

Article

Assessment of the Potential of Music Soundscape Therapy in Psychological Stress Management Among University Students: Water Sound Material and Resonance Effect

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Abstract

In the context of rapid technological advancements, music soundscape therapy has emerged as an innovative psychological intervention strategy, with its potential in alleviating psychological stress gradually being confirmed by scientific research. This study focuses on the university student population and aims to explore the application of water sound material and its resonance effect within music soundscape therapy, while evaluating its impact on psychological stress. The central goal of the research is to assess the potential effects of music soundscape therapy in managing psychological stress among university students, particularly the effectiveness of water sound material in stress reduction and the possible resonance effect. A randomized trial design was employed, with university students as participants. The perceived auditory experience of the sound materials was evaluated using a Psychoacoustic Perception Scale (PPS) questionnaire, while physical data at different stages were collected using a fitness tracker equipped with Heart Rate Variability (HRV) monitoring to quantitatively assess the impact of water sound material on psychological stress levels. PPS results indicate that participants generally perceived the water sound material as quiet, comfortable, and pleasant. HRV data analysis revealed that the sound of light rain most significantly stimulated the high-frequency (HF) component of HRV, potentially by activating parasympathetic nervous activity, thereby promoting stress regulation. This study provides preliminary evidence for the application of music soundscape therapy in psychological stress management, highlighting that specific water sound material can significantly influence participants' psychoacoustic perception and physiological state. The findings support the potential use of water sound material in music soundscape therapy and offer guidance for future research.

Keywords: Music Soundscape Therapy; Psychological Stress Management; Water Sound Material; University Students; Resonance Effect

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1. Introduction

University students frequently experience chronic psychological stress, which calls for accessible, low-cost non-pharmacological interventions for stress regulation. As a branch of sound-based healing practice, music soundscape therapy integrates R. Murray Schafer's soundscape theory with

music therapy, rooted in environmental acoustics and psychophysiological theories. It manipulates structured acoustic environments to modulate human perceptual and physiological responses, representing a promising music-based intervention for mental health management (Wu, 2024). Recent advances in audio technologies have opened new possibilities for soundscape design (Yang & Lee, 2024), though discussions on machine learning, AI composition and quantum algorithmic composition (Yang, Shen, et al., 2024) are only briefly touched upon as peripheral technical context, rather than the focus of this study (Yang, Huang, et al., 2024). This field has become an intersection of research across multiple disciplines, including musicology, biomedicine, acoustics, and environmental science, with particular attention being paid to studies related to natural sound materials and acoustic effects (Kaley et al., 2019). The natural world offers a diverse range of sound materials, and specific physical vibrations can influence the response of the neuromuscular system, regulating Heart Rate Variability (HRV) activity (Kim et al., 2021), which has positive implications for enhancing public well-being and stress management. Although previous studies have demonstrated the stress-reducing effects of natural sounds, limited research has compared different water sound materials using both psychoacoustic evaluation and HRV indicators among university students. In this context, the present study aims to assess the potential of music soundscape therapy in psychological stress management among university students, focusing on the combined use of water sound materials and resonance effects.

1.1. The Impact of Natural Sound Materials on Psychological Stress

Natural sound materials, such as the sound of flowing water and raindrops, have been widely proven by scientific research to have significant positive effects on alleviating psychological stress and enhancing emotional recovery. A study by (Jo et al., 2019) utilized near-infrared spectroscopy to measure the concentration of oxygenated hemoglobin in the prefrontal cortex and found that forest sounds significantly reduced sympathetic nervous activity while enhancing parasympathetic nervous activity, thereby improving participants' comfort, relaxation, and sense of connection with nature. Furthermore, (Chao Liu et al., 2024) revealed the significant impact of natural sounds on brain electrophysiological activity, emphasizing the regulatory role of brain signals in psychological stress. And (Fan & Baharum, 2024) further supported the potential effects of natural sounds in reducing heart rate, blood pressure, and respiratory frequency. These studies underscore the crucial role of natural sounds in psychological stress regulation, deepening the understanding of the human-environment relationship and providing background support for this research.

1.2. Theoretical Foundations and Practical Applications of Music Soundscape Therapy

Music soundscape therapy, which integrates music therapy with soundscape ecology, has become an emerging psychological intervention, attracting growing attention for both its theoretical development and practical applications. And (Viega, 2014) explored the concept of “environmental presence patterns,” highlighting how this model can assist individuals in restoring psychological balance and awakening forgotten aspects of the self, providing a new perspective for the theoretical development of music soundscape therapy. Also (Sonntag et al., 2023) implemented a music soundscape intervention in a hospital setting, improving the acoustic environment and enhancing patient comfort and relaxation, demonstrating the potential for music soundscape therapy in the healthcare field. And (Nur, 2024) conducted a study where natural sound music meditation significantly reduced levels of depression, anxiety, and stress among nursing students, confirming the effectiveness of music soundscape therapy in mental health interventions. These interdisciplinary studies not only provide a solid theoretical foundation for music soundscape therapy but also open new avenues for its practical application in psychological stress management, establishing it as an important branch of this field.

1.3. Feasibility of Psychological Stress Management for University Students

This research focuses on the psychological stress characteristics faced by university students and their needs and expectations for stress management. Given the positive effects of natural sound materials on both physiological and psychological states, studies have shown that natural sounds can effectively improve quality of life by regulating emotions and alleviating stress, particularly in reducing academic and social pressures among university students. And (Lee et al., 2016) found that music therapy significantly improved HRV and autonomic nervous system indicators in university students under stress. Also (Luo et al., 2021) confirmed that a mobile application using natural sounds significantly enhanced positive emotions, attention, and working memory in university students. A randomized controlled trial by (Kantor et al., 2022) found that low-frequency sound vibration therapy could reduce stress responses by improving HRV, offering new insights for stress management in university students. Also (Preißler et al., 2024) conducted a comparative study that further confirmed that an interdisciplinary “rehabilitation soundscape” project, which used computer-generated music, optimized recovery outcomes in hospital spaces, supporting the positive role of natural sounds in stress management. These findings provide a solid scientific foundation for the use of natural sound materials in psychological stress management, guiding future research and practice.

This study aims to offer a new perspective on psychological stress management. Music, as organized sound, contains more complex acoustic information than musical tones (Chung-Heng Hsieh et al., 2023), allowing for more detailed analysis of materials that align with soundscape therapy. HRV is a key physiological indicator for assessing psychological stress, and its relationship with stress is central to this research (Yang, Huang, et al., 2024). In the specific context of university students, investigating the stress-relief pathways of water sounds offers an opportunity to explore this relationship through HRV data. Thus, this study uses three different types of water sounds to investigate the impact on university students, employing both a questionnaire survey and data from fitness trackers with HRV feedback sensors to further analyze the results. The specific research approach is outlined below.

2. Method

2.1. Research Objectives

This study aims to explore the potential effects of music soundscape therapy on psychological stress management among university students, with a particular focus on the role of water sound materials and their resonance effects in alleviating stress. As an empirical investigation into the application of music therapy in the field of mental health, this research integrates questionnaire surveys with HRV fitness tracker feedback to quantitatively assess the impact of water sound materials on students' psychological stress levels. Additionally, the study qualitatively discusses the psychological and physiological mechanisms of resonance effects from an acoustic perspective.

The psychological and physiological mechanisms underlying music soundscape therapy are examined through the combination of questionnaire responses and HRV data. The experiment further investigates the role of resonance effects in enhancing the efficacy of music soundscape therapy, as well as individual responses to various water sound materials.

2.2. Participants

The final sample of this study consisted of undergraduate students from the Shanghai Conservatory of Music. A total of 37 volunteers were initially recruited; however, three participants were excluded prior to the experiment—one due to physical discomfort and two due to withdrawal during the process. Consequently, 34 students were included in the final sample, comprising 13 males and 21 females, aged between 18 and 25 years, with a mean age of 21.

This study was conducted in accordance with the principles of the Declaration of Helsinki and received approval from the Ethics Committee of the Shanghai Conservatory of Music (No. 2023DMKLB001). All participants voluntarily took part in the study and provided written informed consent.

2.3. Experimental Procedure

As shown in Figure 1, the study followed the CONSORT (2010) guidelines (Schulz et al., 2010) and employed a randomized trial design. During the preparation phase, the researchers explained the experimental process to the volunteers. Participants were grouped by gender and uniformly subjected to different types of water sound interventions.

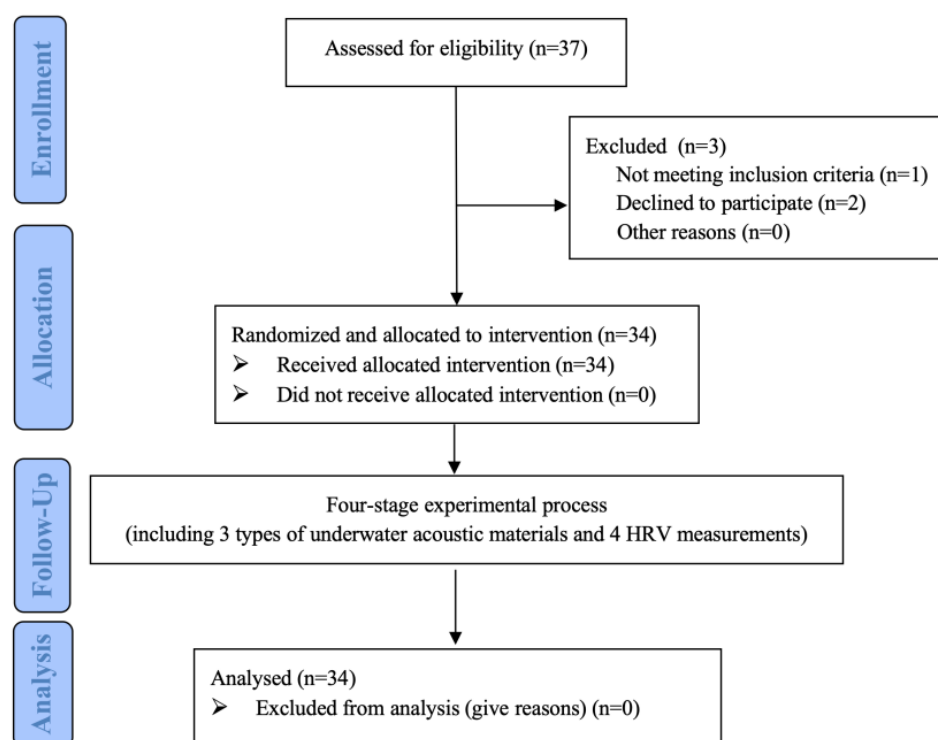


Figure 1. Consort flow diagram.

Throughout the intervention, a fitness tracker equipped with HRV monitoring was used to capture physiological data at various stages of the process, enabling a comprehensive quantitative assessment of psychological stress levels. After the intervention, participants completed an evaluation questionnaire. Upon completion, both the questionnaire responses and HRV data were archived. The experimental results were analyzed using Statistical Package for the Social Sciences (SPSS), providing an overall assessment of the potential of music soundscape therapy in psychological stress management, while also examining individual differences in response to the water sound materials.

During the experiment, three groups of water sounds were used for intervention, alongside an initial silent condition, forming four stages for HRV data observation. The nominal stimulus duration of each stage was 3 minutes. A 10-second fade-in and fade-out transition was allocated between consecutive stages, and data recorded during these transition periods were retained for analysis. The full four-stage experimental sequence lasted 9 minutes and 40 seconds in total. The four-stage experimental process is outlined as follows:

- Group 0: 3 minutes of silence.
- Group 1: 3 minutes of sea wave sound. (Jeff Huang, 2022a)

- Group 2: 3 minutes of stream sound.(Jeff Huang, 2022b)
- Group 3: 3 minutes of drizzle sound.(Jeff Huang, 2022c)

2.4. Evaluation Questionnaire

The evaluation of sound materials was conducted using the Psychoacoustic Perception Scale (PPS) questionnaire. The PPS (Kuen Wai Ma et al., 2020) is designed based on the three dimensions of the “Evaluation, Potency, Activity (EPA) Model” to quantify basic perceptual analyses of sound. Each dimension consists of three semantic differential questions, including: Quiet-Noisy, Relaxed-Tense, Pleasant-Unpleasant, Quiet-Loud, Light-Heavy, Weak-Strong, Deep-Metallic, Low-High, and Dull-Sharp.

Each item was rated on a 7-point scale from -3 to 3. For instance, the “Quiet-Noisy” dimension was scored as follows: “Extremely Quiet” (-3), “Quite Quiet” (-2), “Slightly Quiet” (-1), “Neutral” (0), “Slightly Noisy” (1), “Quite Noisy” (2), and “Extremely Noisy” (3).

The PPS questionnaire allowed for the assessment of the effects of sound materials across these three fundamental perceptual dimensions, providing insight into the underlying logic of how sound environments influence individual psychological and behavioral responses. This structured evaluation method reveals the perceptual quality of sound environments and offers quantitative data to support research in music soundscape therapy.

A pilot test of the PPS questionnaire was conducted with 10 volunteers. The reliability of the questionnaire was evaluated using the standardized Cronbach's α coefficient, with a value of 0.649 for the three factors of the “EPA Model,” indicating acceptable reliability. Exploratory factor analysis (EFA) was conducted to assess the validity of the questionnaire. The Kaiser-Meyer-Olkin (KMO) test yielded a value of 0.577, which, while below the ideal threshold of 0.7, remained within an acceptable range, suggesting that common factors were present in the data and suitable for factor analysis. The test results further showed a chi-square value of 67, degrees of freedom (df) of 36, and a significant p-value of 0.002. This strongly rejected the null hypothesis that the correlation matrix is an identity matrix, indicating significant correlations among variables.

These findings supported the rationale for conducting factor analysis and confirmed the good structural validity of the questionnaire. The pilot test results demonstrated satisfactory reliability and validity, indicating that the questionnaire was suitable for use in the main study.

2.5. HRV Data

Consumer wearable devices including Huawei, Samsung and Apple fitness trackers are generally equipped with HRV monitoring functions. Among these wearable options, Apple Watch was selected as the specific device used to extract HRV data from all participants in the present study (*Apple Watch*, n.d.). The HRV measurements were conducted in phases to capture heart rate data at each stage. Cheng (2020) noted that HRV measurements should focus on three key indicators: Heart Beat (HB), Standard Deviation of NN intervals (SDNN), and the Low Frequency/High Frequency Ratio (LF/HF) (Cheng et al., 2020). Based on these three HRV parameters, the data from each group were compared to observe the effects. The definitions and reference values for these three HRV parameters are as follows:

1. HB (Heart Beat) refers to the heart rate during a resting state without any activity. For university students, typically aged 18–25, the heart rate is approximately 60–100 beats per minute. Actual heart rates may vary depending on individual differences, age, health status, and exercise habits.
2. SDNN (Standard Deviation of NN intervals) reflects the overall variability of HRV. A higher SDNN value generally indicates a more stable autonomic nervous system, which helps the body better cope with stress and emotional fluctuations. The normal reference value for SDNN is (141 ± 39) milliseconds.

3. LF/HF Ratio is used to measure the balance between sympathetic and parasympathetic nervous system activity. A higher LF/HF ratio suggests more active sympathetic nervous activity, while a lower ratio indicates more pronounced parasympathetic nervous activity. In a non-stress state, a lower LF/HF ratio indicates a more balanced nervous system. The normal reference range for the LF/HF ratio is between 1.5 and 2.0.

2.6. Water Sound Materials

According to the meta-study by (Fan & Baharum, 2024), water sounds are highly representative sound materials in the context of music soundscape therapy. As shown in Figure 2, this study selected three types of water sounds for testing: sea wave sound, stream sound, and drizzle sound.

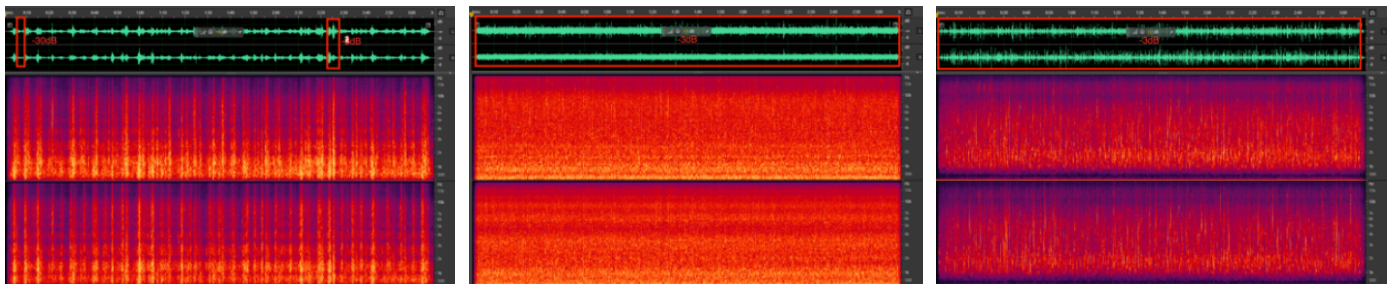


Figure 2. Waveforms and spectrograms of 3 sound materials.

1. The sea wave sound's spectral diagram reveals its energy distribution across different frequencies and times. The waveform fluctuates between -30 dB and -3 dB, with the spectral content extending from 500 Hz to 15 kHz. The low-frequency energy is dominant, while the high-frequency range is relatively weaker. The overall color gradient, from purple to yellow, indicates the periodic fluctuation of the wave sound.
2. The stream sound is characterized by its high density and moderate rhythmic complexity, simulating the flowing sensation of a natural stream. The amplitude remains stable at -3 dB, and the spectral diagram shows a uniform energy distribution. The color is consistently orange-yellow, presenting a dense and balanced frequency distribution visually.
3. The drizzle sound waveform shows a stable sound level at -3 dB, and its spectral content is concentrated in the low-frequency range, especially below 500 Hz. The high-frequency energy is relatively low, giving the drizzle sound a soft and soothing quality, which makes it ideal as background noise.

These detailed descriptions of the water sound materials provide an acoustic analysis foundation for further research in music soundscape therapy.

3. Results

This study used SPSS 27.0 software to summarize and analyze the experimental results. The overall data conformed to a normal distribution and homogeneity of variance, so descriptive statistics and one-sample t-tests were employed to present the experimental measurements.

3.1. PPS Questionnaire Results

The descriptive statistical results of the water sound test questionnaire provided a key perspective for understanding the participants' psychoacoustic perceptions. Combining the PPS questionnaire, descriptive statistical analysis of the 9 semantic differential questions was conducted to describe the participants' subjective feelings towards the water sound materials in the three dimensions. The PPS questionnaire was administered as an overall evaluation after participants completed all three sound interventions (sea wave, stream, and drizzle sounds).

Table 1 presents the variable statistics for the PPS questionnaire. In this study, all variables had a sample size of 34, ensuring consistency and reliability in the assessments. The scale used a seven-point rating system, including negative coding, to finely quantify the participants' subjective perceptions.

Table 1. PPS Data ($N=34$).

	Variable Name	Max	Min	M	SD	Med.	σ^2	Kurt.	Skew.	CV
E	Quiet-Noisy	3	-3	-0.41	1.69	0.0	2.86	-0.55	0.10	-4.10
	Relaxed-Tense	3	-3	-0.12	1.61	0.0	2.59	-0.62	-0.26	-13.68
	Pleasant-Unpleasant	3	-3	-0.44	1.78	0.0	3.16	-0.88	0.17	-4.03
P	Quiet-Loud	3	-3	-0.44	1.73	0.0	2.98	-1.03	0.18	-3.91
	Light-Heavy	3	-3	0.38	1.54	0.5	2.37	-0.52	-0.16	4.02
	Weak-Strong	3	-3	-0.18	1.70	-0.5	2.88	-0.74	0.33	-9.61
A	Deep-Metallic	3	-1	1.68	1.51	2.0	2.29	-0.99	-0.70	0.90
	Low-High	3	-3	0.56	1.50	1.0	2.25	-0.33	-0.38	2.69
	Dull-Sharp	3	-3	0.97	1.80	1.5	3.24	-0.97	-0.55	1.86

The combined analysis of the mean (M) and median (Med.) revealed the overall attitudes of the participants toward the sound materials. Specifically, the average values for Quiet-Noisy, Pleasant-Unpleasant, and Quiet-Loud were close to -0.4, indicating that participants tended to rate these sound materials more negatively, associating them with quietness, comfort, and pleasantness. In contrast, the average values for Light-Heavy, Low-High, and Dull-Sharp were 0.382, 0.559, and 0.971, respectively, showing a tendency toward positive perceptions in these dimensions, with keywords such as dullness, high frequency, and sharpness emerging. The median values were mostly close to 0, suggesting a symmetric data distribution and a trend toward ambiguous perceptions in the middle.

The analysis of the standard deviation (SD) and variance (σ^2) revealed the variability in participants' perceptions across different dimensions. The standard deviation ranged from 1.538 to 1.696, and the variance ranged from 2.254 to 3.242, indicating substantial differences in perceptions across various dimensions, with a more dispersed data distribution. Notably, the Pleasant-Unpleasant and Dull-Sharp dimensions had higher variances, suggesting significant perceptual differences in these areas.

The analysis of kurtosis and skewness further provided insights into the shape of the data distribution. Most kurtosis values were negative, indicating a flatter distribution compared to a normal distribution. The skewness values reflected the symmetry of the data distribution. For some variables, the skewness was close to 0, suggesting a more symmetric distribution, while others showed varying degrees of skewness.

The coefficient of variation (CV), representing the degree of data dispersion relative to the mean, indicated that the Relaxed-Tense and Weak-Strong dimensions had the highest CV values, reflecting greater variability in perceptions related to tension-relaxation and weakness-strength. Conversely, the Deep-Metallic dimension had the lowest CV, suggesting less variation in perceptions among participants, with a relatively concentrated data distribution and weaker perception.

The PPS questionnaire evaluation provided a comprehensive analytical framework to deeply understand psychoacoustic perceptions of different sound materials. Cronbach's α indicated acceptable internal consistency for exploratory research purposes. One-sample t-tests and independent-samples t-tests correspond to distinct statistical procedures adopted for different analytical objectives in this study. The statistical indicators revealed an overall positive attitude toward the psychological relaxation effects of the water sound materials and highlighted the perceptual differences among individuals through the characteristics of the data distribution.

3.2. HRV Data Feedback

The HRV data feedback, combined with independent samples t-tests, was used to assess the significance of fluctuations caused by the water sound stimuli at different stages. The test results, based on the one-sample t-test, revealed the effects of the three types of water sounds on autonomic nervous system activity. Four measurements were taken, resulting in three changes in differences, which were used to observe the significance of HRV differences. Table 2 shows the changes across the three groups, presenting three HRV indicators: HB, SDNN, and LF/HF. For each indicator, the mean (M), standard deviation (SD), and p-value are provided.

Table 2. HRV Data ($N=34$).

Group	HRV Data	M	SD	P
0-1	HB	-1.12	3.76	0.092
	SDNN	-2.21	13.08	0.333
	LF/HF	-0.84	0.75	0.518
1-2	HB	-0.44	2.64	0.337
	SDNN	1.91	13.08	0.400
	LF/HF	0.32	1.51	0.220
2-3	HB	-0.91	3.19	0.105
	SDNN	4.47	11.91	0.036 *
	LF/HF	-5.56	1.36	0.023*

Note: Significant differences in the experiment are indicated by *.

Specifically, the final inter-group change, which corresponds to the third group (drizzle sound), showed significant differences in the SDNN and LF/HF indicators, while the other groups did not exhibit significant differences. For the two changes in sea wave and stream sounds, there were no statistically significant differences observed either in total autonomic nervous system activity ($P_{0-1}=0.333$, $P_{1-2}=0.400$) or the sympathetic balance ratio ($P_{0-1}=0.518$, $P_{1-2}=0.220$). However, the third group, drizzle sound, displayed significant statistical differences in both SDNN ($P_{2-3}=0.036$) and LF/HF ($P_{2-3}=0.023$). This result indicates that the first two sound groups (sea wave and stream) had a relatively mild physiological impact on participants, while the third group (drizzle) produced a more pronounced effect, especially in activating parasympathetic nervous system activity. This may be related to the soothing nature of drizzle sound, which helps promote relaxation and reduce stress.

Overall, the drizzle sound seems to have a more significant effect in regulating autonomic nervous system activity, while the effects of sea wave and stream sounds were relatively smaller. The overall mean of the HB indicator was 75 beats per minute, with values fluctuating within a range of 2 and a standard deviation around 3, suggesting that the three sound materials had little impact on the participants' heart rate, and the test results remained relatively stable.

3.3. Comprehensive Observation

Based on the descriptive statistical results of the PPS questionnaire and HRV data feedback, a comprehensive assessment was conducted to evaluate the impact of water sound materials on participants' psychoacoustic perceptions and physiological responses. The statistical analysis of the PPS questionnaire revealed participants' subjective perceptions of the water sound materials, while the HRV data provided objective measurements of changes in their physiological state.

Figure 3 illustrates the overall psychoacoustic perception pathway of the participants. The four-step perception process—from the HRV smartwatch, headphones, sound waves, to the brain—corresponds to the random testing process of the three water sound materials. The study is designed

around the “PPS questionnaire,” with a word cloud on the far right displaying labels such as “quiet,” “relaxed,” and “noisy,” representing the final sound perception impressions.

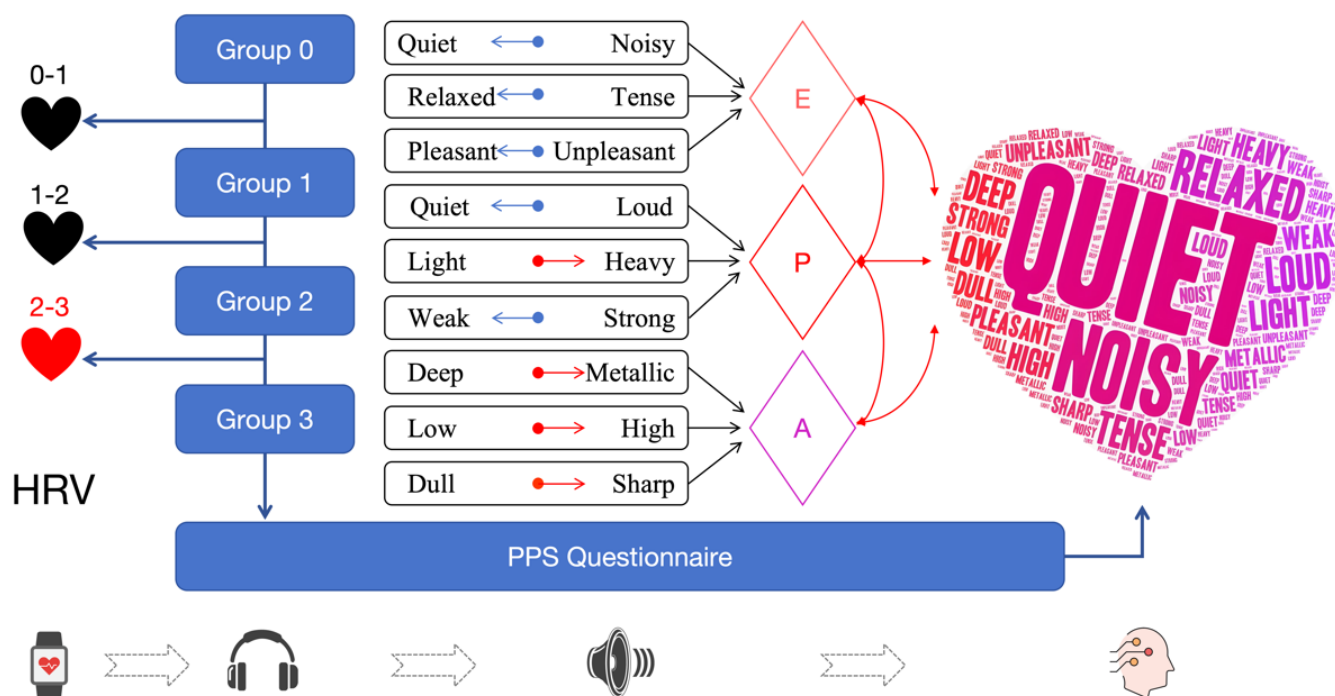


Figure 3. Psychoacoustic perception pathway.

In the PPS questionnaire, the overall positive and negative evaluations of the three dimensions—Evaluation (E), Potency (P), and Activity (A)—reflect the participants' subjective psychological perceptions. The E dimension shows that participants' overall perception of the water sound materials tends to be negative, with impressions of quietness, pleasantness, and relaxation. The P dimension reveals a general tendency: while the water sounds are quiet and faint, participants give a positive evaluation of the sound's energy content. The positive value in the A dimension indicates that participants have a strong positive perception of the time and spectral content of the sound, suggesting that the sound materials possess dynamic changes and complexity. These analyses of the EPA dimensions collectively reflect the psychoacoustic perception of the water sound materials, demonstrating their impact across different psychoacoustic attributes.

The further analysis of HRV data indicates that the significant effect of the drizzle sound is due to the activation of both sympathetic and parasympathetic nervous activities. As shown in Figure 3, the overall autonomic nervous activity and sympathetic nervous activity in the third group (drizzle sound) exhibited significant changes. Figure 4 illustrates the specific scatter and distribution lines of LF and HF for drizzle sound. It is evident that overall changes are minimal, except in the final measurement, where the HF ratio increased by approximately 300 units. This suggests that the stimulation of HF by the water sound is a key factor in activating parasympathetic nervous activity.

By combining the analysis of the PPS questionnaire and HRV data, this study provides an interpretation of the psychoacoustic and physiological effects of water sound materials. The stimulation of HF by water sound plays a crucial role in stress regulation, and this finding is significant for the design of music soundscape therapy. This direction will be further explored later from the perspective of frequency resonance.

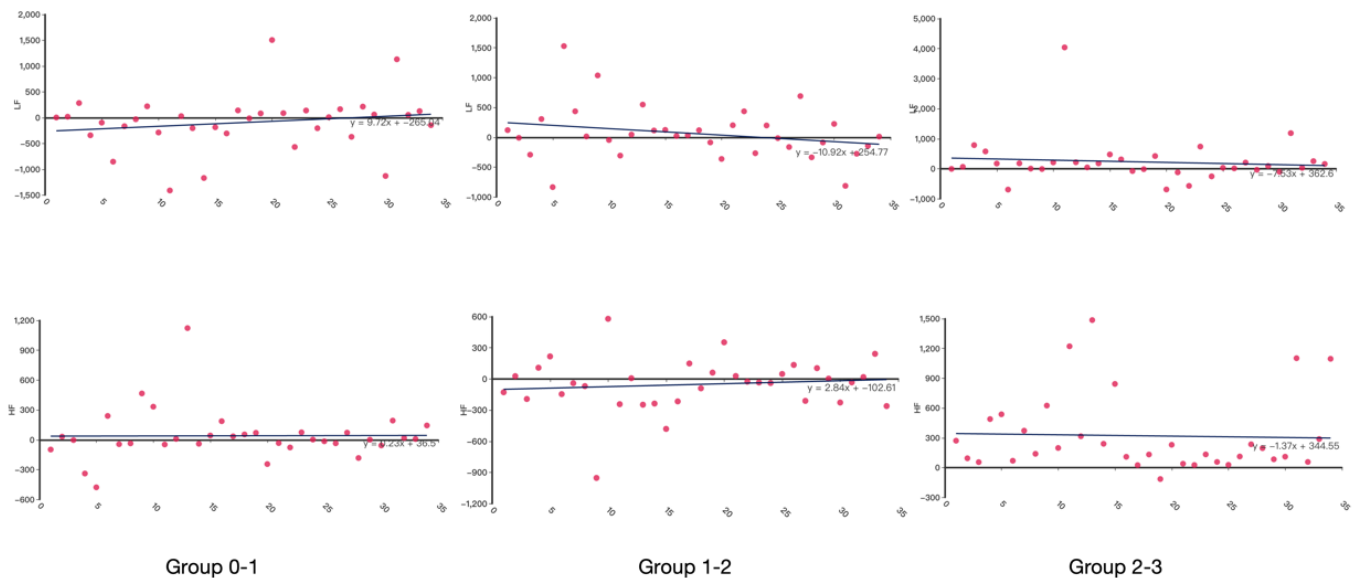


Figure 4. Scatter plot of LF and HF stages of drizzle sound.

4. Discussion

4.1. Hypothesis of Acoustic Resonance Effects

The acoustic resonance effect, which refers to the strong vibration phenomenon that occurs when sound waves at specific frequencies match the natural frequency of an object or system, has been widely studied in the field of physics and applied in various disciplines such as medicine, acoustics, and electromagnetics (Mitrofanova et al., 2024). In the field of psychoacoustics, the resonance effect of sound waves may influence the physiological state of the body, thereby affecting psychological states.

This study explored the effects of water sound materials on the participants' psychoacoustic perceptions and physiological responses, with a particular focus on the stimulation of the HF component of HRV and its relationship with stress regulation. The study suggests that certain frequencies within the water sound materials may match the participants' physiological frequencies, triggering resonance effects that, in turn, influence psychological perceptions and stress levels. For example, the specific frequency of drizzle sound may align with the participant's respiratory frequency or heart rate, inducing resonance that activates parasympathetic nervous activity and increases the HF component of HRV.

Water sounds and music interventions may be linked to stress regulation through their influence on brainwave activity. Brainwaves are classified into four main types based on frequency: β waves, α waves, θ waves, and δ waves. Among these, α waves and θ waves are associated with relaxation and stress reduction (Koudelková & Strmiska, 2018). The frequency range of α waves is approximately 8-13 Hz, and that of θ waves is about 4-8 Hz. Water sounds may reduce stress and anxiety by promoting the production of α and θ waves, thereby facilitating stress regulation (Baloh, 2024). This hypothesis is based on the theory of resonance, which suggests that if the frequency of music aligns with the body's subtle vibrations, it may enhance those vibrations, potentially leading to corresponding physiological and psychological effects.

The acoustic resonance effect is considered an important mechanism by which water sound materials influence participants' psychoacoustic perceptions and physiological responses. The interaction between sound wave resonance and the HF component of HRV may indirectly influence brainwaves, contributing to the regulation of stress. This has significant implications for the design of music soundscape therapy, as it provides a potential explanation that selecting sound materials at specific frequencies can effectively regulate an individual's stress levels.

4.2. Challenges During the Experiment

In this study, individual responses to sound or music were influenced by factors such as living environment, habits, experiences, and cultural background. During the experiment, the research team faced challenges related to headphone selection, player type, and the setting of the testing environment.

Regarding headphone selection, the team considered that inappropriate headphones might cause discomfort, potentially affecting the experimental results. Various types of headphones were compared, including in-ear Bluetooth headphones, bone-conduction headphones, over-ear wired headphones, and over-ear Bluetooth headphones. Based on comfort and participant preference, the team ultimately chose over-ear Bluetooth headphones.

In terms of music player selection, considering the need for portability, the team evaluated various options such as smartphone playback, computer playback, and MP3 players. To facilitate use by student participants, the team decided to use Bluetooth headphones with USB data reading functionality, allowing music to be played directly from a USB flash drive.

As for the testing environment, to minimize external interference, the research team chose to conduct the experiment during break times in a classroom. This decision aimed to control environmental variables, ensuring the accuracy and reliability of the experimental data.

4.3. Limitations and Future Directions

This study aimed to assess the effects of different water sound materials on stress and identify more effective natural sounds for use in music soundscape therapy. However, the study has several limitations, and future research is expected to address these gaps.

Firstly, the generalizability of the experiment is limited by the narrow range of water sound materials used and the inclusion of only university students from a single institution as participants. As such, the applicability of the study's findings is restricted. Nevertheless, the study provides preliminary guidance for music soundscape therapy in managing psychological stress among university students. To enhance generalizability, future research should expand the sample size to include a more diverse population and incorporate a wider range of natural sound materials, such as birdsong and wind sounds.

Secondly, the study is constrained by limitations in the number of participants, experimental duration, and HRV measurement methods, which may affect the sufficiency of the experimental results. Future research should increase the sample size, extend the duration of the experiment and statistical analysis, and employ more rigorous HRV measurement methods to enhance the comprehensiveness and robustness of the study.

Looking ahead, further research could explore the application of the acoustic resonance effect in music soundscape therapy and investigate how adjusting the frequency components of sound materials can optimize therapeutic outcomes. Additionally, research should delve deeper into the effects of factors such as the frequency, intensity, and duration of sound waves on the HF component of HRV, as well as the relationship between these effects and individual changes in psychological states. These explorations will provide a deeper theoretical foundation and practical guidance for music soundscape therapy.

5. Conclusions

This study provides an in-depth exploration of the potential effects of music soundscape therapy in managing psychological stress among university students, with a particular focus on the role of water sound materials and their resonance effects in stress alleviation. By utilizing a combination of the PPS questionnaire and HRV data, the research found that specific water sound materials significantly influence participants' psychoacoustic perceptions and physiological states. Notably, the drizzle sound exhibited the most pronounced stimulation of the HF component of HRV, suggesting its potential effect in activating parasympathetic nervous activity and stress regulation. The

findings provide preliminary evidence for the application of music soundscape therapy in psychological stress management and offer directions for future research. Furthermore, further investigation into the application of the acoustic resonance effect in music soundscape therapy, as well as the impact of frequency components of sound materials on therapeutic outcomes, will provide a deeper theoretical foundation and practical guidance for this field.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Key Laboratory of Artificial Intelligence Music Therapy, Shanghai Conservatory of Music (protocol code 2023DMKLB001 and date of approval 2025/12/10), China.

Informed Consent Statement: Not applicable.

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Data Availability Statement: The datasets analyzed for this study can be found in the Mendeley Data [doi: 10.17632/d54b4fk6pp.1].

Conflicts of Interest: The authors declare no conflicts of interest.

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