet	Rêverie, L. 68
Claude Debussy, Krystian Zimerman	Préludes (Book I)
Claude Debussy, Alice Sara Ott	Suite bergamasque
Claude Debussy, Rafał Blechacz	Pour le piano
Claude Debussy, Nelson Freire	Children’s Corner
Claude Debussy, Daniel Barenboim	La plus que lente
Claude Debussy, Mitsuko Uchida	12 Études, L.136
Claude Debussy, Daniel Barenboim	Préludes, Book 1
Claude Debussy, Pierre-Laurent Aimard	Préludes (Book I)

APPENDIX C – NATURE SOUND

The Nature Sound environment consisted of a 60-minute ambient soundscape composed of different natural sounds. The recording represented a calm outdoor environment and contained multiple layers of natural audio elements, such as birdsong, wind, rustling vegetation, and general ambient background noise. Table 14 provides a detailed description of the sound characteristics.

Table 14. Sound characteristics of the Nature Sound environment.

Sound Source	Description
Birdsong	Distinct and recurring bird vocalizations audible throughout the recording, varying in intensity and frequency.
Wind	A continuous background sound of light wind, with natural variations in intensity over time.
Rustling Vegetation	Soft rustling sounds resembling leaves, grass, or bushes moving in the wind.
Ambient Nature Background	A continuous organic background sound characteristic of a natural outdoor environment.
Occasional Transient Sounds	Brief isolated sounds, likely caused by nearby bird calls or vegetation movement.

Overall, the Nature Sound environment created the impression of a tranquil outdoor setting, similar to a calm forest or park environment. The soundscape was dominated by birdsong, gentle wind, and vegetation movement, with no speech, music, or clearly artificial sounds present.

APPENDIX D – NEUTRAL MUSIC

The Neutral Music sound environment consisted of a playlist of contemporary mainstream-style remixes and electronic tracks. The playlist included music within genres such as pop, tropical house, deep house, disco, and electronic music. Table 15 provides a full track list used for the Neutral Music sound environment.

Table 15. Complete track list for the Neutral Music sound environment (Master Puls).

Artist	Track
Rohn Dahlberg	Mesmerized
MVCA, Nothing In Common	Make You Stay
Max Oazo, Cami	Ain't No Sunshine
Sole Sole	Summer Love
Khalid, Lauv	Tied Up
Sum Wave	Milo's Journey
Sum Wave	For Love
Daxten	Late Nights
Daxten	Sparkles
Tullio	Manhattan At Dusk
Tullio	Afternoon Haze
Thrupence, Wafia	Atmos
Tarjei Nygård, Are Foss	Zehran
ELFL	Temple of Runha
Sonaya	Bahia Del Puento
Rick Sanders	Aphorism
Naomi Lareine	Just Met
Naomi Lareine	Get It
Austin Millz, Aluna	Gold
Kornél Kovács	Szörp
Hosiannah, Rasmus Faber	Reach Out
Sofia Kourtesis, Tourist	La Perla - Tourist Remix
Claes Rosen, Not Now Please	One-Sided Love - Not Now Please's Remix
Approaching Black	Past Times
Purple Disco Machine, Moss Kena, The Knocks	Fireworks
Nile Rodgers	Do What You Wanna Do - The Reflex Revision
Saison	The Art Of Optimism
Claes Rosen	Vivid Lights
Rhode & Brown, Indra Dunis, Kornél Kovács	Everything in Motion

Sune	Elevator Connoisseur
Jonas Blue, AWA, KC Lights	Something Stupid
Folamour, SG Lewis	Lost In Space
jackLNDN	A Little More Love
Clive From Accounts	Gravitate
Matt Johnson, Derrick McKenzie, Roki	Interstellar Love - Radio Edit
Dam Swindle, Nikki O	Breathe
Les Loups, David Bay, YOSIE	Enough - David Bay Remix
Kartell, SG Lewis	Crossing Paths
Kornum & Karma, Gregers, Discotron	Underworld - Discotron Remix
Doohickey Cubicle, Blue Hawaii	Sign Here
gardenstate, GVN, Falden	Take Me There - Falden Remix
Jarami	Fredonia Drive
Kartell	AWAKEN
Maya Jane Coles	Die Hard
Axel Boman	Not So Much
Hubbabubbaklubb, Domenique Dumont	Flyvende Flyndre
Session Victim	Good Intentions - LP Mix
Folamour	These Are Just Places To Me Now
Fouk	Heavy on the Bacon
Fouk	Kill Frenzy
Fouk	Cat Lady
Henrik Villard, Fouk	Don't Want It - Fouk Remix
Rioleval	Improvise at Noon
sunflwr	hyperspeed
Jeff The Fool	The Crime
Berzingue	Quitter Paname
Swales	The City
Third Attempt	Be Yourself - Radio Edit
Ari Bald	Karlaplan
Jeff The Fool	Airport Blossom
Kx9000	Raf's Baggies
Cosmonection	Talamanca
Daniela Rathana, Bella Boo	Havanna - Bella Boo Remix
Bella Boo	Rain On Me
Fabich, Jafunk, Pastel, Bambie	Ecstasy - Mixed
Jungle	All Of The Time
Loure	Keep It Real
Franc Moody	Dopamine

Bluestaeb	Pastis
Boston Bun	Missing You
Harvey Sutherland	Superego
Tycho, Saint Sinner, Harvey Sutherland	For How Long - Harvey Sutherland Remix
SG Lewis	Back To Earth
SG Lewis, Lucky Daye	Feed The Fire
SG Lewis	Lifetime
Paco Versailles	Shangri La
J. Worra	some ppl fall
Chaos In The CBD	Dusty Sundays
Rezident	Reflection
Nuage	Luma
Session Victim	MPFree Now
Moi Je	Suis
Hosiannah, Rasmus Faber	Camper
Chaos In The CBD	Phantom Melodies
Chaos In The CBD	Intimate Fantasy
Chaos In The CBD	816 To Nunhead
Miami Horror	Emagination - B-Side
Miami Horror, Kimbra, Franc Moody	I Look to You - Franc Moody Remix
Moullinex	Take a Chance
Jupiter	Steady Rocking
L'Impératrice, Parcels	Séquences - Parcels Remix
Digitalism	JPEG
Roosevelt	Moving On
Tesla Boy	Strong - Instrumental
Cut Copy	Zap Zap
Bag Raiders, Tora	Back To Myself
Shook	Papaya
E. Live	Boogie For Life
Shook	Sunburst
Vulfpeck	Test Drive (Instrumental)
Roisto	Fool
Shook	Process
Toro y Moi	Still Sound
Modjo	Acknowledgement
Mild Minds	FORMATIONS
Mild Minds	DESTINATIONS
Mild Minds	MOVEMENTS
sunflwr	cul de sac club

sunflwr	porco rosso
Taiki Nulight	Through Glass
John Summit, Guz, Stevie Appleton	What A Life
Ivusm	May 19
Moi Je, Antoine Lartigue, Simon Berard, Kazy Lambist	Profite - Kazy Lambist Remix
L'Impératrice	La lune
Darius	Pyor
Yuni Wa	Easy
Yung Bae	Back to the Classics
Dabeull, Rude Jude, Ferdi	Cosmic Fonk - Intro

BIBLIOGRAPHY

[1] J. C.-Y. Lai and N. Amaladoss, “Music in Waiting Rooms: A Literature Review,” *Health Environments Research & Design Journal*, vol. 15, no. 2, pp. 347-354, Apr. 2022. doi: 10.1177/19375867211067542

[2] A. Curry, *"Music's* effect on the waiting room experience: A patient survey”, The Intake, Tebra, Jan. 3, 2024. [Online].

Available: https://www.tebra.com/theintake/medical-deep-dives/tips-and-trends/patients-preferred-waiting-room-tunes [Accessed: 2026-06-01]

[3] M. Collins, et al., “Pilot Study on Music in the Waiting Room of Outpatient Pain Clinics,” *Pain Management Nursing*, vol. 23, pp. 318-323, Sep. 2021. doi: 10.1016/j.pmn.2021.09.002

[4] J. P. S. Yeoh and C. Spence, “Background Music's Impact on Patients Waiting in Surgery and Radiology Clinics,” *Health Environments Research & Design Journal*, vol. 16, no. 3, pp. 278-290, 2023. doi: 10.1177/19375867231161094

[5] A. Fenko and C. Loock, ”The Influence of Ambient Scent and Music on Patients' Anxiety in a Waiting Room of a Plastic Surgeon,” *Health Environments Research & Design Journal* vol. 7, no. 3, pp. 38-59, Spring 2014.

[6] A. Lundberg, A. Hillebrecht and M. Srinivasan, “Effect of waiting room ambience on the stress and anxiety of patients undergoing medical treatment: A systematic review and meta-analysis,” *Advances in Integrative Medicine*, vol. 11, pp. 47-68, Apr. 2024. doi:10.1016/j.aimed.2024.04.004

[7] G. Kipnis, N. Tabak and S. Koton, “Background Music Playback in the Preoperative Setting: Does It Reduce the Level of Preoperative Anxiety Among Candidates for Elective Surgery?,” *Journal of PeriAnesthesia Nursing*, vol. 31, no.3, pp. 209-216, Jun. 2016. doi: 10.1016/j.jopan.2014.05.015

[8] E. Biddiss, T. J. Knibbe and A. McPherson, “The Effectiveness of Interventions Aimed at Reducing Anxiety in Health Care Waiting Spaces: A Systematic Review of Randomized and Nonrandomized Trials,” *Anesthesia & Analgesia* vol. 119, no. 2, pp. 433-448, Aug. 2014. doi: 10.1213/ane.0000000000000294

[9] R. S. Lazarus and S. Folkman, “Transactional theory and research on emotions and coping,” *European Journal of Personality*, vol. 1, no. 3, pp. 141–169, May 1987.

[10] C. D. Spielberger and E. C. Reheiser, “Assessment of Emotions: Anxiety, Anger, Depression, and Curiosity,” *Applied Psychology: Health and Well+Being*, vol.1, no.3, pp. 271-302, Sep. 2009. doi: 10.1111/j.1758-0854.2009.01017.x

[11] I. J. Busch-Vishniac, et al., “Noise levels in Johns Hopkins Hospital,” *Acoustical Society of America*, vol. 118, no. 6 pp. 3629-3645, Dec. 2005. doi: 10.1121/1.2118327

[12] A. L. Brown, T. Gjestland, and D. Dubois, “Acoustic environments and soundscapes,” in *Soundscape and the Built Environment*, J. Kang and B. Schulte-Fortkamp, FL, USA: CRC Press, 2016, ch. 1, pp. 1–16.

[13] D. Botteldooren et al., “From sonic environment to soundscape,” in *Soundscape and the Built Environment*, J. Kang and B. Schulte-Fortkamp, FL, USA: CRC Press, 2016, ch. 2, pp. 17–42.

[14] I. van Kamp, R. Klæboe, A. L. Brown, and P. Lercher, “Soundscapes, human restoration, and quality of life,” in *Soundscape and the Built Environment*, J. Kang and B. Schulte-Fortkamp, FL, USA: CRC Press, 2016, ch. 3, pp. 43–68.

[15] B. Schulte-Fortkamp and A. Fiebig, “Impact of soundscape in terms of perception,” in *Soundscape and the Built Environment*, J. Kang and B. Schulte-Fortkamp, FL, USA: CRC Press, 2016, ch. 4, pp. 69–88.

[16] P. Lercher, I. van Kamp, E. von Lindern, and D. Botteldooren, “Perceived soundscapes and health-related quality of life, context, restoration, and personal characteristics,” in *Soundscape and the Built Environment*, J. Kang and B. Schulte-Fortkamp, FL, USA: CRC Press, 2016, ch. 5, pp. 89–132.

[17] K. Genuit and A. Fiebig, “Human hearing-related measurement and analysis of acoustic environments: Requisite for soundscape investigations,” in *Soundscape and the Built Environment*, J. Kang and B. Schulte-Fortkamp, FL, USA: CRC Press, 2016, pp. 133–160.

[18] SS-ISO 12913-1, *Acoustics – Soundscape – Part 1: Definition and conceptual framework*. Stockholm, Sweden: Swedish Standard Institute, 2015.

[19] J. Mackrill, R. Cain and P. Jennings, “Experiencing the hospital ward soundscape: Towards a model”, *Journal of Environmental Psychology*, vol. 32, no., pp. 1-8, Jun. 2013. doi: 10.1016/j.jenvp.2013.06.004

[20] R. M. Schafer, *The Soundscaping: Our Sonic Environment and The Tuning of The World.* Rochester, VT, USA: Destiny Books, 1994.

[21] Ö. Axelsson, M. E. Nilsson and B. Berglund, “A principal components model of soundscape perception,” *Acoustical Society of America*, vol. 128, no. 5, pp. 2836-2846, Aug. 2010. doi: 10.1121/1.3493436

[22] H. Fastl and E. Zwicker, *Psychoacoustics: Facts and Models*, 3rd ed. Berlin, Germany: Springer, 2007.

[23] S. Kaplan, “The restorative benefits of nature: Toward an integrative framework,” *Journal of Environmental Psychology*, vol. 15, no. 3, pp. 169–182, 1995.

[24] R. S. Ulrich, “Stress reduction theory,” in *100 Key Concepts in Environmental Psychology*, D. Marchand, E. Pol, and K. Weiss, NY, USA: Routledge, 2023, pp. 143–146.

[25] R. S. Ulrich, ”View through a Window May Influence Recovery from Surgery,” *American Association for the Advancement of Science*, vol. 224, no. 4647, pp. 420-421, Apr. 1984. doi: 10.1126/science.6143402

[26] K. Rogers, “Biophilia Hypothesis”, *Encyclopaedia Britannica* Jun. 13, 2023. [Online].

Available: https://www.britannica.com/science/biophilia-hypothesis [Accessed: 2026-06-01]

[27] M. V. Thoma, et al., “The Effect of Music on the Human Stress Response,” *PLOS ONE*, vol. 8, no. 8, Aug. 2013. doi: 10.1371/journal.pone.0070156

[28] U. Nilsson, "The effect of music intervention in stress response to cardiac surgery in a randomized clinical trial," Heart & Lung, vol. 38, no. 3, pp. 201-207, 2009. doi:10.1016/j.hrtlng.2008.07.008

[29] T. Schäfer, P. Sedlmeier, C. Städtler and D. Huron, "The psychological functions of music listening," *Original research article*, vol. 4, no. 511, Agu. 2013. doi: 10.3389/fpsyg.2013.00511

[30] T. M. Marteau and H. Bekker, "The development of a six-item short-form of the state scale of the Spielberger State-Trait Anxiety Inventory (STAI), *British Journal of Clinical Psychology*, vol. 31, no. 3, pp. 301-306. 1992. doi: 10.1111/j.2044-8260.1992.tb00997.x.

[31] C. D. Spielberger, R. L. Gorsuch, and R. E. Lushene, *Manual for the State-Trait Anxiety Inventory*. Palo Alto, CA, USA: Consulting Psychologists Press, 1983.

[32] P. Carlbring. "State-Trait Anxiety Inventory". carlbring.se. Accessed: 2026-06-01 [Online].

Available: https://www.carlbring.se/fbanken/stai/

[33] A. Field, *Discovering Statistics Using IBM SPSS Statistics*, 4th ed. London, U.K: SAGE Publications, 2013.

[34] A. Bryman, *Samhällsvetenskapliga metoder*, 3rd ed. Solna, Sweden: Liber, 2018.

[35] R. Patel and B. Davidson, *Forskningsmetodikens grunder: Att planera, genomföra och rapportera en undersökning*, 4th ed. Lund, Sweden: Studentlitteratur AB, 2014.

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