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# Acoustic Dynamics in Performance Halls: Enhancing Violin Sound Quality in the FPSD Orchestra Room

*Daniel de Fretes*[*1] and Fitriawati*[2]*

[1]Departement of Music, Institut Seni Indonesia Yogyakarta, Indonesia
[2]Music Study Program, Faculty of Art and Design Education, Universitas Pendidikan Indonesia, Indonesia
*Correspondence: E-mail: danieldefretes@isi.ac.id

**ABSTRACT**

With an emphasis on improving violin sound quality, this study explores the acoustic dynamics of the FPSD Orchestra Room at Universitas Pendidikan Indonesia. Direct and reflected sound are the two factors that impact the phenomena of interior sound. This research emphasizes the crucial balance between sound absorption and reflection to optimize the acoustic environment and ensure clarity and richness in violin performances. Improving acoustic conditions is vital to increase audience experience and performance quality. The study used a qualitative descriptive research style combining literature review and observations. The research site was the FPSD Orchestra Room, renowned for its historical significance and contribution to music education. The observations revealed significant acoustic obstacles that adversely affected the violin sound's clarity, including excessive reverberation and unequal sound dispersion. The literature review revealed the theoretical underpinnings of sound propagation, reverberation, absorption, reflection, and diffraction. The acoustic environment can be greatly enhanced by introducing sound-absorbing materials to optimize reverberation duration, controlling reflections with diffusers, and utilizing adaptive acoustic systems. Furthermore, combining virtual acoustics technology with digital sound processing systems allows for dynamic control over acoustic parameters, increasing the performance space's adaptability. These improvements provide a customized acoustic environment that supports a variety of musical performances and guarantees the audience a clear, engaging auditory experience. This study emphasizes the significance of fusing cutting-edge technology innovations with conventional acoustic design concepts to attain optimal sound quality in performance halls. Innovation and research must never stop to improve these acoustic settings even further.

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## 1. INTRODUCTION

The performance hall is a crucial platform for presenting various artistic performances, including dance, music, and drama. It provides a stage where the audience may completely enjoy the subtleties of each performance. McIntosh (2012) asserts that the spatial requirements of these rooms must be carefully designed to fulfill their intended purpose, guaranteeing the effective communication of the artistic message. The emphasis on spatial design is crucial for ensuring high-performance standards and audience contentment, as patrons expect comfort, safety, suitable illumination, pleasant aesthetics, and exceptional sound reproduction (Picaud, 2023). The acoustic layout is of utmost importance among these factors, especially in improving the auditory experience of concerts such as those featuring the violin. The violin is renowned for its deep, vibrant sound, which flourishes in acoustically advantageous settings (Lopez et al., 2022).

The phenomenon of sound interaction within a performance venue, particularly regarding string instruments such as the violin, is intricate and multifaceted. When a violin is performed in enclosed rooms, its acoustic qualities create a unique auditory experience characterized by a resonant, voluminous, and well-rounded sound, even without amplification (Osborne, 2022). This occurrence highlights the room's significance as a channel for transmitting acoustic energy. The surfaces within the venue are of utmost importance, as their ability to absorb and reflect sound can greatly impact the perceived sound quality for the audience.

The need to prioritize acoustic optimization in performance halls stems from the increasing awareness of its influence on artists and audience members. Efficient sound processing improves performance quality and creates a sense of comfort for the audience, leading to higher pleasure and engagement (Lopez et al., 2022). It is especially crucial for string instruments such as the violin, as the interplay between the instrument and the acoustic environment can amplify or reduce the desired musical expression.

Previous studies have thoroughly investigated the acoustic characteristics of performance venues and their impact on musical instruments. Research has indicated that the acoustic properties of a room, including factors like reverberation, absorption, and diffraction, substantially impact how we perceive sound (Ambarwati, 2015). The acoustic characteristics of an orchestra chamber can affect the violin's timbre, influencing the violinist's technique and the audience's perception of the sound (Allingham et al., 2021). Furthermore, we have examined the architectural design of performance halls, specifically studying using materials that absorb and reflect sound to comprehend their impact on achieving the best possible sound quality (Maeda et al., 2021).

Nevertheless, more research is needed to comprehend the precise acoustic phenomena in confined places such as the FPSD Orchestra Room at Universitas Pendidikan Indonesia. Although there is extensive documentation on the general concepts of acoustics, a lack of research specifically examines the application of these principles in performance spaces and how they directly affect violin performance. This gap underscores the necessity for comprehensive research investigating the use of acoustic science to improve the auditory environment in particular contexts, ultimately improving both performance and audience satisfaction.

The uniqueness and significance of this study stem from its exclusive focus on the FPSD Orchestra Room, which serves as a distinctive environment for musical performances. The study seeks to gain new insights into the influence of room acoustics on violin performance by examining the acoustic phenomena in this situation (Kob, et al., 2020). The aim is to investigate the utilization of acoustic science in this specific orchestra space, analyzing the performance disparities between instruments that employ audio amplifiers and those that do not. The study distinguishes itself from past studies by focusing on a particular location and thoroughly analyzing acoustic principles rather than addressing more general acoustic difficulties (Kent & Rountrey, 2020).

The improvement of sound quality and audience satisfaction heavily relies on the optimization of acoustics in performance venues (Turchet, et al., 2021). This study intends to fill the research gap and offer fresh insights into the use of acoustic science in violin playing by focusing on the specific context of the FPSD Orchestra Room. The study aims to enhance the overall understanding of how performance spaces can be effectively created and controlled to obtain the best possible auditory outcomes by closely analyzing acoustic phenomena and their influence on sound quality.

## 2. METHODS

This study utilizes a qualitative descriptive research approach to investigate the acoustic phenomena of the FPSD Orchestra Room at Universitas Pendidikan Indonesia. Qualitative research is particularly well-suited for acquiring a profound and detailed comprehension of intricate phenomena as perceived by humans in authentic environments (Køster & Fernandez, 2023). The primary objective is to depict the complicated and multifaceted aspects of human behavior, perceptions, motivations and acts using meticulous descriptions and interpretations (Pilarska, 2021). The qualitative descriptive approach entails the gathering and examination of non-numerical data to comprehend concepts, opinions, or experiences. This approach is highly pertinent to this study since it seeks to investigate the complex correlation between room acoustics and violin performance, which is deeply ingrained in the specific environment of the FPSD Orchestra Room.

The investigation was conducted at the FPSD Orchestra Room at Jalan Dr. Setiabudhi No. 229 KM 7, Bandung. This location was selected based on its status as a prestigious higher education institution offering a Music Study Program since 1954. The FPSD UPI Bandung is highly esteemed for its significant contributions to music education and its unwavering dedication to nurturing musical aptitude, rendering it an optimal environment for this research. The data gathering for this study utilized two main methods: observation and literature review. These methods were selected to offer a thorough comprehension of the acoustic environment and its influence on violin performance (D'Amato, et al., 2020).

Observation is a fundamental aspect of qualitative research, allowing us to collect primary data on the behaviors and interactions occurring within a particular situation. This study involved conducting direct observations in the FPSD Orchestra Room to investigate the acoustic properties and their impact on violin performance. It entailed participating in rehearsals and performances, observing the room's architectural layout, materials, and spatial configurations, and analyzing how these factors influenced the sound generated by the violin (Domenighini, 2021). The observational data offered valuable insights into the immediate impact of room acoustics on the clarity, resonance, and overall excellence of the violin sound.

A thorough literature review was undertaken to provide context for the observations and utilize current knowledge in acoustics and music performance. It entailed examining scholarly publications, books, and previous research on subjects such as room acoustics, sound absorption, reflection, and diffusion, and their particular effects on string instruments such as the violin. The literature evaluation facilitated the identification of well-established principles and theories that can explain the observed events (Walsh & Rowe, 2023). Additionally, it brought attention to the deficiencies in the current research that this study intends to fill.

The integration of these two methodologies facilitated a comprehensive examination of the acoustic characteristics of the FPSD Orchestra Room. Observations yielded firsthand, practical knowledge, while the literature review gave theoretical frameworks and comparison data. Collectively, these methods enabled a thorough comprehension of how the room's acoustics impact the performance of the violin, contributing to the wider domain of research on music acoustics.

## 3. RESULTS

The room is the medium of acoustic energy propagating in an enclosed space (Septiawati & Aulia, 2023). Hence, a comprehensive understanding of a room's acoustic phenomena is crucial to effectively managing the auditory environment based on its intended purpose (Bettarello, et al., 2021). The following figure can elucidate the acoustic properties of a room.

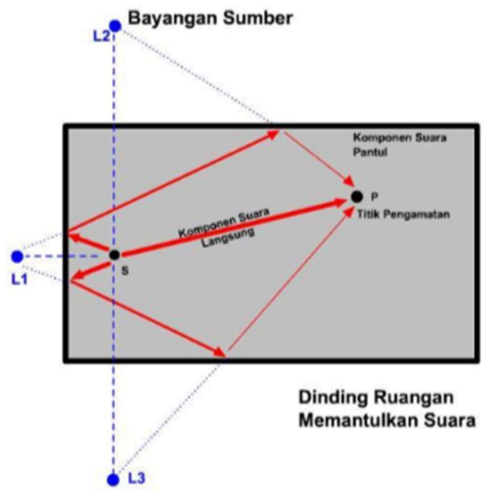


**Figure 1.** The acoustic properties of a room

The sketch illustrates that each observation points or location where individuals experience the sound (listeners) will be influenced by two sound components: the direct sound component and the reflected sound component. The direct sound component refers to the sound that reaches the listener's ears without any reflections or interference, originating straight from the source (Xie, 2020). The sound energy that reaches the ear from this sound component is determined by the listener's distance from the source and the extent to which the air absorbs the energy (Ganchrow, 2021). The reflected sound component refers to the portion of sound that reaches the listener's ears following its interaction with the surrounding surfaces of the room, such as the walls, floor, and ceiling (Ziemer & Ziemer, 2020). These two factors will affect both the amount of sound energy that reaches the listener's ears and the listener's perception of the sound. The reflected sound component significantly influences the creation of hearing perception. The acoustic properties of the room's surface substantially impact the listener's circumstances and hearing perception.

There are two opposite scenarios regarding the properties of surfaces in the room. When all surfaces have a high capacity to absorb sound and when all surfaces in the room have a high ability to reflect sound energy (Amran, et al., 2021). An *anechoic* environment is characterized by highly absorbent surfaces, which result in just the direct sound component reaching the listener (*anechoic chamber*). The reflected sound component will be more prominent in an environment with highly reflecting surfaces than the direct component. This is widely known as "Ruang Dengung' (*reverberation chamber*). The rooms we typically utilize vary according to their respective functions, generally falling within a range that spans between these extremes. A recording studio space, for instance, exhibits characteristics more like an anechoic room, but a room with rigid walls is more similar to a reverberation room (Noviandri, 2022).

The acoustic properties of room surfaces are typically categorized into:

- Sound Absorbing Material (*Absorber*) Surfaces are composed of materials that can absorb a significant portion, if not all, of the sound energy directed towards them (Li, et al., 2022). Examples of insulation materials include glass wool, mineral wool, and foam. It can either exist independently or be incorporated into an absorber system (fabric covered absorber, panel absorber, grid absorber, resonator absorber, perforated panel absorber, acoustic tiles, etc.).
- Sound Reflecting Material (*Reflektor*) An acoustically reflective surface that efficiently reflects the majority of incoming sound energy. The reflection is specular, adhering to the Snelius rule, which states that the incident angle equals the reflected angle. Some examples of this material include pottery, marble, metal (such as aluminium), gypsum board, and concrete.
- Sound diffusing material (*Diffusor*), an acoustically uneven surface is one that scatters the sound energy it receives. For instance, the QRD diffuser, BAD panel, and diffsorber are some examples.

Desired listening circumstances can be achieved by combining the three categories of materials that align with their respective functions. The acoustic parameters commonly employed in enclosed spaces can be categorized into two main groups: temporal monoaural parameters, which can be perceived using a single ear (or measured with a single microphone), and spatial binaural parameters, which can only be detected when both ears are simultaneously engaged (or measured with two microphones simultaneously) (Ambarwati, 2015).

The acoustic performance of the auditorium refers to its capacity to effectively transmit sound created by speakers or musicians, allowing listeners to accurately and comprehensively perceive and comprehend the sound (Jon & Jeon, 2022). The auditorium's acoustic performance is assessed based on the background noise level, distribution of sound pressure levels, and the room's impulse response. The measurement process consists of three stages to get objective metrics of the auditorium space's acoustic quality.

The initial step involves measuring the ambient noise level in the auditorium to assess the extent of noise criteria. This assessment includes evaluating the impact of external factors, such as noise from parking areas, road traffic, and mechanical or electrical equipment within the building, such as air conditioners and sound systems (Farooqi, et al., 2022). The second stage involves measuring the distribution of Sound Pressure Level (SPL), which provides valuable information about how sound is distributed within the auditorium. The third stage involves conducting impulse response measurements to determine various acoustic parameters, including Reverberation Time, Early Decay Time, D50 (Definition), C50 and C80 (Clarity), and TS (Center Time). The measurement was carried out at the Auditorium Orchestra FPSD UPI Bandung.

The spatial-binaural type characteristics encompass LEF and IACC. LEF is derived by comparing room Impulse Response measurements using two closely positioned microphones, one with an omnidirectional pattern and the other with a Figure of Eight patterns (Lee & Johnson, 2021). The impulse response measurement to obtain Interaural Cross-Correlation (IACC) involves employing two microphones placed in either both ears of a dummy human head or in two human ears (Granzotto, et al , 2023). Envelopment parameters and apparent source width can be determined from these two parameters. This concept is typically employed in larger spaces. When dealing with small rooms like studios, it is important to consider the distribution of resonant frequencies, also known as modes, particularly at low frequencies. This was discussed in a previous post on modes.

The acoustic characteristics of an orchestra space have a crucial role in violin performance within an ensemble. The acoustic properties of the location where the violin is performed can significantly influence the instrument's timbre (Nastac, et al., 2022) . The violin's sound in an orchestra can be enhanced in brightness and clarity when performed in a room with favourable acoustics. This occurs because the music emitted by the violin can bounce off the walls and ceiling of the space, resulting in sound interference that enhances the brightness and clarity of the sound.

Conversely, the sound can become more dissonant and less distinct when the violin is played in a room with inadequate acoustics. The violin's sound is not adequately reflected by the room's walls and ceiling, resulting in imperfect formation and an indistinct sound (Kurniawan, et al., 2022).

In order to achieve a vibrant and distinct violin sound within an orchestra, it is necessary to have a venue with favourable acoustics. The venue should possess acoustically reflective walls and ceilings to ensure optimal sound projection, allowing the listener to perceive the violin's sound with utmost clarity. Furthermore, room acoustics can also impact how violinists perform on their instruments. Violinists in a space with favourable acoustics will experience an enhanced auditory perception of the instrument's sound, enabling them to perform with greater proficiency and precision (Luciani, et al., 2022).

Therefore, room acoustics is a crucial factor to consider when playing the violin in an ensemble. An acoustically favourable setting enhances the violinist's performance by amplifying the instrument's sound and rendering it more vibrant and distinct to the listener.

Acoustic phenomena play a crucial role in playing the violin within a confined space. This encompasses how the sound emitted by the instrument is perceived inside the confines of the room, as well as how the sound interacts with the room (De Poli, 2022). Essentially, the music generated by the violin comprises sound waves characterized by varying frequencies and amplitudes. Upon entering the space, the sound will undergo reflection off the walls, ceiling, and floor and may also be absorbed by the materials present in the room. This occurrence is known as room acoustics. The acoustic properties of a room are crucial as they can impact the listener's perception of the sound generated by the violin. The violin's sound will be distinct and harmonious when the space has favourable acoustics. Conversely, the violin sound will be muted or indistinct in a room with unfavourable acoustics.

Several elements, such as the room's dimensions, configuration, and construction materials, influence room acoustics. A smaller, rectangular room will possess superior acoustics compared to a bigger, circular area. Furthermore, the acoustics of a space can be influenced by the materials employed to adorn its surfaces, such as rugs, curtains, or ceilings. There are multiple methods to enhance room acoustics, including using sound panels or acoustic ceilings, incorporating sound-absorbing materials, or altering the room's design. The optimal approach to enhance room acoustics is to meticulously plan the space's design, considering the various aspects that impact its acoustics (Indrani & Cahyawati, 2011).

Ultimately, the acoustic phenomena play a crucial role in the context of violin performance within a room since it directly influences the listener's perception of the violin's sound (Bedoya, et al., 2021). In order to enhance the acoustics of a room, one must consider the space's dimensions, configuration, and composition.

Acoustic phenomena in violin playing in a room can happen at different levels, including the interaction between the sound produced by the violin and the room and the interaction between the sound created by the violin and the listener in the room (Maestre, et al., 2021). Below are several acoustic phenomena that occur while playing the violin in a room:

- Reverberation: Reverberation is the acoustic occurrence when the sound emitted by the violin is reflected off the surfaces of the space, including the walls, ceiling, and floor. Reverberation will manifest across all frequencies of the music emitted by the violin, although it will be particularly noticeable at lower frequencies.
- Absorption: Absorption is an acoustic phenomenon where the sound emitted by the violin can be soaked up by various surfaces in the room, such as carpets, chairs, or fibrous materials. Sound absorption will occur across all frequencies emitted by the violin, emphasizing higher frequencies.
- Diffraction: Diffraction is an acoustic phenomenon where the sound emitted by the violin can be redirected towards the listener after interacting with items in the environment. Diffraction is a phenomenon that happens at all frequencies of the music produced by the violin, but it is more noticeable at higher frequencies.
- Auditory engagement with the recipient: Aside from the acoustic contact between the violin and the room, the sound emitted by the violin will also be influenced by the interaction with the listeners. Listeners can influence the music generated by the violin through the process of absorbing and diffracting sound waves in their bodies.

Any acoustic phenomena that arise during violin playing in a given space will impact the overall sound quality produced by the instrument. These factors can influence the auditory perception of the violin, including the volume, tone quality, and intricacy of the sound. The acoustic phenomena in violin playing in a room arise from the interaction between the sound emitted by the violin and the room in which it is heard (Fulford, et al., 2020). When the music of the violin resonates within the space, it will reflect off the walls, floor, and ceiling. The characteristics of these surfaces will impact both the frequency and intensity of the sound perceived, perhaps leading to alterations in the sound emitted by the violin.

*Resonance* is a potential acoustic phenomenon that can occur when playing the violin in a room. Resonance arises when the frequency of the sound emitted by the violin aligns with the resonance frequency of the room in which the sound is perceived (Klein, et al., 2022). Resonance enhances the amplitude and clarity of the sound emitted by the violin. Furthermore, an additional acoustic phenomenon that might manifest during violin performance in a room is interference. Interference arises when many sounds are perceived simultaneously within a shared space and mutually influence one another. Interference can result in the sound generated by the violin being intricate and erratic. Sound absorption is another acoustic phenomenon that can occur when playing the violin in a room. Sound absorption occurs when the sound emitted by the violin is soaked up by the surfaces in the room where the music is perceived (Postma & Katz, 2020). Sound absorption can attenuate the volume and clarity of the violin's sound. In order to enhance the acoustic properties of violin playing in a room, it is imperative to consider the configuration and composition of the walls, floor, and ceiling of the space where the sound is perceived. Rooms with flat, nonabsorbent surfaces for walls, floors, and ceilings are ideal for playing the violin. Furthermore, the placement of the musician and the audience can also impact the acoustic phenomena of violin performance within the space.

## 4. DISCUSSION

### 4.1 Theoretical Principles of Room Acoustics

Comprehending the acoustic dynamics of a performance hall entails exploring the intricate interaction of sound waves within a confined area. Room acoustics, a specialized area within the subject of acoustics, examines sound behavior in different spaces and how it affects how people hear and feel sound, whether they are performers or listeners (Milo, 2020) . The fundamental principles of room acoustics are based on various essential ideas, such as the transmission of sound, the persistence of sound waves, the absorption of sound, the reflection of sound, and the bending of sound waves around obstacles. Each of these phenomena is essential in determining the acoustic characteristics of sound in a performance venue.

Sound propagation in a room refers to transmitting sound waves from the source to different locations (Embleton, 1996). The process is affected by the medium (air), the sound source's properties, and the room's limits (Wiener, et al., 1965). Within a confined area such as a performance hall, sound waves propagate outward from the origin in a radial manner, engaging with the many surfaces they come into contact with. The propagation of these waves determines the characteristics of the direct sound (sound that travels directly from the source to the listener) and the reflected sound (sound that bounces off surfaces before reaching the listener) (Larsen, et al., 2022).

At room temperature, the air's sound velocity is roughly 343 meters per second (Williams, 2001). The velocity may exhibit minor fluctuations due to temperature, humidity, and atmospheric pressure variations (Snyder, et al., 1981). Gaining a comprehensive understanding of the velocity and characteristics of sound waves is essential for creating performance venues that optimize aural precision and depth (Peters, 2010). Within an orchestra chamber, the objective is to maximize the perception of direct and reflected sounds to enhance the musical experience without introducing any confusion or distortion.

Reverberation refers to the continued presence of sound in a certain area even after the initial sound source has ceased releasing sound (Valimaki, et al., 2012). It arises from the phenomenon of sound waves bouncing off various surfaces, such as walls, ceilings, and floors, many times (Thakur & Jain, 2019). Reverberation time, often known as RT60, is the duration for the sound to diminish by 60 decibels once the source has ceased. This metric is crucial in establishing the acoustic characteristics of a room. An excessive amount of reverberation can result in the blending of sounds and a loss of clarity, while an insufficient amount might create a dull and lackluster sound.

The appropriate reverberation time in performance halls varies depending on the nature of the performance (Hyon & Jeong, 2021). For instance, shorter reverberation periods are necessary in speech and solo performances to preserve clarity, whereas longer reverberation times are advantageous in symphonic music to enhance the sound (Redman, et al., 2023). Attaining the appropriate equilibrium necessitates a meticulous examination of the room's dimensions, configuration, and building materials.

Sound absorption refers to the mechanism through which materials or surfaces absorb sound energy, diminishing the amount of sound reflected back into the room (Jang, 2023). The quantification of a material's ability to absorb sound is determined by its absorption coefficient, which spans from 0 (indicating perfect reflection) to 1 (indicating ideal absorption). Materials such as carpets, draperies, and acoustic panels commonly absorb sound and regulate reverberation in a performance venue.

The positioning and composition of absorbent materials are crucial factors in controlling the acoustic conditions. Strategically positioning sound absorbers in a performance hall can eliminate echoes and diminish background noise, improving the sound's clarity (Mónica, et al., 2022). For example, thick drapes can absorb sounds with high frequencies. In contrast, acoustic panels can be specifically built to focus on particular frequency ranges, guaranteeing an even absorption over the range of sounds that can be heard.

Sound reflection occurs when sound waves rebound off surfaces. Reflective surfaces facilitate the propagation of sound waves in a room, ensuring optimal audibility of the performance for the entire audience, including those seated at the back of the hall (Burfoot, 2022). Nevertheless, inadequately controlled reflections can result in acoustic problems like flutter echoes and standing waves, which can cause sound distortion.

The angle at which sound waves meet a surface, and the characteristics of the material of that surface dictate the properties of sound reflections (Sathish, et al., 2023). The law of reflection states that the angle of incidence, which is the angle at which a sound wave strikes a surface, is equal to that of reflection, which is the angle at which it bounces off the surface. Performance halls utilize this technique to create surfaces that effectively manipulate the direction of sound waves. Concave surfaces can concentrate sound waves, increasing their strength at certain locations, whereas convex surfaces can scatter sound waves, resulting in a more spread-out sound distribution.

Sound diffraction is the phenomenon where sound waves bend around objects and spread out when they pass through apertures. This phenomenon guarantees the distribution of sound over all sections of a performance space, enhancing the listening experience's consistency (Salselas & Bernardes, 2021). Within the realm of violin performance, diffraction plays a role in evenly dispersing sound around the space, improving the overall auditory experience for the listener.

Diffraction plays a significant role in performance venues with intricate shapes or where architectural elements may block the direct propagation of sound (Pisha, et al., 2020). Comprehending the phenomenon of sound wave diffraction around obstacles enables the creation of spaces that guarantee uniform sound quality across the entire hall. One possible solution is strategically positioning diffusers to disperse sound waves and prevent areas of acoustic shadow.

Architectural acoustics refers to the scientific and engineering principles that provide optimal sound quality in a building (Mahdavi & Berger, 2023). It encompasses optimizing room sound quality by carefully selecting materials and deliberately shaping the environment. Architectural acousticians utilize their knowledge of sound transmission, absorption, reflection, and diffraction to design acoustically optimum environments for their intended purpose (Trocka-Leszczynska & Jablonska, 2021). Architects must consider many acoustic factors when designing performance halls to offer an excellent auditory experience. It encompasses the room's configuration, which might impact the propagation and interaction of sound waves inside the area. Rectangular rooms can generate standing waves, which are sound waves that stay in one place and amplify or reduce specific frequencies. To alleviate this issue, architects may employ asymmetrical forms or incorporate features like diffusers and absorbers to disrupt these regular patterns.

Acoustic treatment uses materials and design features to manage sound inside a given area (Arenas & Sakagami, 2020). It involves utilizing absorptive materials to decrease reverberation, reflective surfaces to amplify sound projection, and diffusers to disperse sound waves. Acoustic treatment is crucial in performance venues to guarantee optimal sound clarity, balance, and immersion. To achieve effective acoustic treatment, one must thoroughly comprehend how various materials and designs impact sound. Excessive use of absorbent material can dampen the sound, while an abundance of reflective surfaces might result in excessive reverberation (Paul & Behera, 2021). The objective is to attain an equilibrium that amplifies the inherent acoustics of the instruments and the venue. It could blend pliable materials for sound absorption and rigid surfaces for sound reflection, resulting in a lively and captivating acoustic setting.

### 4.2 Practical Applications of Violin Performance

The acoustic atmosphere of a performance venue plays a crucial role in determining the quality of musical experiences for both performers and listeners. The Orchestra Room at Universitas Pendidikan Indonesia provides a case study on how acoustic dynamics can be precisely adjusted to improve the sound quality of violin performances.

a. Optimizing Reverberation Time

The reverberation time is a crucial aspect that substantially impacts violin playing in a hall. Reverberation, the lingering sound following the cessation of the initial sound, can enhance music by providing warmth and depth (Poćwierz-Marciniak & Harciarek, 2021). Excessive reverberation can cause a loss of clarity in individual notes, making it challenging for the artist and the listener to perceive subtle musical nuances. Observations in the FPSD Orchestra Room revealed an excessively prolonged reverberation time during solo violin performances, resulting in diminished clarity. To tackle this issue, implementing additional sound-absorbent materials can be beneficial. Properly positioning acoustic panels on walls and ceilings makes it possible to absorb excessive sound energy effectively, reducing reverberation duration to an ideal level. These panels can be customized to focus on particular frequency bands, guaranteeing an even absorption over the range of sounds that can be heard. In addition, using thick curtains and carpets can effectively absorb sound, especially at higher frequencies, further improving the precision of the violin's sound (D'Orazio, et al., 2020). By implementing these changes, the natural resonance that enhances the music will be preserved while also preventing the overlapping of notes that causes a lack of clarity.

b. Acoustic Reflection Control

Sound reflection is essential for effectively transmitting sound throughout a performance hall. Utilizing reflective surfaces can optimize the acoustic propagation of the violin's sound, guaranteeing its even distribution across the room and delivering a uniform auditory experience to the entire audience (Schlienger & Khashchanskiy, 2021). Nevertheless, inadequately controlled reflections can give rise to problems such as flutter echoes and standing waves, which alter the sound and diminish its quality. The FPSD Orchestra Room necessitates meticulous study of the design and composition of reflected surfaces. Although a certain level of reflection is essential for maintaining good sound projection, it is crucial to regulate it to avoid acoustic issues. Implementing diffusers can efficiently control reflections. Diffusers disperse sound waves in many directions, diminishing the strength of direct reflections and establishing a more uniform sound environment (Arvidsson, et al., 2021). These can be installed on vertical and horizontal surfaces, especially in regions where reflected sound waves are most troublesome. In addition, altering the shape of the room can help control the bouncing of sound waves. By inclining walls slightly or incorporating uneven surfaces, it is possible to disrupt the production of standing waves and avoid the occurrence of flutter echoes. These architectural modifications can optimize the acoustic environment, improving the tonal characteristics of the violin and guaranteeing the listener perceives the music with clarity and accuracy.

c. Strategies for Absorbing Sound

Sound absorption is crucial for managing reverberation and avoiding excessive reflections (Zhang, 2023). Efficient sound absorption can substantially impact the overall acoustic excellence of a performance hall. Materials with high absorption coefficients, such as acoustic panels, foam, and heavy fabrics, can be strategically positioned to absorb sound energy and minimize undesired echoes. We may effectively tackle unique acoustic obstacles by including various sound-absorbing materials in the FPSD Orchestra Room. Acoustic panels can be mounted on the walls and ceiling to effectively absorb mid to high-frequency sounds that affect the clarity and definition (Fasllija & Yilmazer, 2023). These panels can be adorned with cloth to increase their visual attractiveness while preserving their sound-absorbing characteristics. Large surfaces, such as windows or stage backdrops, can be covered with heavy drapes to absorb high-frequency sounds that could reflect and cause distortion. Carpeting and rugs can be strategically positioned on the floor to effectively absorb sound and minimize noise generated by footsteps and other forms of movement (Iskandar & El-Horabty 2023). By integrating various absorbent materials, the acoustic environment may be precisely adjusted to enhance the clarity and intricacy of violin performances.

d. Diffraction and Sound Dispersion

Sound diffraction is the process of sound waves bending and spreading when they come across obstacles (An & Yoon, 2021). Ensuring sound is evenly distributed throughout a performance venue is important. Efficiently controlling diffraction in the FPSD Orchestra Room ensures a uniform aural experience for all audience members, independent of their seating location. Careful attention should be given to the positioning of diffusers and the room's interior design to optimize sound dispersion. Diffusers are employed to disperse sound waves, inhibiting their concentration in specific regions and guaranteeing a uniform sound distribution across the entire venue. These can be especially efficient when positioned on the ceiling and higher walls, where sound waves are prone to causing unequal dispersion. The sitting area's configuration and arrangement can influence sound dispersal. Optimizing the seating arrangement to reduce acoustic shadows and provide unobstructed sightlines can improve the overall quality of the listening experience. Modifying the seat angle or implementing tiered seating might be beneficial in certain situations to guarantee a uniform sound quality for all spectators, boosting their overall enjoyment of the performance.

### 4.3 Advancements in Technology and Acoustic Design

Technological improvements in performance hall acoustics have offered creative approaches to improve sound quality and create an optimal auditory experience for performers and audiences (Wilson, 2023). These technologies enhance traditional acoustic design concepts by providing additional flexibility and precision in managing sound dynamics.

a. Systems for processing digital sound

Digital sound processing (DSP) devices are a notable breakthrough in acoustic technology, enabling immediate manipulation of many acoustic properties (Vessa, 2020). These systems employ algorithms to alter sound waves, modifying parameters like reverberation time, equalization, and delay to meet specific performance requirements. DSP systems can adjust the acoustic environment in real-time, ensuring the best sound quality for various performances (Tian, et al., 2021). Within the FPSD Orchestra Room, Digital Signal Processing (DSP) technology could be utilized to customize the acoustics to suit different musical genres and arrangements. For instance, the acoustic requirements for solo violin performances differ from those of full orchestral compositions. A digital signal processing (DSP) system can modify the reverberation duration to improve the clarity of individual performances while still providing the desired richness for symphonic compositions (Wilmering, et al., 2020). By changing these parameters in real-time, the DSP system can generate a flexible acoustic setting that adjusts to the particular needs of each performance. Moreover, DSP systems can effectively tackle acoustic problems like feedback and echo. By using sophisticated signal processing procedures, these systems can detect and alleviate frequencies that may cause issues, guaranteeing a clear sound that is free from distortion (Nsalo Kong, et al., 2021). This feature is especially advantageous in venues with several microphones and speakers since it preserves the sound quality by preventing the introduction of undesirable artifacts.

b. Virtual Acoustics Technology

Virtual acoustics technology is an advanced method for controlling room acoustics (Popp & Murphy, 2022). This technology employs a fusion of speakers and microphones to generate virtual acoustic environments, enabling performers to encounter diverse acoustic configurations without departing from the performance space (Ahern, 2022). Virtual acoustics technology can replicate the acoustic properties of renowned concert halls, cathedrals, or outdoor settings, offering significant rehearsal spaces for artists. Integrating virtual acoustics technology in the FPSD Orchestra Room can provide numerous advantages. Performers can train in simulated environments that replicate the sound characteristics of different venues, improving their ability to adjust and prepare for performances in various contexts. This feature can enhance their overall performance excellence since they can adapt and perfect their technique and delivery to match multiple acoustic settings (Barchiesi, et al., 2015). Moreover, virtual acoustics can be employed for teaching objectives. Music students have the opportunity to explore the acoustics of famous performance venues, which allows them to understand how these settings impact the production and perception of sound. Exposure to this can enhance their comprehension of acoustic principles and their practical implementations, enhancing their musical education.

c. Architectural acoustics

Using technical developments in acoustic design increases the significance of conventional architectural acoustics (Fernando, et al., 2023). Instead, it amplifies and supplements these ideas, resulting in a more comprehensive approach to acoustic optimization. The acoustic qualities of a room are significantly influenced by key architectural components, such as its shape and materials. Integrating these components with contemporary technologies can lead to exceptional acoustic environments. The architectural architecture of the FPSD Orchestra Room can be improved to harmonize with technological advances. For instance, the configuration of the space can be planned in such a way as to reduce the occurrence of standing waves and flutter echoes. Uneven surfaces, such as slanted walls or ceiling panels, might disturb these acoustic irregularities, resulting in a more uniform sound distribution. These architectural modifications can be synchronized with DSP technologies to guarantee uniform sound quality across the performance area. The selection of materials greatly influences room acoustics. Strategically positioning materials with high absorption coefficients, such as acoustic panels and thick drapes, can effectively manage reverberation and minimize undesirable reflections (Mónica, et al., 2022). Conversely, materials that reflect sound, such as wood or metal panels, can improve sound projection. The acoustic environment can be precisely adjusted through meticulous material selection and strategic placement to accommodate diverse performances.

d. Adaptive Acoustic Systems

Adaptive acoustic systems result from the merging of architectural design and digital technology (Sanfilippo, 2021). These systems employ adjustable panels, curtains, and other components to modify a room's acoustic characteristics physically. These systems can adjust the acoustic environment in real-time when paired with digital controllers, creating the best possible settings for various performances. An adjustable acoustic system in the FPSD Orchestra Room can modify the area to accommodate different musical genres. Retractable acoustic panels can enhance sound absorption during spoken or solo performances, while reflective panels can be employed for orchestral music (Demming, 2020). The room's versatility guarantees optimal acoustic circumstances for any performance, enriching the experience of both performers and audience members. Adaptive systems can also integrate automated controls, enabling rapid and accurate modifications. These systems can continuously monitor the acoustic environment and make immediate adjustments using sensors and computer algorithms to maintain optimal conditions. This feature is especially valuable in situations that involve dynamic performance settings, where the acoustic demands can quickly and frequently vary.

e. Audience Experience and Placement

Technological progress also encompasses improving the audience's experience. The arrangement and configuration of seating spaces can substantially impact the perception of sound. Contemporary acoustic design considers elements such as line of sight, distance from surfaces that reflect sound, and the even spread of sound across the room (Milo, 2020). By optimizing these components, performance venues may guarantee that every audience member receives a superior auditory experience. The audience seating arrangement within the FPSD Orchestra Room can be deliberately optimized to enhance sound quality. Tiered seating facilitates uniform sound distribution, eliminating acoustic shadows and ensuring unobstructed sightlines for all listeners. Furthermore, seating materials can be selected to provide a harmonious combination of sound absorption and reflection, enhancing the overall acoustic environment. Implementing audience feedback tools can significantly enhance the whole experience. These systems utilize strategically positioned microphones within the sitting area to monitor the sound quality and adjust the room's acoustics. By offering immediate input to DSP systems or adaptive acoustic components, these systems can guarantee that the audience experiences uniform and excellent sound, irrespective of their position inside the hall (Conejo, 2022).

By combining technical advancements with conventional acoustic design concepts, a complete method is employed to optimize the acoustic environment of performance halls. By integrating digital sound processing technologies, virtual acoustics technology, and adaptable acoustic systems in the FPSD Orchestra Room, together with meticulous architectural design, a flexible and top-notch auditory experience may be achieved for both musicians and listeners. These developments provide substantial advantages, such as the capability to modify acoustic characteristics dynamically, mimic various performance contexts, and adapt the room's physical properties in real time. By utilizing these technologies, performance venues may guarantee optimal conditions for diverse musical performances, augmenting the overall caliber and pleasure derived from the music.

## 5. CONCLUSION

The phenomena of interior sound can be illustrated by a sketch, which demonstrates that at any observation point or location where people are listening, they will be influenced by two sound components: the direct and reflected sound components. There are two opposite extremes regarding the surface characteristics of the room. One extreme is when the entire surface in the room is highly absorbent, meaning it absorbs much sound energy. The other extreme is when the entire surface in the room is highly reflecting, reflecting most of the sound energy that reaches it. The acoustic properties of room surfaces are typically differentiated from sound-absorbing materials (absorbers), which are surfaces composed of materials that absorb a portion or majority of the sound energy that impinges upon them. The acoustic parameters commonly employed in enclosed spaces can be categorized into two main groups: temporal monaural parameters, which can be perceived using a single ear (or measured with a single microphone), and spatial binaural parameters, which can only be detected when both ears are engaged simultaneously (or measured with two microphones simultaneously). This occurs because the music emitted by the violin can bounce off the walls and ceiling of the space, resulting in sound interference that enhances the brightness and clarity of the sound. The violin's sound is not adequately reflected by the room's walls and ceiling, resulting in imperfect formation and an indistinct sound. In order to get a vibrant and distinct violin sound within an orchestra, it is imperative to have a room with favourable acoustics. Violinists in a space with favourable acoustics will experience enhanced auditory perception of the instrument's sound, enabling them to perform with more proficiency and accuracy. An acoustically favourable environment enhances the violinist's performance by amplifying the instrument's sound, resulting in a more vibrant and distinct auditory experience for the listener.

## 6. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

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