SOUNDSCAPE OF MUSIC REHEARSAL IN BAND ROOM

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To my teachers, friends and future students in music, architecture and acoustic fields

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It is silence, speech, music… a meaningful and colorful soundscape. It is your caring, guidance, love… my meaningful and joyful life. Without the opportunities given by you, this research cannot exist. Thank you - my teachers, friends and family!

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Band rehearsal rooms in schools require optimized acoustical design to become better core learning environments for music students. Three band rehearsal rooms were selected based on the distinct architectural features, acoustical conditions and levels of user's musical skill for this research. Soundscape study methods including observation and documentation of rehearsal activities; interviewing conductors and student musicians to identify their goals during rehearsals; mapping of acoustical measurements taken to represent the specific communication paths used in the rooms; and modeling were used to investigate these rooms to measure and relate the specific acoustical events and musical issues occur during rehearsals. Video recordings of music rehearsals were analyzed to study the specific acoustical events and musical issues that conductors work on during rehearsals. It revealed that verbal communication between the instructor and students were important components of rehearsals. Additionally, conductors and music students reported in interviews and questionnaires that the ability to hear each other was a primary acoustical requirement for rehearsal spaces. They also identified five fundamental attributes of music; intonation, rhythm,

dynamics, articulation and tone quality; that they were trying to hear while listening and playing in rehearsals.

Acoustical measurements made in these rooms indicated statistically significant differences in measured values at different receiver locations within and among rooms. These values at different locations suggest that the musicians who sit at these locations could perceive qualities of music differently. A listening experiment was conducted by using these measured values to investigate whether the differences of these values within and among rooms could affect the attributes of music heard by musicians during rehearsals. The results indicated that musicians could identify the differences in the attributes of music and which band room better supports their needs in hearing the musical attributes.

The results of the statistical correlation study indicated that in addition to the reverberation time; the floor area, ceiling height, room volume, surface diffusive materials' area, low frequency sound level and fine structure of reflected sounds arriving at a listener location affect the ability of musicians to hear each other and the detailed attributes of music in rehearsal rooms.

CHAPTER 1
INTRODUCTION

Band rehearsal rooms can be found in most of the high schools and colleges that provide music education. Basically, it is a learning space where music teachers and professors address and give specific instructions to the groups of music students (who play different musical instruments) who are learning to play together as a large ensemble. This is also a space where clearly hearing musical attributes is emphasized beyond just the verbal communication that occurs in a normal classroom.

There is an existing ANSI standard S12.60 (2010) that addresses the acoustical design of regular classroom spaces in schools. This standard provides criteria and design guidelines to optimize communication and learning in classroom spaces. Unfortunately, there is no similar research-based design guideline for band rehearsal rooms in schools. In practice, rooms for music education in schools are usually more expensive to build than regular classroom spaces because they are larger rooms with higher ceilings and special acoustical finishes are used on the walls and ceilings. Careful designing and planning of band rehearsal rooms in schools are necessary to optimize the understanding of verbal instruction as well as allowing students to hear each other play in ensemble. A properly designed band rehearsal room will allow students to work on detailed musical attributes such as intonation, articulation, dynamics and rhythm. Band rehearsal rooms with the proper room acoustical responses and sound isolation will enhance the ability of students and teachers to communicate with each other and will result in a more efficient educational environment.

Traditionally, the acoustical design guidelines for band rehearsal rooms used to design these spaces are based on design criteria stated in architectural acoustics text books, design guidelines published by government agencies and non-profit educational organizations, as well as manufacturers' literature[1]. However, these design guidelines do not state which of the acoustical attributes and parameters can support musicians to hear each other during rehearsals. Therefore, understanding what musicians are listening for during rehearsals as well as knowing which acoustical attributes and parameters support musicians' playing is critical to improving the design of these spaces. Consequently, a research-based, user-oriented design guideline for band rehearsal rooms is necessary to ensure that optimal acoustics is achieved by allowing musicians to hear each other during rehearsals.

The initial phases of developing this user-oriented, design guideline for band rehearsal rooms are also the objectives of this study. The first phase of the study is to investigate what conductors and music students are listening for during rehearsals, and which existing acoustical attributes of rooms and measured acoustical parameters can best correlate with these musical attributes to enable acousticians and architects to design rehearsal rooms based on the educational and musical needs of conductors and music students[2].

"Soundscape" theory and study methods[3] were used to investigate the issues as stated above. It essentially describes the procedures about how to listen for sound in any space, to identify the sources and receivers and the paths sound travel between

[1] Further discussions of these resources are included in Chapter 2 – Literature Review.

[2] As stated above, it is author's intention to investigate the user's needs in this research. Therefore, at this phase, other aspects of acoustical design for the rehearsal room such as sound isolation, heating ventilation and air conditioning design and noise control as well as sound system design are not included in the scope of this study.

[3] Further discussions of soundscape theory and study methods are included in Chapter 3 – Background.

them and to understand the meaning of the communications between the different sources, receivers, paths and spaces. Questions like “What are musicians listening for?”, “How are the environments affect their playing?”, “What kinds of support do musicians need architecturally from rooms?”, “Are the architectural features of the room supporting their playing?” and “Are there differences between the needs of musicians (soloist, ensemble, and conductor) and between musicians and audiences?” should be constantly thought through during the visit of a space and the architectural and acoustical design process.

The soundscape study methods and procedures include the:

- Investigation of what specific acoustical events occur during band rehearsals
- Investigation of what conductors and music students listen for during band rehearsals by studying the results of interviews and questionnaires
- Studying band rehearsal room acoustical measurement data with current acoustical parameters
- Studying the possible correlations between the results of the interviews and questionnaires with the acoustical measurement data and architectural properties of the rooms.

In conclusion, this study is based on a series of video analyses of band rehearsals, interviews with music instructors, questionnaires administered to conductors and music students, studying evaluations of sounds by student musicians in rehearsal room settings and deriving statistical relationships between the evaluations of the rooms with acoustical measurements made in actual band rehearsal rooms and architectural features of the rooms. Three band rehearsal rooms with distinct room acoustical and architectural characteristics were carefully selected for this investigation. Users of these band rehearsal rooms were given either interviews or questionnaires in order to identify what they listen for during rehearsals and how the rooms they rehearse in contributes to their listening.

The ultimate goal of this study is to lay the foundation for future work on completing a user-oriented, acoustical design guideline for band rehearsal rooms. The author believes that a well designed music rehearsal room with optimized acoustics is a primary factor that could contribute to a better learning environment and more efficient musical education.

CHAPTER 2
LITERATURE REVIEW

Existing Acoustical Design Guidelines for Band Rehearsal Room

There are some existing acoustical design guidelines for band rehearsal rooms, but these are not based on achieving specific acoustical goals and/or based on evidence from research. These existing design guidelines often only address limited acoustical parameters and architectural features of the rooms. Most of the architectural acoustics textbooks[4] and articles[5] in the technical literature provide simplified design guidelines such as achieving a relatively short reverberation time (RT = 0.5 to 1.0 seconds), quiet background noise levels (NC or RC ≤30), high levels of sound isolation (NIC-65, STC>70), proper ceiling height (16 to 22 feet), room volume (10,000 cubic feet for 20 musicians and 50,000 cubic feet for 120 musicians) and floor area (500 square feet for 20 musicians and 4,000 square feet for 120 musicians). There are some other design guidelines for band rehearsal rooms that show the additional desired surface materials and the needs of diffusing panels. These design guidelines are published by the National Association of Schools of Music (2000), the Department of the Army (1983) and the Wenger Music Corporation (2008). Among these existing design guidelines, McCue's "Rehearsal Room Acoustics" (1990) gives more depth on the user's needs and explains how to use room geometry and absorptive or diffusing panels to control acoustical defects. However, McCue's design guidelines were still limited from the acoustical and architectural perspective.

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[4] Please see List of References for information on Egan (1988), Mehta, Johnson and Rocafort (1999) and Long (2006).

[5] Please see List of References for information on Pirn (1972) and Storyk (1993).

A case study was conducted by Patrick and Boner (1966) to investigate the proper reverberation time of six band rehearsal rooms. The six band rehearsal rooms were selected based on the comments of music instructors that these rooms provided good acoustics. In conjunction with results of the questionnaires given to the instructors who used these rooms regularly and the reverberation times measured in these rooms, the most interesting findings were:

- The proper reverberation time should be 0.3 seconds for 100-250 Hz, 0.45 seconds for 300 Hz, 0.55 seconds for 500 Hz and above
- Warmth[6] is not desired in a rehearsal space

Teuber and Voelker (1993) stated the need for variable acoustics in rehearsal rooms, so that musicians had a chance to balance their performance in the rehearsal room before performing in a concert hall. The required reverberation time for a brass band was 0.5 seconds. The measured reverberation time in the rehearsal room they designed when the curtains were exposed in the room was 0.44s.

In summary, the existing design guidelines for band rehearsal rooms have focused mainly on architectural and acoustical design features of rooms. However, there have been many studies to determine audience listening preferences and impressions for concert hall design since the1960's. The acoustical attributes that are derived from these studies serve as the base knowledge of this research which is summarized in the next section.

[6] According to Beranek (2004), warmth is the ratio of measured reverberation time in the 125 and 250 Hz to 500 and 1000 Hz octave frequency bands.

Development of Acoustical Attributes

The serious study of the acoustical attributes of concert hall acoustics began during the 1950's when acousticians noticed that some concert halls, whose design was based on the theoretical calculation method (Sabine's Reverberation Time), were not perceived by listeners or performers as having "good" acoustics. Concert halls with the same reverberation times were perceived differently, depending on the audience and their seating location. In order to understand the audience's perspective, investigations of the acoustical attributes of concert halls targeted the audience seating area as well as the subjective listening preference of listeners. These studies were conducted by many researchers over the past six decades and are briefly summarized.

Beranek (1962) identified eighteen subjective attributes of musical-acoustic qualities based on acoustical surveys of fifty four concert halls. In his studies, he interviewed conductors, performers and music critics for their overall impression of concert hall acoustics. The eighteen attributes included intimacy/presence, liveliness/fullness of tone/reverberation, warmth, loudness of the direct sound, loudness of the reverberant sound, definition/clarity, brilliance, diffusion, balance, blend, ensemble, response/attack, texture, no echo, quiet, dynamic range, no distortion and uniformity.

Hawkes and Douglas's (1971) study of four British auditoria for subjective preferences of acoustical quality indicated that only six of the acoustical attributes had a significant effect on the subjective preference of their subjects for the acoustical characteristics of concert halls when various types of music were played in the rooms. These acoustical attributes were reverberance, evenness, intimacy, definition, enjoyment and brilliance.

Two decades later, Barron (1988) confirmed these acoustical attributes with revised definitions. He identified five acoustical attributes: clarity, reverberance, envelopment, intimacy and loudness. He used these attributes in his study of twelve concert halls in Britain. According to Barron (1993, p. 37), “the major concerns are that the **clarity** should be adequate to enable musical detail to be appreciated, that the **reverberant response** of the room should be suitable, that the listener should perceive himself surrounded or **enveloped** by sound, that the listener should sense the acoustic experience as **intimate** and that he should judge it as having adequate **loudness**.” The results of the subjective survey in British concert halls suggested that the halls with the best acoustics depended on preferred intimacy and reverberance. This study indicated that intimacy and reverberance were the two main factors that control the subjective impression of the concert hall acoustics.

Some detailed studies were conducted to define clarity, reverberance, envelopment, intimacy and loudness from the objective measurement perspective. These studies revealed that acoustical attributes are highly correlated to the direct, early reflected and reverberant (late reflected) sound energy. From a typical impulse response measurement and analysis[7], the direct sound is the first sound that a listener perceives directly from the source and it usually has the strongest sound energy. The early reflected sound typically occurs due to reflections from the surfaces near the listener. The reverberant sound typically occurs due to multiple orders of reflections from room surfaces and it is sometimes hard to perceive the completed decay of this sound energy by a listener when the background noise level is not quiet enough or due

[7] Please see Figure 6-5 for illustration.

to the successive running speech and music that masked this sound energy. Thus, from a listener's perspective, it is plausible to state that the direct sound and early reflected sound contained the most useful information of the sound quality than the reverberant sound energy during the live speech and music performance. In consequence, the direct and early sounds should have more significant effect on subjective impression than the reverberant sound.

The pioneered studies of clarity were based on results that were proposed by Thiele (1953) and Reichardt et al. (1975), the sound energy of the early reflections after the direct sound should be within 50 milliseconds for speech (Thiele) and 80 milliseconds for music (Reichardt) in order to obtain the useful values of objective measured parameters Distinctness (D50) or Clearness (C80). For speech, all reflected sound energy that arrives at the listener's ears after 50 milliseconds is considered late or reverberant sound. Therefore, clarity of speech depends on the ratio of early to total sound energy. For music, all reflected sound energy that arrives at the listener's ears after 80 milliseconds is considered late or reverberant sound. Therefore, clarity of music depends on the ratio of early to late sound energy.

Reverberance depends on the time that it takes for the sound to decay to a level that is less than the background noise level. Reverberation time (T60) and Early decay time (EDT) are the objective measured parameters[8]. Envelopment depends on the early lateral sound received at the listener due to sidewall reflections. It is a spatial impression of sound in the room and was first proposed by Marshall (1967), as another subjective quality of a concert hall. The lateral energy fraction (LF) is used to measure

[8] Please see "Concepts of Acoustical Parameters" on pp. 30-34 for more information.

envelopment. Intimacy depends on the proximity of the source to receiver. According to Barron (1993, p. 43), intimacy was found to be best related to sound level, rather than the initial-time-delay-gap (ITDG). Lastly, loudness depends on the total sound source level and is measured by strength (G). The judgment of loudness depends on seating location.

Cervone (1990) derived a comprehensive questionnaire on the subjective preference for acoustical evaluation with nine attributes patterned after the studies of Beranek (1962), Hawkes and Douglas (1971), Plenge and Wilkens (1974)[9], Barron (1982), as well as Bradley and Halliwell (1989). The nine attributes were clarity, intimacy, envelopment, balance, reverberance, loudness, overall impression, background noise and echoes. The definitions of these attributes are simple and precise. These definitions are directly cited from Cervone's (1990, p. 18) figure and shown in Table 1-1.

Table 1-1. Cervone's Definitions for Acoustical Attributes

CLARITY
The degree to which notes or words are distinctly separated in time and clearly heard
INTIMACY
The auditory impression of the apparent closeness of the orchestra
ENVELOPMENT
The sense of being immersed in the sound or surrounded by it rather than it appearing to come from a particular point on stage
BALANCE
The relative levels of bass and treble frequencies
REVEBERANCE
The persistence of sound in a space
LOUDNESS
The overall loudness or strength of the sound where you are sitting
OVERALL IMPRESSION
The overall impression of the acoustical quality where you are sitting

[9] Reference quoted by Cervone. Plenge, G., and Wilkens, H. (1974). *The correlation between subjective and objective data of concert halls in auditorium acoustics* (John Wiley & Sons, New York).

Table 1-1. Continued.

BACKGROUND NOISE
The sounds heard other than that from a source on stage or people in the audience
ECHOES
Long delayed reflections that are clearly audible

In addition, Cremer (1976), Blauert (1983) and Ando (1985), contributed to the spaciousness factor with studies of the interaural cross correlation (IACC). These studies are based on the dissimilarity measuring a normalized correlation coefficient of the sound pressure arriving at the two ears of a listener and to the perception of sound energy from all directions.

Based on the studies cited above, the subjective preferences for concert hall acoustics depends on the audience's subjective listening experience and impression. Gade (1989) proposed an important acoustical attribute, known as "support" (ST1), to define the ensemble/balance for the performers on stage. A decade later, Beranek (2004) came up with the holistic acoustical attributes based on previous works that were done by numerous researchers on subjective preference studies for concert hall acoustics. These attributes are:

- Reverberation and Fullness of tone (RT)
- Direct sound , early sound, reverberant sound
- Early decay time/early reverberation time (EDT)
- Speed of Successive Tones
- Definition/clarity (C80) - Horizontal and Vertical
- Resonance
- Intimacy or Presence and Initial-Time-Delay Gap (ITDG)
- Liveness and Mid-Frequencies
- Spaciousness (Binaural Quality Index- BQI)/Lateral Reflection (LF)
- Warmth/Bass Ratio (BR)
- Listener Envelopment
- Strength of sound and Loudness (G)
- Timbre and Tone Color
- Acoustical Glare (SDI)
- Brilliance

- Balance
- Blend
- Ensemble/support (ST1)
- Immediacy of response (attack)
- Texture
- Echoes
- Dynamic range and Background noise level
- Detriments to Tonal Quality
- Uniformity of Sound in Audience Areas

In summary, the evolution of acoustical attributes that acousticians have used to develop the overall impression of concert hall acoustics has been refined through the contributions of many researchers. The subjective listening preference of concert hall acoustics, have been explained by the objective measurement parameters properly. Yet, a set of the acoustical attributes primarily used for the subjective preference assessment of band rehearsal rooms have not yet been developed. The new set of attributes should consider the musicians and conductor having dual listening tasks as both performers and listeners. These attributes should consider how they communicate with each other and the relatively smaller, closed space of a band rehearsal room, rather than the concert hall stage.

Concepts of Acoustical Parameters

Part of the objectives of this study is to investigate the adjusted values of acoustical parameters to be used in band rehearsal rooms, the need of introducing the acoustical measurement parameters and the corresponding acoustical attributes that are necessary in a band rehearsal room.

According to Cremer's (1982, pp. 413-447) "fine structure of reverberation", the concepts of the acoustical parameters are based on impulse response analyses. Since Sabine's reverberation time cannot completely describe other acoustical attributes from different parts of the room, the impulse response has been used by researchers and acousticians to evaluate room acoustics in both subjective and objective manners. An impulse response is created by an impulsive sound source such as a starting pistol or is derived from an electronic signal such as a sine sweep or maximum length sequence signal (MLS). The impulsive sound excites the room and a microphone records the direct and reflected sound produced by this excitation process. Both the sound source and receiver can be located at any desired location for comprehensive studies of the sound qualities in the room. In general, the impulse response consists of direct, early reflected and late reflected (reverberant) sound. These time dependent sound energies are often viewed to contain useful and non-useful information of the sound quality in a room. An echogram or reflectogram is used to plot and analyze the impulse response of a room with a specific frequency and magnitude of the sound reflections. The more effort spent on analysis of impulse response with echograms at different locations of the room with different frequencies, the better the prediction of sound quality can be derived from the room.

Cremer's "fine structure of reverberation" consists of many acoustical parameters that researchers proposed based on impulse response concepts from 1947 to 1976. These criteria are briefly introduced here. Atal et al.'s "Initial Reverberation Time" (1965) which is the time it takes for the first -15 dB decay after the direct sound, Kürer and Kunrze's "Anfangsnachhallzeit" (1967-68) is the time it takes for the first -20 dB decay after the direct sound, whereas Jordan's "Early Decay Time" (1974)[10] is the time it takes for the first -10 dB decay after direct sound. Jordan also proposed "Inversion Index" to

[10] Reference quoted by Cremer (1982). Jordan, V. (1974). 47th AES Convention, Copenhagen.

describe the ratio of the reverberation time of the hall to the reverberation time of the stage. Lehmann's "Strength Coefficient" (1976)[11] is the measure of the direct sound energies with a predetermined distance in the room. Later he used "Strength Index" to show the difference of the sound pressure level at the listener versus the sound power level of the source. Beranek's "Initial Time Delay Gap" (1962) is the time between the direct sound and the first reflected sound perceived by a listener. The closer the time difference between direct sound and the first reflected sound, listener perceives the sound more clear. Thiele's "Deutlichkeit" or "Distinctness" (1953) demonstrated that the limit of the perceptibility[12] of perceive clarity of speech is 50 milliseconds. It is the measure of the useful sound before 50 milliseconds with the total sound. Reichardt (1975) showed that the limit of the perceptibility for music is 80 milliseconds. His "Clearness" is a measure of useful sound before and compared to the sound energy received after 80 milliseconds. Lochner and Burger's "Signal to Noise Ratio" (1958) is a modification of Thiele and Reichardt's D50 and C80. A weighting factor is used to prevent or reduce the effect of the strong reflected energies to either side of the limit of perceptibility before and after 95 milliseconds. Jordan's "Rise Time" (1961) is a time measure of the sound energy below 3 dB and the level of the first 3 dB should be equal to the final level of the sound energy after the steady-state excitation. Likewise, Cremer's "Center Time"[13] is a modification of Jordan's Rise Time. They both were trying

[11] Reference quoted by Cremer (1982). Lehmann, P. (1976). Über die Ermittlung raumakustischer Kriterien und deren Zusammenhang mit subjektiven Beurteilungen der Hörsamkeit (Dissertation, TU Berlin).

[12] It was first proposed by Henry in 1854. Please refer to Cremer's discussion of limit between useful and harmful sound on echo problems. (1972, pp. 71-72)

[13] Please see Chapter 7 for further discussion.

to avoid setting an arbitrary time limit of perceptibility by using the measured sound energy level in the room. Niese's "Echo Coefficient" (1961) is used to detect the echo annoyance of the room and is a measure of excessive sound energies within 33 milliseconds. The echogram of the decay pattern of the first 33 milliseconds is used to compare to a smooth sound energy decay pattern within 33 milliseconds. Kuttruff's "Temporal Diffusion" (1965/66) is used to detect the flutterecho in the room. Thiele's "Directional Diffusion" (1953) is a single number criterion used to describe and measure the directional distribution of the sound relative to the listener's location. Danilenko's "Binaural Distinctness Coefficient" (1968)[14] is used to measure and compare the sound pressure level at left and right ears with the limit time based on Thiele's D50. The difference of the sound pressure level at the left and right ears can be used to detect the source location. Cremer's "Interaural Correlation Coefficient" (1976) is a measure of ratio of sound energies at left and right ears with the consideration of the angle of incidence. Reichardt and Lehmann's "Room Impression Index" (1978) is used to detect the distribution of reflections in both time and direction of arrival by measuring the sound pressure level with omnidirectional microphone and a "frontal directed" microphone within about 40 degree angle of a dummy head. Lastly, Jordan's "Lateral Efficiency" (1980) is the modification of Reichardt and Lehmann's "Room Impression Index". Jordan changed the direction of the directional microphone from frontal incident to lateral incident. Hence, it is the measure of the ratio of the frontal incident sound pressure level versus lateral incident sound pressure level. The criteria mentioned above are the objective measures of the sound qualities in a room. Many of them, with

[14] Reference quoted by Cremer (1982). Danilenko, L. (1968). Dissertation. TH Aachen.

their revisions, are still used to evaluate concert hall acoustics today. For example, Jordan's EDT and Lateral Efficiency, Thiele's Distinctness, Reichardt's Clearness as well as Cremer's Center Time and Interaural Correlation Coefficient.

According to the current acoustical measurement standard ISO-3382 (1997), for auditorium room acoustics, only sound strength (strength-G), early decay time (EDT, T20, T30), balance between early and late arriving energy (Definition-D50, C50, C80 and Center time-Ts), early lateral energy (LF) and binaural measures (Interaural Cross Correlation-IACC) are required to include in the report after the measurement. With consensus (Bradley, 1989), these acoustical parameters are used in present day practice to assess and design the concert hall by most of the acousticians. Therefore, using these parameters as the basis of the rehearsal room acoustical parameters, with adjusted values considering band room architectural design and settings (smaller room volume and the same audience/performer area) would be appropriate for band rehearsal room acoustics assessment and design. Table 1-2 is a summary of the concert hall acoustic studies that are discussed above and shows the typical acoustical attributes to the corresponding acoustical parameters for concert hall acoustical design[15].

Table 1-2. Acoustical Attributes Corresponding to Acoustical Parameters

Acoustical Attributes	Acoustical Parameters
Reverberation and Fullness of tone	Reverberation Time - RT
Direct sound , early sound, reverberant sound	
Early decay time	EDT, T20, T30
Speed of Successive Tones	
Definition (or Clarity)	D50, C80
Resonance	

[15] The acoustical attributes of this table are cited from Beranek (2004). The corresponding acoustical parameters are cited from Beranek (2004) and ISO-3382 (1997).

Table 1-2. Continued.

Acoustical Attributes	Acoustical Parameters
Intimacy or Presence and Initial-Time-Delay Gap	ITDG
Liveness and Mid-Frequencies	
Spaciousness	Binaural Quality Index - BQI, Interaural Cross Correlation Coefficient - IACC
Warmth	Bass Ratio - BR, Bass Strength - Glow
Listener Envelopment	IACC
Strength of sound and Loudness	G, SPL
Timbre and Tone Color	
Acoustical Glare	Surface Diffusion Index - SDI
Brilliance	BR
Balance	
Blend	
Ensemble	Support - ST1
Immediacy of response (attack)	
Texture	Envelop Function - EF
Echoes	
Dynamic range & Background noise level	NC, RC
Detriments to Tonal Quality	
Uniformity of Sound in Audience Areas	
Apparent-source-width (ASW)	Lateral Reflection - LF

CHAPTER 3
SOUNDSCAPE OF BAND REHEARSAL ROOM: SPEECH

Background

According to Siebein (2011), “Soundscape theory offers the possibility to integrate the conscious design of the sonic attributes of the environments as part of the design process for interior and exterior spaces as well as significant natural areas. Environments can be tuned to their inhabitants.” The term soundscape was first used by Murray Schafer in 1977 to describe the sonic attributes and/or events in indoor or outdoor spaces. These sonic attributes could be purposely composed as the spaces are designed and constructed. In a sense, these sonic attributes can be viewed as a musical composition. Schafer stated later (1994, p. 8), “A soundscape consists of events heard not objects seen”. This definition leads to the concept of the soundscape as a sonic environment which involves hearing perception whereas landscape involves visual perception. In addition, Schafer states that a soundscape could be an acoustic environment, a musical composition, or a radio program and suggested that soundscape could be an interdisciplinary subject which allows a researcher to study the relationship between the people and sounds in their environment.

Truax (2001) later used “Acoustic Communication” in order to understand the meanings of a soundscape that is perceived by humans. As stated by Truax, “Acoustic communication attempts to understand the interlocking behavior of sound, the listener, and the environment as a system of relationships.” The complicated communication paths between sources, listeners, and the environment require systematic study methods to approach and analyze the meanings of the sounds; the sounds perceived by the listeners; the effect of the environment on the meanings of the sounds and the communication paths; and to apply the findings to a design process.

Systematic soundscape methods proposed by Siebein (2010) include observation (soundwalk), documentations (focus group discussion and acoustical measurement), mapping and modeling techniques. These methods are used for acoustical design studies and can be applied in any sonic environment.

A soundwalk is a technique used to directly observe the sonic environment. The observer is a listener who not only listens critically for sonic events in the environment but also is able to identify these sonic events and the possible issues that could be discussed with the users of the space. Focus group discussion is a technique used to approach and understand the meanings of these sonic events to the listeners in the environment. The discussion formats could be individual interviews with the users of the space or questionnaires to a group of the users or public meetings of varies types. Thoughtful documentation and critical analysis of the discussions will ensure obtaining useful qualitative assessments of the sonic environment. Acoustical measurement is another documentation technique used to obtain quantitative descriptions of the sonic environment. Performing the acoustical measurements in accordance with appropriated ISO or ASTM standards is basis, but modifications might be needed to investigate the sonic events/issues in the environment based on the results of observations and discussions.

Mapping is a technique used to clearly illustrate the findings of the soundwalk, focus group discussion and acoustical measurement graphically. For instance, sonic events could be recorded in audio or video format. The sonic events recorded in an audio format could be presented as a waveform with time and amplitude to show the time history of events that occurred. The results of interview and questionnaire studies could be presented with tables and charts to categorize and illustrate the results. Modeling is a technique used to study the relationship between the qualitative and quantitative elements of the sonic environment. Statistical analysis methods are used to study the possible correlations between the sonic events perceived by the users and the environment.

Consequently, these soundscape study methods are applied to the band rehearsal room study in order to understand and identify the acoustic events and the meanings of these acoustic events during rehearsals. Three band rehearsal rooms were selected for this study based on their distinct architectural features, acoustical conditions and levels of musical skill of the users. Observation and documentation of band rehearsals in these band rooms were performed accordingly.

Three band rehearsals in one of each band room were observed and recorded. Verbal instruction was giving by the conductors at the beginning of the rehearsal, at the beginning of each piece of music, as well as during frequent points of the rehearsal when the conductor stopped the playing to address a specific musical issue during rehearsal. Three band rehearsal videos have been analyzed to investigate the overall length of time that a conductor addresses or gives verbal instructions to music students during these three band rehearsals. A summary of the length of time which the conductors speak to the students during these three band rehearsals indicates the need for students to be able to understand verbal instruction in the band rehearsal room.

Method

Video recordings were made of one rehearsal session in each band room using a Sony HDR-XR500V digital camcorder. The audio was extracted from the video by using Prism video converter software. The extracted audio was used to show the time history of the rehearsal in a waveform format using a digital audio editing program (Audacity 1.3.12 Beta). These videos were analyzed on a laptop computer with Windows Media Player and an Excel Spreadsheet. Windows Media Player was used to play and pause the video recording while the conductor's speech occurred. The Excel Spreadsheet is used to record the duration of the conductor's speech. At the end of each rehearsal, the total length of time of each rehearsal versus the length of time that the conductors spoke during the rehearsal were totaled and shown in a graphical format.

Results and Discussions

The time history of rehearsal A as a waveform is shown in Figure 3-1. The waveform shows the conductor's speech and the music performance. Since speech is not as loud as music when the band is playing, the valleys of the waveform represent where the conductor was speaking whereas the peaks of the waveform represent the music being played by the band during the rehearsal. Consequently, it clearly indicated the frequent stops in playing when the conductors spoke.

In order to summarize the durations of time when verbal instruction occurred, the video analysis technique as explained in the Method section of this chapter was used. To summarize the durations of time, the total length of rehearsal A measured from the video is approximately 66 minutes. The length of conductor A's speech is approximately 29 minutes. This means that conductor A spoke for approximately 44% of the total rehearsal time. Likewise, the total length of rehearsal B measured from the video is approximately 52 minutes. The length of conductor B's speech is approximately 31 minutes. This means that conductor B spoke for approximately 60% of the rehearsal time. Similarly, the total length of rehearsal C measured from the video is approximately 43 minutes. The length of conductor C's speech is approximately 17 minutes. This means that conductor C spoke for approximately 39% of the rehearsal time. Figures 3-2, 3-3, 3-4 clearly show the results of the band rehearsal video analysis with the percentages of the rehearsal time that the instructor spoke for in each room.

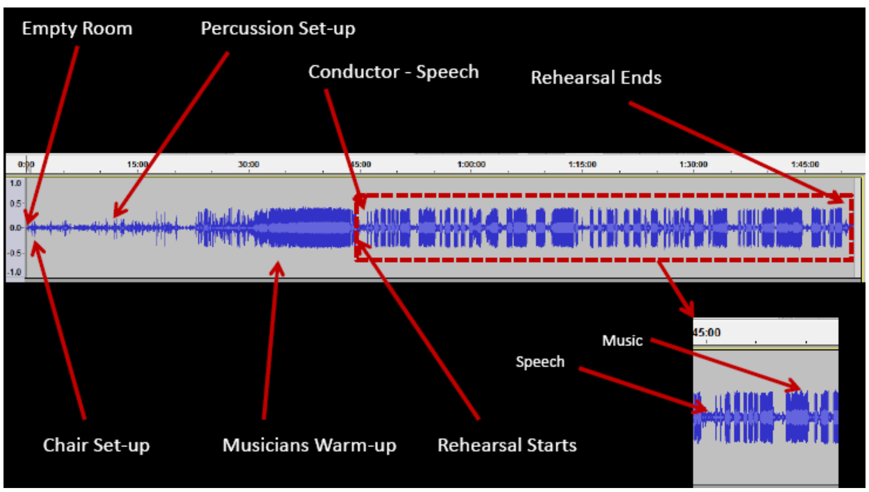


Figure 3-1. Time history of rehearsal A as a waveform format.

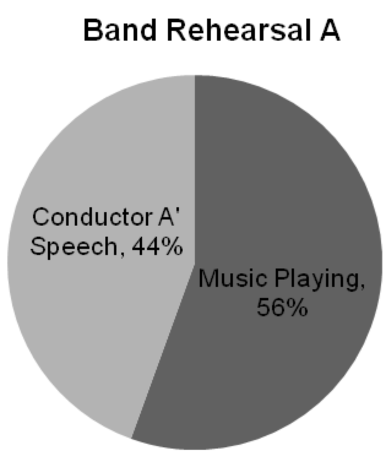


Figure 3-2. Percentages of durations of conductor A's speech during the band rehearsal.

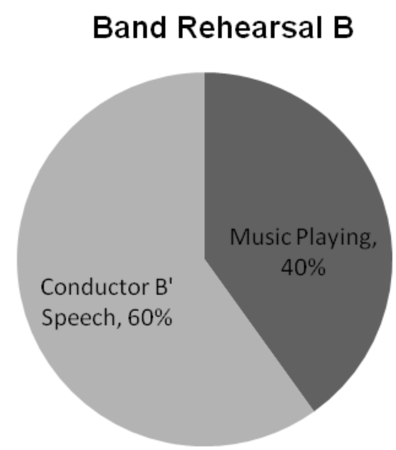


Figure 3-3. Percentages of durations of conductor B’s speech during the band rehearsal.

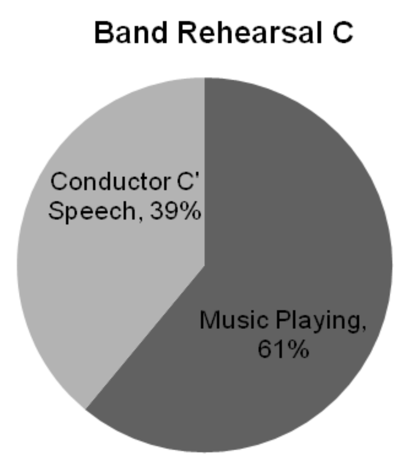


Figure 3-4. Percentages of durations of conductor C’s speech during the band rehearsal.

The overall length of the three rehearsals is approximately 161 minutes. The length of the three conductors’ speech is approximately 77 minutes. This means that approximately 48% of the total rehearsal time was spent listening to the verbal instructions of the conductors. Figure 3-5 shows the percentage of total rehearsal time spent listening to verbal instructions of the conductors.

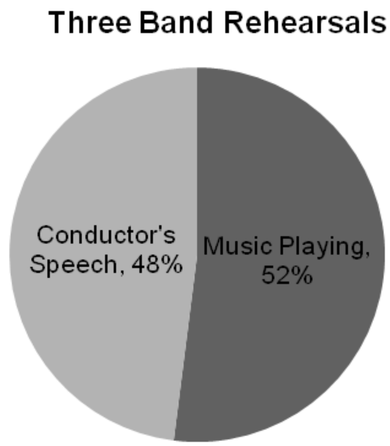


Figure 3-5. Percentages of durations of three conductors’ speech during three band rehearsals.

Summary

Students listened to the verbal instructions of the conductor for approximately 48% of the total duration of the three band rehearsals. The mean and standard deviation of the conductor’s speech in the three videos is 48% and 11%. In addition, a question[16] regarding whether understanding the conductor’s speech was important during rehearsals was contained in a questionnaires administrated to 206 music students who were the members of the bands. Ninety eight percent of the students responded that understanding the conductor’s verbal instructions was important during rehearsals. Therefore, it is plausible to suggest that the speech intelligibility is important to include as a design criterion for the acoustical design of rehearsal room. The current acoustical parameter – Speech Transmission Index (STI) or Rapid Speech Transmission Index (RASTI) could be used to evaluate and serve as a design criterion. Both STI and RASTI

[16] The methods, results and discussions of the 206 student questionnaires will be discussed in Chapter 5 and 8.

can vary range from 0 to 1. A higher STI or RASTI means better speech intelligibility (Houtgast, T., and Steeneken, H.J.M., 1984 and 1985).

CHAPTER 4
SOUNDSCAPE OF BAND REHEARSAL ROOM: LISTENING CRITERIA

Background

In order to design a band rehearsal room with optimum acoustics, understanding what conductors and music students are listening for during rehearsal is key. The three band rehearsal videos were thoroughly analyzed to investigate the specific attributes of music that conductors might address or work on during a band rehearsal. These specific attributes of music required critical listening and therefore can be seen as listening criteria during the rehearsal. These listening criteria are used as the basis design guidelines for band rehearsal room in this research.

Three band rehearsals were chosen carefully to encompass a range of musician's level as well as genres of music. One of the three rehearsals recorded was a high school band rehearsal where the repertoires rehearsed during the rehearsal were melodic and with a marching band style. The others were recorded during a college Jazz band rehearsal and a university Wind Symphony rehearsal. The repertoires rehearsed by the Wind Symphony band required better levels of playing skill to overcome the difficult rhythmic combinations and fast tempo.

The results of each rehearsal, as well as the average of three rehearsals, will be summarized and presented based on the numbers of attributes of music that were addressed and worked on by the conductors during the band rehearsal.

Method

Three band rehearsal videos were separately recorded using Sony HDR-XR500V digital camcorder. These videos were analyzed on a laptop computer with Windows Media Player and an Excel Spreadsheet. Windows Media Player is used to play and pause the video recordings while conductor is addressing specific attributes of music. The Excel Spreadsheet is used to record the numbers of specific attributes of music that are being addressed. For example, the conductor gave the instruction to the trumpet players that they should listen for their intonation. From the Excel spreadsheet, the author will mark “x” under intonation column. At the end of each rehearsal, the ratio of the total numbers of each musical attribute to the sums of all attributes of music addressed was presented. Likewise, the ratio of the overall number of times that each attribute of music was addressed during the three rehearsals to the total numbers of times that of all attributes of music from these three rehearsals were addressed was presented.

Results and Discussions

The conductor often asked the music students to work on intonation, rhythm, dynamics, articulation and other musical attributes such as style and phrasing, tone quality or non-musical[17] issues such as discipline during the recorded rehearsals.

According to the Oxford Music online dictionary, the concise definitions of the above attributes of music are:

- Intonation: accuracy of pitch in playing or singing.
- Rhythm: the systematic arrangement of musical sounds, principally according to duration and periodic stress and/or a particular type of pattern formed by rhythm.
- Dynamics: the varying levels of volume of sound in different parts of a musical performance.
- Articulation: the separation of successive notes from one another and/or refers primarily to the degree to which a performer detaches individual notes from one another in practice (e.g. in staccato and legato).

[17] For this study, non-musical issues will not be studied further due to the natural of these issues will not be affected by the room acoustics.

- Style and phrasing: the grouping of successive notes, especially in melodies.
- Tone Quality: quality of sound, as in 'sweet *tone*', 'harsh *tone*', 'dry *tone'.*

Each attribute is counted when the conductor stopped the orchestra and addressed a specific music attribute. Conductor A stopped 98 times during the rehearsal. Within these 98 stops, conductor A specifically worked and addressed the rhythmic issues 33 times, dynamics issues 23 times, articulation issues 23 times, and intonation issues 3 times. Band rehearsal A was recorded from a university Wind Symphony rehearsal. Figure 4-1 shows the percentages of rehearsal time that these musical issues were addressed and worked on by conductor A with music students during band rehearsal A.

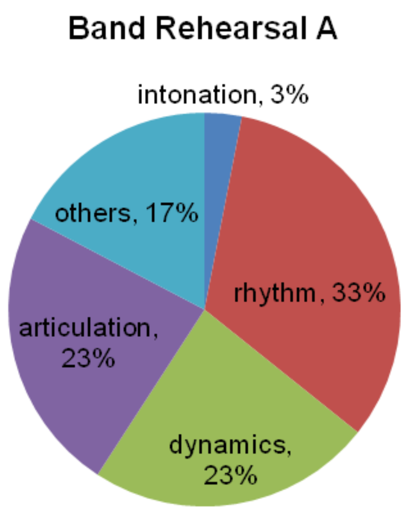


Figure 4-1. Percentages of rehearsal time during school A's band rehearsal that specific musical issues were addressed and worked on by the conductor and music students.

Conductor B stopped 83 times during the rehearsal. Within these 83 stops, conductor B specifically worked and addressed the rhythmic issues 20 times, dynamics issues 24 times, articulation issues 17 times, and intonation issues 6 times. Figure 4-2 shows the percentages of the rehearsal time that these musical issues were addressed and worked on by conductor B with music students during band rehearsal B. Band rehearsal B was a recording of a college Jazz band rehearsal.

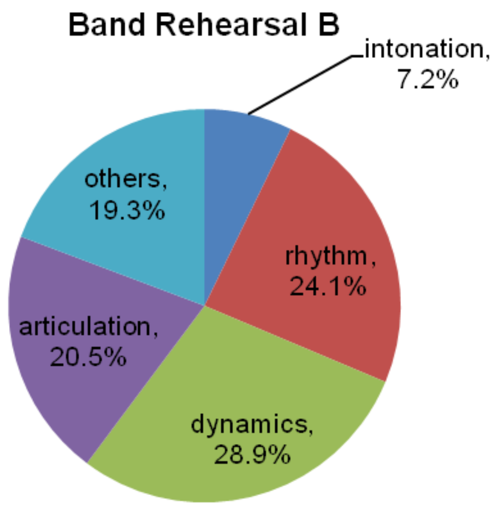


Figure 4-2. Percentages of rehearsal time during school B's band rehearsal that specific musical issues were addressed and worked on by the conductor and music students.

Conductor C stopped 52 times during the rehearsal. Within these 52 stops, conductor C specifically worked and addressed the rhythmic issues 13 times, dynamics issues 1 time, articulation issues 7 times, and intonation issues 21 times. Band rehearsal C was a recording of a high school band rehearsal. Figure 4-3 shows the percentages of the rehearsal time that these musical issues were addressed and worked on by conductor C with music students during band rehearsal C.

Regardless of the different genres of music and level of musicianship of the bands, the three conductors stopped for a total of 233 times during the three rehearsals. Within these 233 stops, three conductors specifically worked and addressed the rhythmic issues 65 times, dynamics issues 48 times, articulation issues 47 times, and intonation issues 30 times. Figure 4-4 shows the percentages of the total rehearsal time that these musical issues were addressed and worked on by the three conductors to music students during the three band rehearsals.

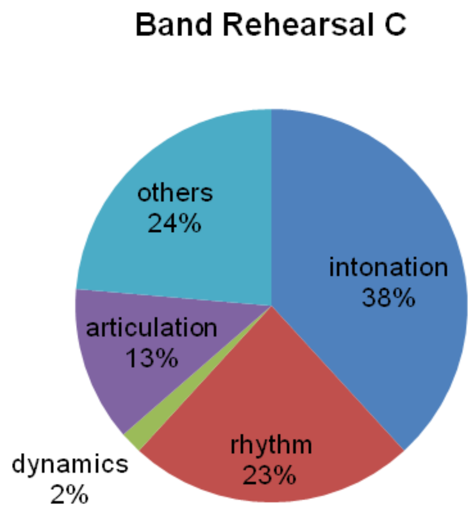


Figure 4-3. Percentages of rehearsal time during school C's band rehearsal that specific musical issues were addressed and worked on by the conductor and music students.

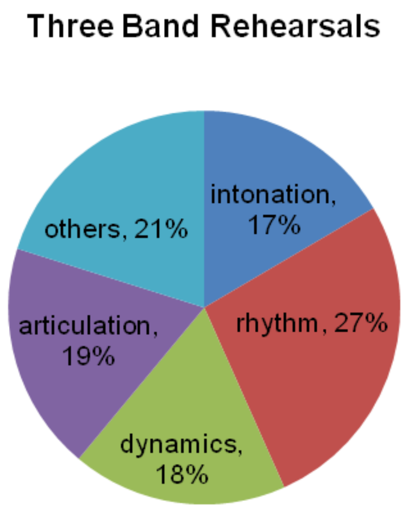


Figure 4-4. Percentages of total rehearsal time during three band rehearsals that specific musical issues were addressed and worked on by three conductors and their music students.

Summary

From the three band rehearsal video analyses, regardless the styles of repertoires rehearsed during rehearsals, conductors addressed intonation 17% of the time, rhythm 27% of the time, dynamics 18% of the time and articulation 19% of the time during rehearsals. This suggests that music students and conductors were both listening to these musical attributes for 80% of the time. Therefore, it is clear that conductors and music students are constantly trying to hear each other on these musical attributes. It is recommended that future acoustical design guidelines for band rehearsal rooms should support the ability for musicians to hear each other on these attributes.

CHAPTER 5
IDENTIFICATION OF MUSICAL ATTRIBUTES DURING REHEARSAL BY CONDUCTOR INTERVIEWS AND STUDENT QUESTIONNAIRES

Background

The results of the video analysis of the band rehearsals show that the musicians were constantly trying to listen to each other during rehearsals. Personal interviews were conducted with six conductors and questionnaires were administrated to music students and an additional seven conductors to determine what specific attributes of music their groups listen for during rehearsals.

Method

According to the University of Florida, all research involving human subjects requires permission to be obtained prior to conducting the research[18]. This is a procedure that the University of Florida takes in advance of any research being conducted in order to evaluate whether or not the research has any potential health damage to the participants.

For privacy reasons, the names of the six conductors will not be listed. Each conductor will be represented as conductor A, B, C, D and accordingly. The results of conductor interviews are summarized in a question by question manner. The music students and the additional seven conductors who completed the questionnaires will also remain anonymous.

Selections of Conductor

The selection of conductors for the interviews was based on their teaching experience and expertise. Among the conductors, five of them use the band rehearsal

[18] UFIRB02 Protocol #2010-U-0088.

rooms where the author conducted the acoustical measurements. Table 5-1, shows the general information of the conductor's teaching experience and expertise in terms of years of teaching, teaching area and school where he/she currently teaches.

Table 5-1. Shows the general information of the conductor's experience and expertise.

Conductor (Interview)	A	B	C	D	E	F	
Years of experience in teaching: more than 30 years	X	X				X	
Years of experience in teaching: more than 10 years	X	X	X		X	X	
Area of teaching: Classical Music	X		X	X	X	X	
Area of teaching: Jazz Music		X					
School where conductor teaches currently: College	X	X		X	X	X	
School where conductor teaches currently: High School			X				
Conductor (Questionnaire)	G	H	I	J	K	L	M
Years of experience in teaching: more than 30 years							
Years of experience in teaching: more than 10 years		X	X	X	X	X	X
Area of teaching: Classical Music	X	X	X	X	X	X	X
Area of teaching: Jazz Music							
School where conductor teaches currently: College	X	X	X	X	X	X	X
School where conductor teaches currently: High School							

Reference of Interview and Questionnaires

The interview questions are prepared and developed with consideration to several researchers' work such as Beranek (1962) and Gade (1981). Beranek conducted interviews with outstanding professional musicians and music critics to learn the ways that musicians evaluate concert hall acoustics and derived a list of acoustical attributes[19] which he used to describe the attributes of music that musicians regularly use. According to Beranek (1962), his interview technique was to show musicians and

[19] Please see pp. 28-29.

music critics some photographs of concert halls and ask them to comment on their experience and knowledge of these concert halls.

Gade (1981) interviewed thirty two professional musicians to understand what the musicians listened for during their rehearsals on stage. The method Gade used was to distribute several questionnaires to the musicians in a chamber orchestra and asked them to rate what they listened for while playing on stage. Gade (1981, pp. 26-27, 44) derived seven acoustical attributes:

- Hearing-Each-Other
- Reverberation
- Support
- Timbre
- Dynamics
- Time Delay
- Change of Pitch

Among these attributes, “hearing each other” is a first priority attribute according to Gade’s research. Fifty percent of soloist or 66% of conductors/orchestra players considered hearing each other as the primary listening criterion on stage. Sixty-six percent of conductors/orchestra players translate to mean twenty one out of thirty two people agreed that hearing each other was first priority. Five of the twenty one people were conductors. There were only five conductors that participated in this study, which means that 100% of the conductors consider hearing each other as the primary attribute they are involved with while they are on stage. The strong agreement among the conductors and orchestra players in Gade’s study was a major reason that what exactly musicians mean by hearing each other during rehearsals was investigated in this study.

Analysis of the video recordings of the band rehearsals showed that conductors spend most of their time during rehearsals trying to bring students to play together by hearing individuals members of the ensemble relative to each other. Therefore, the basic interview questions for the band rehearsal room are:

- What are the most important aspects for students to rehearse to prepare the ensemble for concert?
- What do you try to listen for during a rehearsal?
- What aspects of student/performer playing do you discuss during rehearsal?
- If you are playing or rehearsing the same programs in different spaces, how are the acoustical attributes of the room helpful or harmful for listening and teaching?

Interviews were conducted individually and recorded with a digital audio recorder. All audio recorded files were transcribed into text and the transcriptions are included in Appendix A. In order to compare and summarize the interview results in a clearly manner, only vocabularies or short sentences are cited directly and used in the tables below to summarize the responses to each interview question.

Questionnaires were sent by electronic mail to additional seven conductors were using the same questions as shown above. After the conductors completed the questionnaires, these questionnaires were emailed back to the author. The results for the additional seven conductors will be shown in the same table with the results from the interviews.

Questionnaires were given to the music students during their rehearsal. Due to time constraints, the questions were simplified to one question and as shown in Figure 5-1.

12. While you are playing during the rehearsal, what do you listen for?

Intonation **Rhythm** **Articulation** **Dynamics** **Speech Intelligibility** **Other player's playing**

Others: (please indicate) ____

____

____

Figure 5-1. Question to music students about what musical attributes they are listening for during rehearsal.

Results and Discussions

Conductor Interviews and Questionnaires

A summary of the responses of the conductor to the question "What are the most important aspects for students to rehearse to prepare the ensemble for concert?" is shown in Table 5-2. As expected, the diverse vocabularies used by conductors to express their musical teaching experience were noticed. This was also identified by Beranek and Gade in their research. It was necessary to categorize the musical terms into groups in order to obtain the clearer results. According to conductor F[20], the fundamentals of music means whether pitch/notes are played in tune (intonation), notes are played with precision and in time (rhythm), levels are played in balance (dynamics), notes are played with the right amount of weight as indicated by the composer, phrasing and tone quality. The result of this question is 12 out of 13 conductors agree that students should be able to hear each other and hear the fundamental attributes of music such as intonation, rhythm, dynamics, articulation and tone quality.

Table 5-2. Summary of the interview and questionnaire results on "What are the most important aspects for students to rehearse to prepare the ensemble for concert?"

Conductor (Interview)	Answers
A	Produce the right notes, learn to hear and play with right intonation, precision (rhythm), blend with section (dynamics), hear the orchestra as whole, and develop musicality.
B	Correct notes and rhythms first, then dynamic level, melodic structure, phrases, trills and grace notes.
C	Be able to hear each other. It is a very important to tuning, balance, blending sounds.
D	Match articulation, listening to each other in the hall, be able to hear each other, ensembles tune, constant intonation, balance and blend.
E	The ability to hear across the ensemble, the volume and balance of level, refine the tone qualities.

[20] Additional questions regard the typical rehearsal processes and difference between student musicians and professionals are also listed in Appendix A.

Table 5-2. Continued.

Conductor (Interview)	Answers
F	Think like one, fundamentals of music, together to sound as one, to hear what they sound like in conjunction with others, to hear whether they are in tune, whether they are in time, balance is correct, balance and blend of sound, working on trying to get better intonation, and better togetherness, better dynamics and all the fundamentals.
Conductor (Questionnaire)	Answers
G	I am most concerned about the students' ability to hear themselves and the ensemble clearly.
H	To be able to hear across the ensemble with ease.
I	All elements of music, including: rhythm, intonation, textural balance, timbre (blend), musical dynamics, and musical architecture.
J	Pitch, tone, ensemble, balance, precision, artistry.
K	During rehearsal: Blend and balance within and between sections, including tonal color decisions. Intonation in both unison/octave and chordal contexts. Elements of rubato and tempo continuity. Elements of style specific to the repertoire being rehearsed. Elements of Phrasing, articulation, note weighting.
L	An identification of the total sound and the spectrum of colors within the ensemble.
M	The ability to hear and listen in an environment similar to the most often performing environment. No carpeted floor, enough cubic space for the sound to resonate in the room without overwhelming the space with condensed sound.

A summary of the conductors' responses to the question of what would he/she like the students to rehearse as an ensemble is shown in Table 5-3. This table lists the most important aspects of rehearsing, from the highest to lowest percentage. Hearing each other, intonation, blend of sound, balance dynamics, musicality/tone quality, rhythm, articulation and phrasing are the 8 most important aspects of music that conductors would like to work on during rehearsals. In fact, in terms of hearing each other, it can be considered as hearing all of the fundamentals of music that are mentioned above. Additionally, players are constantly aware of themselves and others playing during the rehearsal and making appropriate adjustments relative to other players and the space that they played in. Balance and blend are often used by musicians to describe balance the dynamics and blending the sound with the right tone qualities within the section and the ensemble. However, the adjustments of tone quality, phrasing and blending of sound during rehearsal often required musicians to have better musical skills to achieve. The conductor in the band is the one who makes the ultimate decision on these music qualities. Thus, from the conductor's point of view, the most important aspects for students to rehearse for a concert would be, rephrased appropriately, as "hear oneself and others in the rehearsal room to play together by getting the right intonation, rhythm, articulations, balance dynamics and blend of sound or tone quality".

Table 5-3. Summary of the interview results with grouping and percentage on "What are the most important aspects for students to rehearse to prepare the ensemble for concert?"

Conductor/Answers (Interview)	A	B	C	D	E	F	Total Number	%
Hear the orchestra as whole, be able to hear each other, listening to each other in the hall, the ability to hear across the ensemble, together to sound as one, total sound	X		X	X	X	X	5/6	83%
Produce the right notes, correct notes, fundamentals of music, learn to hear and play with right intonation, tuning, ensembles tune, constant intonation, fundamentals of music, together to sound as one, in tune, intonation, togetherness	X	X	X	X		X	5/6	83%
Blend with section (timbre), blending sounds, fundamentals of music, together to sound as one, blend of sound, refine the tone qualities	X		X	X	X	X	5/6	83%
Dynamic level, balance, volume and balance of level, fundamentals of music, together to sound as one, balance is correct, togetherness, better dynamics		X	X	X	X	X	5/6	83%
Develop musicality, think like one, refine the tone qualities, melodic structure, artistry	X	X			X	X	4/6	67%
Precision (rhythm), correct rhythms, fundamentals of music, together to sound as one, in time, togetherness	X	X				X	3/6	50%

Table 5-3. Continued.

Conductor/Answers (Interview)	A	B	C	D	E	F		Total Number	%
Trills and grace notes, match articulation, fundamentals of music, together to sound as one, togetherness		X		X		X		3/6	50%
Phrases, fundamentals of music, together to sound as one, togetherness		X				X		2/6	33%

Conductor/Answers (Questionnaire)	G	H	I	J	K	L	M	Total Number	%
Hear the orchestra as whole, be able to hear each other, listening to each other in the hall, the ability to hear across the ensemble, together to sound as one, total sound	X	X	X	X	X	X	X	7/7	100 %
Develop musicality, think like one, refine the tone qualities, melodic structure, artistry		X		X	X	X		4/7	57%
Blend with section (timbre), blending sounds, fundamentals of music, together to sound as one, blend of sound, refine the tone qualities			X	X	X	X		4/7	57%
Produce the right notes, correct notes, fundamentals of music, learn to hear and play with right intonation, tuning, ensembles tune, constant intonation, fundamentals of music, together to sound as one, in tune, intonation, togetherness				X	X			2/7	29%
Dynamic level, balance, volume and balance of level, fundamentals of music, together to sound as one, balance is correct, togetherness, better dynamics				X	X			2/7	29%
Precision (rhythm), correct rhythms, fundamentals of music, together to sound as one, in time, togetherness				X	X			2/7	29%
Trills and grace notes, match articulation, fundamentals of music, together to sound as one, togetherness				X	X			2/7	29%
Phrases, fundamentals of music, together to sound as one, togetherness					X			1/7	14%

A summary of the overall results from the interviews and questionnaires administrated to the 13 conductors is shown in Table 5-4 and Figure 5-2. Ninety two percent of the conductors stated that hearing each other was a primary concern; 69% mentioned blend; 62% mentioned musicality and tone quality; 54% mentioned intonation; 54% mentioned dynamics; 38% mentioned rhythm; 38% mentioned articulation; and 23% mentioned phrasing and style. The findings from the band rehearsal videos analyses have been completely identified by the 13 conductors' comments.

Table 5-4. Summary of the overall results of the interviews and questionnaires for "What are the most important aspects for students to rehearse to prepare the ensemble for concert?"

Conductor/Answers (Interview and Questionnaire)	Total Number	%
Hear the orchestra as whole, be able to hear each other, listening to each other in the hall, the ability to hear across the ensemble, together to sound as one, total sound	12/13	92%
Blend with section (timbre), blending sounds, fundamentals of music, together to sound as one, blend of sound, refine the tone qualities	9/13	69%
Develop musicality, think like one, refine the tone qualities, melodic structure, artistry	8/13	62%
Produce the right notes, correct notes, fundamentals of music, learn to hear and play with right intonation, tuning, ensembles tune, constant intonation, fundamentals of music, together to sound as one, in tune, intonation, togetherness	7/13	54%
Dynamic level, balance, volume and balance of level, fundamentals of music, together to sound as one, balance is correct, togetherness, better dynamics	7/13	54%
Precision (rhythm), correct rhythms, fundamentals of music, together to sound as one, in time, togetherness	5/13	38%
Trills and grace notes, match articulation, fundamentals of music, together to sound as one, togetherness	5/13	38%
Phrases, fundamentals of music, together to sound as one, togetherness	3/13	23%

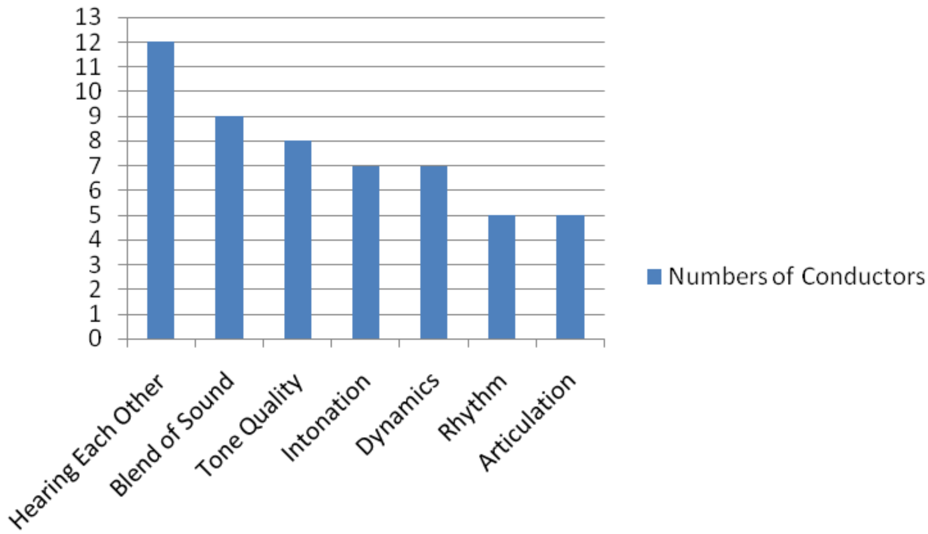


Figure 5-2. Results of 13 conductors' interview and questionnaire on the most important aspects for students to rehearse to prepare the ensemble for concert.

The conductors' responses to the questions "What do you try to listen for during a rehearsal?" are summarized in Table 5-5. Among the 13 conductors, only conductor A mentioned that he/she would listen for room acoustics and make adjustments to playing based on the room acoustics. Most of the conductors mentioned that they would listen for either all or some of the fundamental elements of music (intonation, rhythm, dynamics and articulation). Conductor E did not specify clearly about the layers that he listened for except the harmonics and the counter lines. Conductor H thought this was a complex question and thought it depended on the musicians. However, based on all the conductors' answers, it was concluded that most of the conductors were listening for students' playing of the most fundamental musical attributes and making sure these elements were played correctly by students. Then, they continued and taught students about how to make music with good tone qualities, balance, blend, phrasing and style so that the music sounded as one.

Table 5-5. Summary of the interview results on “What do you try to listen for during a rehearsal?”

Conductor (Interview)	Answers
A	Listen to the hall about whether the room has the right amount of reverberation and warm round sound (room acoustics), then adjust your playing in accordingly to produce good tone, play in time and articulation with others
B	Once I got all the notes and rhythms done, then I go make music by listening for tone quality, phrasing, timber of the instruments, balance of the dynamic level in room, togetherness
C	Everything. I listen for timber, quality of sound, intonation, volume levels of different sections to create an appropriate balance. I listen for rhythmic precision and accuracy, all the elements in to making a performance as accurate and musically correct as possible
D	In a rehearsal what I am listening for is errors amongst individuals on notes, rhythm, out of tune, articulation and dynamic; checking what they are playing against your instrumental image, the mental image of what it is I want to hear as the sonorities that I want to hear from a particular piece; constantly checking from your mental image from what you want, how you want a piece to sound like, tone, balance
E	Depends on the repertoire, every work has a different requirement. I normally listen in terms of layers; I listen for formality layer, mid-devise layer, etc; a purely harmonic layer. When I’m talking about layers I’m usually talking in terms of function. I rarely listen only for timber. I rarely go in rehearsals trying to listen for a trombone, I’m listening for counter lines, and sometimes it’s for trombones, sometimes for others.
F	I listen to everything. Ask students how to play and learn to listen for the pitch. You’re constantly tweaking those kinds of things. So you’re listening for everything. All the fundamentals of music.
G	I am listening for balance/blend of the various instruments, intonation of the ensemble, and tone of the instruments.
H	This is a complex question that I will not be able to answer adequately in this answer. The abbreviated answer to this question is that listening in rehearsal is determined solely by one’s knowledge of the score and reacting to the sounds that you are receiving by the ensemble.
I	Same as question 1. All elements of music, including: rhythm, intonation, textural balance, timbre (blend), musical dynamics, and musical architecture.
J	Pitch, tone, ensemble, balance, precision, artistry.

Table 5-5. Continued.

Conductor (Questionnaire)	Answers
K	Same as question 1.During rehearsal: Blend and balance within and between sections, including tonal color decisions. Intonation in both unison/octave and chordal contexts. Elements of rubato and tempo continuity. Elements of style specific to the repertoire being rehearsed. Elements of Phrasing, articulation, note weighting.
L	Multiple balance concepts, timbre, intonation, timing and musical relationships within the ensemble.
M	Balance and clarity of voice colors, accuracy of sounds rhythmically, blend of colors both like and different voices.

The responses of the conductors to the question “What aspects of student/performer playing do you discuss during rehearsal?” were summarized in Table 5-6. Under the main heading of being able to hear oneself and each other, all conductors worked on or discussed with their students the fundamentals of music. However, for this particular question, matching tone quality or blending of sound was the dominant focus of the fundamentals of music. Matching tone quality or blending of sound involves critical listening skills and excellent playing skills. As conductor A states from Table 5-5, a player not only needs to listen for the room acoustics, but also needs to play with adjustments due to the room acoustics in order to produce good tone. In this case, matching tone quality or blending of sound is a technique that a player has the final control over. For instance, blending of sound for a trombone player during the band rehearsal means he/she will make whatever adjustments on the dynamics and tone quality are needed to match the trombone section first, then to match tuba, and finally to match the orchestra. Therefore, even though room acoustics has effects on tone quality; a player has the final control of how to blend the sound during the rehearsal.

Table 5-6. Summary of the interview results on “What aspects of student/performer playing do you discuss during rehearsal?”

Conductor (Interview)	Answers
A	When you have a rehearsal with the orchestra, you can’t become too personal you can’t spend too much time with each section, each individual. But it’s the same thing with tone quality, blend, intonation, slurs and articulation all those things in lessons and sectionals. Sectionals are so important.
B	I try to make them aware, once they’ve got the piece down, I really try to focus on hearing it in tune, getting to play in tune and also, the quality of the tone is coming out of the instrument so it is not too harsh. I would say you know, we talk about the quality of sound, reading and playing very precise, those kinds of things.
C	Pretty much what I discussed above. Being able to listen across the ensemble. They must be able to hear each other and match note length.
D	I think one of the things I focus on the great deal is tone quality. Matching tone quality. So I stress on their ability to listen and match the tone and be unified tone. Being able to listen, you constantly try to tune them to it. How and when to end a phrase or where to breath.
E	Articulation, intonation, balance blend ensemble alignment and rhythmical alignment. Those are the basic. I think every ensemble that has rehearsed well rehearsed the fundamentals. Depends on work. Some element might be more in this piece than that piece of music.
F	Just the same things we all discussed fundamentals of music as well as the blending of tone and/or quality of sound.
Conductor (Questionnaire)	Answers
G	Same as above question. I am listening for balance/blend of the various instruments, intonation of the ensemble, and tone of the instruments.
H	All aspects, once again, dependent upon what is coming from the ensemble. This question is a complex issue that cannot be answered simply.
I	Same as above question. All elements of music, including: rhythm, intonation, textural balance, timbre (blend), musical dynamics, and musical architecture.
J	Pitch, tone, ensemble, balance, precision, artistry.
K	Same as above question. During rehearsal: Blend and balance within and between sections, including tonal color decisions. Intonation in both unison/octave and chordal contexts. Elements of rubato and tempo continuity. Elements of style specific to the repertoire being rehearsed. Elements of Phrasing, articulation, note weighting.
L	Multiple balance concepts, timbre, intonation, timing and musical relationships within the ensemble, especially musicality and musicianship.

Table 5-6. Continued.

Conductor (Questionnaire)	Answers
M	Stylistic conviction and projection of style to the audience. Listening, listening, listening.

The responses of the conductors to the question "If you are playing or rehearsing the same programs in different spaces, how are the acoustical attributes of the room helpful or harmful for listening and teaching?" are summarized in Table 5-7. This question was not asked during the interview with conductor A. Thus, conductor A is not listed in table 5-7. Conductor B preferred a quiet room so the control of different level of dynamics can be achieved. Conductors C, D, F and H preferred a less reverberant room, so they could hear more. Conductor D and G had concerns about the high sound level in a room because it could lead to hearing damage. Conductors B and E responded that musicians learn how to compensate for the room and make the necessary adjustments to produce good music. Conductors J, K, L and M seemed to prefer variable acoustic settings.

Table 5-7. Summary of the interview results on "If you are playing or rehearsing the same programs in different spaces, how are the acoustical attributes of the room helpful or harmful for listening and teaching?"

Conductor (Interview)	Answers
B	Check and learn the room acoustics first for the spaces, to make sure that you get the best set up for the room, you learn how to compensate, you have to compensate and do your best what you can unless you are a professional musician, a lower background noise level is desired, control of dynamic level.
C	I prefer a slightly deader acoustics in a rehearsal setting because I can hear more. I do want it to deader so it is truer to what is coming out of the instrument.
D	You want the last person from the last row to hear you, size of the room (practice room) decibel level is so high in a room like that is also harmful, dead room gives you better details but it also lies to you.

Table 5-7. Continued.

Conductor (Interview)	Answers
E	First thing it affects is programming. Rehearse resonance rather than reverberation we rehearse how to end a note so to make it sound like a natural reverberation. To create artificial reverberation. And length of this, the reverb of the decay, is dependent on the acoustic environment we're going to perform in.
F	Because we record in there. I would be happy if it were dry all the time, open up curtain and sound like in the hall in the last rehearsal.
Conductor (Questionnaire)	**Answers**
G	The amount of reverberation can determine clarity of the ensemble. This can help/hinder the rehearsal process. Also, certain instruments will speak more loudly in different environments.
H	Different acoustics will influence tempos and articulations. Rooms that are too reverberant are often very difficult for the ears to perceive a true indication of what has actually been played.
I	Performers must be able to hear one another as accurately as possible.
J	Can be both. It challenges the players to listen in different ways. I alter set ups depending on the room.
K	Less reverberant spaces assist detailed listening for note lengths, precision, etc., and erode the confidence of the players. More reverberant spaces assist in preparing for normal concert room acoustics, and build confidence in the players.
L	Acoustic dryness can assist quantification, but can hinder musicality and balances.
M	Extremes are harmful – "dead or live". I prefer rehearsal acoustics to be slightly less resonant than performing area acoustics. Also, important that recording in the rehearsal space be possible—enough space behind the conductor to capture sound before immediately bouncing off a wall behind the conductor.

Student Questionnaires

There are a total of 206 questionnaires collected from two university wind and jazz bands and one high school wind band. One hundred twenty five wind band members completed the questionnaires at University A. The results shown in Figure 5-3 reveal that more than 70% of the students were listening for intonation, rhythm, dynamics, articulation and other player's playing while they played during rehearsals. This is an indication that student musicians are constantly trying to hear themselves and other players during band rehearsals at University A. Only about 1% of students mentioned that they also listened for other musical attributes such as tone quality, phrasing, style, blend of sound and pulse.

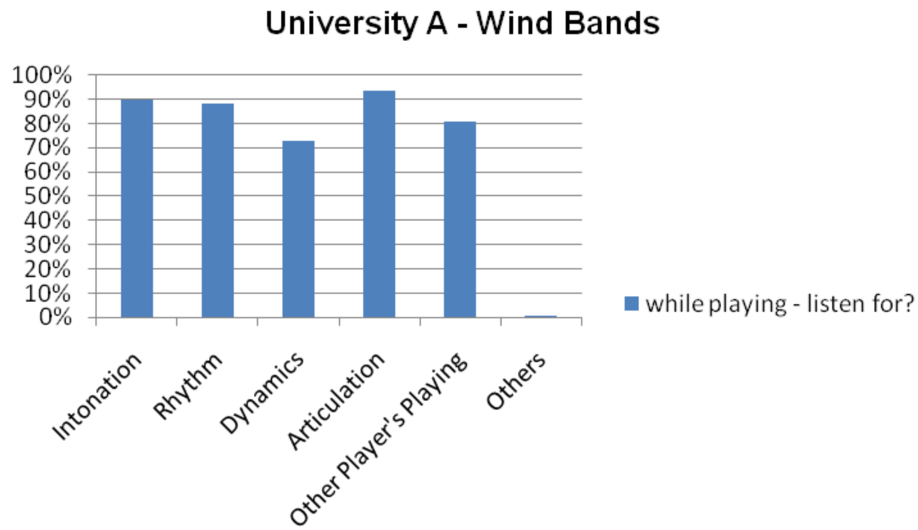


Figure 5-3. Results of student questionnaire about what musical attributes they are listening for during rehearsal for University A.

At University B, 49 wind and jazz band members completed the questionnaires. The results shown in Figure 5-4 reveal that 78%, and above, of students were listening for intonation, rhythm, dynamics, articulation and other player's playing while they were playing during rehearsals. These results indicated the student musicians were constantly trying to hear themselves and other players during band rehearsals at University B. Only 18% of students mentioned that they were also listening for other attributes of music such as phrasing, style, breaths, inflection and balance.

The High School Band had 32 wind band members who completed the questionnaires. The results shown in Figure 5-5 show that 68% and above of the students are listening for intonation, rhythm, dynamics, articulation and other player's playing while they are playing during rehearsals. Evidently, the results indicated that music students were constantly trying to hear themselves and each other during band rehearsals. Twenty two percent of the students mentioned that they were also listening for other attributes of music such as tone quality and phrasing.

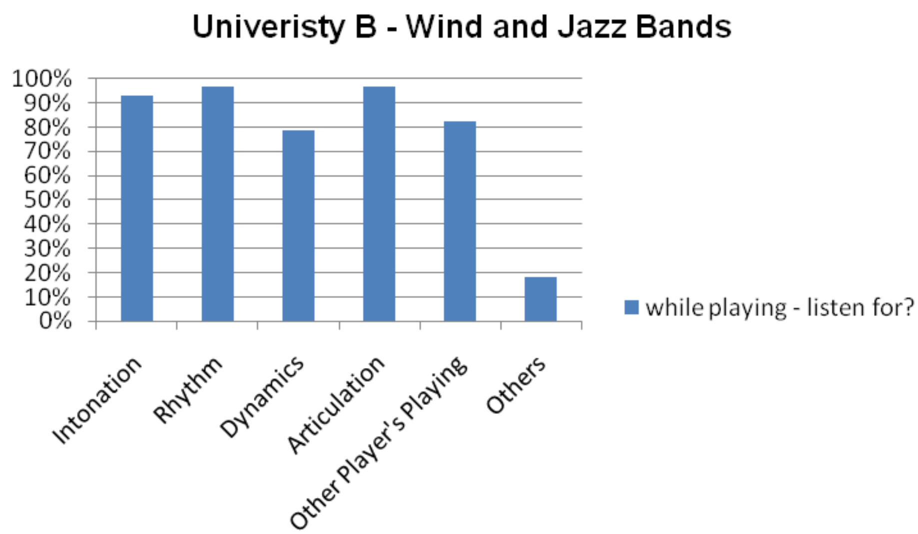


Figure 5-4. Results of student questionnaire about what attributes of music they are listening for during rehearsal for University B.

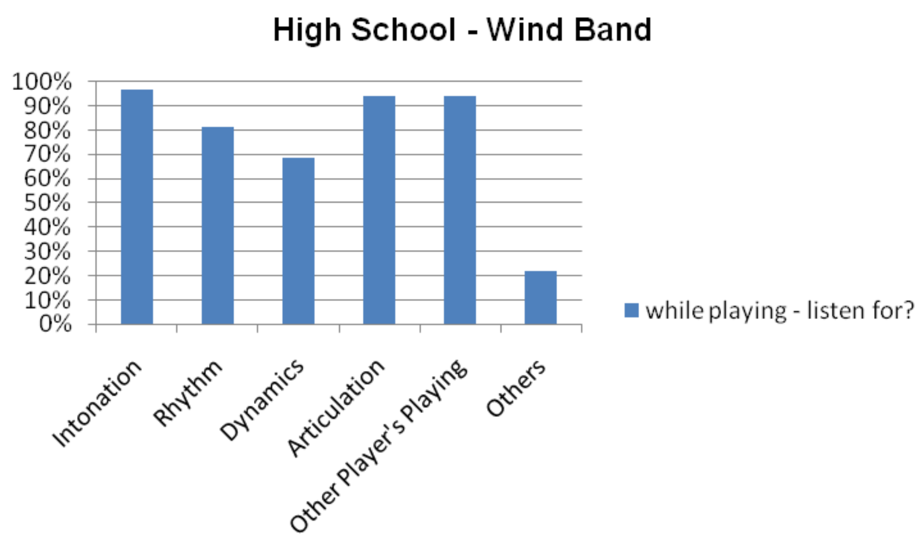


Figure 5-5. Results of student questionnaire about what attributes of music they are listening for during rehearsal for High School

The overall results of the responses of the 206 students on the questionnaires are shown in Figure 5-6. Student musicians are constantly listening to each other so they can play in time, in tune, balance dynamics and articulate notes properly. Hearing oneself and each other has been broken down in the following categories in the responses of the 206 students' questionnaires: 93% of the students listened for intonation, 89% of the students listened for rhythm, 73% of the students listened for dynamics and 95% of the students listened for articulation. This is an indication that student musicians are constantly trying to hear themselves and other players during rehearsals. Only about 14 % of the students mentioned that they also listened for other musical attributes such as tone quality, phrasing, style, breath and blend of sound.

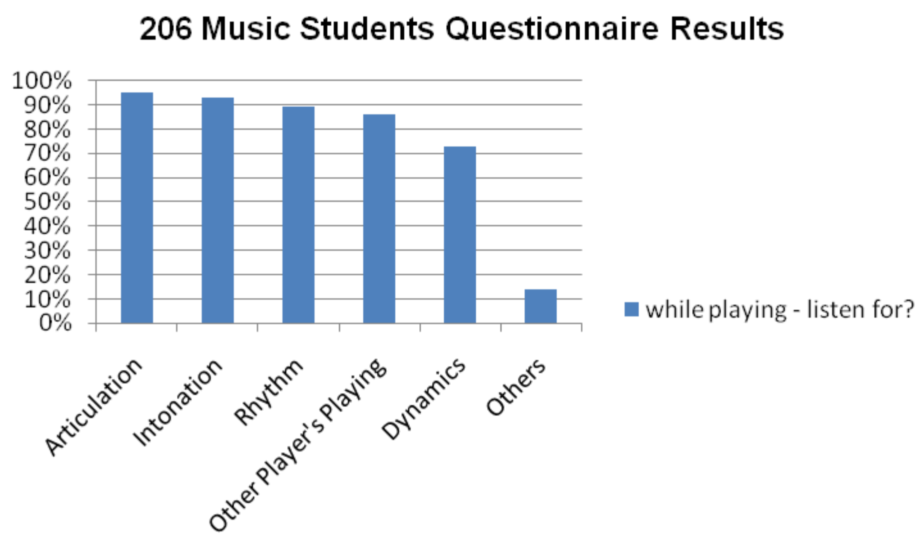


Figure 5-6. Results of 206 students' questionnaire about what attributes of music they are listening for during rehearsal.

Summary

The objective of conducting the interviews with the conductors/instructors and administrating the questionnaires to music students was to study what both groups are listening for during rehearsals. The results can be used to understand what listening criteria and rehearsal room acoustic conditions would be helpful or useful for conductors to teach and music students to rehearse in as an ensemble. The results of interviews and questionnaires indicated that hearing each other has been identified as the main criterion to rehearse as an ensemble in the band room by both conductors and music students. Twelve out of 13 conductors (92%) stated that hearing each other is the primary factor for students to rehearse together. Results of the 206 music students' questionnaires also identified 73 to 95% of the times student musicians were listening to themselves and other players' intonation, rhythm, dynamics, articulation; and 14% of the students were also listening for other musical attributes (tone quality, blend, breath, phrasing and style).

The students and instructors are constantly listening for the fundamentals of music to ensure that the entire band plays everything together and sounds like one. Musicians were constantly being asked to listen to the fundamentals of music such as dynamics (balance), intonation (notes, togetherness, tone quality and blend), rhythm (togetherness) and articulation (note length, togetherness). Therefore, it is appropriate to state that band rehearsal rooms should be designed to allow both conductors and music students to hear each other clearly on the most fundamental attributes of music. Most of the conductors mentioned that a less reverberant room allows both conductors and music students to hear oneself and each other easier. This is the key to playing together as an ensemble.

CHAPTER 6
ACOUSTICAL MEASUREMENTS OF BAND REHEARSAL ROOMS

Background

Acoustical measurements were performed in the three band rehearsal rooms to study the acoustical conditions of these rooms. From the impulse response concepts and site observations, different receiver locations in the room perceive sound quality differently. Likewise, different source locations or numerous sources generating sound in unison result in different sound quality at a receiver location. Due to multiple source and receiver paths in the band rehearsal room that have different impulse responses, musicians could perceive different sound qualities. In addition, assuming that the perceived sound qualities influence a musician's ability to hear themselves and other musicians' playing, then the acquired acoustical attributes and corresponding acoustical parameters from the data can be used to study the attributes of music that musicians are listening for during rehearsals.

Method

As mentioned earlier, three band rooms were carefully selected for their distinct room acoustic responses due to architectural characteristics such as room volume, room dimensions, and acoustical treatments in the room. Acoustical treatments are the average absorption coefficient of the surface areas (Alpha_Bar) and the average surface diffusivity (SDI). The average absorption coefficient can be obtained from the reverberation time and calculated surface area of the room. The average surface diffusivity is based on the ratios of area for the diffusive panel to the surface area where the panel is located. Figure 6-1 shows the interiors of these rooms. Table 6-1 shows the architectural characteristics of these rooms.

Figure 6-1. Interiors of three band rehearsal rooms. A) Band Room A, B) Band Room B, C) Band Room C. (Photos courtesy of Lucky Tsaih)

Table 6-1. Architectural Characteristics of three band rooms.

Room Name	Room Volume, (ft^3)	Max. Length (ft^2)	Max. Width(ft^2)	Ceiling Height(ft^2)	Average Absorption (Alpha_Bar)	Average Surface Diffusivity (SDI)
Band Room A	184738	84.5	66.25	33	0.48	0.38
Band Room B	35840	56	32	20	0.40	0.16
Band Room C	20545	48	38	11.47	0.28	0.21

In order to study the room responses due to the different sound source and receiver paths, four source locations with multiple receiver locations for each source was used for this study. Since these rooms are symmetrical, source and receiver locations were chosen based on even coverage of the seating area. However, the multiple receiver locations were particularly chosen based on rehearsal conditions. This means setting locations with the perspective that a player is sitting and listening to another player close to him/her (on the side, in front and at the back) and far from him/her (mid and far distances) in all direction. Receivers that are close to the source are categorized as near condition. Receivers that are far from the source are categorized as far condition. Near and far conditions will be used for the measurement report. Figures 6-2, 6-3 and 6-4 show the floor plan sketches with source and receiver locations for the three band rooms.

A laptop pre-installed with the WinMLS software is used for the measurement. A Maximum Length Sequence is used as the testing signal that is played through a directional self-powered loudspeaker[21]. The playback loudspeaker was moved to the four source locations (S1, S2, S3 and S4) as indicated on Figures 6-2, 6-3 and 6-4. An omnidirectional microphone[22] and a dummy head (binaural microphones) are separately connected to the laptop and moved to the multiple receiver locations during the measurements. The reason to use a directional loudspeaker as a playback source is because musical instruments have directional patterns, thus the recommended omnidirectional loudspeaker from ISO3382 is replaced by the directional loudspeaker.

[21] JBL Eon 15 G2 Self-Powered Loudspeaker.

[22] Earthworks M30BX Type 1 Microphone.

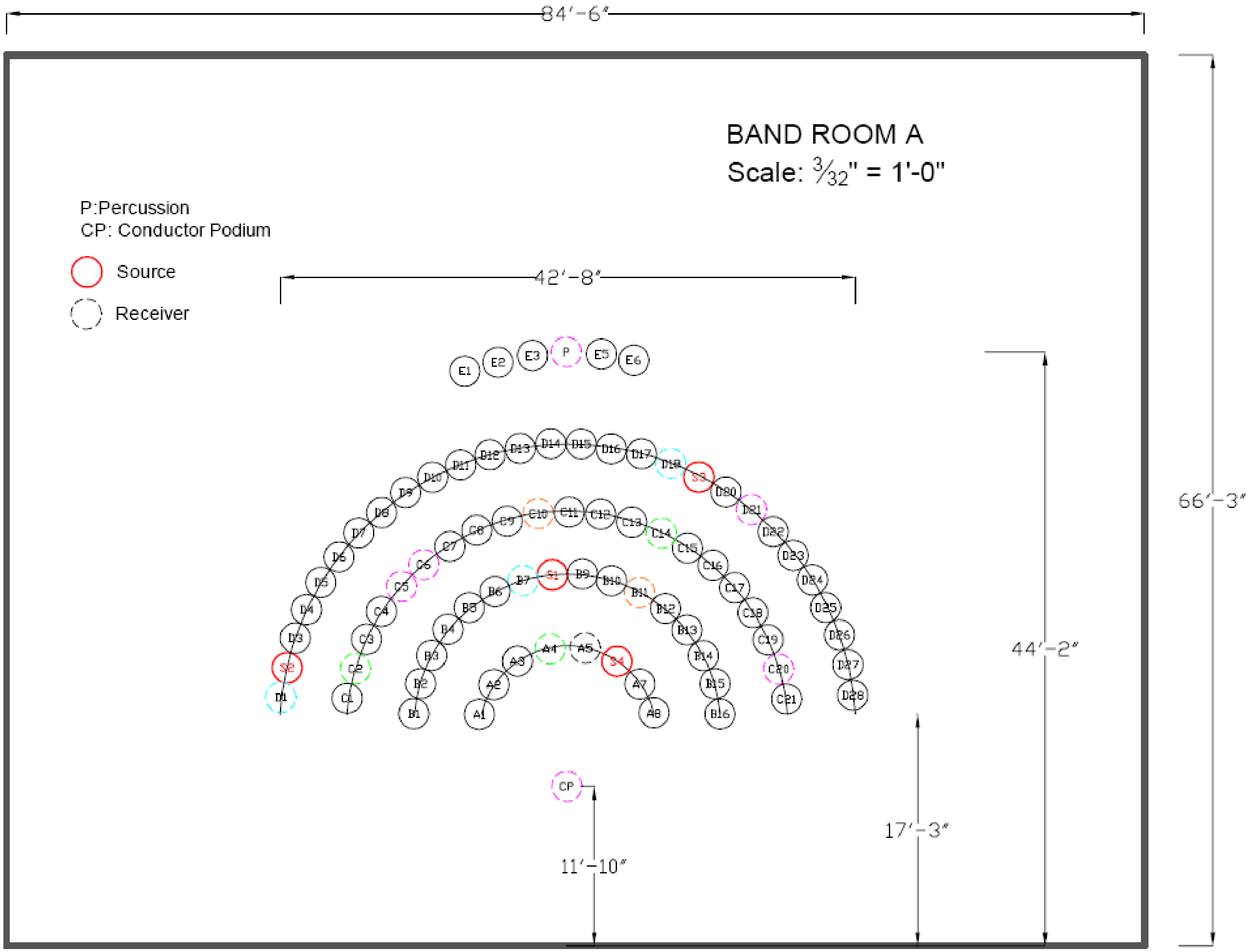


Figure 6-2. Band room A floor plan showing the acoustical measurement locations of the sound sources and receivers.

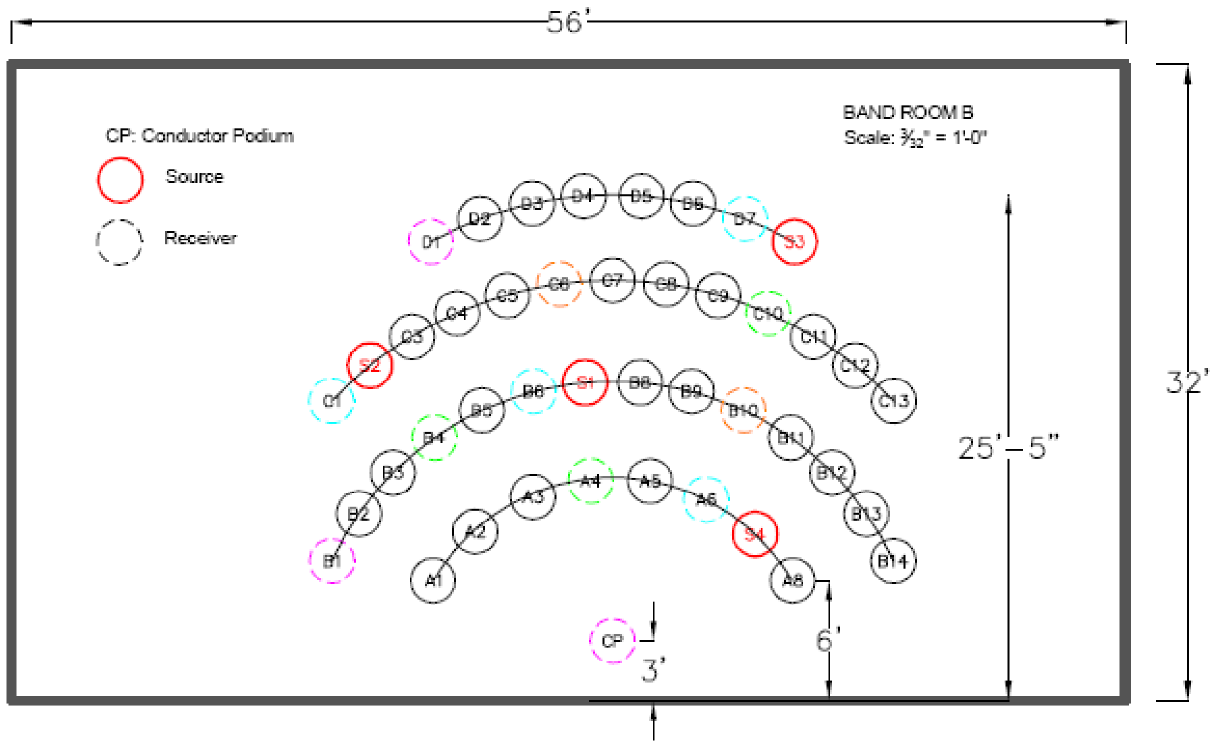


Figure 6-3. Band room B floor plan showing the acoustical measurement locations of the sound sources and receivers.

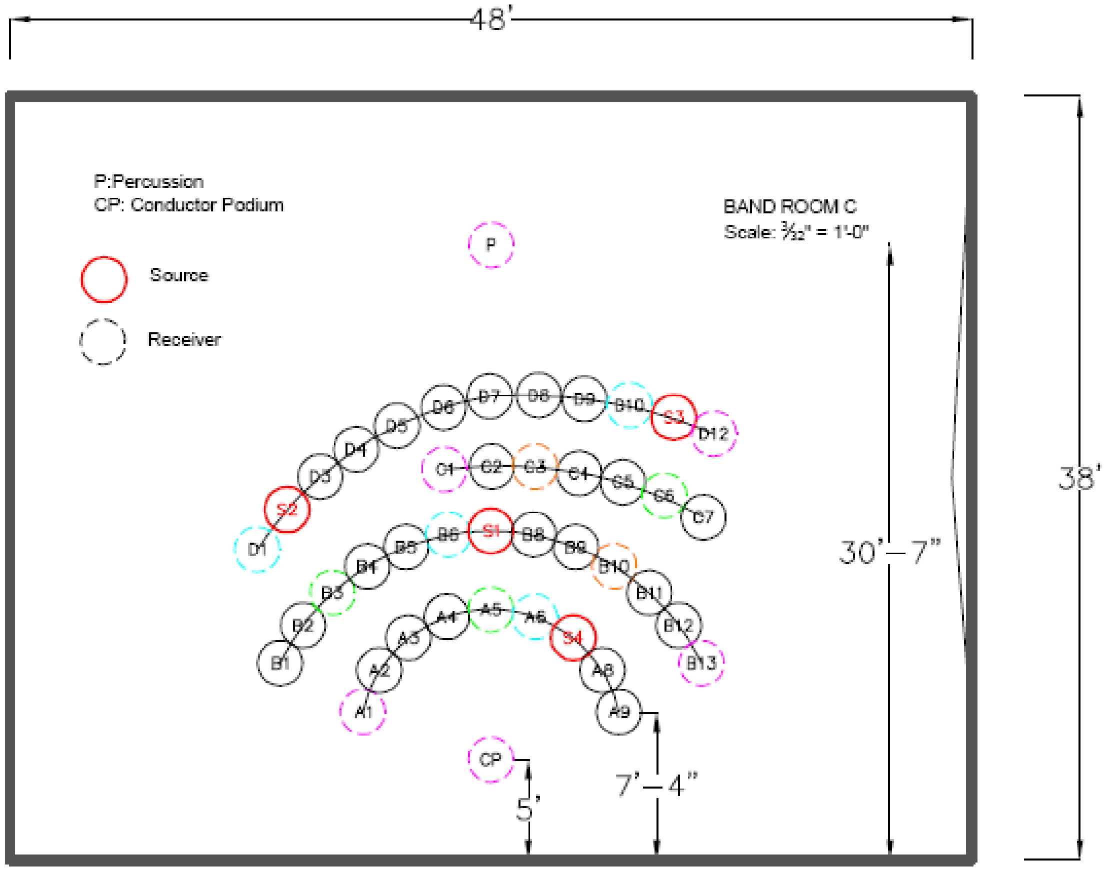


Figure 6-4. Band room C floor plan showing the acoustical measurement locations of the sound sources and receivers.

The selected acoustical measurement parameters as discussed in Chapter 2 in conjunction with the parameters that suggested by ISO-3382 (1997, pp. 12-19) are used to report the room responses. These acoustical measurement parameters include Early Decay Time (EDT), Reverberation Time (T30 and T20), Center Time (Tc), Clarity Index (C80), Definition (D50), Support (ST1), Strength[23] (SPL), Interaural Cross Correlation (IACC). Speech Transmission Index (STI) is included in this study due to the importance of verbal communication during rehearsals. These parameters are calculated based on the impulses response measured at a receiver location in the room. An impulse response as shown in Figure 6-5 consists of direct sound, early sound and reverberant sound. The impulse response is a graphical analysis of sound perceived by a listener at a specific location in the room.

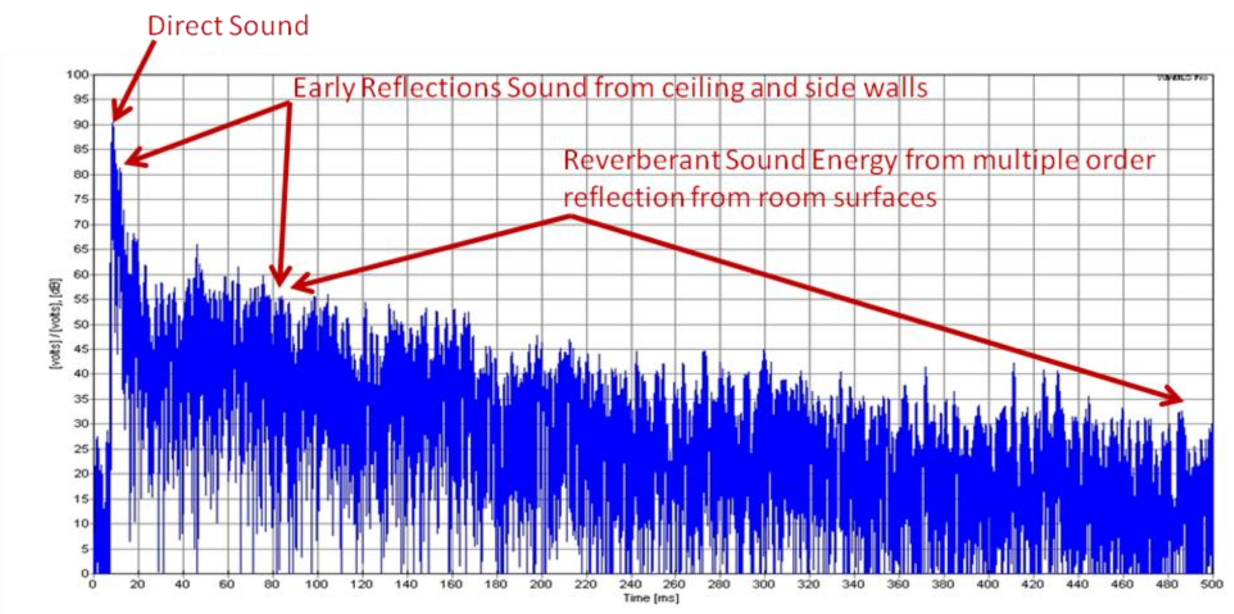


Figure 6-5. Impulse response concept.

[23] Strength for this measurement is the actual sound pressure level measured at the receiver location.

According to Cremer (1982, p. 414), individual syllables or notes of running speech and music can often be masked by the following syllables and notes. Therefore, Jordan's early decay time (EDT) is the time it takes for the first 10 dB of decay of an impulse response extrapolated to a 60 dB decay and can be used to indicate the perceived reverberance as suggested by ISO-3382 (1997, p.14). Reverberation time, T20 and T30, are the time measurements sound energy has to decay from -5 dB to -25dB and from -5dB to -35dB respectively extrapolated to a 60 dB decay. T20 and T30 can be used to indicate the overall reverberation of the room due to room properties. EDT, T20 or T30 are the modifications of reverberation time (T60) proposed by Sabine (2009). The measured decay time of EDT, T20 and T30 is often multiplied by 6, 3 and 2 respectively to be reported as reverberation time.

Center Time (TC) is proposed by Cremer (1982, p. 434) and can be derived from the equation as shown in Equation 6-1. Center time is a measure of center point of the impulse response where the early sound energy equals the reverberant sound energy. It indicates whether or not the listener perceives direct and early sound or the reverberant sound as the dominant part of the impulse responses. Center time is reported in seconds or milliseconds. When the value of center time is close to 0 millisecond, it means the direct sound and early sound energy is dominant.

$$TC = \int_0^\infty t p^2_{(t)}\, dt \;/\; \int_0^\infty p^2_{(t)}\, dt \qquad \text{(Equation 6-1)}$$

Distinctness or definition (D50) is proposed by Thiele (1953) and can be derived from the equation as shown in Equation 6-2. Distinctness is a measure of the ratio for the first 50 milliseconds early sound energy to the total sound energy. Fifty milliseconds is the limit of perceptible speech. It is used to measure the subjective evaluation on clarity of speech. Distinctness is reported as a fraction between 0 and 100. A higher percentage means clearer speech as perceived by the listener.

$$D50 = \int_0^{50ms} p^2\, dt \;\; / \int_0^{\infty} p^2\, dt \qquad \text{(Equation 6-2)}$$

Clearness or Clarity Index (C80) is proposed by Reichardt (1975) and can be derived from Equation 6-3. It is a ratio for the first 80 milliseconds of early sound energy to the sound energy after 80 milliseconds in logarithmical format. Eighty milliseconds is the limit of perceptible music. Clearness is used to measure the subjective evaluation on clarity of music. Clarity Index is reported in decibels (dB). A positive value means clear music as perceived by the listener.

$$C80 = 10 \log \int_0^{80ms} p^2\, dt \;\; / \int_{80ms}^{\infty} p^2\, dt \qquad \text{(Equation 6-3)}$$

Interaural Cross Correlation (IACC) is based on the concept of the law of first wavefront and the direction of sound energy being perceived by the listener binaurally. Equation 6-4 shows the mathematical equation to derive the entrance of sound perceived by the left and right ear (Beranek, 2004, p. 635). Since IACC is a measure of time that sound arrives at the left and right ear, the value of t_1 and t_2 from the integral term will point out which subjective sound quality is being perceived by the listener. For example, if the value of t_1 and t_2 equal 0 and 1000 milliseconds, the difference of sound perceived at two ears is measured and is denoted as $IACC_A$. When the value of t_1 and t_2 equal 0 and 80 milliseconds, the result is denoted as $IACC_E$. According to the definition of ISO-3382 (1997, p. 19), $IACC_E$ is used to describe the “broadening of the source” or "spaciousness". Likewise, when the value of t_1 and t_2 equal 80 and 750 milliseconds, the result is denoted as $IACC_L$. According to the definition of ISO-3382, $IACC_L$ is used to describe the "the state of diffusion of the reverberant sound field" or "envelopment".

$$IACC = \frac{\int_{t1}^{t2} p_L(t) p_R(t+\tau) dt}{\left[\int_{t1}^{t2} p^2{}_L \, dt \int_{t1}^{t2} p^2{}_R \, dt \right]} \qquad \text{(Equation 6-4)}$$

Support or ensemble (ST1) is proposed by Gade (1989) and can be derived from Equation 6-5. It is a measure of the ratio for the direct sound energy within the first 10 milliseconds of the impulse response to the early sound energy between 20 and 100 milliseconds in logarithmical format. Support is measured with a microphone located at 1 meter from the omnidirectional source on stage[24] and is used to measure the subjective perception on perceived loudness of sound energy arrives at listener's ears. Support is reported in decibels (dB). A negative value means more support for the musician, hence clear music is perceived by the musician.

$$ST1 = 10 \log \int_{20ms}^{100ms} p^2 \, dt \ / \int_{0ms}^{10ms} p^2 \, dt \qquad \text{(Equation 6-5)}$$

Strength (G) is often recommended to be used in reporting the sound strength at a measured location in a room. It is measured by using a calibrated omnidirectional

[24] The ST1 values measured and reported in this research were based on the modifications of Gade's proposed measurement procedures. The modifications included the microphone distance and the use of the source playback device. The microphone was placed at a seat that is in the front of the source, at the back of source and next to the source, since these are the actual locations where the musicians sit during rehearsal. The distances of these seats to source are approximately 2 to 4.5 feet apart. Directional loudspeaker was used instead of the omnidirectional loudspeaker, since most of the musical instruments have directivity characteristics.

loudspeaker in the room and in a free field with a microphone at a 10-meter distance. The measured value is the difference of the field measurement and the free field measurement. However, for ease of comparison, the actual perceived sound pressure levels (SPL) at the listener's locations as the sound pressure levels were measured at these locations were used in lieu of strength in this research. Relative sound pressure level from a listener is the sound pressure level measured from the source to receiver. The directional loudspeaker output level was set to have the same sound pressure level output for the three band rehearsal rooms during measurement.

Speech Transmission Index (STI) and Rapid Speech Transmission Index (RASTI) are used in this study to evaluate speech intelligibility. It is based on Houtgast and Steeneken's findings (1985) that the Modulation Transfer Function with individual octave frequency bands could be useful to predict the speech intelligibility between the original speech signal to the speech with different reverberation times, levels of echo and noise. As signal to noise level increases, STI will increase. On the other hand, as reverberation time increase, STI decreases. There are 98 modulation factors for STI. RASTI has 9 modulation factors only. With averaged weighting of 98 factors for STI and 9 for RASTI, STI and RASTI range from 0 to 1. Values close to 1 means a listener has better speech intelligibility.

Results and Discussions

The impulse responses of a source at the center of the room and the multiple receiver locations for the three band rehearsal rooms are shown in Figure 6-6. These impulse responses are used to identify the sound energy decay pattern at specific receiver locations in the room. For example, from Band Room A (Figure 6-6-A), the upper left circle points out that receiver #A4[25] has strong direct sound whereas the right bottom circle points out that receiver #D1 has no strong direct sound energy. The different direct sound patterns are due to the receiver location. The upper left impulse response is measured at the receiver location directly in front of the source, within 5.5 feet distance. The right bottom impulse response is measured at the receiver location that is 22 feet away and off axis from the source. This implies when an oboe player who sits in the center of the room plays a melody, the flute player who plays accompaniment, and sits directly in front of the oboe player, will perceive attributes of music more clearly than the trumpet player who sits far away from the oboe player. It is apparent by seeing the two different kinds of decay patterns from these impulse response graphics of the three band rooms. The receiver locations at the front or near the source had stronger direct sound energy. The receivers located off-axis and far away from each source has less direct sound energy. The amount of direct sound will probably affect the music quality. Entry notes played by different instruments simultaneously at different locations will not sound together as one.

In order to see the individual room response in a clear manner, the following acoustical measurement results for the three band rooms with multiple receiver locations as well as to each acoustical parameter are presented in a graphical format. Within each graphic, the dotted line means the receivers are near the source. A solid line means the receivers are far away from the source. The legend of the receiver location on the right side of each graphic is based on the near to far distance relative to the source. Reading the graphical data with the measured floor plan from page 69, 70

[25] Please refer to the measurement floor plan on page 71 for relative receiver location.

and 71 will help to locate the source and receiver locations clearly. The mean value of all receiver locations is shown with the pink broken line. The standard deviation is shown with the black vertical broken line.

Figure 6-7 shows the early decay times (EDT) for multiple receiver locations for the three band rooms. Band Room A has larger ranges than Band Room B and C due to wide spread of the receiver locations. The floor area of Band Room A is twice as large as Rooms B and C. However, within each band room, it shows that the receiver that is located in front of the source has a very short EDT compared to the other receiver locations. This might be due to the fact that the direct sound is perceived rapidly by the player in front of the source.

Figures 6-8 and 6-9 show the reverberation time (T20 and T30) of the three band rooms. Both figures show small variations responses of T20 or T30 when compared to EDT (Figure 6-7). This might be due to the diffusive theory that the reverberation time is not sensitive to receiver location. However, it is interesting to note that Band Room A has a longer reverberation time response at low frequency bands than Band Rooms B and C. The longer reverberation times in the low frequency bands may provide a sense of warmth and fullness of tone during rehearsals since the high frequency bands of the music notes decay sooner. On the other hand, the longer reverberation time in the low frequency bands might affect the entry of the notes, as well as the precision of rhythm.

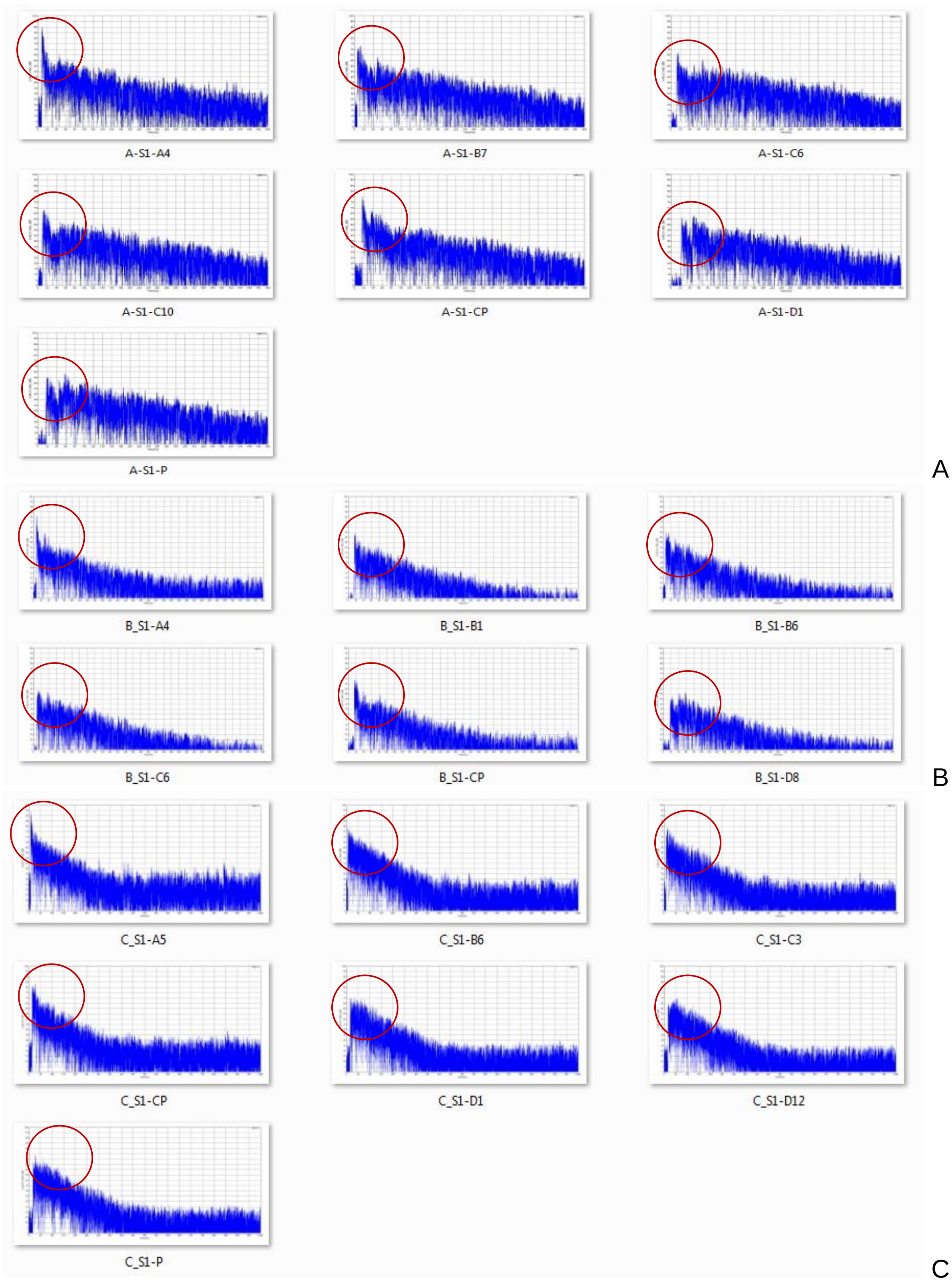


Figure 6-6. Impulse responses of three band rooms. A) Band Room A, B) Band Room B, and C) Band Room C.

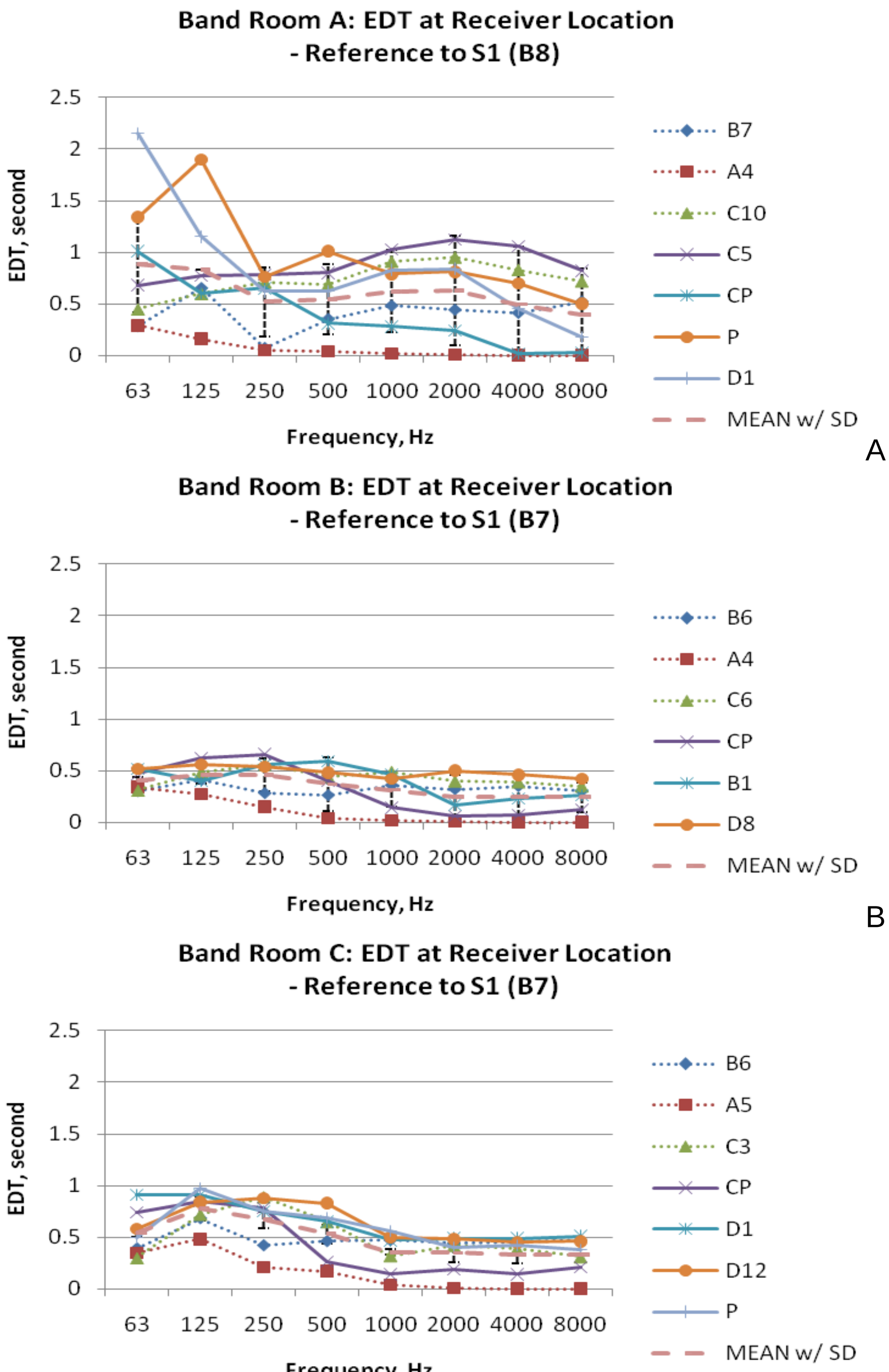


Figure 6-7. Early decay time (EDT) responses in octave band center frequencies (Hz) in A) Band Room A, B) Band Room B, and C) Band Room C.

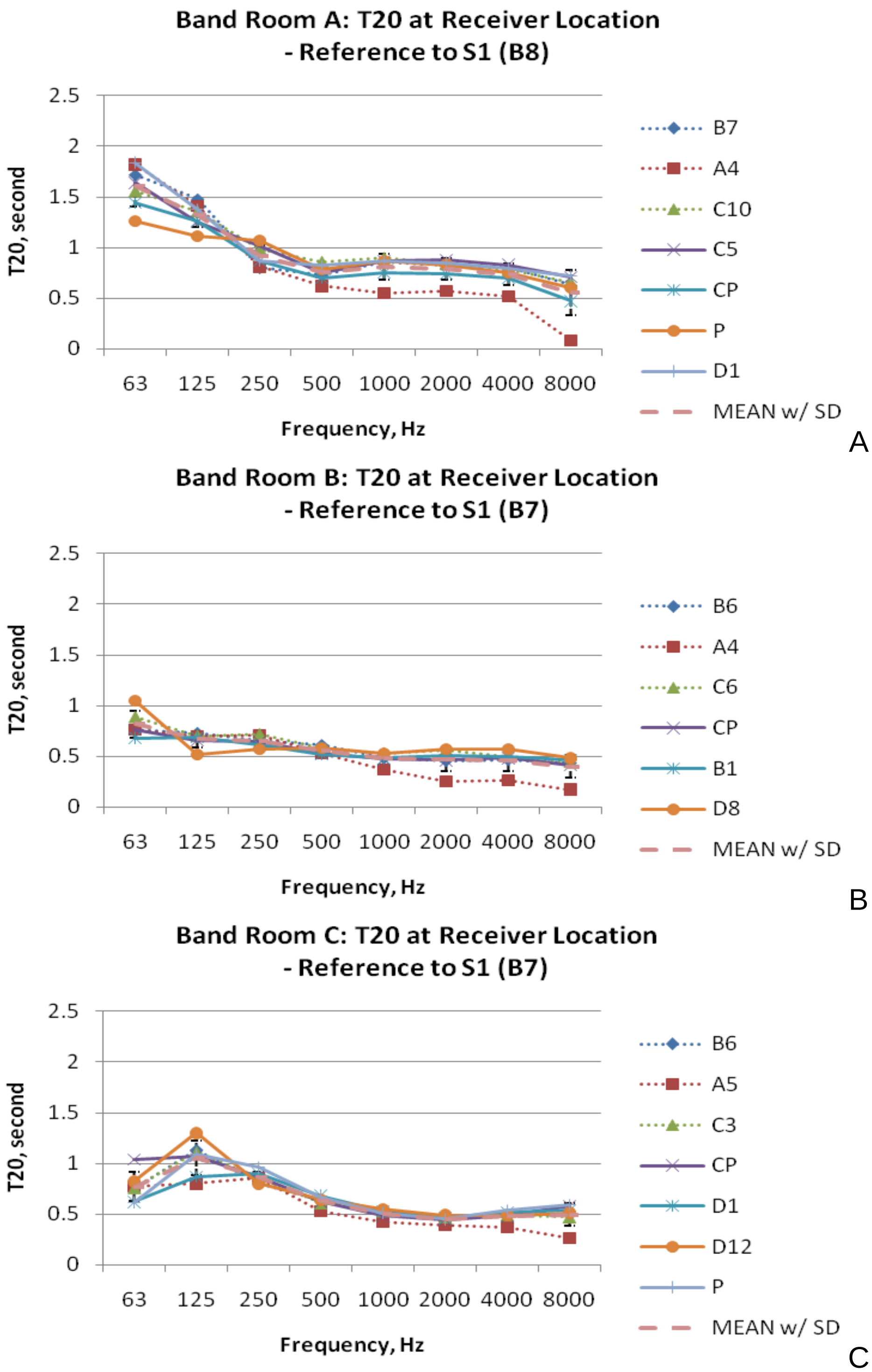


Figure 6-8. Reverberation time (T20) plotted in octave band center frequencies (Hz) in A) Band Room A, B) Band Room B, and C) Band Room C.

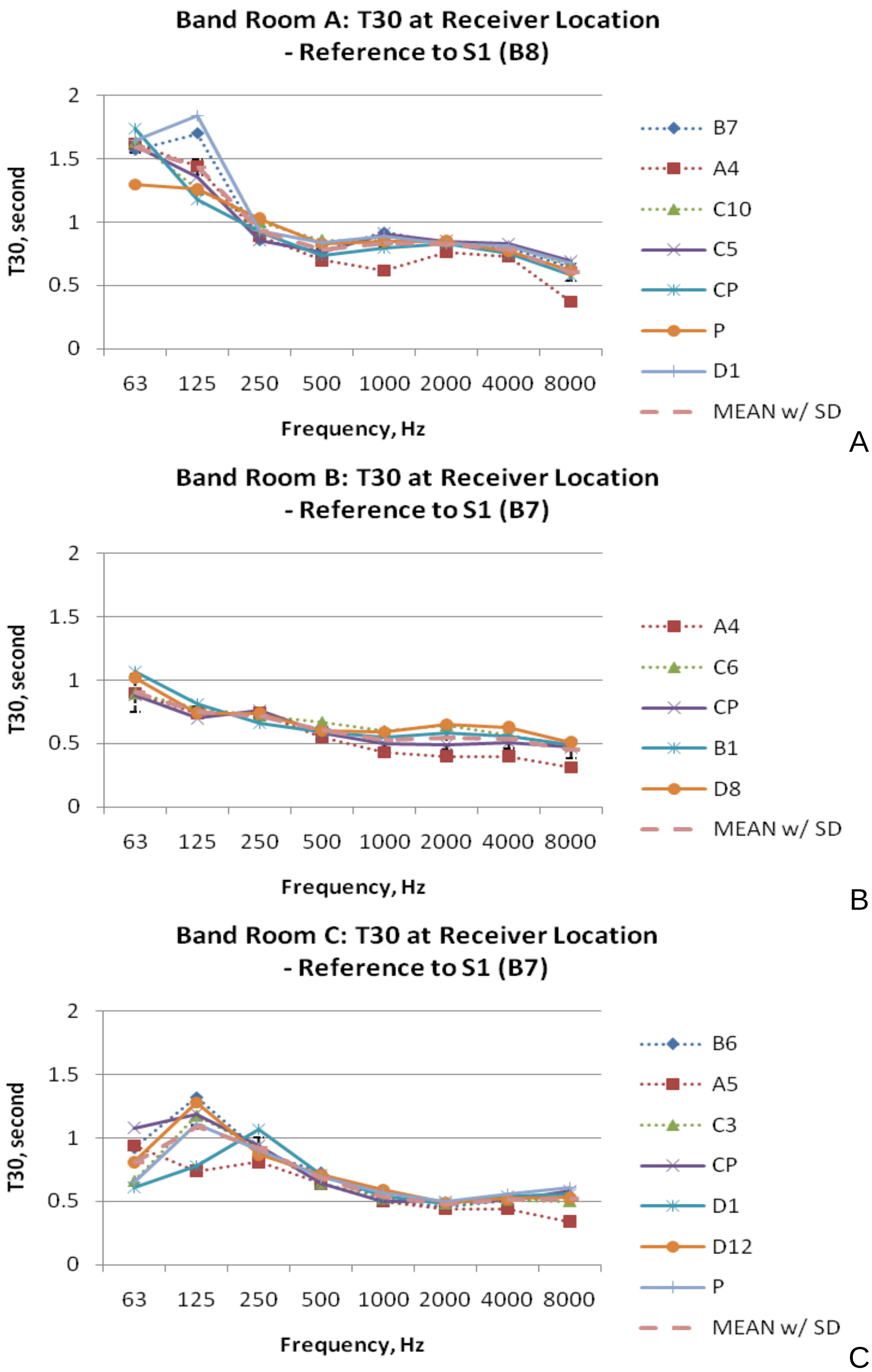


Figure 6-9. Reverberation time (T30) plotted in octave band center frequencies (Hz) in A) Band Room A, B) Band Room B, and C) Band Room C.

The values of center time (TC) measured in the three band rooms are shown in Figure 6-10. Center time shows the same pattern as early decay time in that Band Room A has larger variances than Band Room B and C. As mentioned earlier, center time is to measure the center point where the early sound energy equals the reverberant sound energy. Thus, the data suggest that receivers located closer to the source encounters more direct sound, whereas the receivers located farther away from the source encounter more reverberant sound. Consequently, a player who experiences direct and early sound energy higher and quicker than other players might react faster in terms of adjusting what he/she is playing than other players. This raises questions about how to design a band rehearsal room that can balance the perception of sound over the seating area with architecture elements. This topic requires a detailed future study.

Figure 6-11 shows values of Distinctness (D50) for the three band rooms. D50 is the measured ratio of early to total sound energy of an impulse response. Interestingly, D50 and TC's response patterns are mirror-like. This might suggest that the higher percentage of D50 has a lower center time value. D50 is intended to be used to check the clarity of speech. It suggests that a higher direct sound level will have a significant effect on the clarity of speech. As shown in Figure 6-11, the near receiver positions have higher values of D50 than the far receiver locations such as the percussion position and the location behind the source. In addition, the overall D50 response seems narrower in Band Room B than in Band Rooms A and C. Thus, Band Room B might have overall better speech intelligibility.

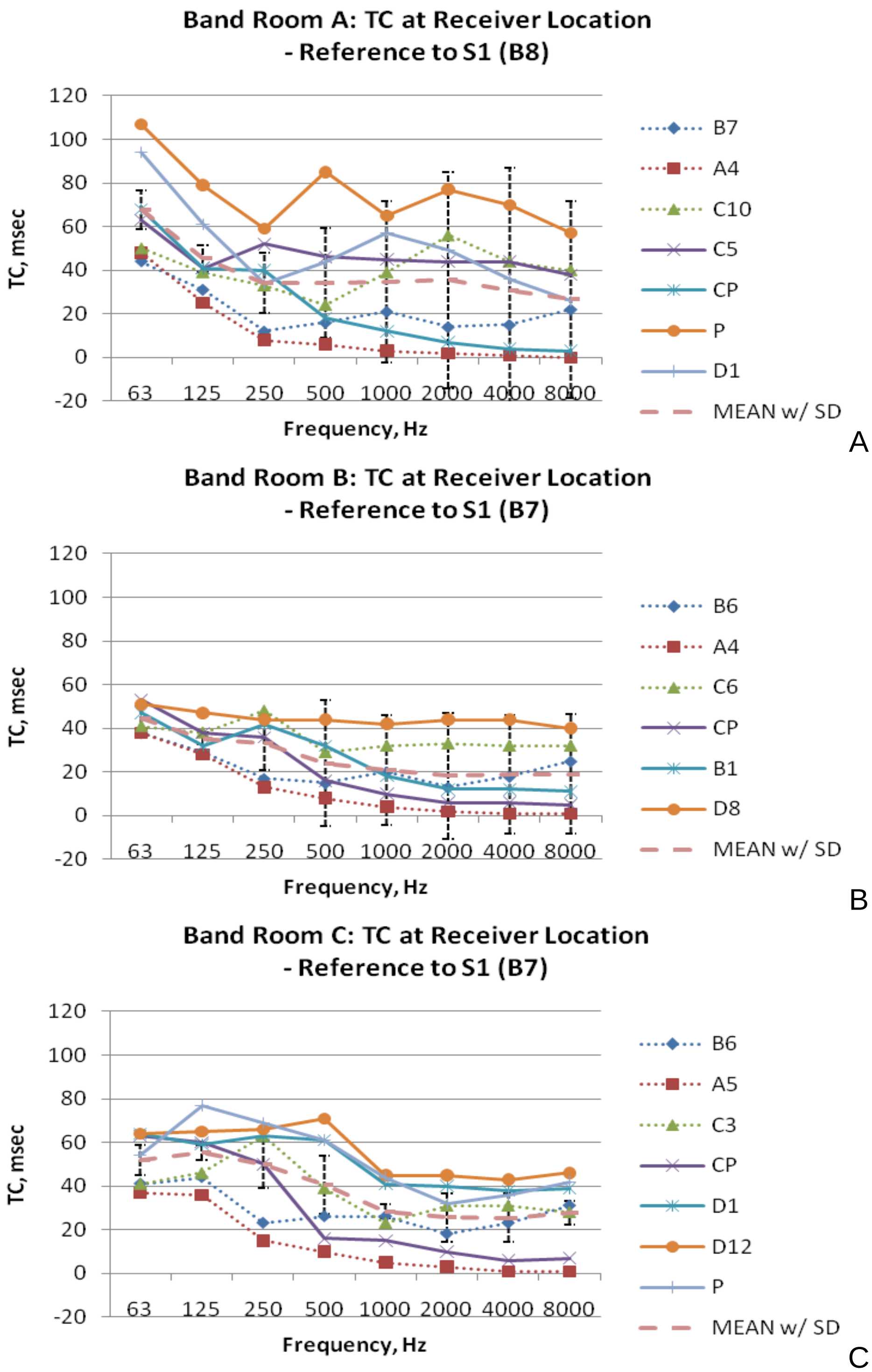
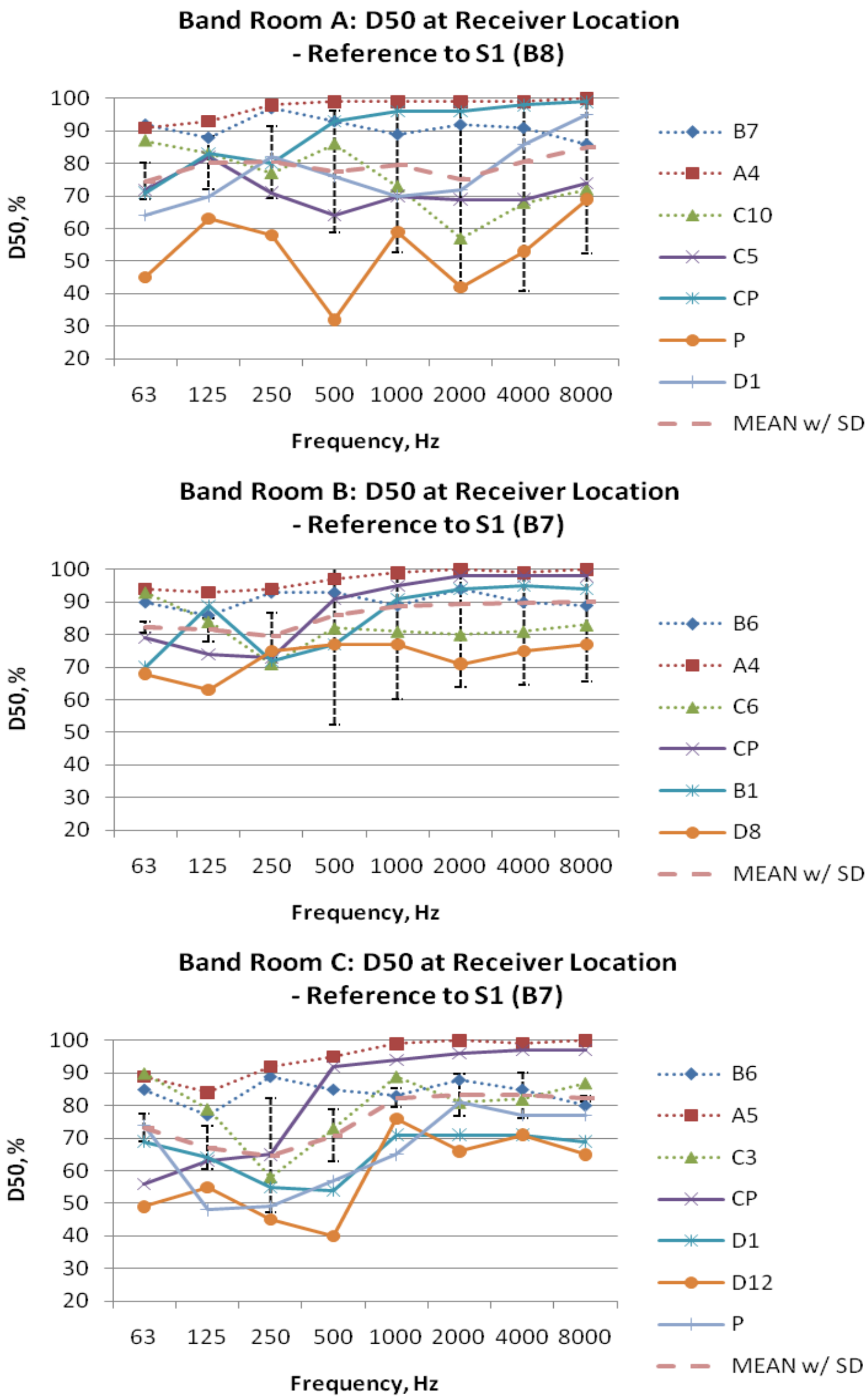


Figure 6-10. Center time (TC) plotted in octave band center frequencies (Hz) in A) Band Room A, B) Band Room B, and C) Band Room C.



A

B

C

Figure 6-11. Distinctness (D50) plotted in octave band center frequencies (Hz) in A) Band Room A, B) Band Room B, and C) Band Room C.

Figure 6-12 shows the Clearness (C80) responses of the three band rooms. The figure shows that all three band rooms have positive C80 responses for all receiver locations. This means musicians are able to perceive the attributes of music well while they are playing. However, the ranges of the C80 for all receiver locations are between 5 to 30 dB, with the receivers located in front of the source having a higher value than the receivers located far from the source. This large difference might need some architectural elements to balance it if playing together and balance is the main goal of the ensemble.

Figure 6-13 shows the values of Support (ST1) for the three band rooms. According to Gade (1989), ST1 is used to study whether or not the musicians on stage can hear themselves sufficiently when playing in an ensemble. A negative value of ST1 means the players can hear themselves better than the positive value. The receiver locations near the source versus the receiver locations farther from the source have 8 to 30 dB ranges of ST1 across the frequency bands. Evidently, the percussion locations for all source locations have lower ST1 values than the receiver locations that are in the front of sources. This might suggest that ST1 is affected by the directivity pattern of the source. The ranges of ST1 values increases in higher octave bands. Therefore, musicians who sit off-axis of the source will not hear clearly in high frequencies compared to a musician who sits within the coverage of the source directivity pattern. This could affect the adjustment of intonation during rehearsals.

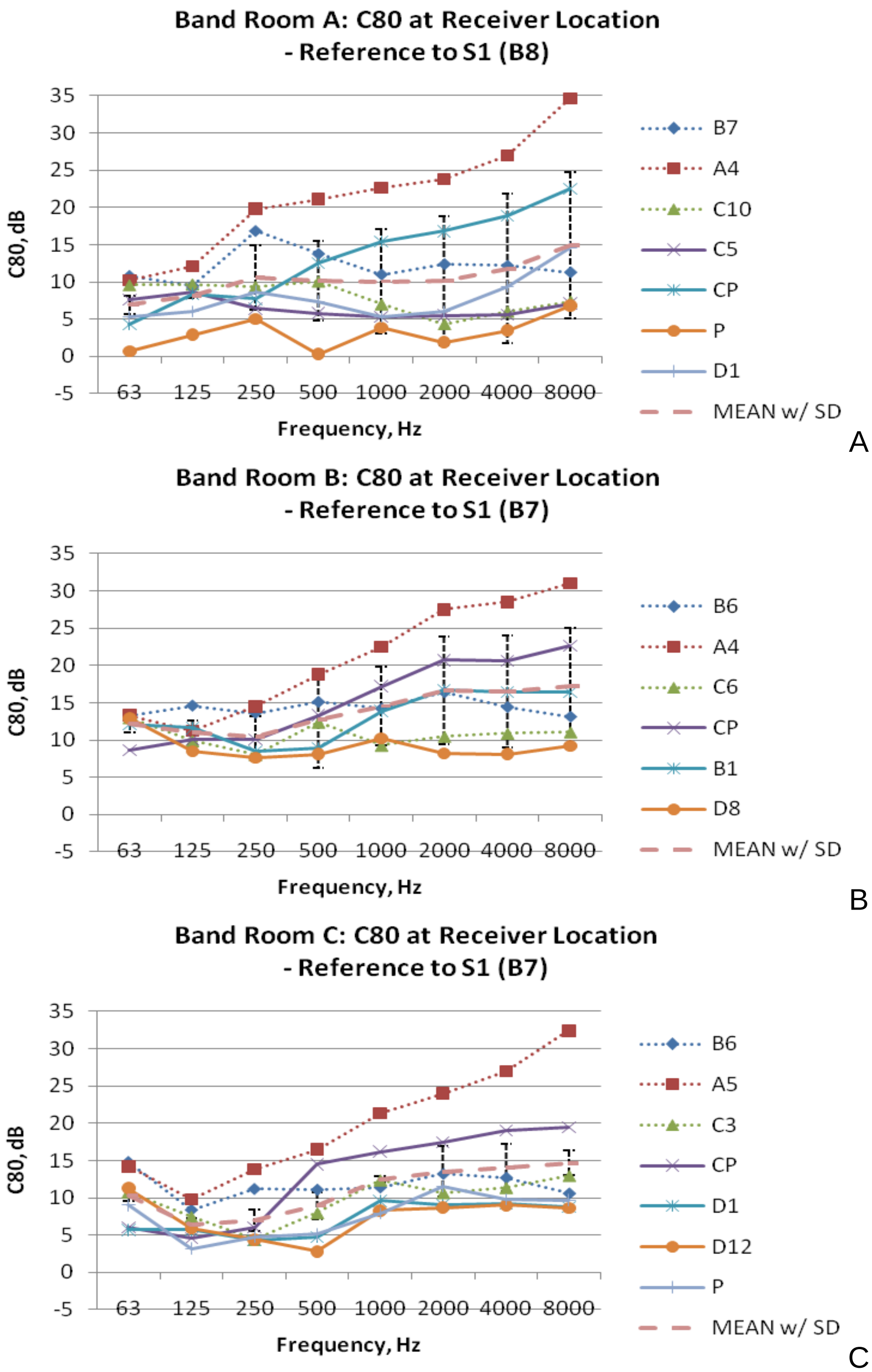


Figure 6-12. Clearness (C80) plotted in octave band center frequencies (Hz) in A) Band Room A, B) Band Room B, and C) Band Room C.

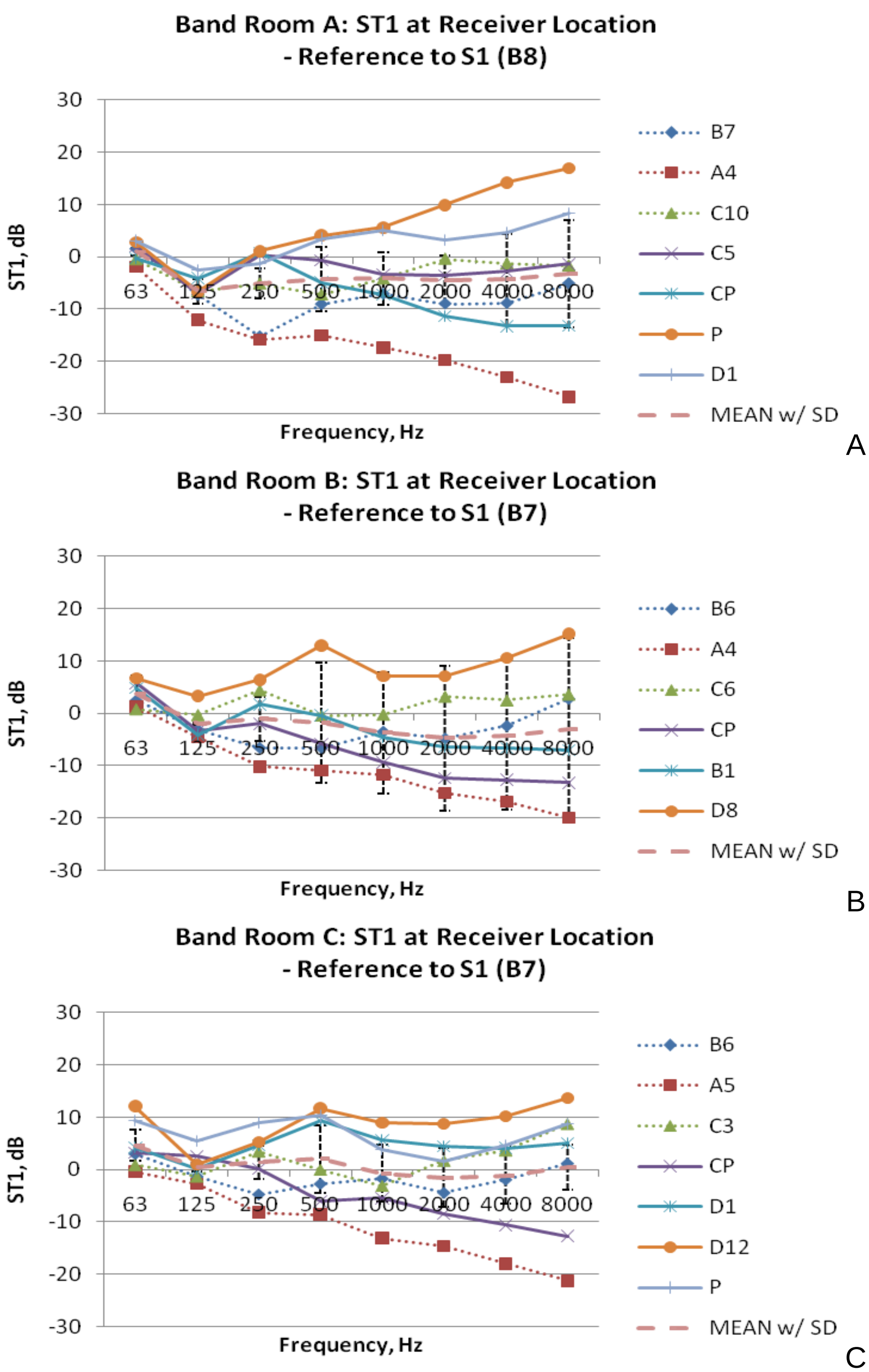


Figure 6-13. Support (ST1) plotted in octave band center frequencies (Hz) in A) Band Room A, B) Band Room B, and C) Band Room C.

The relative sound pressure level measured (SPL) at receiver locations in the three band rooms are illustrated in Figure 6-14. As expected, the receiver locations that are in front of the source have higher sound pressure levels than other receiver locations. The receiver locations near source versus the receiver location far from source have 8 to 25 dB variances of SPL across the frequency bands. In Band Room C, the receiver locations in front of the source have SPL higher than 110 dB. Band Rooms A and B have SPL below 110 dB. The difference of SPL for the three band rooms is due to the room volume and the placement of absorbent material on the room surfaces. From an audiological perspective, humans perceive sound as twice loud when there is a 10 dB difference between two sound levels. Therefore, the 10 dB difference for near and far receiver locations will affect the musicians' ability to listen for dynamics during the rehearsal. In addition, the high sound pressure level in Band Room C might damage the hearing of the conductor and music students. The proper room volume as well as the placement of absorption material on surfaces could be used to reduce the high sound pressure level as well as the chance of hearing damage.

Figures 6-15, 6-16 and 6-17 show the Interaural Cross Correlation (IACC) values of three band rooms. IACC measures the source level differences at left and right ears. It has been relate to the spaciousness of the source (IACC_A) and describes the dissimilarity of the signal as it arrives at each ear, either for early reflections (0 to 80 ms – IACC_E) or for the reverberant sound (80 to a time greater of the reverberant time of the enclosure-IACC_L).

Response patterns of IACC_A and IACC_E are alike. The receiver locations that are in front of the source have narrow source width but even spaciousness across the octave bands whereas the far receiver locations have a wider sound source and uneven spaciousness if the listener is focused on certain frequency bands. In Figure 6-17, it shows similar IACC_L responses among three band rooms and all receiver locations. According to ISO-3382 (1997), IACC_L is used to evaluate the “state of diffusion of the reverberant sound field” or “Envelopment”. By definition of envelopment (Beranek, 2004, p. 30), this means that the listener perceives the reverberant sound arriving from all directions. Thus, it is plausible to state that the listeners in these band rooms could perceive even reverberant sound fields regardless of near or far condition.

Figure 6-18 shows the Speech Transmission Index (STI) and Rapid Speech Transmission Index (RASTI) responses for the three band rooms. Both STI and RASTI are based on weighted sums of the modulation transfer function values and are used to check whether the receiver inside the room has good speech intelligibility. Higher STI and RASTI value means better speech intelligibility. The results of STI and RASTI indicate the receiver locations in front of the source will perceive better speech intelligibility than the receiver locations far from the source. However, all receiver locations for the three band rooms have STI and RASTI rating above 0.6. This means all receiver locations should have good speech intelligibility in these rooms.

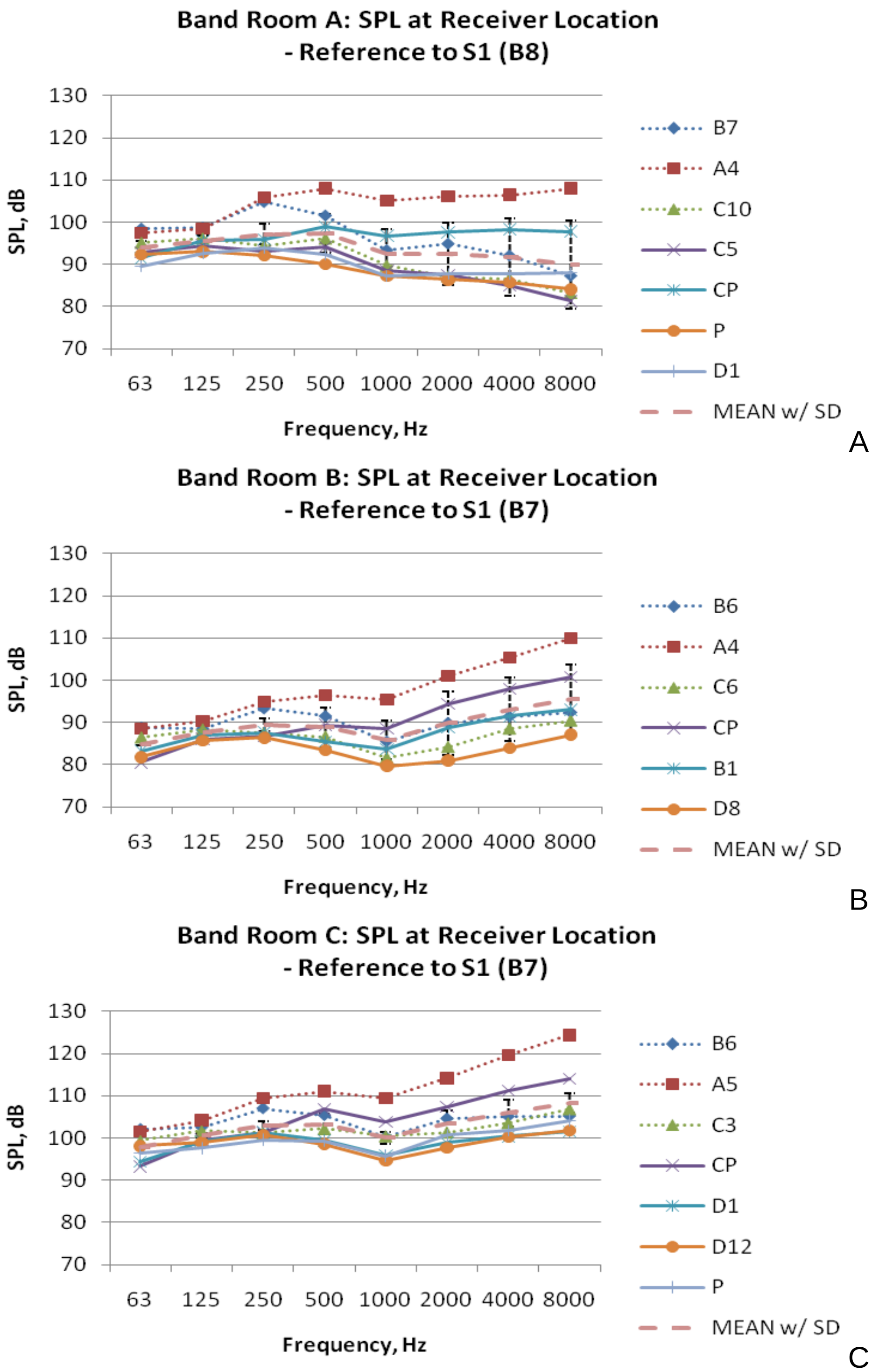


Figure 6-14. Sound Pressure Level (SPL) plotted in octave band center frequencies (Hz) in A) Band Room A, B) Band Room B, and C) Band Room C.

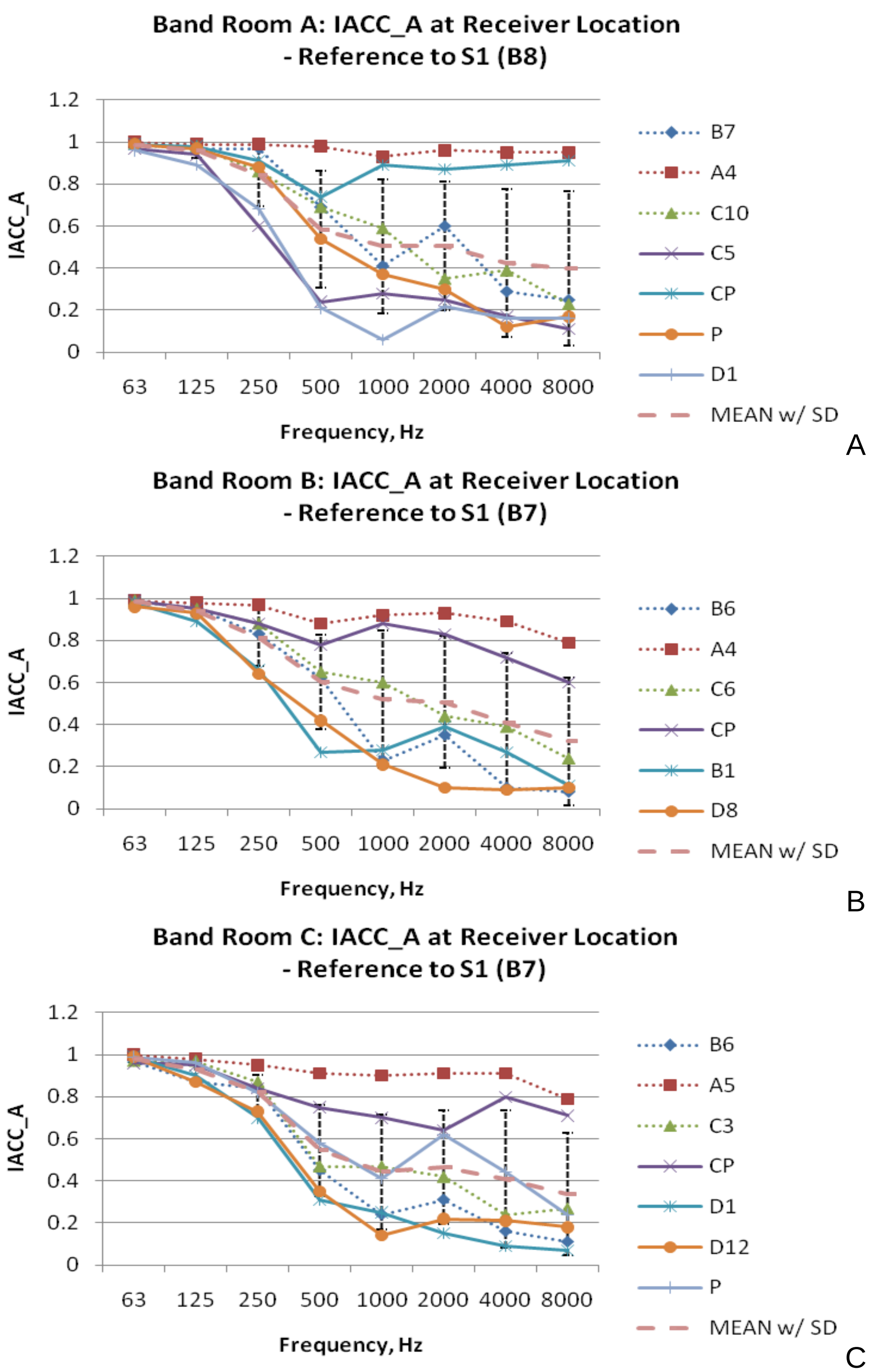
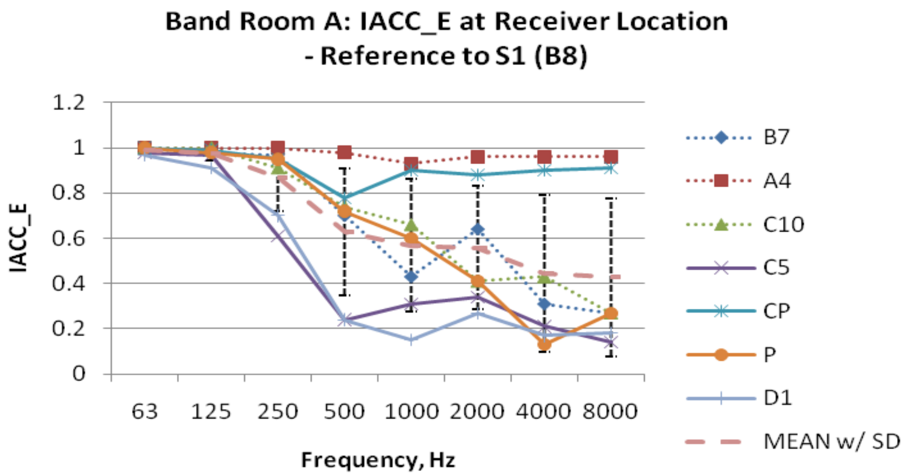
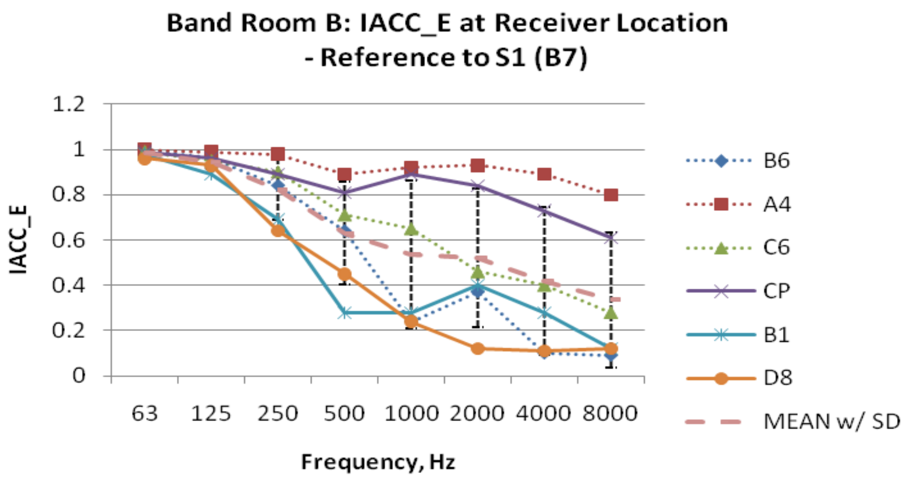


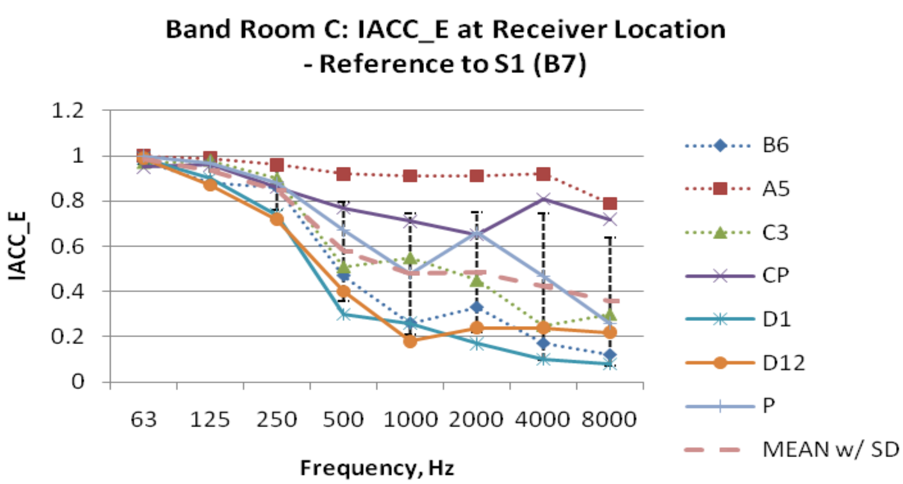
Figure 6-15. Interaural Cross Correlation (IACC_A) plotted in octave band center frequencies (Hz) in A) Band Room A, B) Band Room B, and C) Band Room C.



A



B



C

Figure 6-16. Interaural Cross Correlation (IACC_E) plotted in octave band center frequencies (Hz) in A) Band Room A, B) Band Room B, and C) Band Room C.

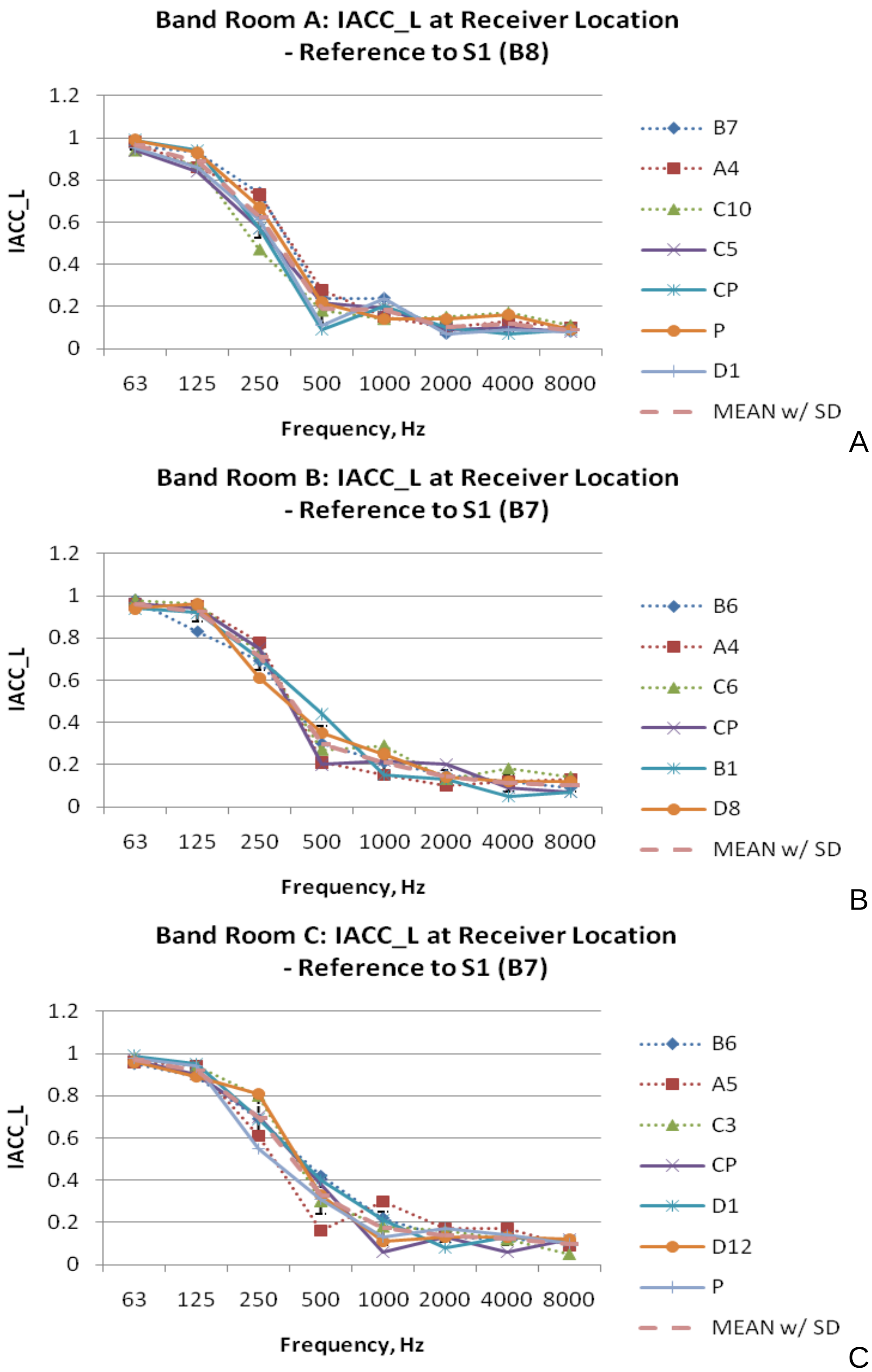


Figure 6-17. Interaural Cross Correlation (IACC_L) plotted in octave band center frequencies (Hz) in A) Band Room A, B) Band Room B, and C) Band Room C.

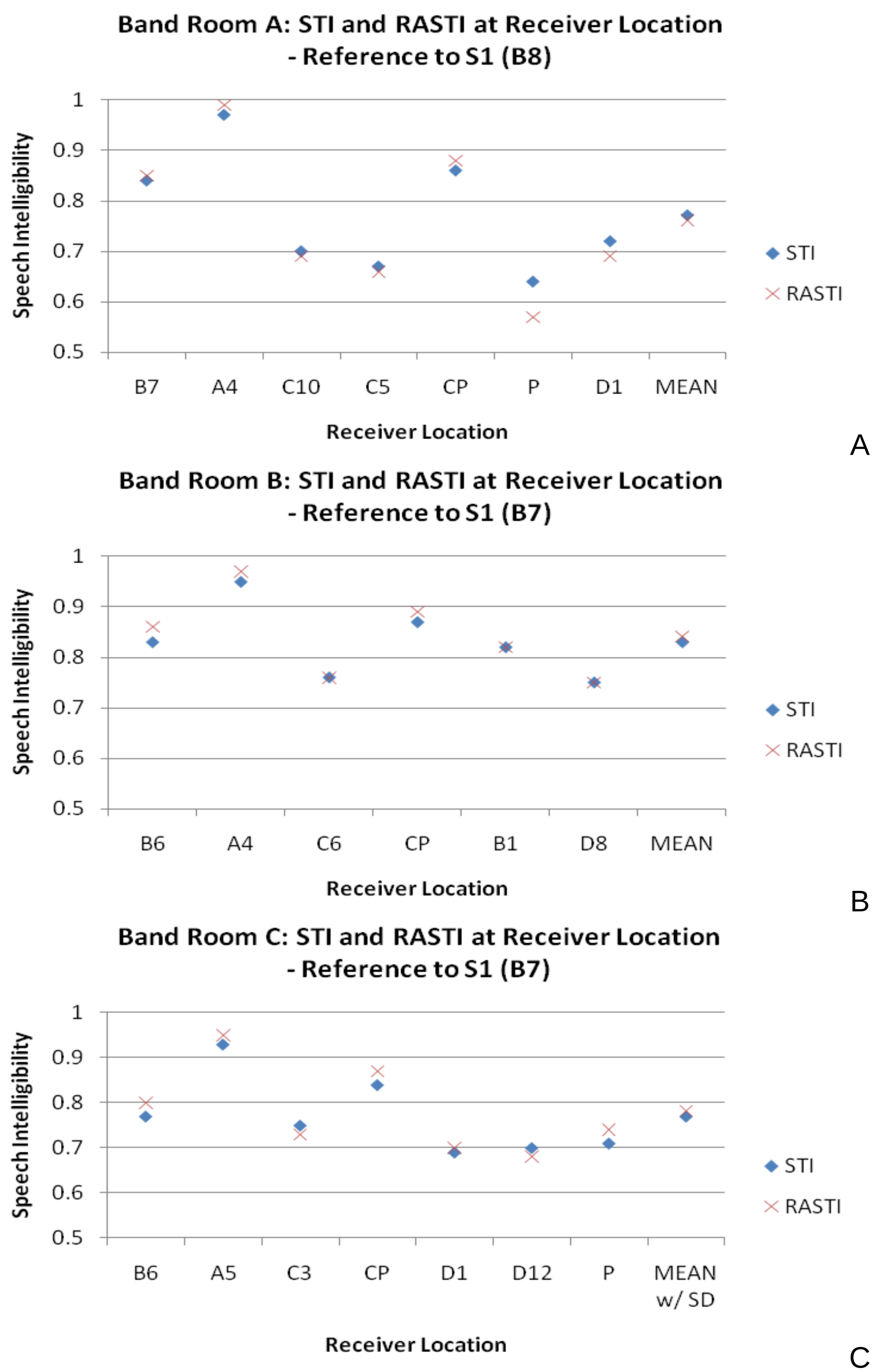


Figure 6-18. Speech and Rapid Speech Transmission Index (STI and RASTI) values of A) Band Room A, B) Band Room B, and C) Band Room C.

Summary

The near and far receiver locations show significant differences of EDT, TC, D50, C80, ST1, IACC_A, IACC_E and STI. On the other hand, T30, T20 and IACC_L have pretty similar results amongst the three band rooms and all receiver locations. The different room acoustic responses for near and far receiver locations in the band rooms might affect how music students hear each other and how they play together as an ensemble. In addition, the measured values for parameters across different frequency bands also showed large differences. This raises the question about the appropriateness of using one single average value to represent the measured value of each acoustical parameter in each frequency band.

CHAPTER 7
CAN MUSICIANS HEAR DIFFERENT ATTRIBUTES OF MUSIC IN DIFFERENT ROOM ACOUSTICS?

Background

Based on the findings from the previous chapter, the different acoustical responses among rooms and among the receiver locations within each room have been identified with respect to same source location. The near and far receiver locations have significantly different values for most of the acoustical parameters measured. A listening experiment is conducted to find out whether the musicians can hear the different attributes of music as they claim from the interviews and questionnaires in rooms with different acoustic responses.

Method

There are 36 musicians participating in the listening experiment. Among the 36 musicians, 6 of them are conductors. The rest of the participants are members of the university wind symphony with an average of 12.5 years playing experience.

The 12 audio tracks were created based on one near and one far receiver location in the three band rooms as well as two different music types. The receiver location directly in front of the source and the receiver location farther away from and off-axis of the source were used to represent and simulate the different room acoustics in the test audio tracks. Woodwind duet (Clarinet and Bassoon) and brass duet (Trumpet and Trombone) are used to represent the simple ensemble playing condition.

The audio tracks were created by using the Mirror Acoustics function from Sony Sound Forge Audio Editing Software. The Mirror Acoustics function allowed adjustment of the cut-off time from the measured impulse responses to create a closer simulation of live conditions in these rooms. Impulse responses of the chosen near and far receiver locations selected for the three band rooms were convolved with the anechoically recorded woodwind and brass duet music tracks[26].

In order to minimize the playback distortions (Zwicker, 2007, p. 8), a Rane HC-6S Six-Channel Headphone Amplifier and six Sony MDR-V600 Studio Monitor Stereo Headphones were used during the listening experiment instead of using loudspeakers as playback devices. The calibration of the headphones outputs were performed by using a B&K 4100 High Quality Head and Torso Simulator (Dummy Head), Smaart Live Software, Windows Media Player and a Norsonic Piston Calibrator. In order to set the same output level for the six headphones, calibration was performed using binaural microphones on a dummy head. For the dummy head calibration, the outputs of binaural microphone from the dummy head were connected to a laptop computer with Smaart Live Software pre-installed. Then, the Norsonic Piston Phone Calibrator input 104 dB into each microphone separately. The level of the signal picked up by each microphone was measured by the Smaart Live Software. A second laptop computer with Windows Media Player pre-installed was used to playback the test signal through the headphones. The output levels at the headphones were measured by Smaart Live Software through the dummy head. The approximate sound levels of a normal conservation level at 1 foot (Harris, 1998, p. 16.10) was used as a comfortable listening level. The comfortable listening level of 70 dBA was set on all six headphones by adjusting the volume from the Rane Headphone Amplifier.

A questionnaire with a 7-point semantic rating scale was used for this listening experiment due to the need for a detailed evaluation of attributes of music. Since the

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objective of the experiment is to learn whether the musicians can hear the different attributes of music, questions about intonation, rhythm, dynamics, articulation and tone quality were asked for each audio track. A question asking listeners to evaluate their overall impression on the ease of playing together as an ensemble was added to the questionnaire which can also be viewed as an evaluation of the overall response of the effect of room acoustics on the ability of musicians to hear each other. Figure 7-1 shows the sample of the question used in the listening experiment.

7. Can you hear the following **Audio Track #1** **clearly** of:

Playing **"in tune"**? (Intonation)	1 Not clearly	2	3	4	5	6	7 Very clearly	0 cannot tell
Playing "**in time**"? (Rhythm)	1 Not clearly	2	3	4	5	6	7 Very clearly	0 cannot tell
Playing "**at different dynamic levels**"?	1 Not clearly	2	3	4	5	6	7 Very clearly	0 cannot tell
Playing "**with different styles of articulation**"?	1 Not clearly	2	3	4	5	6	7 Very clearly	0 cannot tell
Playing **"tone quality"**?	1 Not clearly	2	3	4	5	6	7 Very clearly	0 cannot tell
Overall impression? (About ease of playing together as ensemble)	1 Not good	2	3	4	5	6	7 Very good	0 cannot tell

Figure 7-1. Sample of question for listening experiment.

The orders of audio tracks were randomized to prevent bias. At the beginning of evaluation, participants were given instructions not to judge the playing skill of the musicians on the recorded music but to focus on whether they can hear the attributes of music.

Results of 36 participants were analyzed using SPSS statistical software. Kruskal-Wallis and Mann-Whitney Non-Parametric Tests were used to test whether or not the results of semantic scales have significant differences between groups. The Non-Parametric method was used based on a small sample size. No assumptions were made of the distribution of the tested parameters (Kuzma, 2004, pp. 254-261) for means and variances. One-way ANOVA required a larger sample size and assumptions were made that the tested parameters have a normal distribution curve for means and variances. The Kruskal-Wallis test is a one-way analysis of variance by ranks.

Results and Discussions

The semantic scale points were transformed into a ranking scale in order to see clear results on the semantic scale evaluation. Figure 7-2 shows the result of the listening evaluation based on Band Room A, B and C. This is the case where the near and far receiver locations were calculated together for each band room. It clearly shows that Band Room C had the worst acoustical condition for musicians to hear the musical attributes of music. The Kruskal-Wallis test was performed to test where there were significant differences among the semantic scale results between these band rooms. The results shown in Table 7-1 confirm that there were significant differences of scoring for the musical attributes between the three band rooms. This means musicians could hear the attributes of music definitely in different room acoustics condition.

Based on the results from previous chapter, the near the far receiver locations have very different room responses. Additional sets of data analyses were based on receiver locations. Figure 7-3 shows the listening evaluation results based on the near receiver condition for the three band rooms. It shows that the near receiver location of Band Room A had the highest mean ranking on all musical attributes and overall impression. Therefore, it is appropriate to state that Band Room A was the preferred room acoustical condition for musicians to rehearse in.

Table 7-1. Kruskal-Wallis Test on three band rooms.

	Intonation	Rhythm	Dynamics	Articulation	Tone Quality	Overall Impression
Chi-Square	33.349	24.234	14.922	26.167	19.689	26.813
df	2	2	2	2	2	2
Asymp. Sig.	.000	.000	.001	.000	.000	.000

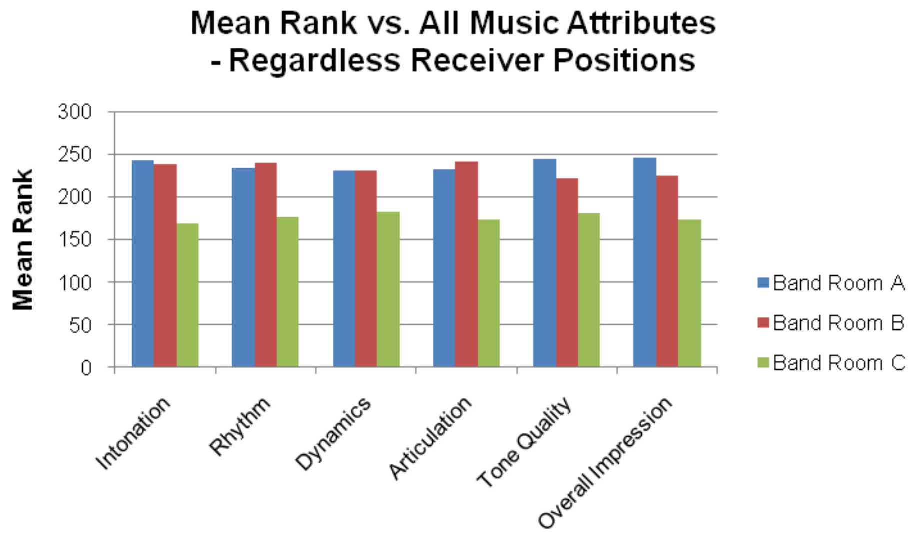


Figure 7-2. Listening evaluation results based on three band rooms.

Likewise, the results of the listening evaluation for the far receiver location of the three band rooms is shown in Figure 7-4. It clearly indicates that Band Room B had a higher mean ranking than Band Room A and C. The reason for the different results for near and far conditions could be that the far receiver location for Band Room B had stronger direct sound energy and a smoother decay slope than Band Room A. The stronger direct sound results higher sound pressure level. Our ear mechanizm general perceives twiced louder when sound pressure level increases 10 dB than the original signal. In addition, the smoother decay slope indicates that there are no strong echoes will perceive at the receiver location. Hence, the origianl signal could be perceived by the listener more clearly than with echoes. From the impulse responses of the far receiver location for Band Rooms A and B (Figure 7-5), the stronger direct sound and smooth decay slope in Band Room B can be identified. The stronger direct sound energy was indicated by shorter TC higher values of D50, C80 and ST1. These parameters are used to evaluate the clarity of speech and music. Additionally, the far receiver location of Band Room A seems to have a strong early reflection. This early reflection has a higher sound energy than the direct sound. The higher stronger reflection may have been perceived by listeners as an echo or delay and reduced the clarity of speech or music.

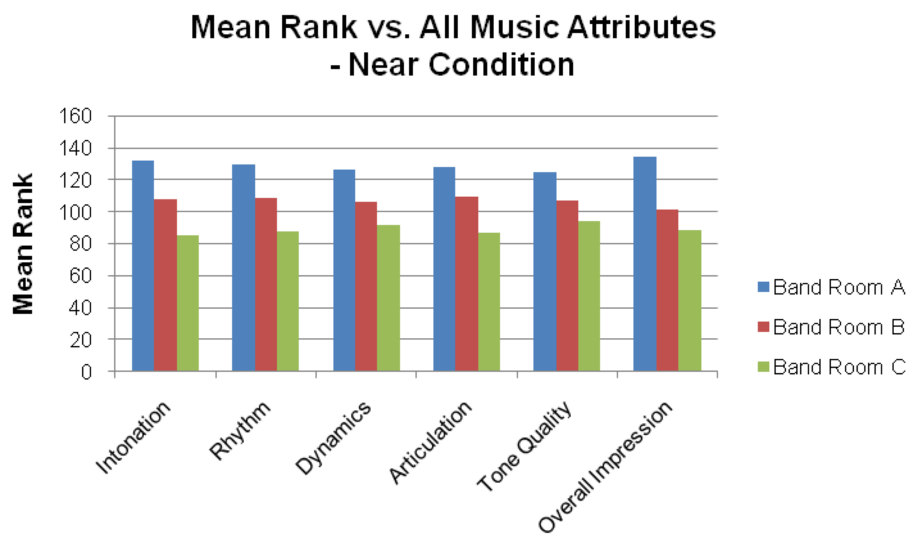


Figure 7-3. Listening evaluation results based on near receiver condition.

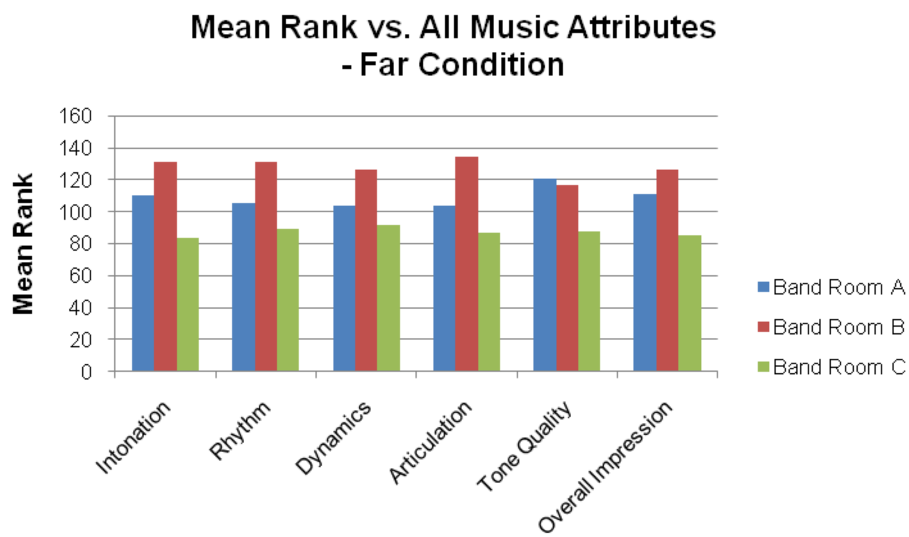


Figure 7-4. Listening evaluation results based on far receiver condition.

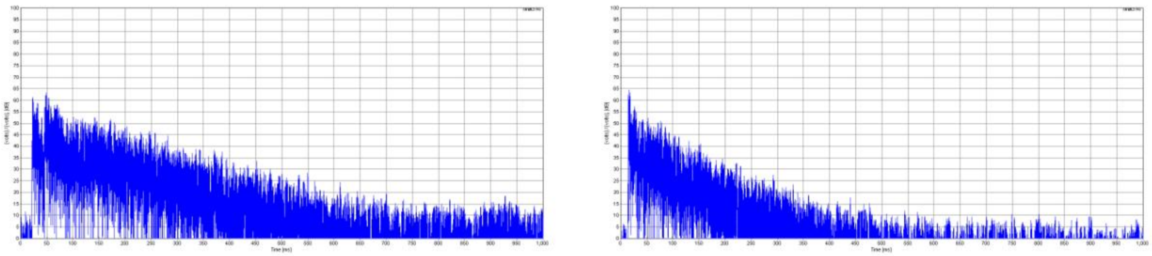


Figure 7-5. Impulse responses of far receiver location of Left) Band Room A and Right) Band Room B.

In order to study which attributes of music can be identified better in these rooms, the additional analysis was performed based on the type of music used in the audio tracks. The results of the listening evaluation of the three band rooms based on woodwind and brass duets and regardless of receiver locations are shown in Figure 7-6 and 7-7. Based on these figures, it might be appropriate to state that intonation, tone quality and overall impression can be heard better in Band Room A. On the other hand, rhythm, dynamics and articulation can be heard better in Band Room B.

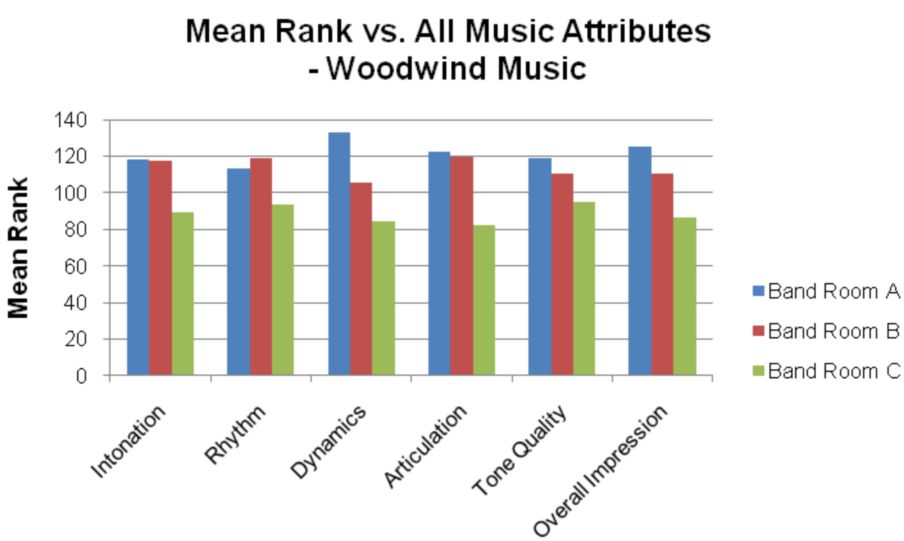


Figure 7-6. Listening evaluation results based on Woodwind music.

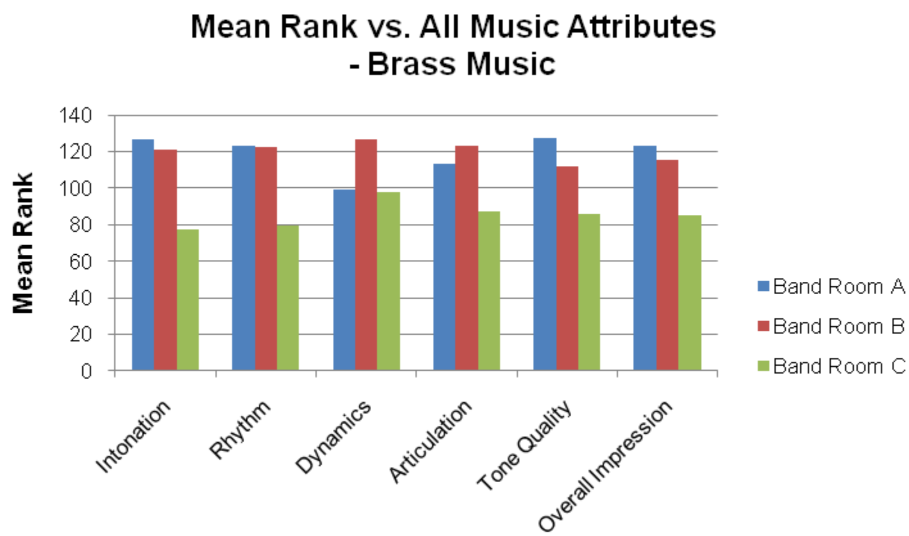


Figure 7-7. Listening evaluation results based on Brass music.

Summary

Musicians can hear different attributes of music in different rooms. With semantic scale evaluation, musician could hear the attributes of music better with Band Room A acoustical conditions (regardless of the receiver locations). Band Room B had better acoustical conditions to hear the attributes of music in the far condition due to the strong direct sound and smooth decay slope. Band Room A was rated higher in hearing attributes of music for the near condition. Overall, Band Room C was rated the lowest for in all conditions. Additionally, based on the analysis of woodwind and brass music, Band Room A was ranked better for hearing intonation, tone quality and overall impression whereas Band Room B was ranked better for hearing rhythm, dynamics and articulation. The semantic results indicated that musicians not only could hear the different attributes of music in different room acoustic condition but also know which room supports their playing.

CHAPTER 8
CORRELATIONS AMONG ACOUSTICAL PARAMETERS AND STUDENT QUESTIONNAIRES IN THREE BAND ROOMS

Background

The purpose calculating the correlations among the musical attributes and acoustical parameters is to understand which acoustical parameters have major effects on hearing each other and the attributes of music in the three band rooms. In order to study which attributes of music and acoustical parameters have the significant correlations with each other, a questionnaire was administrated to the music students who use these three band rooms regularly.

Method

Student Questionnaire

Questionnaires were given to music students who rehearse in these three band rooms to determine how well they hear each other and the attributes of music from the instruments surrounding them or across the room in the ensemble (near and far receiver locations).

The questions in the questionnaire were based on the observations made during rehearsals that a player might or might not be playing all of the time. The impulse response graphs indicated that the acoustical response of the room depends on the receiver locations. There are significant differences in measured acoustical parameters at the near and far receiver locations in each room. This survey was produced and used as shown in Figure 8-1. The use of yes-no, forced-choice response was based on modifications of yes-no procedure described in the psychoacoustics literature[27].

[27] Please refer to Zwicker (2007), p. 9.

*Please answer **"yes"** or **"no"** for the following questions.*

6. While you are playing, can you hear the **surrounding instruments clearly** in terms of playing:
   "**in tune**"? ______ "**in time**"? _______ different "**dynamics**"? ______ different "**articulation**" ?_________

7. While you are playing, can you hear **other instruments** that are across the ensemble and on opposite sides of you (instruments that are far away from where you sit) clearly in terms of playing:
   "**in tune"**? ______ "**in time"**? _______ different "**dynamics"**? ______ different "**articulation**" ?_________

8. While you are **<u>not</u>** playing, can you hear the **surrounding instruments clearly** in terms of playing:
   "**in tune**"? ______ "**in time**"? _______ different "**dynamics**"? ______ different "**articulation**" ?_________

9. While you are **<u>not</u>** playing, can you hear **other instruments** that are across the ensemble and on opposite sides of you (instruments that are far away from where you sit) clearly in terms of playing:
   "**in tune**"? ______ "**in time**"? _______ different "**dynamics**"? ______ different "**articulation**" ?_________

Figure 8-1. Sample of questions for music students' subjective impressions during rehearsal.

Typically, during psychoacoustic experiments, in order to get responses from subjects, subjects are forced to answer yes or no if they could hear that stimuli or not. Instead of using test signals, music students were forced to choose whether they could hear each other and whether they could hear the details of intonation, rhythm, dynamics and articulation played by other musicians in the ensemble during rehearsals. The yes and no responses were transformed into ones and zeroes for each question for the three band rooms for statistical analysis. Tone quality was not included in student questionnaire because only 14% of the 206 student musicians responded that they were listening for this musical quality. However, the correlation for tone quality based on listening evaluation results is included in Appendix C.

Additional Uses of Parameters

Beside the most frequently used acoustical parameters in the acoustical consulting field (EDT, T30, C80, D50, IACC) as stated in most of the architectural text books and the ISO-3382, there were some additional parameters used in this study. The additional parameters were based on the distinct architectural elements of the three band rooms.

The architectural parameters included the room volume, ceiling height, floor area, total surface area, ratio of ceiling height to room volume, distance from the ears of the listener to the ceiling, surface diffusivity index (SDI), mean free path (MFD), average absorption coefficient (α-bar) and room constant (RC) for frequency bands from 63 to 8000 Hz, low frequency bands (63 to 250 Hz), mid frequency bands (500 to 1000 Hz) and high frequency bands (2000 to 8000 Hz). Room volume, floor area, total surface area, and the ratio of ceiling height to room volume were calculated based on measured room dimensions. The distance from the ear of the listener to the ceiling was based on ear height at 1 meter above the floor assuming that a player is seated in a chair during the rehearsal. For Band Room A, the ceiling height was measured to a point where the reflecting panels hung below the actual ceiling. The room constant and average absorption coefficient of the surface materials were calculated from the measured room reverberation time and room dimensions. The Mean Free Path according to Long (2006, p. 299) was calculated based on using the room volume divided by the total surface area of the room. Surface diffusivity or sound diffusivity index (SDI) was calculated based on a modification of the method proposed by Haan and Fricke's study (1993). The original method proposed by Haan and Fricke to determine the "degree of diffusivity" for each surface was based on the details and placement of diffusive materials. However, in the band rehearsal rooms, due to the irregular room shapes which affected the seating layout and the ratio of music stands and chairs covering the floor area, the calculated SDI also accounted for the ratio of the area of the diffusing elements to the total area of each surface. In addition, the signal to noise ratio (SNR) and effective decay range (EDR) were used in the study. The signal to noise ratio is the sound pressure level difference of the source signal to the background noise level perceived by the listener. The effective decay range describes the range of the decay curve[28].

Statistical Analysis Methods

Factor Analysis, Pearson Correlation Coefficient, Multiple Linear Regression, One-Way ANOVA and Non-Parametric statistical analysis were conducted. The Principal Component Method of Factor Analysis was used to derive the principal components that could explain the variances of the data. The Pearson Correlation Coefficient was used to identify which parameters had significant effects on each musical attribute without experiencing the effects from other parameters. Multiple Linear Regressions were used to identify which acoustical parameters could have significant effects on hearing each other and the ability of student musicians and conductors to hear the details of intonation, rhythm, dynamics and articulation of the other musicians' playing. One-way ANOVA was used to obtain the mean plots of each music attribute and the corresponding parameters to show the relationship of the questionnaire results and the measured value of the parameters. A Non-Parametric Chi-Square Test was used to test whether the questionnaire results showed significant differences among the three band rooms.

Due to the limited sample sizes (three band rehearsal rooms); the results of using these methods should be viewed as the basis for studying the tendency of the relationship between the subjective and objective data rather than using the results to

[28] WinMLS help manual.

design the room. A future study with adequate sample sizes should continue to support the results of using these methods.

Results and Discussions

Results of Questionnaires

Table 8-1 shows the percentages of 206 students who responded that they could hear each other in general terms in their rehearsal rooms and the percentages of students who responded that they could hear the details of intonation, rhythm, dynamics and articulation in the playing of the other musicians. Eighty five percent of students responded that they could hear each other in Band Room A; 57% in Band Room B; and 79% in Band Room C.

Table 8-1. Results of questionnaires for the three band rooms.

	Hearing each other	While playing	Near	Ave. Near	Far	Ave. Far
Band Room A	85%	Intonation	86%	88%	67%	68%
		Rhythm	97%		81%	
		Dynamics	87%		73%	
		Articulation	82%		50%	
Band Room B	57%	Intonation	61%	63%	29%	33%
		Rhythm	82%		51%	
		Dynamics	59%		33%	
		Articulation	51%		20%	
Band Room C	79%	Intonation	88%	84%	63%	61%
		Rhythm	97%		78%	
		Dynamics	84%		66%	
		Articulation	66%		38%	
		While not playing	Near	Ave. Near	Far	Ave. Far
Band Room A		Intonation	95%	96%	92%	89%
		Rhythm	98%		91%	
		Dynamics	96%		93%	
		Articulation	93%		78%	
Band Room B		Intonation	82%	78%	53%	53%
		Rhythm	98%		76%	
		Dynamics	76%		47%	
		Articulation	55%		37%	

Table 8-1. Continued.

	Hearing each other	While not playing	Near	Ave. Near	Far	Ave. Far
Band Room C		Intonation	88%	91%	88%	81%
		Rhythm	100%		97%	
		Dynamics	97%		75%	
		Articulation	81%		66%	

Since some percentages of the results are quite close to each other, a non-parametric chi-square test was used to test whether there were significant differences under 95% confidence levels (Agresti, 2009). The Chi-Square test results shown that there were significant differences in Table 8-2 for the scores of three band rooms; and for all of the attributes of music in each room and playing condition, except intonation in the far receiver condition while playing the music.

There are statistically significant differences among the percentages of the responses for a given musical attributes at the 95% level when the p-value shown in Table 8-2 smaller than 0.05. On the other hand, when the statistical results shows there are no significant differences at the 95% level (p ≧ 0.05) of the percentages of responses of these rooms, it means the results of the student questionnaires are the same. Likewise, when the statistical results show that there were no significant differences of the impression to hear musical attributes in these rooms, meaning that the acoustical conditions are the same.

Table 8-2. Results of Chi-Square Test on questionnaires for the three band rooms.

While playing and hearing instruments surrounding (Near Condition)						
	Yes/No Score	Intonation	Rhythm	Dynamics	Articulation	Good Speech Intelligibility
Chi-Square	71.427[a]	72.252[b]	146.971[b]	69.903[b]	37.592[b]	
df	2	1	1	1	1	
Asymp. Sig. (p)	.000	.000	.000	.000	.000	

Table 8-2. Continued.

While playing and hearing instruments across ensemble (Far Condition)						
	Yes/No Score	Intonation	Rhythm	Dynamics	Articulation	Good Speech Intelligibility
Chi-Square		3.282[b]	42.893[b]	10.272[b]	7.010[b]	
df		1	1	1	1	
Asymp. Sig. (p)		.070	.000	.001	.008	
While playing and hearing instruments surrounding (Near Condition)						
	Yes/No Score	Intonation	Rhythm	Dynamics	Articulation	Good Speech Intelligibility
Chi-Square		130.563[b]	185.488[c]	136.044[c]	81.176[c]	
df		1	1	1	1	
Asymp. Sig. (p)		.000	.000	.000	.000	
While not playing and hearing instruments surrounding (Near Condition)						
	Yes/No Score	Intonation	Rhythm	Dynamics	Articulation	Good Speech Intelligibility
Chi-Square		79.534[b]	117.195[c]	66.776[c]	20.610[c]	175.243[b]
df		1	1	1	1	1
Asymp. Sig. (p)		.000	.000	.000	.000	.000

a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 68.7.
b. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 103.0.
c. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 102.5.

A further analysis was conducted to find out if there were significant differences between Band Rooms A and B, since intonation at the far receiver location in the three band rooms data showed no significant difference. The results of Band Room A and B for this case are shown in Table 8-3. Similarly, the results of Band Rooms A and B show that there are significant differences of hearing all musical attributes except intonation at the far receiver location while playing the music.

Table 8-3. Results of Chi-Square Test on questionnaires for Band Room A and B.

While playing and hearing instruments surrounding (Near Condition)						
	Yes/No Score	Intonation	Rhythm	Dynamics	Articulation	Good Speech Intelligibility
Chi-Square	33.195[a]	55.195[a]	119.172[a]	55.195[a]	34.966[a]	
df	1	1	1	1	1	
Asymp. Sig. (p)	.000	.000	.000	.000	.000	

Table 8-3. Continued.

While playing and hearing instruments across ensemble (Far Condition)						
	Yes/No Score	Intonation	Rhythm	Dynamics	Articulation	Good Speech Intelligibility
Chi-Square		1.862[a]	33.195[a]	7.448[a]	5.172[a]	
df		1	1	1	1	
Asymp. Sig. (p)		.172	.000	.006	.023	
While playing and hearing instruments surrounding (Near Condition)						
	Yes/No Score	Intonation	Rhythm	Dynamics	Articulation	Good Speech Intelligibility
Chi-Square		112.644[a]	153.578[b]	108.491[b]	68.676[b]	
df		1	1	1	1	
Asymp. Sig. (p)		.000	.000	.000	.000	
While not playing and hearing instruments surrounding (Near Condition)						
	Yes/No Score	Intonation	Rhythm	Dynamics	Articulation	Good Speech Intelligibility
Chi-Square		62.161[a]	90.318[b]	58.965[b]	17.486[b]	143.471[a]
df		1	1	1	1	1
Asymp. Sig. (p)		.000	.000	.000	.000	.000

a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 87.0.
b. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 86.5.

Table 8-4, shows the results of the analysis on Band Room B and C. There were no significant differences between the percentage of responses in these rooms except intonation, rhythm and dynamics at the far receiver condition while playing. Rhythm and articulation for the far receiver condition while not playing and hearing instruments surrounding also show significant differences. This means that both rooms have the similar acoustical conditions for music students to listen for rhythm and dynamics.

Table 8-4. Results of Chi-Square Test on questionnaires for Band Room B and C.

While playing and hearing instruments surrounding (Near Condition)						
	Yes/No Score	Intonation	Rhythm	Dynamics	Articulation	Good Speech Intelligibility
Chi-Square	3.568[a]	15.123[a]	45.938[a]	11.864[a]	1.494[a]	
df	1	1	1	1	1	
Asymp. Sig. (p)	.059	.000	.000	.001	.222	

Table 8-4. Continued.

While playing and hearing instruments across ensemble (Far Condition)						
	Yes/No Score	Intonation	Rhythm	Dynamics	Articulation	Good Speech Intelligibility
Chi-Square		2.086[a]	4.457[a]	.605[a]	16.901[a]	
df		1	1	1	1	
Asymp. Sig. (p)		.149	.035	.437	.000	
While playing and hearing instruments surrounding (Near Condition)						
	Yes/No Score	Intonation	Rhythm	Dynamics	Articulation	Good Speech Intelligibility
Chi-Square		37.346[a]	39.200[b]	8.450[b]	9.000[a]	
df		1	1	1	1	
Asymp. Sig. (p)		.000	.000	.004	.003	
While not playing and hearing instruments surrounding (Near Condition)						
	Yes/No Score	Intonation	Rhythm	Dynamics	Articulation	Good Speech Intelligibility
Chi-Square		39.200[b]	2.450[b]	.050[b]	77.049[a]	39.200[b]
df		1	1	1	1	1
Asymp. Sig. (p)		.000	.118	.823	.000	.000

a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 40.5.
b. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 40.0.

Table 8-5, shows the results of the analysis for Band Rooms A and C. There were significant differences among the percentages of responses for all of the attributes of music except articulation at the far receiver location.

Table 8-5. Results of Chi-Square Test on questionnaires for Band Room A and C.

While playing and hearing instruments surrounding (Near Condition)						
	Yes/No Score	Intonation	Rhythm	Dynamics	Articulation	Good Speech Intelligibility
Chi-Square	55.089[a]	78.478[a]	130.248[a]	78.478[a]	48.210[a]	
df	1	1	1	1	1	
Asymp. Sig. (p)	.000	.000	.000	.000	.000	
While playing and hearing instruments across ensemble (Far Condition)						
	Yes/No Score	Intonation	Rhythm	Dynamics	Articulation	Good Speech Intelligibility
Chi-Square		14.070[a]	55.089[a]	25.280[a]	.516[a]	
df		1	1	1	1	
Asymp. Sig. (p)		.000	.000	.000	.473	

Table 8-5. Continued.

While playing and hearing instruments surrounding (Near Condition)						
	Yes/No Score	Intonation	Rhythm	Dynamics	Articulation	Good Speech Intelligibility
Chi-Square		112.669[a]	137.637[a]	126.631[a]	96.363[a]	
df		1	1	1	1	
Asymp. Sig. (p)		.000	.000	.000	.000	
While not playing and hearing instruments surrounding (Near Condition)						
	Yes/No Score	Intonation	Rhythm	Dynamics	Articulation	Good Speech Intelligibility
Chi-Square		99.522[a]	105.994[a]	90.197[a]	37.764[a]	130.248[a]
df		1	1	1	1	1
Asymp. Sig. (p)		.000	.000	.000	.000	.000

a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 78.5.

Results of Factor Analyses

Factor Analysis was used to select the most promising of the 191 parameters used in the study to explain the variance among the data. Five components were identified and shown in Table 8-6 from the Principal Components Analysis from the Factor Analysis. Five components explained 100% variance in the data.

Table 8-6. Principal Component Analysis of three band rooms' data.

Total Variance Explained			
	Initial Eigenvalues		
Component	Total	% of Variance	Cumulative %
1	86.804	45.447	45.447
2	62.572	32.760	78.208
3	31.644	16.567	94.775
4	6.182	3.237	98.012
5	3.797	1.988	100.000

Extraction Method: Principal Component Analysis.

Table 8-7 shows the extrapolated Component Matrix based on the results of the Principal Component Analysis. Component 1 refers to the early reflected sound energy, acoustical parameters D50, C80, TC, ST1 and EDT have the highest loadings and least amount of correlation with other components. Most of these acoustical parameters were based on ratio of the early sound energy to total/late sound energy. Component 2 refers to architectural features of the room. The parameters with the highest loadings and the least amount of correlation with the other components are based on the architectural elements and reverberation time. Parameters having the highest loadings and least amount of correlation with other components are based on sound pressure level below 1 KHz for Component 3. For Components 4 and 5, the parameters with the highest loads (0.71 and 0.85) are the Room Constant in High Frequency Bands (2000 to 8000 Hz) and the average sound absorption coefficient (Alpha-bar) in the 63 Hz octave band.

In general, researchers are allowed to choose the parameter that has the highest loadings from each component and use these parameters to predict the linear relationship among the parameters by using a Multiple Linear Regression procedure. However, as shown in Table 8-7, the loadings between the parameters in each component are very high and have very small differences. Therefore, it is not plausible to use the parameter that has the highest loadings to represent the entire component. Yet, the Principal Component Analysis clearly points out that five components could be used to explain data in the three band rooms.

Table 8-7. Results of Component Matrix for three band room's data.

Component Matrix[a]					
Parameter	Component				
	1	2	3	4	5
D50_125	.992	.105			
D50_LOW	.991				
C80_500	.989				
TC_500	-.987		.119		
D50_500	.986				-.122
ST1_2K	-.986	-.113			
ST1_4K	-.985	-.135			

Table 8-7. Continued.

Component Matrix[a]					
Parameter	Component				
EDT_250	-.984			.127	
Floor_Area		.993			
ClgHt_RV		-.993			
T20_1K		.992			-.108
T30_63		.991			
T20_63	.141	.990			
T30_1K		.989			-.114
RC_63	.120	.987			
T30_MID	-.127	.986			
SPL_125			-.991		
SPL_LOW			-.988		
SPL_250	.149		-.987		
SPL_MID	.161		-.983		
SPL_500	.170		-.983		
SPL_1K	.124	-.104	-.980	.100	
SPL_63	.199	.105	-.964	.144	
SPL	.106	-.256	-.956		
RC_HIGH	-.416	-.141	.512	.706	.217
RC_8K	-.485	-.447	.400	.615	.162
IACC_L	.509	.443	-.441	-.574	-.140
Alpha_bar_63	-.206	.163		-.445	.852
IACC_L_250	.409		-.690		.596

Extraction Method: Principal Component Analysis.

a. 5 components extracted.

Table 8-8 shows the Principal Component Analysis for the near receiver condition data in the three band rooms. One hundred percent of the variance of this data set can be attributed to two components.

Table 8-8. Principal Component Analysis of three band rooms' data for near condition.

Total Variance Explained			
	Initial Eigenvalues		
Component	Total	% of Variance	Cumulative %
1	112.140	58.712	58.712
2	78.860	41.288	100.000

Extraction Method: Principal Component Analysis.

Table 8-9 shows that component 1 based on the ceiling height and IACC. Component 2 is based on the signal to noise level and effective decay range. Therefore, the perception of relative loudness and correlation of the difference in sound energies at the left and right ears are the dominant factors for the near locations.

Table 8-9. Results of Component Matrix for three band rooms' data for near condition.

Component Matrix[a]

Parameter	Component	
	1	2
Ceiling_Height	1.000	
IACC_E	1.000	
IACC_A_250	1.000	
IACC_A_LOW	1.000	
IACC_A	1.000	
IACC_E_250	.999	
RC_2K	.999	
Alpha_bar_250	.997	
IACC_A_125	.996	
RC_4K	.996	
IACC_E_LOW	.996	
RC_125	.996	
C80_250	.995	.103
SNR_MID		1.000
EDR_500		1.000
SNR_500		1.000
EDR_250		.999
SNR_1K		.999

Extraction Method: Principal Component Analysis.
a. 2 components extracted.

Table 8-10 shows the Principal Component Analysis for the far receiver conditions in the three band rooms. One hundred percent of the variance in this data set can be attributed to two components. Table 8-11 shows that component 1 based on the reverberation time, IACC and architectural elements. Component 2 is based on sound pressure level, effective decay range and IACC. Therefore, in terms of far condition room responses, perception of reverberance and binaural hearing are the dominant factors.

Table 8-10. Principal Component Analysis of three band rooms' data for far condition.

Total Variance Explained			
	Initial Eigenvalues		
Component	Total	% of Variance	Cumulative %
1	105.274	55.117	55.117
2	85.726	44.883	100.000

Extraction Method: Principal Component Analysis.

Table 8-11. Results of Component Matrix for three band rooms' data for far condition.

Component Matrix[a]		
Parameter	Component	
	1	2
T30_MID	1.000	
T30	1.000	
IACC_L_2K	-.999	
T20_HIGH	.999	
RC_63	.998	
T20_4K	.998	
T20_1K	.998	
IACC_L_500	-.998	
T20_63	.997	
Floor_Area	.995	
ClgHt_RV	-.995	
IACC_E_125	.995	-.103
SPL_500		-1.000
SPL_250		-1.000
EDR_HIGH		1.000
IACC_L_250		-1.000
IACC_L_LOW		-1.000
D50_125		.999
SPL_MID		-.999
SNR_LOW		.998
EDR		.997
ST1_2K		-.996
SPL_1K		-.996
IACC_A_1K		.995
SNR_125		.995

Table 8-11. Continued.

Component Matrix[a]		
Parameter	Component	
	1	2
EDR_4K	.100	.995

Extraction Method: Principal Component Analysis.

a. 2 components extracted.

Results of Multiple Linear Regressions

The 191 parameters were used in a Multiple Linear Regression Analysis. A Stepwise selection method was used because this method only allows for parameters that have significant correlations to stay in the model. The model(s) were derived from the regression analysis based on the parameter(s). The derived parameter(s) is/are used to predict the best correlations with dependent variables such as hearing each other and a specific music quality like intonation, rhythm, dynamics and articulation. Note that it was not in the scope of this research to predict values by using regression models. Hence, a limited sample size was used for this study. The predicted parameter(s) are only used to determine the correlation between acoustical and architectural parameters for hearing each other and the attributes of music.

Hearing each other – overall condition

Table 8-12 shows two models that were derived from the data. Model 1 has an r^2 = 0.610 whereas model 2 has an r^2 = 0.785. The r^2 is the determination index of the linear relationship between the dependent and independent variables. The r^2 ranges from 0 to 1. A 1 means that the model has a perfect linear relationship between the variables. Therefore, model 2 was used to explain the linear relationship of acoustical/architectural parameters to hearing each other. The best predicted parameter to be heard clearly of each other was Sound Pressure Level in the 63 Hz octave band and Interaural Cross Correlation for late sound energy in the 500 Hz octave band.

Sufficient loudness level in the low frequencies is needed for musicians to hear each other could be related to human hearing ability as stated in equal loudness contour that human are less sensitive to low frequency sound. The differences timing of the sound arrives at musicians' ears allow musicians to locate the direction of the sound and hence knowing which instruments are playing. The late energy measures of IACC could be used to detect when the players sit across from the ensemble which has a longer sound path.

Figure 8-2 shows the Mean Plots of the predicted parameters versus hearing each other in the three band rooms. It clearly shows that increasing the sound pressure level in the 63 Hz octave band results in higher scores for hearing each other. According to the three band room data, for IACC_L in the 500Hz octave band, the time differences of late sound energy arrived at two ears needs to have a ratio of 0.21 and 0.29 for hearing each other clearly.

Table 8-12. Multiple Linear Regression versus hearing each other for three band room.

Model Summary

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.781a	.610	.571	.12183	.610	15.645	1	10	.003
2	.886b	.785	.737	.09539	.175	7.313	1	9	.024

a. Predictors: (Constant), SPL_63

b. Predictors: (Constant), SPL_63, IACC_L_500

Table 8-12. Continued.

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	Correlations Zero-order	Correlations Partial	Correlations Part
1	(Constant)	-1.653	.605		-2.730	.021			
	SPL_63	.026	.006	.781	3.955	.003	.781	.781	.781
2	(Constant)	-1.139	.511		-2.230	.053			
	SPL_63	.027	.005	.820	5.283	.001	.781	.870	.817
	IACC_L_500	-2.396	.886	-.420	-2.704	.024	-.343	-.670	-.418

Coefficients[a]

a. Dependent Variable: Hearing_Each_Other

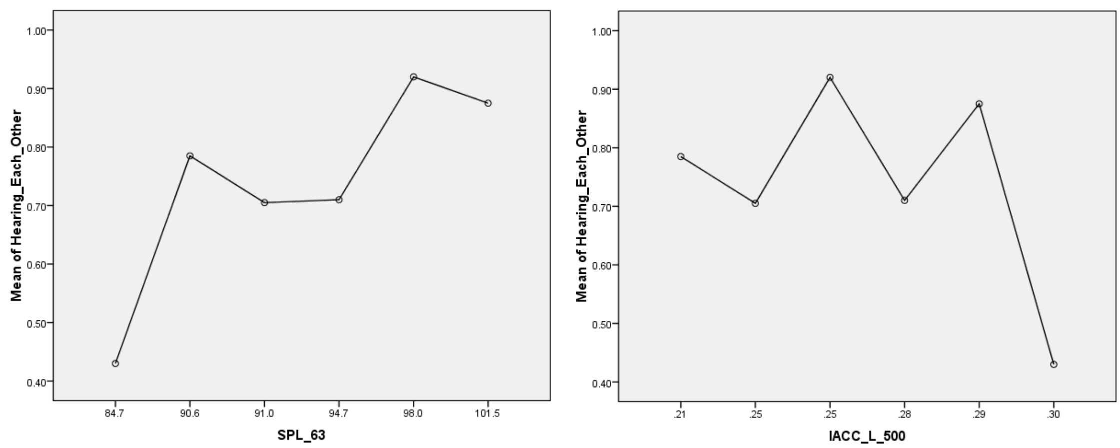


Figure 8-2. Mean Plots of predicted parameters versus scores of hearing each other in the three band rooms.

Intonation – overall condition

Table 8-13 shows two models that were derived from the data. Model 1 has an r^2 = 0.568 whereas model 2 has an r^2 = 0.727. The parameters most strongly related to intonation was Sound Pressure Level in the 63 Hz octave band and Interaural Cross Correlation for late sound energy in the 500 Hz octave band.

The perception of pitch of a pure tone depends on frequency and sound pressure level from psychoacoustic literature (Zwicker, 2007, p. 113). The example given in Zwicker's study showed that louder tones produce a lower pitch than the softer tone at frequencies of 200 Hz and below. The louder tone produces a higher pitch than the softer tone at a frequency at or above 6000 Hz. Thus, he stated that the “pitch sensation depends on frequency and level”. A sound produced by a musical instrument consists of many frequencies. The sounds produced by musical instruments are considered as complex tones. Zwicker (2007, p. 120) found that “the pitch of harmonic complex tones depends on level” and the “pitch of a complex tone is based on the spectral pitch of its lower components”. Thus, it is plausible to accept the predicted parameter (SPL_63) of the regression analysis.

There are at least two pitches that occur when playing and listening for intonation during rehearsals. One pitch comes from the listener and one from the other player. The two pitches are needed to be compared and matched. According to Zwicker (2007, p. 111), the sensation of pitches is based on a comparison of two tones/frequencies or “half pitch”. With the increasing duration, the strength of pitches is increased. Hence, dissimilarities in the timing of sounds arriving at both ears might allow the brain to compare and distinguish the pitch better.

The acoustical parameter IACC calculates the cross correlation between the sound energy arriving at the left and right ear after 80 milliseconds to 750 milliseconds after the direct sound (IACC_L). This parameter could be used to explain the procedure during a general psychoacoustic experiment. Traditionally, subjects are often being asked to listen for one stimulus, and with pause, while the second stimulus was played. The subject was asked to listen and compare the two stimuli. Therefore, if discarded, the original definition for IACC_L that was used for acoustics was the time differences of the late sound energy (frequency and sound pressure level) as it arrives at the listener’ two ears. This effect enables the listener to hear intonation better. Figure 8-3 shows the Mean Plots of the predicted parameters versus intonation in the three band rooms. The plots show that increasing the sound pressure level in the 63 Hz octave band results in higher scores for hearing intonation. The IACC_L in the 500Hz octave band, the cross correlation between the sound energy arriving at the left and right ear after 80 milliseconds to 750 milliseconds after the direct sound should fall between 0.21 and 0.29 for intonation.

Table 8-13. Multiple Linear Regression versus intonation for three band room.

Model Summary

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.754[a]	.568	.525	.13730	.568	13.152	1	10	.005
2	.853[b]	.727	.667	.11499	.159	5.257	1	9	.048

a. Predictors: (Constant), SPL_63

b. Predictors: (Constant), SPL_63, IACC_L_500

Coefficients[a]

		Unstandardized Coefficients		Standardized Coefficients			95% Confidence Interval for B		Correlations		
Model		B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound	Zero-order	Partial	Part
1	(Constant)	-1.727	.682		-2.531	.030	-3.247	-.207			
	SPL_63	.026	.007	.754	3.627	.005	.010	.043	.754	.754	.754
2	(Constant)	-1.201	.616		-1.952	.083	-2.594	.191			
	SPL_63	.028	.006	.791	4.526	.001	.014	.042	.754	.834	.788
	IACC_L_500	-2.449	1.068	-.401	-2.293	.048	-4.866	-.033	-.327	-.607	-.399

a. Dependent Variable: INTONATION

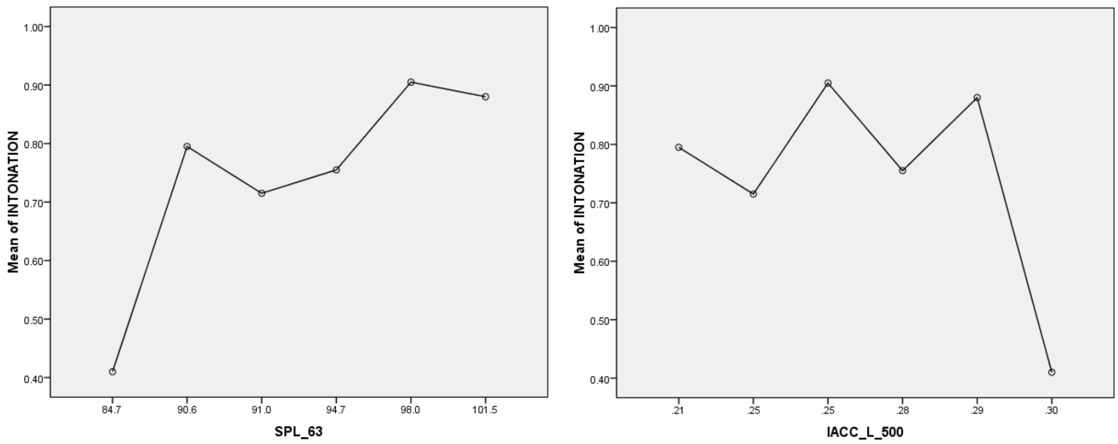


Figure 8-3. Mean Plots of predicted parameters versus scores of hearing intonation in the three band rooms.

Rhythm – overall condition

Table 8-14 shows one model that was derived from the three band room data. Model 1 has an r^2 = 0.577. The best predicted parameter for hearing rhythm is the Sound Pressure Level in the 63 Hz octave band. According to Zwicker (2007, pp. 275, 204), "rhythm is perceived by human with accordance to the loudness of notes." In addition, our hearing is less sensitive to low frequency sounds than high frequency sounds as shown in Equal Loudness Contour. Therefore, the sound pressure level in the 63 Hz octave band could be the key for musicians to hear the rhythm. Figure 8-4 shows the Mean Plot of the predicted parameters versus hearing rhythm in the three band rooms. The mean plot shown the increasing the sound pressure level in the 63 Hz octave band resulting in higher scores for hearing rhythm clearly.

Table 8-14. Multiple Linear Regression versus Rhythm for the three band rooms.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics: R Square Change	F Change	df1	df2	Sig. F Change
1	.760[a]	.577	.535	.09831	.577	13.647	1	10	.004

a. Predictors: (Constant), SPL_63

Table 8-14. Continued.

Coefficients[a]									
		Unstandardized Coefficients		Standardized Coefficients			Correlations		
Model		B	Std. Error	Beta	t	Sig.	Zero-order	Partial	Part
1	(Constant)	-.930	.489		-1.904	.086			
	SPL_63	.019	.005	.760	3.694	.004	.760	.760	.760

a. Dependent Variable: RHYTHM

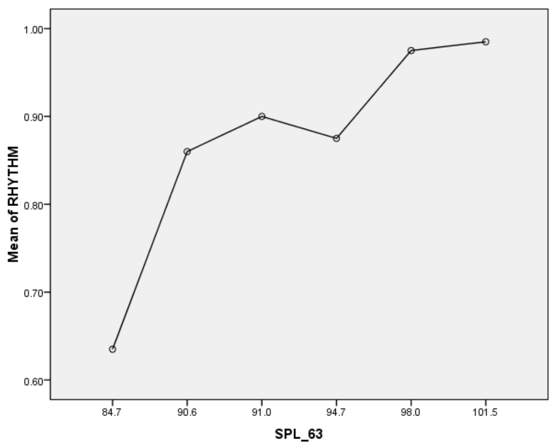
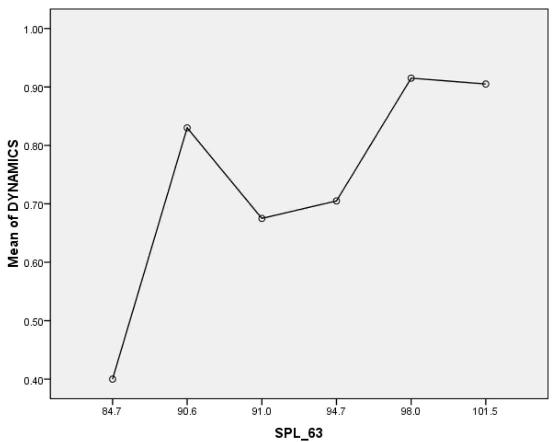


Figure 8-4. Mean Plot of predicted parameters versus scores of hearing rhythm in the three band rooms.

Dynamics – overall condition

Table 8-15 shows two models that were derived from the three band room data. Model 1 has an r^2 = 0.638 and model 2 has an r^2 = 0.848. The best predicted parameters to dynamics are the Sound Pressure Level in the 63 Hz octave band and the Interaural Cross Correlation for late sound energy in the 500 Hz octave band.

According to Zwicker (2007, p. 331), “Binaural hearing has 6 to 8 dB higher than monaural hearing for louder and softer sound.” Similarly, our hearing is less sensitive in low frequency bands as shown in Equal Loudness Contour. Therefore, the stronger sound pressure level in the 63 Hz octave band is needed for musicians to hear the dynamics clearly. Figure 8-5 shows the Mean Plots of the predicted parameter versus dynamics in the three band rooms. The plots shown that the increasing the sound pressure level in the 63 Hz octave band, results in higher scores of dynamics. The IACC_L in the 500Hz octave band, the cross correlation between the sound energy arriving at the left and right ear after 80 milliseconds to 750 milliseconds after the direct sound should fall between 0.21 and 0.29 for intonation.



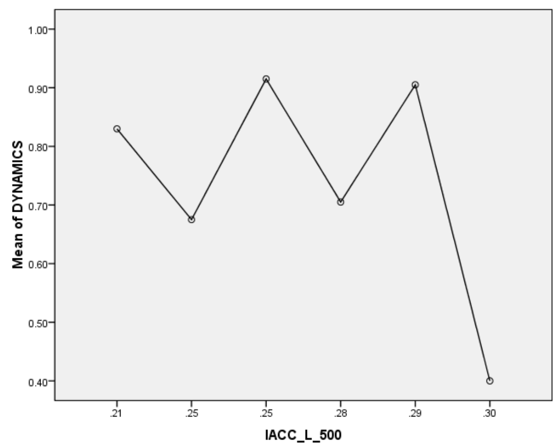


Figure 8-5. Mean Plots of predicted parameters versus scores of hearing dynamics in the three band rooms.

Table 8-15. Multiple Linear Regression versus Dynamics for the three band rooms.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics: R Square Change	F Change	df1	df2	Sig. F Change
1	.799[a]	.638	.602	.12540	.638	17.647	1	10	.002
2	.921[b]	.848	.815	.08558	.210	12.473	1	9	.006

a. Predictors: (Constant), SPL_63

b. Predictors: (Constant), SPL_63, IACC_L_500

Coefficients[a]

Model		Unstandardized Coefficients: B	Std. Error	Standardized Coefficients: Beta	t	Sig.	Correlations: Zero-order	Partial	Part
1	(Constant)	-1.875	.623		-3.009	.013			
	SPL_63	.028	.007	.799	4.201	.002	.799	.799	.799

Table 8-15. Continued.

Coefficients[a]										
		Unstandardized Coefficients		Standardized Coefficients			Correlations		
Model		B	Std. Error	Beta	t	Sig.	Zero-order	Partial	Part
2	(Constant)	-1.273	.458		-2.778	.021			
	SPL_63	.029	.005	.842	6.459	.000	.799	.907	.838
	IACC_L_500	-2.808	.795	-.460	-3.532	.006	-.382	-.762	-.458

a. Dependent Variable: DYNAMICS

Articulation – overall condition

Table 8-16 shows two models were derived from the data. Model 1 has an r^2 = 0.596 and model 2 has an r^2 = 0.784. The best predicted parameters to articulation are the Interaural Cross Correlation for early sound energy in the 8000Hz octave band and the averaged frequency bands of Signal to Noise Ratio.

By definition, articulation for music is the weight given or subtracted from the note. A common phrase heard in music is that a performer attacked the note with different weights. Therefore, articulation is distinguished by the time differences of the early sound energies at high frequency arriving at two ears. A person should hear articulation before pitch and loudness. The short time differences of early sound energies arriving at the two ears, as well as with the sufficient signal to noise level could be the key contributing to hearing articulation clearly. Figure 8-6 shows the Mean Plots of the predicted parameter versus articulation in the three band rooms. It is clear to see the trends of shorter time differences ratio for left and right ear of IACC_E in the 8000Hz octave band results in better scores of articulation. However, the overall signal to noise ratio for the six locations of the three band rooms might not be sufficient to explain the reason at this point.

Table 8-16. Multiple Linear Regression versus Articulation for the three band rooms.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics: R Square Change	F Change	df1	df2	Sig. F Change
1	.772[a]	.596	.556	.14526	.596	14.778	1	10	.003
2	.885[b]	.784	.736	.11211	.187	7.787	1	9	.021

a. Predictors: (Constant), IACC_E_8K

b. Predictors: (Constant), IACC_E_8K, SNR

Coefficients[a]

Model		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.	95% Confidence Interval for B Lower Bound	Upper Bound	Correlations Zero-order	Partial	Part
1	(Constant)	.075	.142		.531	.607	-.241	.392			
	IACC_E_8K	1.413	.368	.772	3.844	.003	.594	2.233	.772	.772	.772
2	(Constant)	1.171	.408		2.873	.018	.249	2.093			
	IACC_E_8K	1.426	.284	.779	5.026	.001	.784	2.068	.772	.859	.779
	SNR	-.036	.013	-.433	-2.791	.021	-.065	-.007	-.420	-.681	-.433

a. Dependent Variable: ARTICULATION

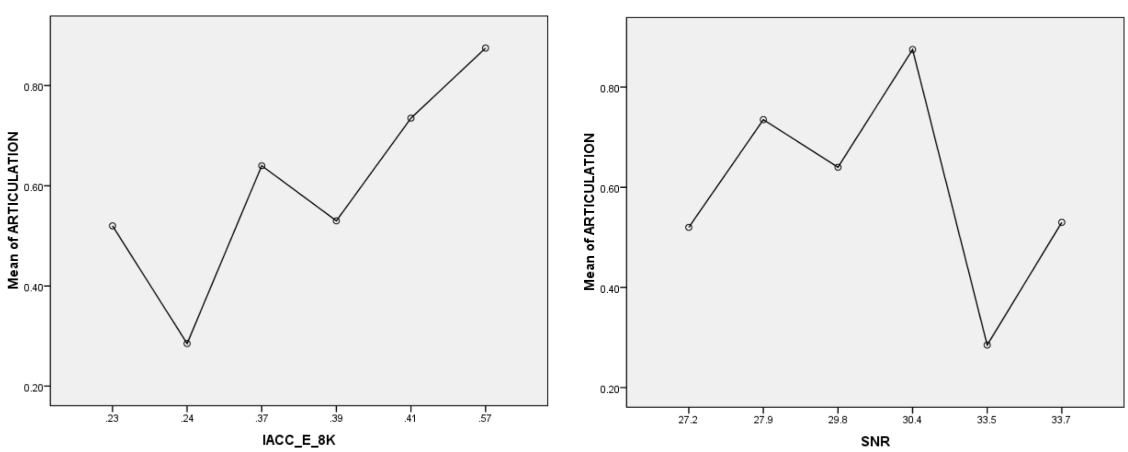


Figure 8-6. Mean Plots of predicted parameters versus scores of hearing articulation in the three band rooms.

Hearing each other – near condition

Table 8-17 shows one model was derived from the near receiver condition of the three band room data. Model 1 has an $r^2 = 0.752$. The best predicted parameter for hearing each other at near condition is the Clearness Index (C80) in the 8000 Hz octave band. Figure 8-7 shows the Mean Plot of the predicted parameter versus hearing each other at near condition in the three band rooms. It is clear to see the trend of decreasing the C80 in the 8000 Hz octave band results in better scores for hearing each other clearly.

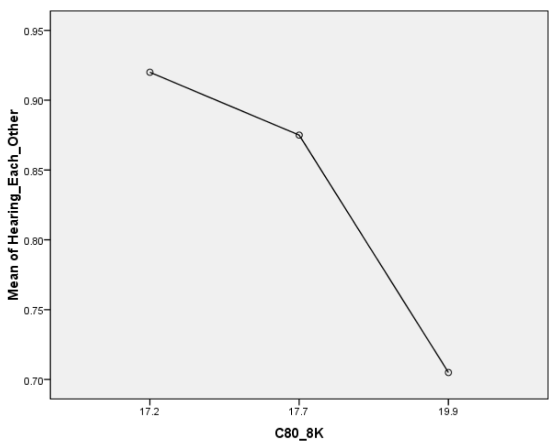


Figure 8-7. Mean Plot of predicted parameters versus scores of hearing each other at near receiver condition in the three band rooms.

Table 8-17. Multiple Linear Regression versus hearing each other at near receiver condition for three band room.

Model Summary									
					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.867[a]	.752	.691	.06502	.752	12.161	1	4	.025

a. Predictors: (Constant), C80_8K

Table 8-17. Continued.

Coefficients[a]									
		Unstandardized Coefficients		Standardized Coefficients			Correlations		
Model		B	Std. Error	Beta	t	Sig.	Zero-order	Partial	Part
1	(Constant)	2.242	.405		5.538	.005			
	C80_8K	-.077	.022	-.867	-3.487	.025	-.867	-.867	-.867

a. Dependent Variable: Hearing_Each_Other

Hearing each other – far condition

Table 8-18 shows one model was derived from the far receiver condition of the three band room data. Model 1 has an $r^2 = 0.693$. The best predicted parameter for hearing each other clearly at far condition is the Center Time (TC) in the 2000 to 8000 Hz octave bands. Figure 8-8 shows the Mean Plot of the predicted parameter versus hearing each other at far condition in the three band rooms. It is clear to see the trend of decreasing the TC in the 2000 to 8000 Hz octave bands results in better scores for hearing each other.

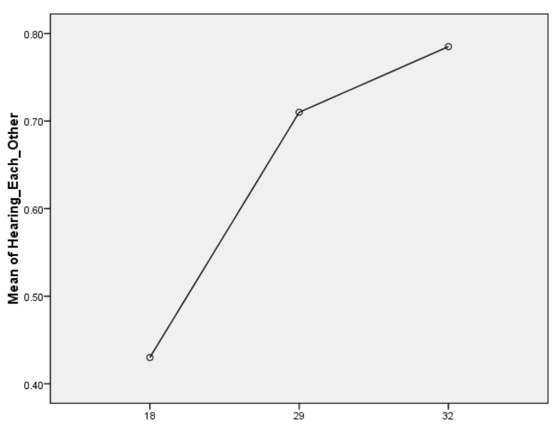


Figure 8-8. Mean Plot of predicted parameters versus scores of hearing each other at far receiver condition in the three band rooms.

Table 8-18. Multiple Linear Regression versus hearing each other at far receiver condition for three band room.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics: R Square Change	F Change	df1	df2	Sig. F Change
1	.832[a]	.693	.616	.12460	.693	9.016	1	4	.040

a. Predictors: (Constant), TC_HIGH

Coefficients[a]

Model		Unstandardized Coefficients: B	Std. Error	Standardized Coefficients: Beta	t	Sig.	Correlations: Zero-order	Partial	Part
1	(Constant)	-.033	.230		-.141	.895			
	TC_HIGH	.026	.009	.832	3.003	.040	.832	.832	.832

a. Dependent Variable: Hearing_Each_Other

Intonation – near condition

No parameters have significant correlations with intonation at the near condition in the three band rooms.

Intonation – far condition

Table 8-19 shows one model that was derived from the far receiver condition of the three band room data. Model 1 has an $r^2 = 0.622$. The best predicted parameter for clearly hearing intonation is early decay time in the 250 Hz octave band. Early decay time is the time for the first 10 dB of decay that a listener perceives in a space. To recognize a pitch, as stated previously in intonation for overall receiver locations, listeners need a bit longer time as well as sufficient strength of signal. Figure 8-9 shows the Mean Plot of the predicted parameter versus hearing intonation for the far receiver condition in the three band rooms. It is clear to see the trend that increasing the early decay time in the 250 Hz octave band had results in better scores of hearing intonation clearly.

Table 8-19. Multiple Linear Regression versus Intonation for far receiver condition in the three band rooms.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.814[a]	.662	.578	.15113	.662	7.845	1	4	.049

a. Predictors: (Constant), EDT_250

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations		
		B	Std. Error	Beta			Zero-order	Partial	Part
1	(Constant)	-.391	.378		-1.035	.359			
	EDT_250	1.506	.538	.814	2.801	.049	.814	.814	.814

a. Dependent Variable: INTONATION

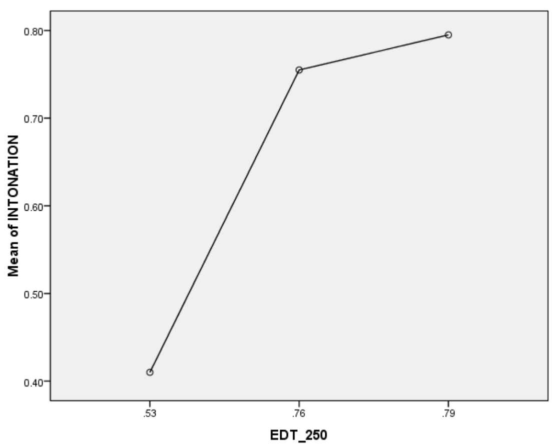


Figure 8-9. Mean Plot of predicted parameters versus scores of hearing intonation for the far receiver condition in the three band rooms.

Rhythm – near condition

No parameters have significant correlations with rhythm at the near condition in the three band rooms.

Rhythm – far condition

No parameters have significant correlations with rhythm at the far condition in the three band rooms.

Dynamics – near condition

Table 8-20 shows one model was derived from the near receiver condition of the three band rooms' data. Model 1 has an $r^2 = 0.732$. The best predicted parameter to hear dynamics clearly at the near condition is Distinctness (D50) in the 63 Hz octave band. The acoustical responses at the near receiver condition typically have strong direct and early sound energies. Therefore, the less direct and early sound energies might be desired for a listener to hear the sound played by other players.

Figure 8-10 shows the Mean Plot of the predicted parameter versus hearing dynamics for the near condition in the three band rooms. It is clear to see the trend of decreasing the D50 in the 63 Hz octave band resulting in better scores of hearing dynamics clearly.

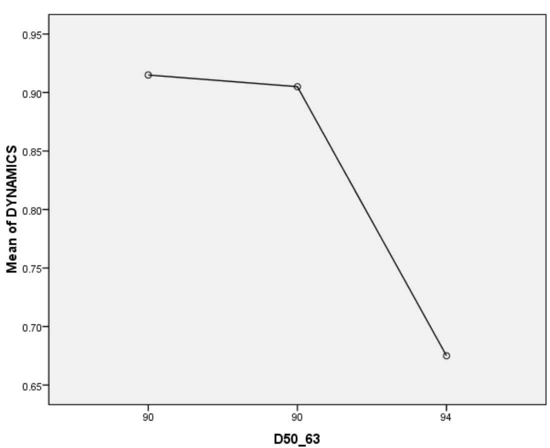


Figure 8-10. Mean Plot of predicted parameters versus scores of hearing dynamics of near receiver condition in the three band rooms.

Table 8-20. Multiple Linear Regression versus Dynamics for near receiver condition in the three band rooms.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics: R Square Change	F Change	df1	df2	Sig. F Change
1	.856[a]	.732	.665	.08209	.732	10.940	1	4	.030

a. Predictors: (Constant), D50_63

Coefficients[a]

Model		Unstandardized Coefficients: B	Std. Error	Standardized Coefficients: Beta	t	Sig.	Correlations: Zero-order	Partial	Part
1	(Constant)	6.359	1.671		3.805	.019			
	D50_63	-.060	.018	-.856	-3.308	.030	-.856	-.856	-.856

a. Dependent Variable: DYNAMICS

Dynamics – far condition

Table 8-21shows one model that was derived from the far receiver condition of the three band rooms' data. Model 1 has an r^2 = 0.852. The best predicted parameter to hear dynamics clearly for the near condition is Clearness (C80) in the average higher frequency bands of 2000-8000 Hz octave bands. The acoustical responses of the far receiver conditions typically have more even sound energies for direct, early and reverberant sounds. The balance point of the direct, early and reverberant sound energies is the key for a listener to hear the sound played by other players. A future study could be conducted to investigate this issue.

Figure 8-11 shows the Mean Plot of the predicted parameter versus hearing dynamics for the far condition in the three band rooms. It is clear to see the trend of decreasing the C80 at high frequency bands results in better scores for hearing dynamics clearly.

Table 8-21. Multiple Linear Regression versus Dynamics for far receiver condition in the three band rooms.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics: R Square Change	F Change	df1	df2	Sig. F Change
1	.923[a]	.852	.815	.09210	.852	23.063	1	4	.009

a. Predictors: (Constant), C80_HIGH

Coefficients[a]

Model		Unstandardized Coefficients: B	Std. Error	Standardized Coefficients: Beta	t	Sig.	Correlations: Zero-order	Partial	Part
1	(Constant)	1.694	.222		7.642	.002			
	C80_HIGH	-.083	.017	-.923	-4.802	.009	-.923	-.923	-.923

a. Dependent Variable: DYNAMICS

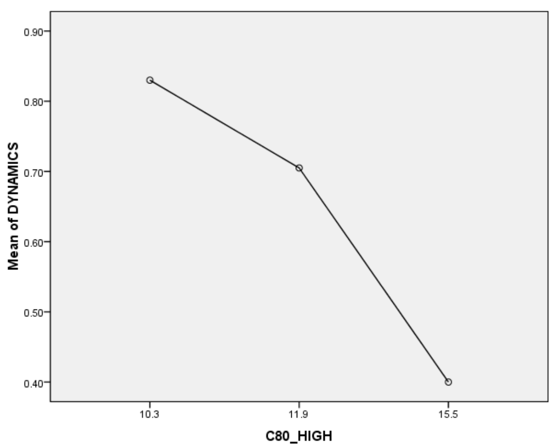


Figure 8-11. Mean Plot of predicted parameters versus scores of hearing dynamics of near receiver condition in the three band rooms.

Articulation – near condition

Table 8-22 shows one model that was derived for the near receiver condition of the three band rooms' data. Model 1 has an $r^2 = 0.869$. The best predicted parameter for clearly hearing articulation at the near receiver condition is the Distinctness (D50) in the 4000 Hz octave band. As discussed above from the dynamics at near condition, a less strong direct and early sound is the key for musicians to better hear their playing while listening to someone else. However, for articulation, the D50 at high frequency band allows listener to detect the transient of the note. Figure 8-12 shows the Mean Plot of the predicted parameter versus hearing articulation at near receiver condition in the three band rooms. It is clear to see the trend of decreasing the D50 in the 4000Hz octave band resulting in better scores for hearing articulation clearly.

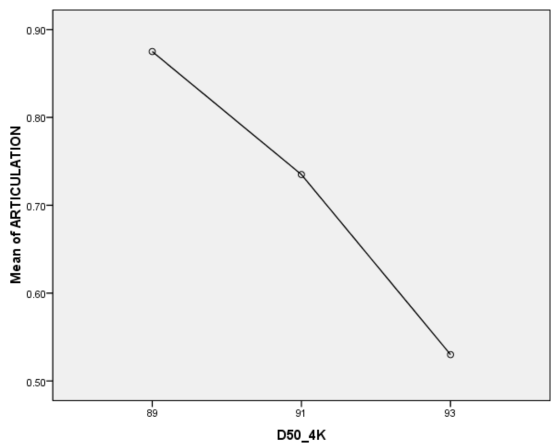


Figure 8-12. Mean Plot of predicted parameters versus scores of hearing articulation of near receiver condition in the three band rooms.

Table 8-22. Multiple Linear Regression versus Articulation for near condition in the three band rooms.

Model Summary

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.932[a]	.869	.836	.06732	.869	26.566	1	4	.007

a. Predictors: (Constant), D50_4K

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	Correlations Zero-order	Correlations Partial	Correlations Part
1	(Constant)	8.074	1.428		5.653	.005			

Table 8-22. Continued.

Coefficients[a]								
	Unstandardized Coefficients		Standardized Coefficients			Correlations		
Model	B	Std. Error	Beta	t	Sig.	Zero-order	Partial	Part
D50_4K	-.081	.016	-.932	-5.154	.007	-.932	-.932	-.932

a. Dependent Variable: ARTICULATION

Articulation – far condition

No parameters have significant correlations with articulation at the near condition in the three band rooms

Architectural Parameters versus Attributes of Music

Although the architectural parameters did not show up as the best predicted parameters of attributes of music from the three band room data, there are some clear trends that can be detected from the Mean Plots for the correlations between the two parameters. Figure 8-13, shows the Mean Plots of the larger floor area will benefit musicians to hear each other and the attributes of music better. It is clearly to see the trends of increase floor area for better scores of hearing each other and the attributes of music. Figure 8-14, shows the Mean Plots of the ratio of ceiling height to room volume will benefit musicians to hear each other and the attributes of music better. It is clearly to see the trends of less ratio of ceiling height to room volume for better scores of hearing each other and the attributes of music. Additional Multiple Linear Regression analysis and Mean Plots based on the data obtained from the listening evaluation are included in Appendix C. The amount of sound diffusing surfaces in the band room was identified as another important factor for better scores of hearing each other and the attributes of music.

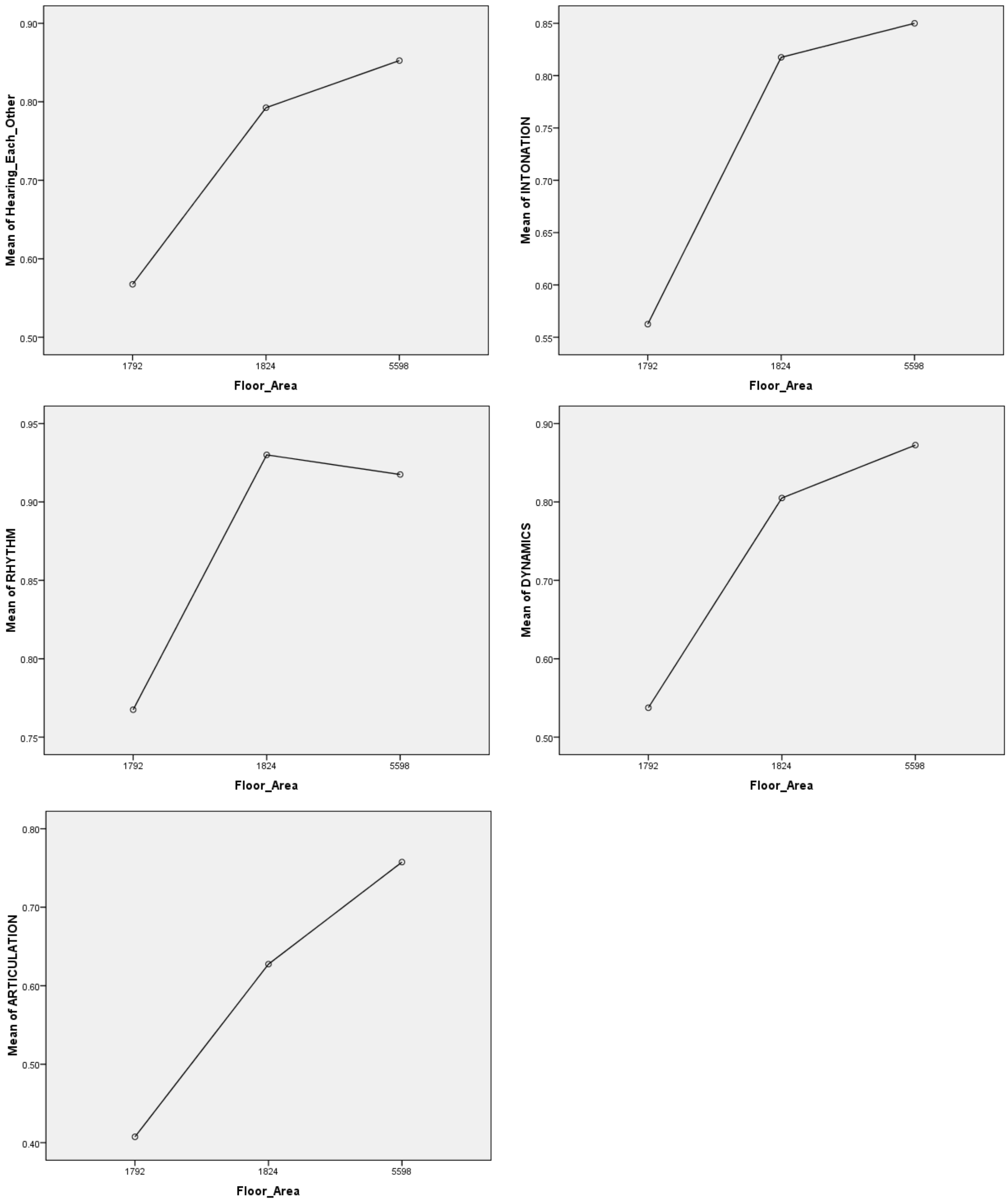


Figure 8-13. Mean Plots of floor area versus scores of hearing each other and attributes of music in the three band rooms.

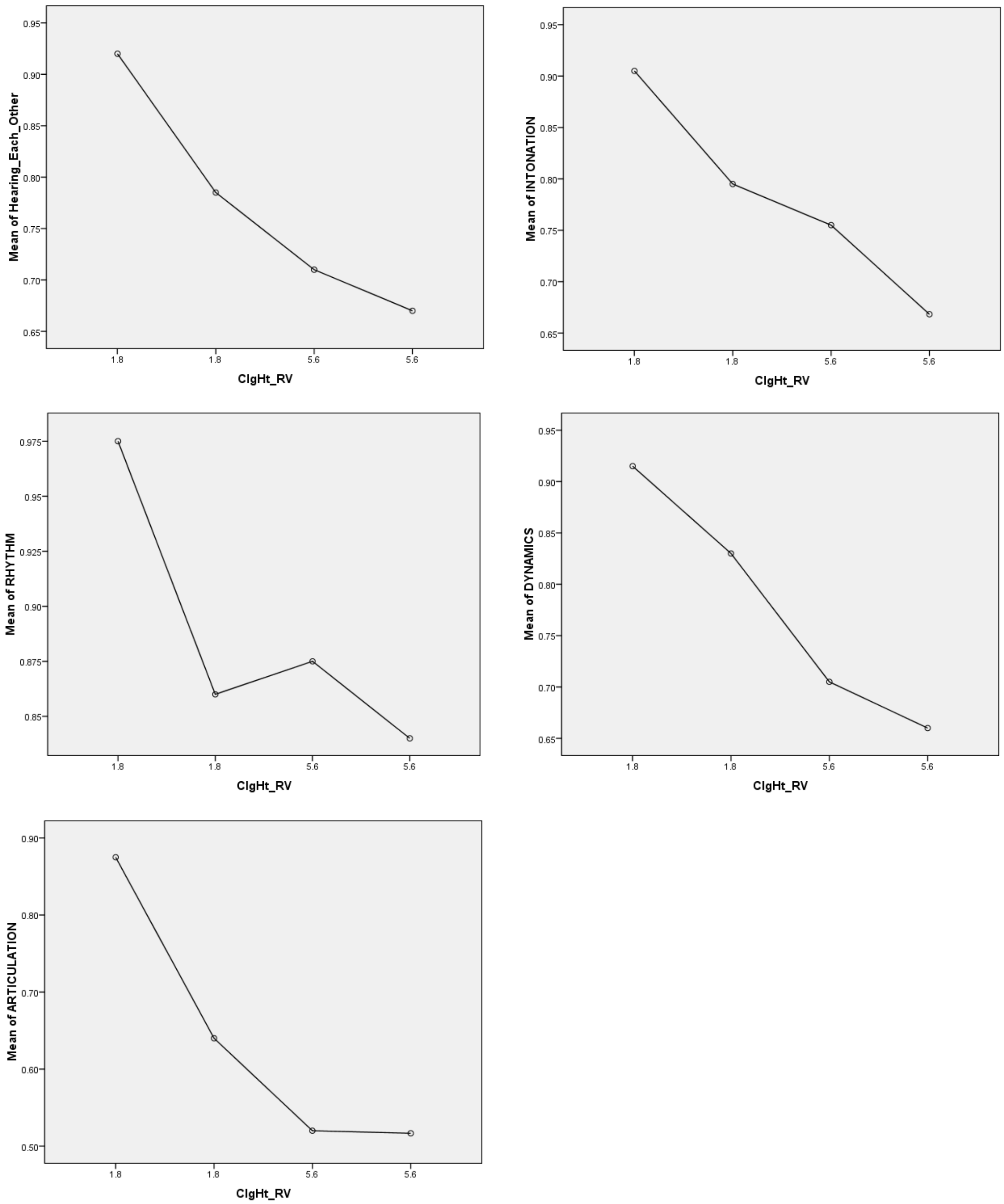


Figure 8-14. Mean Plots of the ratio of ceiling height to room volume versus scores of hearing each other and attributes of music in the three band rooms.

Summary

The results of the student questionnaires have shown that for both near and far conditions, a 14 to 20% more student musicians could hear the attributes of music asked about in the questionnaire when they are not playing their instruments (88.3%, 74.3%) compared to while they were playing their instruments (74.3%, 54%). For both playing and not-playing conditions, a 14% to 20% more student musicians could hear the attributes of music asked about in the questionnaire played by other students nearby compared with instruments being played from far across the ensemble. In addition, a greater percentage of student musicians could hear the attributes of music asked about in the questionnaire in Band Room A (85.3%) compared to Band Rooms B (56.8%) and C (79.3%) for all playing conditions and receiver locations.

The results of Factor Analysis have identified five components of acoustical and architectural parameters that are related to room acoustical conditions of the three band rooms. These acoustical and architectural parameters are used to explain the different room acoustical conditions in the three band rooms. The five components with the percentage of variance explained the different acoustical conditions in the three band rooms are the ratio of the early to total or late sound energies (45 %), architectural elements and reverberation time (33%), sound pressure level below 1000 Hz (17%), room Constant at 2000 to 8000Hz (3%) and averaged absorption coefficient at 63 Hz (2%).

However, the results of the Factor Analysis that consider the near and far receiver locations in the three band rooms separately have identified two components from the acoustical and architectural parameters that are related to the room acoustical conditions of the near receiver locations. The two components for the near condition are the architectural elements and IACC (59%) and signal to noise level and effective decay range (41%). The two components for the far condition are the reverberation time, IACC and architectural elements (55%) and the sound pressure level, effective decay range and IACC (45%).

In addition to the architectural elements, the variations in room responses for the near condition depend on IACC and sound energy strength. Likewise, beside the architectural elements, IACC and sound energy strength, the variations of the room responses for the far condition also depend on reverberation time.

The best way to determine which architectural and/or acoustical parameters of the room can be used to predict the questionnaire scores of the attributes of music listened for by student musicians during rehearsal is by using Multiple Linear Regression analysis in conjunction with the mean plot. The coordination of the mean plot shows the questionnaire scores by human subjects (vertical axis) and the values measured in the three band rooms with the predicted architectural and acoustical parameter of Multiple Linear Regression (horizontal axis). The predicted parameters can be explained by most of the psychoacoustics principles. For near and far conditions, the acoustical attributes of the rooms could be used to directly explain the predicted parameters. Table 8-23 summarized the parameters with the highest r^2 that can be used to predict each attributes of music.

The mean plots of architectural elements (Floor Area and ratio of ceiling height to room volume) show useful trends for obtaining higher scores in hearing the attributes of music better, despite not being included in the regression predications.

In summary, the method used in this study derived some acoustical and architectural parameters that could be explained by both psychoacoustic principles and acoustical attributes of rooms to show the correlations between architectural/acoustical parameters and the attributes of music that student musicians listen for during rehearsals.

Table 8-23. Summary of predicted parameters versus attributes of music for the three band rooms.

Music Attribute	Predicted Parameter	R^2	Zero-order Correlations	Sig. (95%)
Hearing each other	SPL_63	0.785	0.781	0.003
	IACC_L_500		-0.343	0.024
Hearing each other – near	C80_8K	0.752	-0.867	0.025
Hearing each other - far	TC_HIGH	0.693	0.832	0.040
Intonation	SPL_63	0.727	0.754	0.005
	IACC_L_500		-0.327	0.048
Intonation-near	No predicted parameter.			
Intonation- far	EDT_250	0.662	0.814	0.049
Rhythm	SPL_63	0.577	0.760	0.004
Rhythm – near	No predicted parameter.			
Rhythm – far	No predicted parameter.			
Dynamics	SPL_63	0.848	0.799	0.000
	IACC_L_500		-0.382	0.006
Dynamics – near	D50_63	0.732	-0.856	0.030
Dynamics – far	C80_High	0.852	-0.923	0.009
Articulation	IACC_E_8K	0.784	0.772	0.001
	SNR		-0.420	0.021
Articulation – near	D50_4K	0.869	-0.932	0.007
Articulation – far	No predicted parameter.			
2nd set data – Listening Evaluation				
Tone Quality	IACC_L_HIGH	1.000	-0.897	0.000
	ST1_63		0.274	0.000
	IACC_L_2K		-0.516	0.000
	IACC_A_1K		-0.057	0.000
	RC_LOW		0.736	0.000
Overall Impression	Alpha_bar_250	1.000	0.846	0.000
	IACC_L_MID		0.005	0.000
	RC_HIGH		-0.227	0.000
	SDI_CLG		0.643	0.000
	T20_125		0.507	0.000

CHAPTER 9
ADDITIONAL COMMENTS BY MUSICIANS

Background

Additional comments by musicians were also obtained through both students questionnaires and listening evaluations. It is important to look at these comments because additional insights can be obtained about room acoustical responses that affect a musicians' hearing of attributes of music. In addition, these insights could be used to explain the correlations of architectural/acoustical parameters to attributes of music.

Method

A question about the additional comments on each individual band rehearsal room was given at the end of the students' questionnaires and listening evaluation. As mentioned above, the purpose of the additional comments was to learn other possible insights from these musicians that were not covered by the questions from questionnaire and listening evaluation. Thus, the question used in questionnaire and listening evaluation was "Do you have any other comments or suggestions about rehearsing in this band room on room acoustics? (i.e., the room was too dry, or too reverberant, so that adds to the difficulties of playing together with your section or the whole ensemble. Or, the room generally supports good rehearsal conditions, so it allows you to work on your musical skills and playing in ensemble.)"

Musicians' comments were transcribed directly from the answer sheet to the Excel spreadsheet with the information of the instrument played by the musician who made the comments. The comments made more sense knowing the instrument played by the musicians. Also, the seating locations of the instrument in the band room were more or less the same for most of the bands. For example, the brass players usually sat at the back of the woodwind and in front of the percussion. Oboe players usually sat in the center of the band.

Results and Discussions

There were 129 music students from Band Room A that participated in the questionnaires and an additional 30 music students and 6 conductors who participated in the listening evaluation. For Band Room A, the average years of experience for musicians who have played their own instruments was 12.3. The average years of experience for conductors who also have played their own instruments was 22.2. For Band Room B, there were 49 music students who participated in the questionnaires. Since it was an optional question at the end of the questionnaire, only 28 students provided a comment. For Band Room B, the average years of experience for musicians who have played their own instruments was 10.09. For Band Room C, there were 32 music students who participated in the questionnaires. 9 students provided comments. For Band Room C, the average years of experience for musicians who have played their own instruments was 5.66. It was necessary to show the average years of playing experience because different years of experience means musicians have different playing skills and listening abilities. Therefore, the needs of the room acoustics to support their playing as a large ensemble could be different. A professional musician with better listening abilities knows how to adjust his/her playing in any space due to different acoustics. On the other hand, the less skilled music student who is still learning to play in an ensemble, a suitable acoustical condition could help him/her to listen and support his/her playing.

Table 9-1 shows the comments obtained from the questionnaires and listening evaluation. For Band Room A, the general comments from the students were that the room had good acoustical designs that supported their needs to hear the attributes of music. However, many of them thought the room was too dry and, at a point, they could not clearly hear the attributes of music played by other musicians who sit far away from them. A comment from the saxophone player, who sat 20 feet away from conductor podium, states “Too dry, speech doesn't carry well from podium”. This comment points out the need for balancing reverberation time. Comments from the conductors generally stated that they preferred the variable acoustics provided by the design and that the current acoustical condition supports their needs to teach the students. Interestingly, there were also comments regarding room temperature. These comments described the room as being generally too cold for some to rehearse in. Indeed, the room temperature affects the intonation. Thus, a future study in this area is necessary.

For Band Room B, the general comments were that the room was too dry and this resulted in difficulties for them to hear anything during the rehearsal. The dryness was due to the room’s lack of reverberance. The musicians rehearsing in this room primarily heard the strong direct sound from everywhere. These comments supported the acoustical measurement data shown in Chapter 6 that the average value of T20 and T30 was approximately 0.5 seconds for the octave bands. The mean value of Center Time was 1000Hz is approximately 20 milliseconds. However, the stronger direct sound also showed that musicians could hear rhythm better in the listening evaluation.

For Band Room C, the comments showed that the room was too small that musicians could not hear each other clearly during rehearsals. Indeed, the floor area, ceiling height and room volume of Band Room C was the smallest among the three band rooms for this study. The high sound pressure level can be seen from the acoustical measurement result that ranges from 94 to 124 dB across octave frequency bands and all receiver locations. The acoustical measurement data and results of the questionnaires did not have matching responses. Interestingly and surprisingly, through observations during the live rehearsal in this band room, conductors managed to train these music students to hear more clearly on intonation and rhythm by using a keyboard and a pair of loudspeakers. The keyboard and loudspeakers were used to play the pitch of the note and beats of tempo, so the students could hear the pitch and beats clearly and match the tone and rhythm in accordance.

Summary

With comments from the users of these rehearsal rooms, the acoustical measurement data, correlation analyses and questionnaires made more sense about the room acoustical responses to hearing the attributes of music. The reasons of the musicians preferred Band Room A better than Band Room B for intonation, tone quality and overall impression can be seen from the comments made by students from Band Room B. Through the observations of the rehearsals, musicians learn to adopt the room acoustics and cope with it to achieve the better playing as an ensemble. In addition, comments on room temperature setting raised the issue that acoustical consultant, mechanical engineer and architect should consider it during the band room design process. On top of all, acquiring comments from the users of these band rehearsal rooms are necessary during the design process to ensure the potential acoustical issues being identified and provided solutions.

Table 9-1. Summary of comments from questionnaires and listening evaluation for the three band rooms.

Room	Instrument	Comments
Band Room A	bassoon	I can hear myself and my mistakes more clearly
	bassoon	It is sometimes so dry that it is hard to hear the other instruments because they do not carry. This makes listening across the ensemble difficult at times
	bassoon	Sometimes it’s too hot. Mostly good though
	bassoon	It's too cold a lot of the time
	bassoon	I think the room is very professional! I can hear the resonation
	Clarinet	Too dry!
	Clarinet	High school - moldy- allergies prevented my ears from working well as possible. This room - trumpets are a little loud but only in concert band, it’s hard to balance in the concert hall, b/c it’s very echoic but it’s beautiful with strong brass section
	Clarinet	The room has good acoustics
	Clarinet	This room is nice, but can be very dry at times. I prefer a little more reverberance
	Clarinet	This room has a nice sweet spot
	Clarinet	The rehearsal room is conducive to good sounds and many things can be heard
	Clarinet/Saxophones	Generally, a good, "dead" rehearsal environment wish that, in some ways, more natural overtones could be heard
	Clarinet	The room does support good rehearsal conditions, as it is easy to hear individuals and more difficult to work together as a group. It is hard to hear across the room sometimes, however.
	Clarinet	The acoustics make it easy to rehearsal, but the temperature often affects our tuning. It is usually very cold or very warm
	Euphonium	This room is awesome
	Flute	too cold
	Flute	The difference between concert hall and this room acoustics is annoying
	Flute	The room is great, each instrument can be heard clearly
	Flute	It's a great rehearsal space but I feel that the overall sound sometimes does not come across as well when we record in there
	Flute	It is great!
	Flute	The room has good rehearsal conditions through sometimes tuning is difficult

Table 9-1. Continued.

Room	Instrument	Comments
Band Room A	Flute	Occasionally it would be nice to hear the room more live to get a better idea what it will sound like in the UA
	horn	It’s easier to hear w small wind ensemble. Past my own section and the ones next to and behind me I usually can't hear (everything)
	horn	sometimes the horns end up too far left or too close to the tubas
	horn	It's a great room, the chairs are uncomfortable.
	horn	Dry is great for rehearsal but makes player felt exposed and loud compared to others.
	horn	So far, this room is the best acoustic setting I've played in. (As far as band rooms are considered)
	horn	When there is a soloist, it is very easy to hear their articulations, intonation, and dynamics
	Horn	Large room sometimes makes it difficult to listen across the ensemble or for instruments facing backward to be heard
	Horn	With so many people in such a large ensemble it can be hard to hear all the parts going on. It sometimes feels like a wall of sound and you just have to do your best to stay with the conductor
	Horn	Variability in acoustics is nice (i.e. movable curtains)
	Oboe	It is hard to hear director speak often
	Percussion	It is dry
	Percussion	No, this room has much better acoustics than my high school
	Percussion	No, it's just as good if not better
	Percussion	It is good for rehearsal purposes but fails to recreate an actual performance environment
	Percussion	Good setting. Can hear very clear
	Percussion	It's a good, dry sounding space - allows performers to better hear rhythms/timing and articulation - at least in the back of the ensemble
	Saxophone	too cold
	Saxophone	Previous ones have deadened the sound and made dynamics differ when we played elsewhere
	Saxophone	I think it would be easier to play in-tune if it weren't so cold
	Saxophone	Too dry, speech doesn't carry well from podium
	Trombone	This room is awesome
	Trombone	Too cold hard to be in tune

Table 9-1. Continued.

Room	Instrument	Comments
Band Room A	Trombone	Not great for recording in and making music/rehearsal sound much different than our performance venues
	Trombone	It makes it easier to hear the other parts as well as yourself
	Trumpet	At first the room is surprising dry, everything is very audible. It is a great hall - when the curtains are closed that is!
	Trumpet	Great room to play in
	Trumpet	A little too dead
	Trumpet	No. The size of the ensemble makes it difficult to hear some of the woodwind sections
	Trumpet	This room is really "dry"
	Trumpet	It is the best rehearsal space I have been in
	Trumpet	The room is very "dead" and it is sometimes hard to hear across the ensemble
	Trumpet	This room is the best rehearsal hall I have ever performed in
conductors	Trumpet	The curtains make a drastic difference in the amount I hear in rehearsal
	Percussion	The room has the added advantage of changing acoustical environments by altering curtain
	Flute	The room allows performers to hear clarity and articulation easier
	Clarinet	Room is good; difficult to hear from back of room
	Tuba/Trombone	The room supports proper rehearsal conditions - you can hear the various sections of the group easily
	Trombone	Having the volume of air in the room helps. Elimination additional echo or resonance helps with rehearsing
Band Room B	Clarinet	Doesn't ring
	Clarinet	You cannot hear individual sections or players. Very dry room!
	Clarinet	Too dry
	Euphonium	Its vary dry, and there is no warmth or resonance to the sound. There is no space for the sound to grow as it leaves the instruments
	Flute	Hard to listen across to other sections when playing
	Flute	It’s hard to hear anyone else besides the person on my left because her sound goes into my ear
	Flute	Very loud. Hard to distinguish different voices and instruments
	Flute/piccolo	The room sucks up the middle voices, especially the saxophones

Table 9-1. Continued.

Room	Instrument	Comments
Band Room B	Horn	Difficult to hear across room, bad acoustics, deadened ensemble sound
	Oboe	The room is too dry. I can't hear across the ensemble
	Oboe	Totally sucks up saxophone sound
	Percussion	The room is too dull and too dry
	Percussion	The room is so dry. No reverb, sound just dies everything's seems so loud
	Percussion	The room is too reverberant
	Percussion	The room is very dry and does not resonance at all. It makes the instruments sound muffled, makes it hard to hear many of the musical attributes listed above. The FAU Band Room is a terrible environment for rehearsing bands in
	Percussion	The room has -no- reverb, and is completely dry. Rehearsals are pretty unproductive and working on ensemble intonation is almost pointless
	Trumpet	Dead, very dry
	Trumpet	Room is dead acoustically speaking, lacks any warmth or resonance
	Oboe/Saxophone	The sound is sucked into the room, especially brass
	Drum set	Too reverberant
	Drum set	This room is so big; I think it makes everything sound very muddy
	Piano	It's not bleed, I don't know really
	Piano	My main issue is the volume is really loud (+ horn heavy) hearing piano (or "keys") amongst all of this is next to impossible. :(When rhythm section is playing alone, it is not too bad!
	Saxophone	Too loud, difficult to hear whole ensemble, individual players in it
	Saxophone	The room is too dry
	Saxophone	Can't hear myself at all! Can't hear my tone, my intonation. Hard to tune to the ensemble when I can't hear myself. I feel like all sound is lost immediately after it leaves my horn
	Saxophone	The practice rooms are horrible. You sound like you're playing in a box. The combo room is the worst it gets so hot in there it starts to smell. And you can't hear everything clearly
	Trombone	Room is very dry. Hard to judge dynamic levels
	Trumpet	Too boomy

Table 9-1. Continued.

Room	Instrument	Comments
Band Room C	Clarinet	Difficult to hear the way we blend
	Clarinet	Sometimes it is hard to hear the intonation of players right around me - I hear other instruments, just not the ones near me
	Clarinet	Sometimes it is difficult to discern the blend of our instruments with others and the band as a whole. When we cut off a chord we rarely hear the "ring" every band loves to hear
	Saxophone	I know concrete block is not good for acoustics and I built acoustic panels for my middle school band room
	Saxophone	I like the new room
	Trombone	The room is too dry
	Trumpet	From my position, the room is just fine
	Tuba	Instruments can be too close together to each other
	Tuba	I can't hear right side of room at all

CHAPTER 10
CONCLUSION AND FUTURE WORK

Conclusions

Soundscape study methods have been applied to this research to investigate what musicians are trying to listen for while playing as an ensemble during rehearsals in the three band rooms.

Direct observation by attending the rehearsals in each band room and video recorded of each rehearsal were used to study the amount of time conductors spend during rehearsals addressing various attributes of music with student musicians and the amount of time the students actually spend playing their instruments during typical band rehearsals (Chapters 3 and 4). The ability of student musicians to understand verbal instruction from the conductor has been identified as an important activity during band rehearsals from the analysis of the three music rehearsal recordings. Therefore, an acoustical metric related to speech intelligibility should included in the design criteria for these rooms since band rehearsal rooms are core learning spaces where verbal communication is important. Current band rehearsal room design guidelines have not included this criterion.

In addition, the analysis of the three music video recordings show that conductors and music students were constantly hearing self and each other on intonation, rhythm, dynamics and articulation for 80% of the total rehearsal time. This was also supported by the results of the interviews and questionnaires to the conductors and music students.

Personal interviews with six conductors and questionnaires administrated to an additional seven conductors and 206 student musicians were used to determine what each group is trying to listen for during rehearsals (Chapter 5). The results indicated that both groups were constantly trying to hear themselves and each other on the five primary attributes of music during rehearsals. Intonation, rhythm, dynamics, articulation and tone quality are the five primary attributes of music heard by musicians during the rehearsal. Therefore, the future acoustical design guidelines for band rehearsal room should support the ability for musicians to hear themselves and each other on these attributes of music.

Mapping and modeling were the techniques used to illustrate the distinct acoustical responses of the near and far receiver locations in the three band rehearsal rooms and the differences in the rating of the attributes of music heard by student musicians at these locations (Chapters 6, 7 and 8). From the three band rooms' acoustical measurement data analysis, the room acoustics responses of near and far receiver locations had shown significant difference. The acoustical parameters that had the measured values with greater differences between the receiver locations included EDT, TC, D50, C80, ST1, IACC_A, IACC_E and STI. These differences are a result of the early reflection from the architectural features of the room. T30, T20 and IACC_L did not show much difference for different receiver locations because the reverberant sound energy is affected mostly by room volume not receiver locations. The different room acoustics responses for near and far receiver location as well as for the different frequency bands in these band rooms indicated the difficulty for music students to listen for attributes of music and to play together as an ensemble.

Additionally, the results of the listening experiment based on these measured values indicated that musicians not only could identify the differences in the attributes of music at different seats and rooms but also could identify which band room better supported their needs in hearing the musical attributes. Therefore, the measurable differences among seats within rooms and among different rooms for acoustical measurements, architectural features and qualitative evaluations of the rooms suggest that the architectural design of the rooms influences the music instruction quality. Furthermore, the results of the statistical correlation study indicated that the ceiling heights, room volumes and area of sound diffusing surfaces were found to be important to achieve preferred listening conditions in the rooms. The low frequency sound level, spatial distribution of later sound energy, early reflected sound energy and reverberation were found to be important acoustical attributes of the rooms.

In summary, the importance of the verbal communication between the conductors and music students, the attributes of music that both conductor and music students are trying to listen for during the rehearsal, as well as the above suggested architectural features and the acoustical attributes of the room should be considered as the design criteria for these rooms and be included in the future acoustical design guidelines for band rehearsal rooms.

Future Work

In order to complete a user-oriented acoustical design guidelines for band rehearsal rooms, the work of this research will be continued by obtaining a larger sample of band room measurements and student questionnaires relative to these band rehearsal rooms, as well as using multiple receiver locations for acoustical measurements in the band rooms. At the same time, questionnaires should be given to music students who sit at these receiver locations of the band rooms for improved correlation analysis. Statistical analysis methods such as factor analysis, multiple linear regressions and mean plots to derive the correlations between architectural/acoustical parameters to attributes of music will be used as well.

Analyzing the effects of musicians playing or not playing their instruments which listening for the attributes of music during rehearsals and conducting multiple source impulse responses tests in more of the rooms with a regular grid of receiver locations will be conducted.

APPENDIX A
TRANSCRIPTIONS OF CONDUCTOR INTERVIEWS

Interview with Conductor A

Conductor A: From a conductor's point of view, what are the most important aspects for students to rehearse to prepare the ensemble for concert? Put to self you are now a student and I am the teacher if we look at the question. And then what are you asking me. Ask me the question.

Lucky: Ha, Okay, this one I was thinking… is a conductor or a teacher, when you rehearsal you're asking your students to listen to the intonation, rhythm…

Conductor A: are you talking about the lesson? Or are you talking about playing in the section? Or preparation for..? Well first of all, as you know when you have lessons, we prepare excerpts so we can play the notes, number one, the league has to be able to produce the right notes and the arm has to slide on the position so technically that's where you start. You have to learn how to play the instrument, and when you play the instrument well enough so you can do the excerpt in question that we talked about, then we talk about the musicality so we can draw a line so it sounds beautiful. Now, when you've done that then you go into the orchestra and you see in the orchestra. But before that, you want to talk about playing the excerpt in context. By that I mean that, when you play an excerpt for me in a lesson it has to be exactly the way it's supposed to be done when you sit in the orchestra. So when you play that excerpt, you have to hear the orchestra so that is very much part of preparation- for a student to hear orchestra and knowing what goes on and what it sounds like when you come in with when that specific very difficult passage. When you sit in the orchestra it becomes a whole different level, dynamics become different and then of course we talk about blend. In lessons you can't blend because there is nobody to blend with. So, then you have you know then you have 3 trombones and tuba, that's number one thing you think you want the whole section to blend and we talked about direction of sound and the bells so that they blend in that way so by the time when the sound comes to the conductor it should be a homogenous sound that's blended. So by the time it gets to the audience, you know person number 3,000 to hear a good blend as well as the conductor and everybody else. Blend is very important, and then of course precision. Precision, so that everyone in your section and the whole orchestra so that they hear the rhythm that the conductor gives (gigs), also when you play your excerpt you have an entrance, then you have to hear the orchestra. You always, your entrance, what comes before the entrance what leads the entrance; you have to hear what instrument that what should I say, you take over from. You often take over a passage from somebody. So that's very important to hear the whole. This take a lot of time and experience and you will not be able to that as your first time you sit in the orchestra as a student. As you develop and you become a personal player, then that aspect of your intellective develops and develops, and professor decision of how his caliber can, most part hears the orchestra. Except when you sit in the back of the orchestra you play the trombone and you play very loud, and of course you can't really hear the orchestra. So there are so many aspects. Is that something you wanted me to comment on? Are we going in the direction or what?

Lucky: Yes yes, and maybe think about… so usually as a professional musician even you are in the room, concert hall where the acoustic are not really good, echoing, you can still be able to adjust?

Conductor A: Yes, as a student that is very difficult, but as a professional you have to. You come into a place where there is a lot reverberation like church or something you have to play much softer because the sound carries, it just comes out of the instrument in the place. If you come into another room that is very dead, then you have to play more sustained because you get no help of the acoustics, so you have to play sustained and try to play a sound that projects outward. Um, If you don't do that the sound will just fall right down in front of you and goes nowhere. This is a big problem, and orchestras, you are in different halls, all the time. And most orchestras you have a rehearsal in the concert hall where they will play before the concert that's extremely important. And great experienced orchestras know how to handle that aspect. They change their play for the different concert halls they go into.

Lucky: so usually do you think all the professional musicians, hm... I was going to say the conductor is the first person that goes into a new concert hall and listens to it so they can make a comment to the musicians or you think both of them do it at the same time?

Conductor A: yes, that's right first thing is that you yourself have to balance it so you hear it and then after that, hopefully it is a good conductor that can balance the orchestra. It is a very difficult thing to do after one rehearsal. Because all the instruments and all the different acoustics and specifics when it comes to acoustic for each individual instrument. So it is a very hard thing to do. And in this case, it is very good to have a person in the concert hall itself to listen so then you have at least 3 aspects, the performer himself, the conductor and the listener.

Lucky: And then also as an acoustic consultant, I notice that doing rehearsal you sometimes as the conductor as well as the assistant conductor sit in the audience area to sort of listen to the acoustics.
But then also, another problem is that during the rehearsal usually there is no audience. So, that room is more reverberant and so how do you adjust?

Conductor A: Yes, exactly. The same thing, that's a whole, of course you can't rehearse, as if people were in the audience. That is a very good point. When the audience is there and you play the concert, that's different again. And also, if the concert hall has reverberation, it will be not as much when you have the concert. And not only the people there, it is about how many there are. Half a hall of a full hall makes a difference. And especially if it is a rainy day and people come in with wet clothes, it soaks up all the sound. So, that's what I can think of with the differences and just a little a side step when it comes to playing sections, let say 3 trombones and tuba, students especially must have sectionals beforehand. So that the sectionals of 3

trombones and tuba practice again so they can give a homogenous sound and it balances in the practice room that you are. So then, you are way ahead of the game when you come to rehearsal room of the orchestra.
Lucky: I see, yeah, okay and if we are not talking about professional musician, so if you encounter a freshman student do you when you coach them for chamber music of something or a quintet or something, do you ask any same difference? Different mat…..

Conductor A: The thing is that take it personally to your high school. You might remember that yourself playing trombone, it was so much fun, so easy, remember? And then when you got to college, your teacher or myself started pointing things out to you, maybe your intonation wasn't right, maybe this slur wasn't right, and all these kinds of things and then you know in High school you don't hear those things. So it's so much matter of developing your ears. So some people would say about the intonation, well it's you hear it or you don't. Not so, not so the ear can't be developed to encounter intonation, so that's part of education when you come to college. So that's one thing you want to point to students. So just an example, you yourself play a middle high F on the trombone, you know how sharp that can be. And in high school you probably played that note all the way in third position, it was very sharp but then you don't really hear it. So then, your ear starts hearing that pitch, too sharp and so when you come to me and study, and I say "that note is sharp", then you say, "well I didn't notice", then I ask you to move the slide down and then you play the high F, you move the slide down then I say "this is fine" but then you hear it as flat. Then what happens, the slide is down but the lip goes up. The lip wants it higher and the slide goes lower. And then you end up playing a middle high F in second position and then lip goes up half a step so, that's an interesting aspect I think about developing. First of all they have to learn, their individual parts so that when they come to rehearsal we don't have to stop because of one person can't play his part. And after that, you then have to teach them to listen to each other. Because if you are very young, first year in college it's almost like seniors (well I shouldn't say this, but) in quintet you have own part in front of you, you see the music and you play your part. But what about the rest of you? D you really hear the five voices? So you put your own voice and part into the context? And here is a give and take all the time when you play trombone in a quintet, suddenly you have a little solo that is a little louder than your company and maybe it has all the same dynamics but dynamics are relative and you have to play stronger when you play solo and softer when you play with company. So, those are you know very basic ideas. And then of course after that, comes musicality. And see if they can find the musicality the basic rule of music, so not only the technique is in order but also the musicality and tracings from all the three sections playing. That's what I can think of.

Lucky: Yes, thank you covered a lot.

Conductor A: Yes, you asked that question you could answer that almost as well as I can.

Lucky: well yes, but I am looking other professional answers as a student. And I wouldn't be able to cover like….etc.

Conductor A: well Of course you can't, but I think this is a good conversation nevertheless.

Conductor A: What do you try to listen for during a rehearsal?

Yes, we basically covered this also. And when you listen back to this tape here, you will discover and remember what we forgot to say or do you will remember what I forgot to say. So insert that!
So you know, we covered most of it, so then we want to go over the very beginning one.

Lucky: So as the profession or the musician, it isn't going to cost you problems because you know how to listen and adjust but as a student if I'm talking about..
Conductor A: Yes, that's hard. If I come into the concert hall to play a solo, whether if it is with orchestra or piano, what I'm looking for is that it has <u>right amount of reverberation and that it has acoustics</u>, that it creates a <u>warm round sound</u>. Because that is ideal. So then, conversely if you come into a place, a <u>"boomy" place</u> and the sound is...well some halls can give you a <u>**nasal** sound</u>, it won't be very pleasant so then you have to adjust to that. So how do you do that? How do you adjust to sort of a thin sound, well I have or you have a certain sound in your ear you want to produce. And if the circumstances aren't favorable, still your ear tells you "this is the sound I want" –so that has to do a lot with ears. So I think, somewhat automatically you start putting warm juicy thick air into the instrument to make it juicy round and dark. So that does matter. So it isn't the matter of coming into the hallway and playing same all the time, and then articulation is the same. If the hall is very reverberant then you have to ….front to the note, it comes out not too late. And talking about articulation, think about someone sitting back there and let's say you have an entrance with piccolo and ____(Glackens squeal), then what do you have to do. And the (Glackens squeal) goes "ping" so you have to spit it out quickly. And then same with piccolo comes out so fast, sometimes you have anticipate when it comes to that. Back to the solo in a hall that is not so favorable, those are the things that I would think about. It is same thing as before, is that the acoustics is dry you have to play much more sustained and it is much harder to do because you need more air, so you know, technically, hopefully you've practiced enough so you have little extra air when you play.

Lucky: Okay, so do you think when students rehearse for ensembles or symphony, do you think they should try to rehearse in a dry, less reverberant room or more reverberant?

Conductor A: that is a very good idea if you have the opportunity to do so. But a student's ear is not developed like the professionals so for students it should be much harder and more difficult to adjust and maybe they won't be able to adjust at all, may they'll play they always did. SO, that becomes a little more advanced, when you talk about changing your playing style according to acoustics whether it's necessary. Your idea to play in different rehearsal room is fantastic. If you play in a very dry room, it is very challenging. And then at least you have been in that position, that situation so that you know what that feels like. And conversely if you play in a very reverberant room, you know how to make it drier.

Lucky: for band room, rehearsal room, so when they practice, the curtain is close. So the room has really dry, about .6 or .7 seconds dry acoustics. And the conductor because he thought he wants a drier condition, he can ask students to listen to intonation and rhythm so they can play together.

Conductor A: I think that is right actually, that is a very good idea. And when they come into a good concert hall it will be so easy to play.

Lucky: Yes they are thinking about that. Because the concert hall they, they play usually is much more reverberant.

Conductor A: But for an inexperience student, if that student played exactly the same way in good acoustics as he did in a dry acoustics, then that will not going to be good either because you have to blow harder, you have to use more air and you probably have to play louder in a dead room. So then, when they play in a room with good acoustics, they have to adjust to that and hold back a little back because otherwise it will be too loud and too hard.

Lucky: So you suggest students should rehearse in a not too dry room, it should be somewhere between the…uh…

Conductor A: Yes I agree with that. Because if it is too dry, it will be too different when you come into a room with good acoustics. So because you have good acoustics, it doesn't mean that the orchestra needs to sound fantastic. It depends how they're used to playing. So if they're used to playing in a dead room where sound falls right down, then that is so different when they're playing during good acoustics. So, that is not THE solution as such. So to rehearse, for the reason that you said, it is great, it's find but they shouldn't rehearse in a completely room all the time they have to get the feeling what the difference is. You draw the curtain.

Lucky: Sometimes, when they draw the curtain. The reverberations go to about 1.8 seconds. It is similar to concert hall, usually the concert halls are that.

Conductor A: Yes, I would actually say that is nearly perfect. That is actually fantastic. What you're telling is a very good way of doing it. Yea I think so. You know you go from very dry, where you have to really put out to have your sound out, and also in the same thing as except that the conductor is here, and use the intonation and do everything, maybe the orchestra can do that too. And if you can open it gradually, a little by little until you have the acoustics that are in the hall, I think that's a great idea.

Lucky: What do you discuss with students during rehearsal?

Conductor A: <u>When you have a rehearsal with the orchestra, you can't become too personal you can't spend too much time with each section, each individual. But it's the same thing with tone quality, blend, intonation, slurs and articulation all those things in lessons and sectionals. Sectionals are so important.</u>

Lucky: Okay, so from there, you can see the speech intelligibility**, so you can perceive the speech well, students can hear basically what you are talking about, and you can hear student comments. So do you consider that is important criteria, when an acoustical consultant in band room or concert hall they should think about?

Conductor A: That is very interesting question. Because again you can look at concert halls or halls that are made for music, theater and speech. So for the human voice, speech you need much drier acoustics, when music you need some reverberation and then projects ones voice-that is a very individual thing of course. The conductor has to learn what volume he has to speak at in order for them to hear. So, it also depends I mean if the orchestra is much quiet, then it should be easier. But if orchestra is not so disciplined then it's a different game. So the conductor, always must project so that they can hear. I myself, tendency to look down a little, and then the voice don't project then you only hear first two players. But for brass and percussion, you have to raise your head and so you know, the opening of the bell goes where it needs to go. So I'm at fault myself for not doing that so well.

Lucky: This is just to show you. I recorded a rehearsal from beginning from an empty room to two hours later. This is when musician warmed up, and the conductor came in. This is the very first rehearsal. So musicians warm up and conductor comes in, and suddenly they all become quiet. So conductors start talking about what you should be careful something. And then so as you can see each gap between the lines, gap represents when conductors stop the rehearsal. Okay so when you have _______ where the music rehearsal is going on. So each gap is where conductor stops and speaks to students. So when you added it from here to there, you see a lot of gaps. So when conductor tries to talk to students, actually stops a lot. And this if very first rehearsal. And the last rehearsal you see that the conductor does not stop so much. So hence, this is just to show conductor's speech is very important because they do spend a lot of time during the two hour rehearsal.

Conductor A: Oh, sure. That is right. Just a little side step, if he talks a lot and stops a lot. If this was first rehearsal, I give the ensemble a chance to go through the passages and not go too detailed right away because I think they should sort of get it in their fingers and start hearing what the piece sounds like. So I won't, I don't stop too much first time around. The second time around I go into detail. Then it would look like this one right here.

Lucky: So I see. The first time, you will have them go over the whole piece.

Conductor A: Yes, if it is short piece, whole piece, big piece, etc, I will do sections. Because for orchestras, even professional orchestras and students especially, it sounds so much better the second time around, the third time around because then they get the feel. You certainly know that, you've been in that situation many times.

Lucky: Yes, okay so. I never really realized that the speech is very important and an important criteria.
So, I think you covered this too…This one, How might teaching be different?...

Conductor A: How might this be different in a smaller ensemble or individual lesson? The aspects you discuss among students... Teaching single lessons and teaching quartets, quintets and larger and larger? And some of it becomes very different. And when you have a large orchestra especially with professional orchestras, and when you rehearse them, this might not have to do so much your project but the approach of the conductor, when the conductor conducts a good professional orchestra you can rehearse but you can't really teach too much. Because these people are more they're professionals and they know much more about their own instruments that I know about their instruments. So you when you teach, you have to ask them so you don't become too personal. If you ell a person that doesn't sound good, do it this way do it that way, whatever, if you are negative in that term, you get the orchestra against you right away. So when that happens, you might as well pack up and go home. You have to be careful. You have to be somewhat diplomatic and get your message your through without becoming too personal in large orchestra. In a lesson, you very well know that there are times when you could even be unpleasant, if I think that student is not working hard. You know, I will try to push the student really hard, like say "if you want to do this, you know you got to work. You have to practice." But see, I cannot tell this to the orchestra. But I can tell it to like students from brass quintets or so. But of course, you have to try to be somewhat diplomatic.

Interview with Conductor B

1. What are the most important characteristics of a room that support your coaching/playing?

Conductor B: For me, in a small room where I'm teaching private students, I will like a happy medium-not too dead sounding, but not too live either. You know old recording studio used to be very dead, not it is very dead with wood and glass, very alive. So I would say for me to really work with the student and get the mature sound out of the instrument, It can't be too dead yet it can't be too live. For me it has to be in the middle. When I hear a student, I don't want to hear too dead, as that there is no life to the sound. This room is too dead, where I teach my students, it's a little too dead. So I never really get the real feel as to what it will sound like (instrument). But the other band room is actually good for instrument playing alone with piano accompaniment. It sounds good in there, single player or 3or 4 players playing. It sounds fine to me it doesn't bother me. But here, it is too dead but then you got rugs and wall all that. So I would say that for small group of instruments with let's say a piano accompaniment, a room like 260 although it's too big, but something like that with that kind of sound to it is good.

2. From a conductor's point of view, what are the most important aspects for students to rehearse to prepare the ensemble for concert?

Conductor B: My first emphasis is always setting the <u>correct notes and rhythms first</u>. Then I would say second area I look at is the <u>dynamic level</u> that everything we are playing. Are the dynamics correct and coming close as possible, to what the composer had in mind , things like that or, what has been played before in other orchestra bands or jazz bands, and third I try to imagine the <u>melodic structure</u> of what I am hearing-how are the <u>phrases</u> going, how do I want to phrase something. I would say this is the order. Even with students that I am having private lessons, and for a solo, I just say <u>I want all the right notes, all the right rhythms first. Once you get that, we can make music</u>. Always those first. Of course with a large group as well as solos we're concerned about <u>intonation, pitch</u> and everything else, I always try that as well but my reasoning my main focusing is that if they got all the right notes and rhythm, then I go see if that note is too flat or sharp, and the next thing I do is dynamics. As a matter of fact, I tell them in the beginning don't even play it up to tempo when you're practicing, etc just play really slow. Secondly make sure with the wind instruments, make sure you're supporting it with air all the way through. And also, be very careful about rhythm and <u>don't worry about trills, or grace notes anything like that, not until got all the basics</u> down, then you can put in all the rest.
So for first couple rehearsals, we just read the music and go through. Then we go back make comments like this has to be soft or this has to be loud. And then we work on putting everything else together, getting pitch and intonation.
3. From a **performer'**s point of view, what are the most important aspects for students to rehearse to prepare the ensemble for concert?

Conductor B: Yes for this I would say the same-from performer's point of view I would say to listen and go for getting all the notes and rhythms first then become acquainted with all the dynamic levels, all the embellishments that you can add to music, that are there, grace notes, trills, whatever. And then of course, applying this after having it gone through once you know what the melodic line is and how to phrase the different parts. And then you start listening for intonation. But I don't think you can do anything until you got all the notes and rhythm.

4. From an **educator**'s point of view, what are the most important aspects for students to rehearse to prepare the ensemble for concert?

Conductor B: Basically same thing. As far as being teacher and doing this for 48 years, all of those things from 2, and 3 I see that same for teaching. You have to have all the basics there and then you go on to make music.

5. What do you try to listen for during a rehearsal?

Conductor B: If I feel that they've rehearsed enough and got the concepts down, then I start listening for tone quality, start working on phrasing, start looking for the timber of the instruments and how I think the overall sound should be. Then I really try to go for the, I guess you would say the acoustics. Sound level, if it is balance, are they playing together, and this is unison line so is this guy playing too loud comparing to other players-so those are the kinds of things I look for in a rehearsal. Once I got all the notes and rhythms done, then I go make music.

6. What aspects of student/performer playing do you discuss during rehearsal?

Conductor B: I try to make them aware, once they've got the piece down, I really try to focus on hearing it in tune, getting to play in tune and also, the quality of the tone is coming out of the instrument so it is not too harsh. Because when you play everything is in relationship. Dynamic level for example, how soft is a piano how loud is a forte, it is all in relation. So I tell the student, look, when you start a piece of music, if its piano, you're the one who sets the level so whatever you said in the beginning, every other piece dynamic that comes after has to in relationship to what you started. So if you're piano is a little louder, then that's fine, because the listener doesn't really know it, but if you're going play forte you have to make sure the listener knows and hears the difference. So I would say you know, we talk about the quality of sound, reading and playing very precise, those kinds of things.

7. How might this be different in a smaller ensemble or individual lesson?

Conductor B: I don't see how this can be so different with smaller ensembles because smaller ensembles made up with individuals. So when you've been working with individuals and you put them in a group, they should be really thinking about the same thing. And the other thing, smaller groups, you have to make sure the balance is there, the instruments are balanced with one another, if not one instrument is sticking out or so. So there, there might be a difference. But as far as playing the correct note and correct rhythm, it is same even in small ensembles.

8. If you are playing or rehearsing the same programs in different spaces, how are the acoustical attributes of the room helpful or harmful for listening and teaching?

Conductor B: If every place you go to perform is different and you don't have a chance beforehand and play and get the acoustical properties in the room, you are doing it in the spot. So you have to be aware and then group has to be aware if you want to indicate soft maybe different in one room and different in another room, for an example, our rehearsal room is not very good and also the same place that we play in the acoustics are not very good. So, what we have to do is as a conductor I have to imagine and rehearse what it will sound like out there. And then, when we actually do go in stage, all we do for 2 hour period is to acoustically balance and we use a lot o microphones because we want to be able to isolate the sound. So, what I have to do with our group, I have to push it all the way to the back in the stage where it doesn't blow people out of their seats and then let the sound people set it up, for it is not ringing all over the place, so that they can get something for definition. And it's been working because the live sound courses have taught them pretty well and they know what they are up against in these different rooms. You walk into a room where it is great and you drop a pen and everyone from all the way from back stage can hear it and then you go to a bad room where it just cluttered and bouncing all around, and sometimes situations like this you have to compensate and do your best what you can unless you are a professional musician and you are playing with let say Cleveland orchestra (professional one) There, I would say 90% of the time, they are playing in the same hall with same air conditioning with same acoustics with same musicians with same conductor so that's the elite. They know what it will sound like, they are there all the time. Now, when they fly out Cleveland they go to some place like Miami, to do concert they get couple days of rehearsal to adjust to what they are doing to play. But if you have a college group, that doesn't have that it's hard. I mean I know how the theater sounds like here and now after doing it for number of years I kind of know how to compensate but you also know it will loud with the audience. But there is nothing much you can do about that. The other group here uses shelves. I can't do that because if I did that, it will really bring me___. So I need in a stage that all sounds all absorbed, we make sure the curtains are closed, and backstage is okay, etc. I play and play so that we are acoustically nearly perfect, and some places you just know, that no matter what you do, you couldn't make the sound.

Lucky: I know the band room here school is trying to do renovation if it is possible, if it is possible, do you prefer a room that you can adjust acoustics, like curtains, and change reverberation time, etc.

Conductor B: Yes absolutely it is important because if it is number of different groups that using that facility, it's very difficult to balance. I remember I was at university of Miami and I built a Guzman hall down there, they couldn't put the jazz band in there because it was just too loud. Too live. I haven't been there in number of years so I don't know it they did to change that, I'm sure they have but its very difficult. We used to go in that room with a quintet and a quintet sounded wonderful. Orchestras also had beautiful sound, good reverberation. But if you put a band in there or a jazz, it was just too much. So for a while, they started using it for recitals and such. But here, you need a facility for rehearsal that will accommodate these different groups of strings, naturally loud as jazz bands would or wind ensembles. And we need a theater that is acoustically good. How do you do that though? You know, acousticians here think differently then musicians, I've been teaching years in a small college where physics teacher had me come into class one day and said "oh I know exactly all the waves that come out in the clarinet, and the way it does, etc "and then I went in I played the clarinet and he couldn't explain to the class why it sounded that way. He could show them but if you duplicated them in a synthesizer it didn't sound like a clarinet. That's how humanity is, everybody got different bony structures, the waves that are bouncing off and all that, so I mean it's very difficult. I'm trying to think of any place that I played, hm, maybe down in Miami where they have symphony hall and then they have the hall for Broadway play, and opera and ballet then they have a beautiful hall. They have a hall that is beautiful in there; it seemed to me when I played there that anyone who played there would sound great. You totally would. They have one thing there that comes down from the ceiling, and that's it, for the microphones. And half the times they don't even need it. But what they could do here I had no idea.

Lucky: from your experience you're used to dealing with such….?

Conductor B: Yes I am used to dealing with it, when you do this long enough, you get to the point where you compensate rehearse in 260 and I listen and take in regards what the trumpets are playing and then I say "well here, the lower range of the trumpets don't carry well so I need to carry them a little loud"-so they practiced that way and when they go in there, we do acoustical check and do some balance. Let say it was a Sunday concert, then we'll do acoustical check on Thursday and then I tell them "you're going to have to watch this now, I told you play louder here but then you have to come down a little because it is being carried very really well in here so you don't have to play as loud as before" so the students have done it enough that they know how to respond to it. And then once we get up there before the concert, when the sound crew comes in 45 minutes before us and sets up, and then we get up in the stage, then my instruction to the sound people is "what we want to hear on stage are the monitors, so we can hear we're doing it all spread out. Your job is to make it sound good to the audience, that's what you get paid for." But we need to hear ourselves in the stage. And then I hope that the acoustical balance is all right, and usually when I hear it in the back it sounds pretty good. So they know what they are doing out there you know and you have good professors teaching those courses. And we may to some adaptations to what is going on, so I think the students when they are here long enough they also adapt. But that I mean this is the only way you can do it. If a student comes into this room, I know that at all edge, student can push into the instrument, it's going to be gone. It's going to be absorbed. And then, when they do that, during their juries, etc when they go play, they sound wonderful because I kind of compensated my brain to the way it's going to sound. And I've been associated to this place as a part time since 1970s, I was full time another university, there we had a very good auditorium and they spent half a million dollars improving and improving sound systems and did a very good job. It's down in Miami Dade college, north campus. But here, it's always been a problem. They spend a lot of money trying to fix the theater, but then it was never built for music it was built for people to come in and speak and those kinds of things. To me, here they should tear it down and start all over again. Build a good concert hall and good rehearsal hall. I work with what I've got. But I would love the idea, of like wood, because it helps project the sound. I don't know if I've ever done any jazz work in a concert hall like that. I've done strings, classical work, orchestral work etc as a performer playing and worked in a lot of recording studios, best recording studios and they will change their concert hall from a dead sound to a live one. I walk in and rehearse, walk out, it is what it is it would be great if they did something, don't have the high hopes. I know for 260, they would have to rip the whole thing, change the ceiling and everything else.

Interview with Conductor C

1. What are the most important characteristics of a room that support your coaching/playing?

Conductor C: Okay for me personally, first of all the sound has to be able to dissipate. There needs to be enough space in the room so that I can accurately hear all the frequencies and all the instruments that are playing in the room. If it is too loud, it makes it difficult to be able to focus to what I need to communicate with the students regarding their playing. So to get a correct representation of the frequencies those are being played in the room.

2. From a conductor's point of view, what are the most important aspects for students to rehearse to prepare the ensemble for concert?

Conductor C: Is for them to be able to hear each other. It is a very important to tuning, balance, blending sounds.

3. From a **performer'**s point of view, what are the most important aspects for students to rehearse to prepare the ensemble for concert?

Conductor C: The same, they need to be able to hear each other.

4. From an **educator**'s point of view, what are the most important aspects for students to rehearse to prepare the ensemble for concert?

Conductor C: Sort of what I said in number one, I need to be able to hear everyone, all voices.

5. What do you try to listen for during a rehearsal?

Conductor C: <u>Everything. I listen for timber, quality of sound, intonation, volume levels of different sections to create an appropriate balance. I listen for rhythmic precision and accuracy, all the elements in to making a performance as accurate and musically correct as possible.</u>

6. What aspects of student/performer playing do you discuss during rehearsal?

Conductor C: <u>Pretty much what I discussed above.</u> And I always talk about listening to, for example, if trumpets are playing with the flutes, I tell those trumpets "trumpets, you must be able to hear the flutes and match them or vice versa". So again, that to <u>being able to listen across the ensemble</u>. Another thing is that we talk about is note length and style. Sometimes, note length don't match even same instruments are playing exact same line, quarter notes might be longer for this group than they are for this group, and they must match each other. <u>They must be able to hear each other and match note length</u>. Acoustics and players both affect the sound but the room has to allow and give the musician an ability to be able to hear not only themselves but other instruments as well that are playing because otherwise they can't match something they can't hear.

7. How might this be different in a smaller ensemble or individual lesson?

Conductor C: I don't it is. I think you listen critically when you are in a small group.

8. If you are playing or rehearsing the same programs in different spaces, how are the acoustical attributes of the room helpful or harmful for listening and teaching?

Conductor C: <u>I prefer a slightly deader acoustics in a rehearsal setting because I can hear more.</u> I like it to be less forgiving so that when we get into a hall which generally has more reverberation the sounds better. In the end in the university they had a practice building with individual practice modules in there and it was always nothing. You went "clap" like this and it was nothing, you almost got no reverb and the first couple of times I played in there I felt like I was a terrible player. Terrible, because there was no reverb but it did force me to create resonance from within myself and that sort of thing. So I prefer something like that in a rehearsal setting, a little bit that you know not like a close. But <u>I do want it to deader so it is truer to what is coming out of the instrument.</u>

Lucky: Okay, and there are two more I didn't include. First one, I see two speakers in the corner. Do you use this for recording or..Recording studio?

Conductor C: Yes because of how small the room was, I have not to this point but I would like to. Just really not for publication, to publish a cd, but for review purposes, for myself. Just for study.

Lucky: And I know you have different group for ensemble, Do you think each student has different musicianship level?

Conductor C: Absolutely yes. You just saw the youngest brass players. My wind symphony is my top group and they come in before and I combine them. You noticed that this is just brass, I try doing that this year; grouping brass to teach brass __, maybe you are available you can come in and help me. And, first period I have the wood winds that are the younger ones and 4^{th} period are the wind symphony combined. Also the percussion is combined in a class and so there we have the battery percussion as well as the mallet instruments. The decibel levels go up a lot especially when the entire percussion section is playing.

Lucky: Yes, so sectional rehearsals….trombone….etc

Conductor C: Yes I'm trying to do that this year and it seems so far to be working well because I am able to work with them because they are so young, and still immature developmentally I can really focus on their basic skills. And then they are ready to move on to big ensemble.

Interview with Conductor D

1. What are the most important characteristics of a room that support your coaching/playing?

Conductor D: For me I think a room that supports what I want to do is a room that is big and that has a lot of space. Small rooms, especially if you have so many instruments whether high or low, and especially the lower instruments though, because as far as though waves have to travel it's really kind of, you know, before they refract back, I mean the bigger the room the better. Though I really think you get the sense of what is being played, and you're not constantly hearing different types of sound waves that are coming back off the walls. So, I think the bigger the group the more you want a stage that can allow the sound to really fill it up. I think that's so much harder to listen to if the sound bounces back and forth.

Lucky: And do you prefer the reverberation time drier?

Conductor D: Well, I'll tell you, it's always a fine line between whether you want to hear some reverb I think, it's important. But I think that, the back side of that, if you're in rehearsal you want ear detection, you want to be able to hear the group and go from there, be able to tell that it's "that clarinet" or "that instrument" because if there's too much reverb, it is nearly impossible to make such distinction. Or, room reverb into a wall that is behind you, that's not going to give you any sound, it could be very tough like that. At the same time, you want a little bit because sometimes that facilitates for people who aren't in the right area, it's obviously easy to hear the flutes and clarinets that are right next to you but you want the reverberation for the trumpets and whoever that are sitting in the back and the percussion especially for them to be able to hear the sound. I do prefer a room that is somewhat live, I don't want a room to be totally dead because it'll be just impossible to hear anything because you'll only be able to hear what's next you and that's it. So it's a mix I think. I definitely don't want too live though. I want somewhat a balanced reverb for the entire ensemble. It's also different when you perform. When you perform in a space and you need to make musical decisions based on how the space sounds there, then you might go to a stage that is very live, then you have another change. So you have to adjust and those are what dress rehearsals are for, to figure out the halls, if articulation is being heard, depending how dry or how live the hall is.

2. From a conductor's point of view, what are the most important aspects for students to rehearse to prepare the ensemble for concert?

Conductor D: I think in terms of what they have themselves I think it imp for them to <u>match articulation</u>. Entrances and releases all go <u>into listening to each other in the hall</u> and again it's related to the space that you perform and that not only the conductor wants to be able to hear but you want them to <u>be able to hear each other</u>. That sort of goes to how do <u>ensembles tune</u>, does it make difference where you seat people. And I think it does to a certain point because seating people differently helps more in the sense for them to communicate more than hearing each other or how affective their ensemble sounds. So in terms of what aspects I want them to rehearse is definitely is articulation, matching articulation. Obviously entrances and releases, and then of course constant intonation, all deals with being able to hear each other. Many ways, it doesn't have anything to do with the conductor; it has to do with them being able to hear one another because you can't change something you don't hear from one another. Final thing is balance and blend. Being able to hear how their parts fit with everything else to be able to decipher or not they are over playing their part, because so often they do that, and many musicians are often very stubborn about that or they have no idea how they sound compared to rest of the ensemble.

3. From a **performer'**s point of view, what are the most important aspects for students to rehearse to prepare the ensemble for concert?

Conductor D: From performer's view, sitting on the other side is very different or in the audience place. If you never played in an ensemble or orchestra, you don't understand what it is to be engulfed in sound, you know what you're hearing. Because too often, this may be your experience too but to days with players playing in a section, I remember how I used to be concerned about how we as a section were playing not necessarily what the ensemble was doing. You try to get that information from the conductor if you're too loud or so, but I remember always concentrating on who is or are we all playing together, or balanced and I think as a performer that becomes a big thing. Lining things up, making sure that all musicians are playing the right units and does all sound the same.

Lucky: So when you say playing together…?

Conductor D: Like I said, about conductors about articulation but I think it's self served. I think they're not, well, 35 ensembles do this, where saxophones listen to the clarinets on articulation wise and trying to match that. But I think actually for younger players, it is all about how our section is doing and do we sound as a section correct.

Lucky: yes, my dissertation is for band room rehearsal acoustic. And just for high school or college, so I'm not talking about professional…, etc…

Conductor D: Yes that is one of the things. The young ones are all into what they are playing. Wind ensemble actually most of the time you're playing unison with the sections, it's not as though you're playing second or first trombone part and yea you're matching articulation but you're playing your own individual line you want to make sure it is hear and balanced with everything else. Many times you're one of the three saxophones that are playing first saxophone or clarinets all playing so you're trying to give an ensemble sound to that particular part. So I think that's a focus a lot because they need to actually, it's very important. But I think they don't listen enough across the group, in terms of matching and all that. Sometimes it's hard to do that, it's hard because for conductors, you stop and you say "this is not happening". The conductor is very important.

4. From an **educator**'s point of view, what are the most important aspects for students to rehearse to prepare the ensemble for concert?

Conductor D: This funny because many people interchange educator and conductor simultaneously but the thing is that as a conductor, the end product is that, if you want to talk absolute end products for conductor is how the ensembles sound. And educator it is innate in the title, because you want them to understand why it is happening. So when you're asking this question, I think it's about them understanding of the hows and whys of making it happen as oppose to a conductor who can sing something, wrote to somebody, having them singing back to them correctly with correct tone, and then be happy with that, that is great. Whether or not they actually understood what the rhythm was on the page, or not, but for an educators point of view in terms of rehearsing, it is to rehearse the instruments with right dynamics, accurate and all that but the back side of that is, and it might very similar to what a conductor would say, is that they want it to sound good in an ensemble. But I think the educators view is a little different, they want them to perform in high level and want them to understand how to do that so you can apply to any situation as opposed to, you know, so often younger ensembles, conductors might butcher in the fact that the group can't play the correct rhythm instead of working it through them and deciphering them together, they just give it to them saying "this part goes tta tta tta tta" and of course they can immediately just replicate that and now, it's just about getting through piece and not learn it, understanding so that next time this appears in another piece I don't have to sing it to you again, you can just play it down. And of course a lot of the times, it's because they are not in such tight rehearsal schedule. I think that in terms of concerts, the why and how of the back side of making them still sound great making them know appropriately and correctly.

5. What do you try to listen for during a rehearsal?

Conductor D: You know, I try to make sure that I have set up my score correctly, and hopefully I have a <u>mental image of what it is I want to hear</u>, and not only in terms of what I want to hear note wise but also in terms of <u>blend</u> I want to hear and <u>the seniorities I want to hear from a particular piece</u>. But of course, that's where our interpretation comes in and asking people to play certain things certain way to articulate and be in a mental image you have. In terms of what I listen to are all those things. The thing is there are certain levels of that because on many cases you know, you can't get to certain level of musicianship on a piece until <u>rhythms are right</u>. I mean you can still talk about it and talk about what the <u>style</u> is going to be but one of the first things you do is you have to make sure all can play right stuff and then you start move away from specific contents. But I think most all, <u>in a rehearsal what I am listening for is errors amongst individuals</u>. Because you don't' have the time in ensemble to stop and test everyone at every measure to make sure that it happens. Going through a course of a rehearsal schedule such and such time every day 20 minutes every day on this section every day, is to take it slowly little it down, maybe through home practice or sectional work. In that rehearsal, you're again <u>checking what they are playing against your instrumental image</u>, so a lot of the times I will listen for error detection and be able to isolate so that when I stop I can be able to say "<u>that person was playing a wrong rhythm, or that person is out of tune</u>" I think that's one of the real things to listen to. I think it <u>changes through the rehearsal process</u>. I think you might listen more for error detection stuff during the early part of rehearsal process because they are still in terms of getting the <u>notes and rhythms</u> as a section but as you progress out and prepare the piece, you assume that they've got that down and at that point you are focusing on the bigger picture, about <u>balance and blend</u> and on how they are <u>sounding together</u>. And of course assuming too that the students are too going a lot the journey with you. It becomes more and more obvious if someone plays a wrong note, you'll be going through it and you'll be aware of all the parts and say "that didn't sound right" because you've gone through so many times before this and you know you've never heard that one before. But I think it changes so. I think you're <u>constantly checking from your mental image from what you want, how you want a piece to sound like, tone, balance, etc</u>.

6. What aspects of student/performer playing do you discuss during rehearsal?

Conductor D: <u>I think one of the things I focus on the great deal is tone quality. Is matching tone quality</u>. The thing is that, be it singers and everybody in the ensemble everyone is going to have a slightly timber and tone, and they will all be in different level of development. <u>So I stress on their ability to listen and match the tone and be unified violin tone</u> or unified clarinet tone because there are so many variations there. <u>Being able to listen, you constantly try to tune them to it</u>. So for younger players that's an ongoing process. Even the older players are still working at it but then they get it more. So constantly try to talk with students about how their individual tone is and I can think, maybe one of it is even if it not <u>matched perfectly</u>, is it a beautiful tone? Does it sound beautiful? And usually, if you as a performer can hear that it is a nice beautiful tone, and then you're going to be pretty much be in a ball part, also the other thing is that your students, do they know what a characteristic tone because after you listen you might not know what is, and you might be capable of. But I think that it is a focus-individual tone. And then, not only that in terms of performer playing its also about how they treat the ends of phrases a lot of the times. Because so many times, especially wind players, we are slaves to the brass. And so we learn early stages what are the best things, you might have <u>learned rules of breathing</u> from your first teachers, breathe from the bottom line or never breathe it here or breathe with your neighbors but at the same time what happens is that many times the music suffers for the brass. <u>End a phrase instead of playing a full note</u>, or cut that to an eighth or clip it or they don't know how to go about <u>making a nice release but still have good resonance</u>, but I think that's important thing to talk about you know, when you're playing in rehearsals.

7. How might this be different in a smaller ensemble or individual lesson?

Conductor D: Again, difference is that, well I don't know if it changes that much because the thing I notice is most often between smaller ensembles is that students who are always , even professional players do this. There is a way to play an ensemble, there is a way to play you play in a small group or a solo. You most often or not you play softer than you normally would in a solo, and you play with different tone in some cases because in that area, you're trying to match, trying to match and make a section sound good and sometimes if you'd ever put a spot mike on a trombone player inside of a section and listen to what they are playing in an ensemble, they might sound very awful to hear by itself. So to put it isolated inside the whole section, or entire brass section whole ensemble, you'd think that's a great job because moans aren't coming from the trombone because they're doing different things to accomplish their goal as a unit. So soon as you move into small ensemble type, that point you want to really work hard to get them, especially with younger students. Younger students, their opportunity to do well, most of their experience in playing in a horn is in small ensembles so when they come in college they have to more solos and more team work, I spend so much time trying to open their sound up, trying to make them play a beautiful sound until themselves because they're so use to playing with less air to not stick out too much and so it's a real different change. So you should be able to switch, to be able to play the solo, I control the dynamics, I get to control what piano, what forte is, and that makes a real difference, especially in a small play like this.

8. If you are playing or rehearsing the same programs in different spaces, how are the acoustical attributes of the room helpful or harmful for listening and teaching?

Conductor D: Well, just kind of before this. I'm a tuba player and I just came from a tuba lesson before this. And my students were sitting down in a room, a small room about this size, and for tuba it's not a great place to be for tuba. I don't know for any actually because practice rooms are always so small and because of that we think we are doing very well in terms of air support in terms of because we're always getting immediate feedback that is only 2 feet away from us. We think our forte is too loud or too much air, but as soon as we move them into a bigger room, it's miniscule. It's funny because one year or couple years ago they made the practice rooms have reverb out and stuff like that and yeah that will give a…

Lucky: Do you like it?

Conductor D: Well, I don't know if I like it, you know what I'm saying? Because it lies to you a little bit. You can pick up anything and put reverb on it. Whereas if you're in a hall, only so many, only sound of certain amplitudes is going to give you something back but we constantly talked about let say for my tuba players when their waves are coming out of the hall because they are such low instruments so because they are such low instruments those waves have to have a lot of distance to kind of open up, before they come back. We always talk about trying to play in that small room, as if we are playing in the large hall and <u>you want the last person from the last row to hear you</u>. It's that idea that to of that dynamics in a solo inside and outside of the room, is to always move up because piano becomes bass level for your piano moves way up, so often and not that is a real harmful perspective. Are they helpful things to it? Yes to some extent. If you are in a dead practice room, you can hear yourself and what you're playing more often but I think it lies to you too much I think you're going to practice the better thing is to have small room. Then you get a really good idea of what is happening there. Of course, you don't get the nice reverb, but you'll be able to tell a little more. The bigger the instrument the harder it is. When it comes right down to it tubas should be practicing in a huge room all the time, because it's just their nature of their acoustics of their instruments. It gets them a better idea of how their tone is reacting, how their sound is filling up the space and then with that respect, of course with all of the places that we perform, I think at the same time you have to be able to be in a room that is conducive to the instrument that you're playing. I'm not saying that clarinets can't be in a bigger room either and they should be as well but I don't think it affects them as much because for like tuba players to be in a room, any sub. Vibrations rattle light fixtures anything that's in that room. You know, it's hard. Also, just the decibel level given that are given in some of these rooms, depending on the instrument you're playing, percussion particularly if you're in a small room, because of the size of the room decibel level is so high in a room like that that is also harmful.

Lucky: have you ever rehearsed in band in any variable acoustic room?

Conductor D: well I don't know if we ever be in a place where we were able to make changes on the acoustics but I guess the most we can ever do is let say for most halls have curtains drawn or curtains open and I've been in halls where I've done that and determine if we want bare walls . But most often depending, let say for instance 800 seat, you want those curtains drawn because most of the times you might get sound from those back wall that you won't want. For choirs many times, they open the curtains because they want that reverb bounce of the walls, but I think that's pretty much the most acoustical changes you can have really aside from obviously from any type of shelves that can give you any type of projects to the audience. Like is said I've been in many times like that, and then I don't know if that is too variable acoustic thing? I think it is just technological, etc. It's like putting an amp on a guitar. It's going to give you give you something out of anything you play. So I think that's the big difference. I think going back, moving people around will definitely make some difference and affect how you sound because understanding the instrument amongst and obviously directionality like instruments like horns as opposed to clarinets, which really has a sphere sound, so I think that features in as well. And so you can start playing with that all of it.

Interview with Conductor E

1. What are the most important characteristics of a room that support your coaching/playing?

Conductor E: Sure. I guess. You have to forgive me. I don't know all the terms. But it is diffusion, so the player can hear themselves or hear themselves across the room. The range and the adequate ability of diffusion of the sound, so the player in this quadroon and the players in this quadroon are hearing the people on the outer side of room, and the reasonable level of room is not overwhelming and that is acoustically legitimate that actually as the level equal to the volume that has been perform back, so that is not artificial and attenuation or artificial increase and the volume. Does that make sense? So that is primary, especially in a chamber situation. Just to make sure people can hear adequately and what they are hearing is honest reflection – the sound has been produced from the instrument.

2. From a conductor's point of view, what are the most important aspects for students to rehearse to prepare the ensemble for concert?

Conductor E: Well, this is really good. There is two different elements. In terms of rehearsal and performance. Again, the diffusion, <u>the ability to hear across the ensemble</u> is so important. But for the performance, well that is absolutely vital that they hear across the ensemble. The throat, the ability to projecting that the mixture of the sound out to the house or the audience. And again the honest way that actually reflects <u>the volume and balance of level</u> that we retrieve. You know in our theater and most theaters, so much crank it up of the concerns that I have was to spend a lot of time trying to really <u>refine the tone qualities</u> to reflect the certain overtone. And then all that work will be dismissed by the wrong facility.
I guess the most important characteristics is to project the complete sound into the audience in an authentic way that relates those have been created by the ensemble. That is to say I am not looking for necessary a theater that helps, but just to reflect what we are doing. I think that there sometimes you get houses or halls that are artificially reflective and they trying to create the activity in that environment. Sometimes there are misleading but there is too much reverberation.

Lucky: Yes, you could not hear a lot of details.

Conductor E: Right, some people like that. It reduces the degree of what we are trying to do. Everything has to sound like an organ or else they sound out of the place.

Lucky: So, I just wonder, beside the loudness that you were talking about and also students to be able to hear each other. Do you think intonation, rhythmic, articulation or dynamics …

Conductor E: Oh, I see in terms of elements of sound.

Lucky: Yes, or musical quality

Conductor E: Sure, well, it is really good question. In terms of pitch, I supposed it really end it up that hall affects pitch in terms of which overtone is going to be reinforced. So the hall reinforces the upper overtone, the upper most overtone that obvious going to be a challenge. Because there are not going to be the true to… The further up, the series you get for the further the way you are from just the intonation, which makes the problem because I mean you can't tune those, like eight partial of a tuba to the third partial of the flute that to have a chance to be really in tune. Does that make sense? So, when they really exaggerate the upper overtones, that is when they facing the problem. We are trying to flight physics.

3. From a **performer'**s point of view, what are the most important aspects for students to rehearse to prepare the ensemble for concert?

Conductor E: For performers, I think it is the same thing. They want to hear themselves- clearly. And then be able to with only a little bit of intellectual engagement, to be able to focus their ear on other players across the stage. It is very intellectual process to dis-engage everyone's playing and somebody else, they want to be able to do that, but at the same times not be overwhelmed by other sounds to be able to hear themselves, is that compromise, and to be able to switch to one to the other. For instance, the very complex composition that the player was about their own work. If you were playing Kandinsky, you were only focusing on yourself, where as if you were doing Rachmaninoff, it's about creating this blend this wash up sound. So it is having a facility that is flexible for both-in a hall which allows a player to really concentrate on their own sounds, for that sort of repertoire and that is particularly 20th century.

Lucky: Do you prefer band room with acoustics?

Conductor E: Sure, in terms of rehearsal hall I've never had one of those it so I couldn't say I prefer it but I would say that if I were in a conducting ensemble, and traveled in variety of halls, I'd love the ability for the students to be able to play with a variety of reverberation situations from one location, without having them move around across state lines to be able to different lines. Plus to prepare for professional musicians, they're never going to play in a same hall twice.

Lucky: My dissertation is for specifically for students, so after you become real performer you are adjusted to it but most of college students some of them might have that ability but most of them..not.

Conductor E: Yes that helps a lot. My goal for the acoustic situation is to be predictable so the students can have consistent and a standard which to judge. To degree to which they can hear an instrument 20 feet away is consistent from day one to day two. Cross repertoire.

4. From an **educator**'s point of view, what are the most important aspects for students to rehearse to prepare the ensemble for concert?

Conductor E: I guess I would consider those the same, educators from conductors. But again, that comprise from being able to hear their own sound with clarity and being able to hear other voices.

5. What do you try to listen for during a rehearsal?

Conductor E: Well, that is a loaded question. <u>Depends on the repertoire, every work has a different requirement. I normally listen in terms of layers, I listen for formality layer, mid-devise layer, etc, a purely harmonic layer. When I'm talking about layers I'm usually talking in terms of function. I rarely listen only for timber. I rarely go in rehearsals trying to listen for a trombone, I'm listening for counter lines, sometimes it's for trombones, sometimes for others.</u>

Lucky: Do you have to stop and tell your students their intonation is not correct? Or rhythm?

Conductor E: Yes in the band room I do a great deal of that. Band room, one of the most common phrases I use is “please direct your listening to…” like trombones to saxophones who share the same pitch, etc. that is mainly, in terms of rehearsal I’m trying to help focus them on a specific voice which will help them play more musically, to unlock the piece. What I am listening for is to see if they have accomplished that.

6. What aspects of student/performer playing do you discuss during rehearsal?

Conductor E: Well, I try to analyze rehearsal like that. To see effective I’ve been over a course of a month, is to see in a rehearsal how many times have I discussed about articulation, how many times did I discuss intonation, how many times balance, blend, tone quality, …to determine if I’ve been varied enough. Because everyone ends up falling in holes where you’ve spent three rehearsals talking about dynamics all day long. All of those things and try to be balanced with all those. Some works is more articulation then blend, some more other elements. <u>So depends on work. Articulation, intonation, balance blend ensemble alignment and rhythmical alignment. Those are the basic. I think every ensemble that have rehearsed well rehearsed the fundamentals.</u>
7. How might this be different in a smaller ensemble or individual lesson?

Conductor E: Well when I’m coaching chamber music my goal is to detach myself as much as possible to have great independent learners. Often becomes self coaching, and they learn to, they address what to listen for and what to create and I try to give an intuitive atmosphere. When you have 70 people in the band, it’s a lot of authority, you just have to be. It would be great if everyone could unlock their musicianship but if there are 70 of you, you have to do what I say. Or for 12, it’s a little more communication on one and one and try to get more of the individual listening and adjusting to be much more rapid. Allow more musical freedom and decision making. This phrase can go to 4 different ways but you can pick which one, because you’re the one playing it.

8. If you are playing or rehearsing the same programs in different spaces, how are the acoustical attributes of the room helpful or harmful for listening and teaching?

Conductor E: I program based on space. I program different repertoire to see if space will be a little different. For instance, worst case scenario, many of invitational conferences that bands play at, are involved. They play portable stage in a ball room. This is dead as door nail. So I specifically program to make energetic music and I won’t program an organ transcription because there is no reverberation and anything that is created there would have to artificial. <u>So first thing it affects is programming</u>. But <u>rehearse resonance rather than reverberation we rehearse how to end a note so to make it sound like a natural reverberation.</u> How to end a note with resonance so that you can artificially re create.

Lucky: so does that mean if end note has two beat, you try to ….?

Conductor E: Well we try to rehearse to end a note exactly there and then well the process I use is that I will have a whole note and indicate different dynamics and then we do the same with two beats then same thing with one beat and finally open to eighth note and then I'll have another whole note followed by that. <u>To create artificial reverberation. And length of this, the reverb of the decay, is dependent on the acoustic environment we're going to perform in.</u>

Interview with Conductor F

Speaker: Ultimately what those numbers mean are the matter of judgments and opinions that people that listen. So one of the struggles is to try to find links between the judgments and opinions of people like yourself relative to qualities of music and what's some of the scientific or quantitative measurements that we can make in rooms and models of rooms we're designing are actually telling us about what is in the room. So notion of trying to get from experienced musicians conductors and what their impressions are from the acoustics of a room and acoustical situations, how the room can affect what they hear and how they teach is it the heart of Lucky's dissertation. We've been really trying to deal with this so that those more qualitative judgments about music qualities in the room can rise to the top as the way of interpreting what the measurements tell.

Conductor F: probably the best thing to do, for your sake, because I'm going to give you my opinion and my opinion is probably, on the national level you might want to get like 10 people's opinion, and ask maybe basic questions to. And then in your study you might even want to say these are the ten people I consulted, famous conductors from bands around the country, and here's what they thought. You can sample on hundred band directors and come up with something but if you sample the 10 really good ones you're going to get more accurate representation than if you would sample 100 mediocre ones. So you might get some people that might disagree with me on a few things but I will tell you what they are. IN general, I told Gary this when we were building the room-I said "I want a dead environment, not like a concert hall". Now, the difference between me and some people is that I want to rehearse in a dead room all the time where some people, on last rehearsal or two would like to throw open curtains out there and make it sound more like the concert hall. Which they do have that option. So you have a multifaceted room here where you, we record with the curtains completely open and it sounds like a concert stage. We shut the curtains and its dead and the other issue is it's also a much safer environment if you get a large band in there. So that being said, my goals might be slightly different with my colleagues at the University of Texas and University of Michigan. It might be same, I can't speak for them. But I can speak for who's qualified to answer. And who the best people are to give you an answer. And then you can ask as many as you want but I would say if you ask 10 people, you might get a little bit different answer from 10 people but at least they will be cut up in a people that are going to tell you whereas if you go fishing around for a bunch of directors, you're going to get a lot of people that don't know what they are doing. It's like doctors and physicians, you just don't know it because they all look the same. And also, who's got nice facility, like this guy at Colorado; he's got a wonderful new facility like ours. And he loves to rehearse in his room. I don't know if his room is like ours but he might have a room that has it sound like the way he want-like a concert hall. It's possible. His name is Alan McMurray. So his one of the names I can give you. I can come up with ten fairly quickly I can even give you their addresses.

Lucky: are they all going to go to the conference in Chicago?

Conductor F: They will all be there. Most likely but they would be hard to track down because they just go to Chicago to mess around. There are several that would give you qualified answers, like the guy at Texas, Chicago, Illinois, etc. (Prof now goes over the questions…)

Q: How many people are there usually in a wind band?

Conductor F: So, if you define a wind band as a concert wind band like most people do, the size band 40 though a large symphony band of 120, with the average band being 60—70 players. Now, a marching band would not be really referred to as wind band. Wind band refereed to concert band. Marching band is 60-400. Quite large difference, depending on size of school. With the average 200-250 for university, maybe 100 average for high school.

Q: There are couples different wind bands in school, is there a rank for each band, and why? For example, Wind Symphony at UF is formed by the best students for each instrument group out of entire school of music.

Conductor F: There is couple of different bands in the school. For instance, yes, almost every university has a top ensemble called the wind ensemble or wind symphony. Wind ensemble refers to one of the part players. And even still wind ensemble might double parts, like some clarinets and trumpets. So wind ensemble could be around 40-60 players. Wind symphony implies a hybrid symphonic band in wind symphony and it might be slightly larger but could be same size as wind ensemble. Players are grouped in bands based on ability. Top group has best players, in this case, our wind symphony has the best players, next is the symphonic band and then concert bands are pretty much even. That would be mirrored in almost every school. Top group called wind ensemble or wind symphony. Even in some schools that are more old fashioned could call their top band symphony band or symphonic band. Like at University of Michigan, top band is called symphony band. So you kind of have to ask what the names of the top band are but they are grouped by their abilities. At Florida State, it is called wind orchestra. South Florida, it is called wind ensemble. University of Texas, it is called wind ensemble, University of Illinois, wind symphony. Michigan, symphony band. Wind ensemble implies one person at a part; concert band implies a smaller wind band for about 60 players. And a symphony band could be as many as 80-100 players, with multiple players at each part.

Q: Do you agree that there is a difference in level of musicianship and musicality for professional musicians and college/high school student musicians?

Conductor F: There is a difference in musicianship and musicality for professionals and high schools, yes. The difference is professional musicians, college students are half way between high school and professional. There are difference levels of players. Most college players aspire to be professionals. And often times, outstanding high school and college groups can sound professional, this has to do if they make characteristic and fundamental good sounds they can confuse you and sound like a professional band. I would suggest to you recordings of our band, would sound as good as recordings of top service bands. You wouldn't expect that. But it is possible. And also you will find some outstanding high school bands that will sound like college bands or even professional, depending on their quality of conductor, or number of rehearsals. We have more rehearsals in college, and they have even more rehearsals in high schools. Professionals do it minimum rehearsals. Group rehearsals as supposed to individual rehearsals. Professionals don't need practice a lot of things, they practice other things and they just come in and read the music. They know the music already for the most part. They learn it faster so they don't need much rehearsal.

Q: What is musicianship?

Conductor F: Musicianship, it doesn't mean ears to playing an instrument. In relation with music theory, it is just small part of it. Musicianship is just those undefined things that people that posses it know what it is, and people who don't, have no idea what it is. Musicianship is the ability of an individual based on his level of ability and level and all those things kind of conglomerate. So, most people thing they are good musicians but…it's like the movie karate kid, where someone always know more. Somebody might be a 6th degree black belt as supposed to a 4th degree black belt. A great musician like a "Yo-Yo Ma" or someone that has achieved success maybe playing in top orchestra in this country. Probably has a lot better musicianship than someone else. Whatever level of ability someone has attained in total knowledge of music and artistically development on one instrument.

Q: What is musicality?

Conductor F: Musicality is basically the same thing as musicianship, means the level of performance ability that a person posses either as a conductor or performer. It is safe to say best player has better musicianship than normal player; it's safe to say that. Although, sometimes people have very fine musical ability but maybe they are on their edge in music playing. In other ones, they once were great musician but through lack of practice or maybe illness they've lost the ability to perform at high level but maybe you wouldn't necessarily say that they have lost all the musician skills. It's like one of those things you can't take away from someone. It's like saying you are taking away all of their knowledge they might not just perform anymore but they might still be a superior musician, they might write music or conduct music. They still have a high level of musicianship even though they might not perform anymore. Most of us start as performers, in other words. So, the best player has best musicality than normal player? I mean, not necessarily, some people are gifted in terms of having or being technical experts like you might find a child prodigy of age to 5 that technically who can play well and sound fantastic and he may have better technical skills than a college professor might. But their knowledge would maybe not be as refined and maybe they might not know anything much about music. So if you say best player, the best player may not have developed musicality all that far but they might just be all just very talented at something at one particular skill of playing.

Lucky: So if a student came to school or ensemble, as part of reason is to develop musicality?

Conductor F: They want to become better musicians and that not only includes technical expertise but also includes total education about music and styles and history and theory, it involves a lot of different things.

Lucky: So musicality, the word definition is like…you develop your technical skills?

Conductor F: musicality is the total musical education that a person posses at whatever level they are at so the more time they spend studying and working on music probably the better musicianship they have. Now just the skills of playing the instrument is all a part of that but musicianship is all kind of very elusive terminology to talk about. Technical skill, good tone, are finite things. Musicianship is harder to define.

Lucky: I was trying to define, high school music students have different level ….?

Conductor F: Different level of everything, of expertise of instruments, different level of musicianship because they haven't had very many life experiences like music experiences. Like, if you say play this in the style of Prokofiev, rather Stravinsky they won't know what you're talking about… Even a college student might not know the difference. Professionals have years of expertise. Years of experience, experience is a key element of musicianship. But not necessarily, in terms of playing expertise. So younger the students are, the more they need a conductor, a leader and more experienced performers are, the less they need a conductor. Conductor kind of helps them stay together because they play extraordinarily well without them.

Q: What are the most important characteristics of a room that support your coaching/playing?

Conductor F: Well, I think the most important characteristics of a room are the ones that musicians can hear and musicians can see. So you have t have enough light, an environment that makes it possible to hear things around them. And hopefully is somewhat pleasant environment for the one who sat there. So comfort is also important.

Q: Do you think the room acoustics will affect phrasing, tempo and style of music?

Conductor F: No I don't think so. Only musicians and conductors would affect those things. I think acoustics can make it sound better.

Q: Do you agree there are affects with different reverberation in a rehearsal rooms?

Conductor F: Yes.

Q: Do you think the rehearsal room has less reverberation (dry condition) can help you and /or students to listen for intonation, rhythm, dynamics and articulation clearly than the room has reverberant condition?

Conductor F: Yes, it definitely can. The less stuff is bouncing around in a room, the less confusing it is for the players. So if they play true sound in dry environment, like if they are playing outside, which soaks up all sound, they can hear themselves very well. They might like the sound playing in the bathroom, but the truth of it is if you have two or three people playing in the bathroom, sound will be bouncing off the tiles all the time, they won't be able to discern anything by it, only the fact that they are pleased by it. So that is why I say whether its pleasing to a player, is really not that important. But rather if they can hear, that's important. They are reverberant environments where players can hear better than others. So, it doesn't mean just because there is more reverberation, that they can't hear. There are some concert stages that are really for listening to the other players. So it is like having an environment that's drier on stage that they can but the hall kind of pulls out and enhances the quality of sound and actually gives a little reverb to it, I guess that would be a fairly desirable thing.

Q: What about for rehearsal as a group?

Conductor F: For rehearsal, they want to be able to hear. So it is true that it can be so dry, playing too loud on one side and loud on the other, maybe there isn't enough sound traveling back and forth. I mean that is possible too but I would say in general, in our room we've been pleased with the ability to hear from all over the place.
So yes, it definitely could help, tuning, listening, dynamics, and articulation.

Q: From the conductor's point of view, what are the most important aspects for students to rehearse to prepare ensemble for concert?

Conductor F: Well, the most important thing to do is, it takes time to 60 people to <u>think like one</u> and to match and to do all the things necessary. All of the <u>fundamentals of music</u>, there are different difficulties involved in making them come <u>together to sound as one</u>. So that take a little bit of time and younger the player, the longer it takes. The more professionals, the less time it takes.

Q: From the previous interview with you, you mentioned "I just want them to be able to hear themselves and other players during the rehearsal". Can you explain more about what do you want them to hear?

Conductor F: I want them <u>to hear what they sound like in conjunction with others</u>, I want them <u>to hear whether they are in tune</u>, <u>whether they are in time</u>, and these are all fundamentals. I want them to hear if <u>balance is correct</u> and I want to be able to let them know what I want to hear in terms of <u>balance and blend of sound</u>. I give them the opportunity to play in tune with a nice sound and then we start <u>working on trying to get better intonation, and better togetherness, better dynamics and all the fundamentals</u>.

Q: When you mentioned “balance and blend”, what do you mean of these two terms? Do you mean to ask students to listen for dynamics and adjust their playing to get balance or their section to other section? What about “blend”?

Conductor F: <u>Balance and blend</u>. Balance is what you want to hear as opposed to another. If there is a solo in one instrument and everybody else is accompanying, obviously you want to hear more of the solo and less of the accompaniment. However the balance of those two, how much of each, the conductor decides. And to a certain degree the players decide until the conductors says otherwise. But usually you have to address balance. Now, also it could mean you want to hear more from one chord tone than another, if you have , not enough ones but too much of a third, you might back off part of a triad and part of a chord root third or fifth, or whatever. Let’s say a third of a chord is too much. Then you would have to balance that by saying, I need less third here, would you play quieter if you are playing that third, English horn, or tenor sax, a little quieter please. And so you’re getting a proper balance. Blend is a little more complicated. It implies qualities of sound and how it mixes with other instruments. It’s exactly what you would think of when you blend much of ingredients together when you’re cooking. You want a certain blend of sound. It also is connected to balance. Like trumpets and trombones, I want you to play into the stands, and then I want a lot of clarinet. You’re blending sound just like you’re mixing together a nice cake and you’re chef. Blends of all these sounds and what kind of sound they are, which again is very complex. The hardest thing for a conductor is to draw the blend of the sound and mostly professionals, you don’t really with them. Most conductors don’t do it. They used to, 50 years ago. Conductors would have ensembles making specific sounds, depending on what the conductors wanted to do with them. Now, it’s changed. Professionals sound like they sound in one orchestra and another because they sound that way. Not so much because the conductors want them to sound that way. Most other groups in the world like school groups, etc, are very affected by way the conductors’ image of the sound is. Even in professional world, you’ll find professional conductors will get a certain amount of sound and other conductors will get different sound. And a lot of it is based on the way they conduct, how their gestures are, and mostly affected by what their concepts are in terms of what they want to hear. Some people like very brass dominated sounds, so they are always working on getting a little bit more brass. Some people don’t like edgier sound, some people like darker, this is all about blend. Balance is simply more of this less of that. Blend is the right balances but also a different quality controlling the quality of the sound with the balance.

Lucky: so can I say blend is more like, conductor listening to the whole….hall..??

Conductor F: The hall is going to contribute to the quality of sound so it has impact in blend a little bit. Yes balance is affected as well. Here’s why, in our hall I don’t hear enough trumpet. The bad thing about that because they are seated in the further back, I am always wanting them to play louder. That's one of the problems of wanting a dryer environment the things that are further away, you're not going to hear much of it in rehearsal. So we realize that when you get on stage, the trumpets might have to tone it down a little bit, or percussion too because they will bound off back of the stage when they get in there. So bad thing about rehearsing in a different acoustical environment is that you have to realize what is going to be like when you change places. And are you going to have to change what they've done in every rehearsal. Now, if you taught good ensemble skills they will naturally adjust to the new environment when they get there. Or you can say, percussion a little bit less, you have to be careful here. Maybe that's all you have to say. They've already rehearsed their parts, they already know how to play it, they already know what to hear. We change our halls all the time when we play and it's our minimum problem. But it sounds different in ever place and in some places you don't hear compared to others. Well rehearsed group can adapt to a change of environment with a very little consequence. Weaker groups might have more trouble with this.

Q: From a performer's point of view, what are the most important aspects for students to rehearse to prepare the ensemble for concert?

Conductor F: I would say as conductors really. They might hear it differently from sitting in a chair when they do in front. That's one of the things players have trouble with. They hear themselves and they think about themselves a lot and their parts but they don't think about the whole thing. So their perspective of it is completely different when they are in middle of ensemble. Some things they'll hear better, something's they will not hear at all.

Q: From an educator's point of view, what are the most important aspects for students to rehearse to prepare the ensemble for concert?

Conductor F: From an educator's point of view in rehearsals, I think all the same things I mentioned, all the fundamentals of music, good quality tone is most important thing, intonation , dynamics, technique, rhythm,, style, phrasing, those are all the fundamentals that every educator, all the conductor, performer should be concerned about.

Q: What do you try to listen for during a rehearsal?

Conductor F: <u>I listen to everything.</u> And the more experience conductor hear more. One of the things I told my conducting students yesterday was that we'll spend more time working on ears next semester and what that means is that we're going to work on what they'll hear. A younger conductor probably, no one is created equal when it comes to the ability to hear. And so when they started out ear training, some of them did better than the other. So with experience and musicianship you hear more. You might hear the slightest finite difference in terms of <u>pitch</u> whereas in younger conductor might not hear at all. Professionals, you shouldn't have to talk about pitch. But with everybody else, you do and even if professionals, sometimes you have to say guys, we need tune this/chord, trombones and oboes play that chord for us please. Okay. Now lets go back and take it in A. You wouldn't have to say Oboe, your pitch is flat or trombones your pitch is sharp. They are professionals. With my students, I give them a chance to fix it, then I'll fix it for them, I tell them that's a little high, to can you bring it down, or fifth needs to be higher, can you bring that up a little bit. I'll tell them and then when they hear they say "oh okay". You isolate it sometimes in rehearsal and then they hear it and then you move on. And that's what you do, you're constantly tweaking those kind of things. So you're listening for everything. All the fundamentals of music.

Q: According to three band rehearsal videos; intonation, rhythm, dynamics and articulation are identified as being addressed frequently by the conductor to student musicians. These elements are separately agreed and rated by student musicians as the listening criteria during the rehearsal. The overall percentages of 206 student questionnaires for the four fundamental musical elements are 90% (intonation), 89% (rhythm), 73% (dynamics) and 94% (articulation). Therefore, do you think if it is safe to say that these four elements are the most fundamental listening criteria during a rehearsal for both conductor and student musicians?

Conductor F: I guess, that's everyone thinking that we all work on the same stuff. Which is right, now, inexperienced conductor will not spend much time working on blending of tone, and he won't spend much time on tuning. Because he won't hear it, he won't know what to do. What he'll hear is precision maybe articulation and precision and tempo and dynamics. Because those are much easier to hear then quality of sound you want, molding that quality of sound and the tuning, that's what they hear last.

Q: What aspects of student/performer playing do you discuss during rehearsal?

Conductor F: Just the same things we all discussed. (same as 17)

Q (19): Do you think intonation, rhythm, dynamics, articulation and speech intelligibility can be affected by room acoustics? And why?

Conductor F: Yes, 19 is yes they are all affected by room acoustics. Because if they can't hear, they can't tune. And if it is really reverberant, they have trouble playing together so rhythm can suffer, when they can't even hear if they are playing the right rhythm. If it's too live. Dynamics can become confusing because a reverberant room can expand the dynamics to such a plan where you don't know whether they are too loud or not. And articulation is covered. So for a dry environment, you can hear precisely what kind of articulation somebody has. Whereas reverberant room, it's all covered up. You can't get to the source of the sound which is articulation, the tongue, with the wind instrument and with the attack in percussion instrument you can't hear what they're doing, so you can't really fix it.

Q: How might this be different in a smaller ensemble or individual lesson?

Conductor F: In smaller ensemble, where there are fewer people it's less of a people. The more players you have, the more you have the possibility of 60 different articulation. So you want everybody to tongue the same way. It might be "ts ts ts ts ts"-- there might be a specific articulation you want. Like "Guys, very legato" D D D D , play that. Maybe a little heavier on articulation. And then you try multiple times you try to get a match there. But if it's reverberant, you might not even hear it.

Q: If you are playing or rehearsing the same programs in different spaces, how are the acoustical attributes of the room helpful or harmful for listening and teaching?

Conductor F: Yes, because <u>we record in there. I would be happy if it were dry all the time.</u> I also would have people get to last rehearsal and open up some curtains. Some of my colleagues, I think that's fine, it's personal conductor discussion. They want to get closer to what it's going to <u>sound like in the hall in the last rehearsal</u>. Personally there are many more things to worry about than that for me. Just happy to be in a nice room.

Q: From conductor's podium, can you hear the four fundamental criteria clearly for each instrument section? From closer distant section such as flute, clarinet, oboe, bassoon; to medium distant section such as horn, saxophone; and to the farther distant section such as trombone, trumpet, tuba and percussion.

Conductor F: You're talking about the 4 fundamental criteria of each instrument; I would say that tone is one you left that in number 19. Tone, quality, intonation, rhythm, dynamics, articulation, balance, blend of sound, these are all fundamentals. The 4 fundamentals you've mentioned are articulation, dynamic, rhythm and intonation. There's more than that. But let's see.

Conductor F: Again, this depends on what you can hear. Some people can hear more than other .you can go stand there and say "I don't know…." And I might say I do hear something. Because some people, we're used to listening to things. Some people can hear things better than others. The timber of instruments identifies quicker in my mind. If I want to focus in trombones, I can do that. Trombones don't really sound like euphoniums. But they would confuse the average listener. They would all think euphoniums are all trombones. But there's a different sound and so schooled conductors will know the difference. And they would hear where the sound is coming from. But from a closer distant, it is easier to hear, being right in front of you. It is also easier to get the balance right.

Q: Do you think it's appropriate to say that these four fundamental music elements are most important listening criteria that you would think and like your music students to listen for during the rehearsal?

Conductor F: well, I'll always wanted my students to listen to their sounds, how it fits in, the blend and balance of their tone, their tone, nice tone whether it is balanced and blended with everyone else, that their matching style, articulation, phrasing, that they are playing in tune, that they are playing in time, that they are playing in same style, other words by style means articulation and spacing. So, all of those things and then dynamics and etc, all those are fundamentals and all those things are what I want them listening for from beginning of rehearsal till the end. That's what they are listening for until they are playing.

Q: Can you rank these four fundamental listening criteria (intonation, rhythm, dynamics and articulation) in terms of difficulty for an average high school player?

Conductor F: You can't really rank them, you can just say what they are. I wouldn't rank them.

Lucky: I guess, I was trying to find out which….?

Conductor F: I'll tell you what's more difficult for average high school player. I think it is easier for them to hear, whether they are loud or soft. That's the easiest thing for a high school player to hear. I'm loud, I'm soft That's something that does not take a whole lot thing to figure out. Rhythm, they can probably discern whether they are playing the correct rhythm or not, at least to find out what it is. If they can't read music. Articulation is harder than that to do because it involves, technique of articulation is sometimes very subtle thing and there's difference level of that so that will be harder for them to discern and then rhythm ir dynamics. Hardest of all will be the tuning part. Eventually if they learn to listen for tuning, none of them are difficult. These are all things that could be taught. But if you work with an average kid, they will hear first whether they are loud first, they're going to be able to hear rhythm next, articulation, they will be able to match that after that and then tuning is probably will be a little more difficult.

Lucky: and then get to more high level symphony band, then from intonation and down, students work on more phrasing and style …? I mean for high school it is very basic and ….?

Conductor F: For high school bands and all bands, they will work on same things. They will just be less skilled. You said average high school band, I say it's true for everybody. I'd say at all levels, people are easy, it's easy to tell whether its loud or soft , it's less easy for them to tell about tuning.

Lucky: so that means, in rehearsal in high school conductor will spend more time in intonation?

Conductor F: not necessarily because he won't hear it, the average high school band director isn't very good. And they don't spend too much time on tuning, they might, if they are good. Younger conductors will spend more time on precision trying to make things line up. And dynamics because they hear those things. They might not spend too much time on tuning, even though they need to because they don't hear it you can't work on what you don't hear. That's why ears are so important to develop as a conductor. Most people don't realize that. But it takes a lot of skill in terms of listening and refining sound because your ultimate goal is to make it sound as good as it can.

APPENDIX B
MULTIPLE SOURCES AND RECEIVERS MEASUREMENT PLOTS

In order to see the individual room response in a clearly manner, the following acoustical measurement results for the three band rooms as well as for the multiple sources and receivers with acoustical parameters (EDT, T30 and TC) are presented in Figures B-1 to B3. Each figure contains three columns and four rows. The order of columns from left to right separately represent band room A, B and C measurements. The order of rows for each column from top to bottom represent location of source 1, 2, 3 and 4 for each band room. Within each individual graphic, the dotted line means the receivers are near the source whereas the solid line means the receivers are far away from the source. The legend of the receiver location on the right side of each graphic is based on the near to far distance relative to the source. Reading the graphical data with measurement floor plans from page 71, 72 and 73 will help to locate the source and receiver locations clearly.

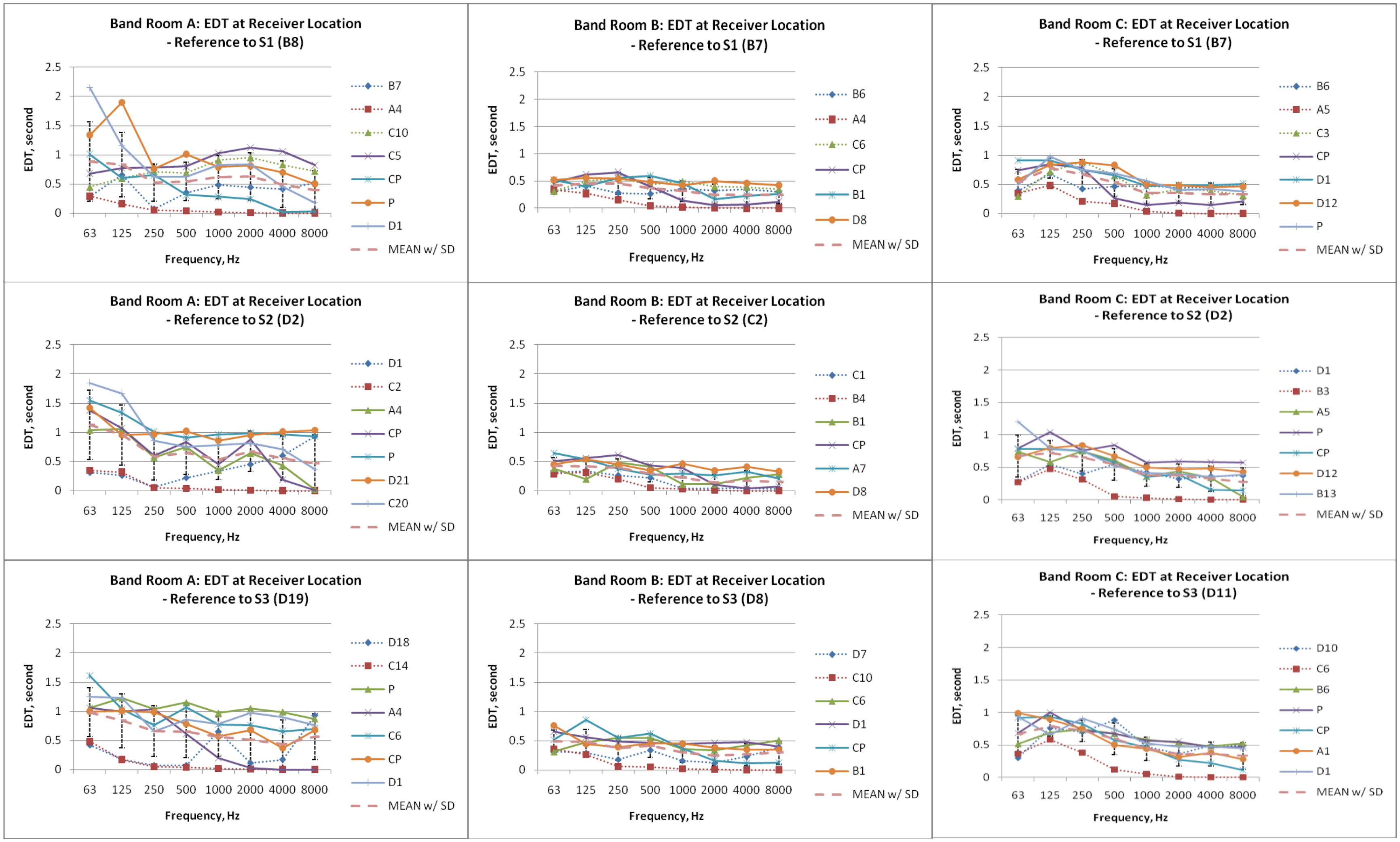


Figure B-1. Early Decay Time (EDT) in the three band rooms.

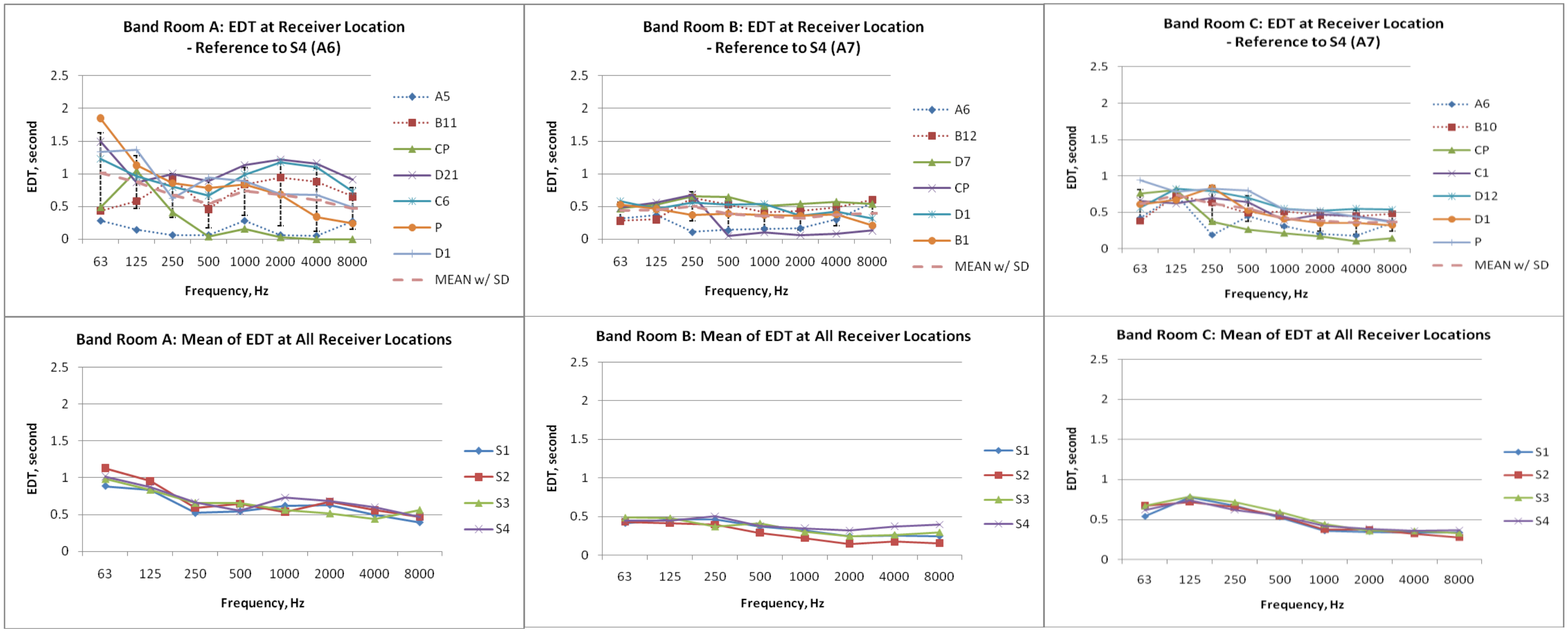


Figure B-1. Continued.

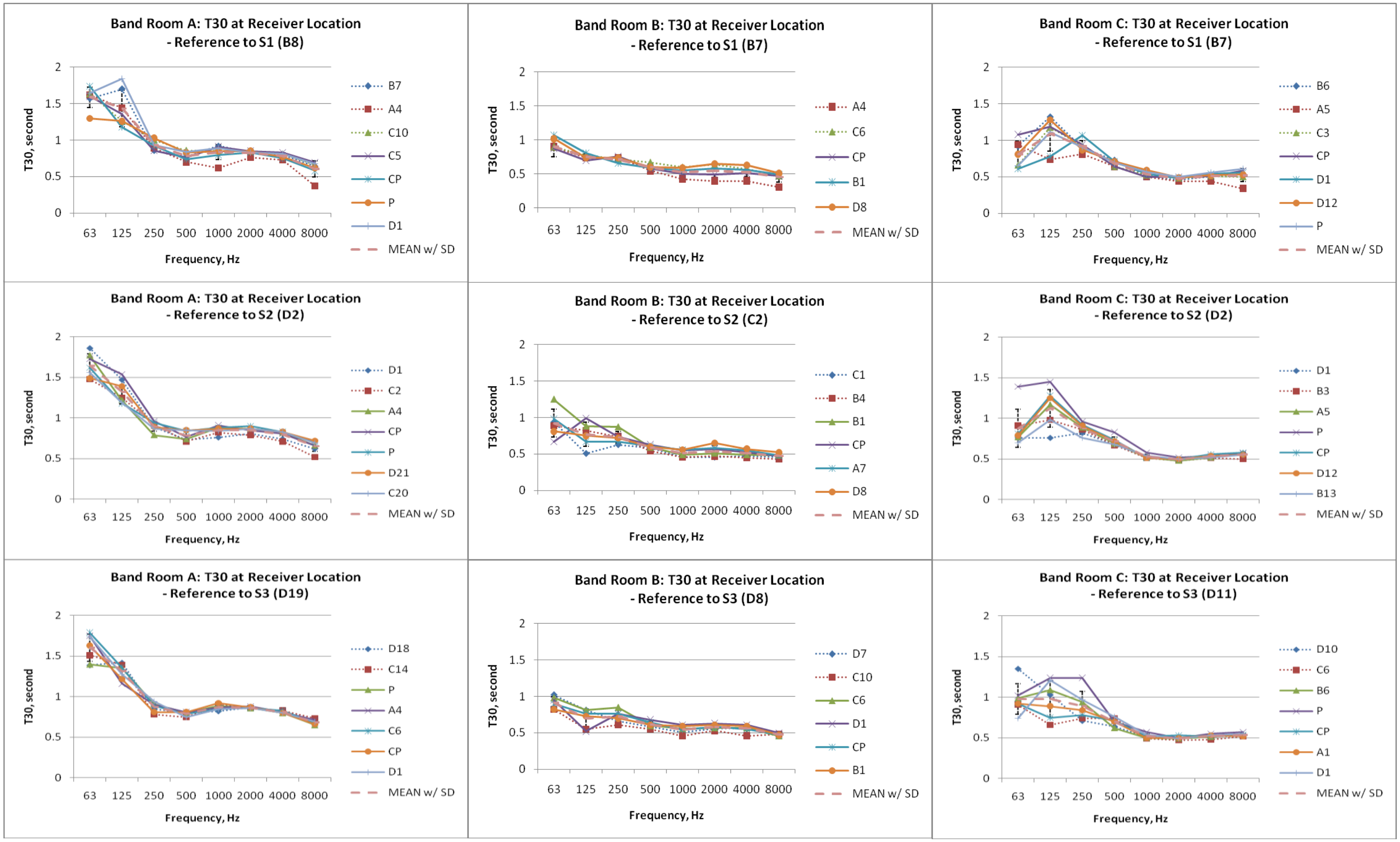


Figure B-2. Reverberation Time (T30) in the three band rooms.

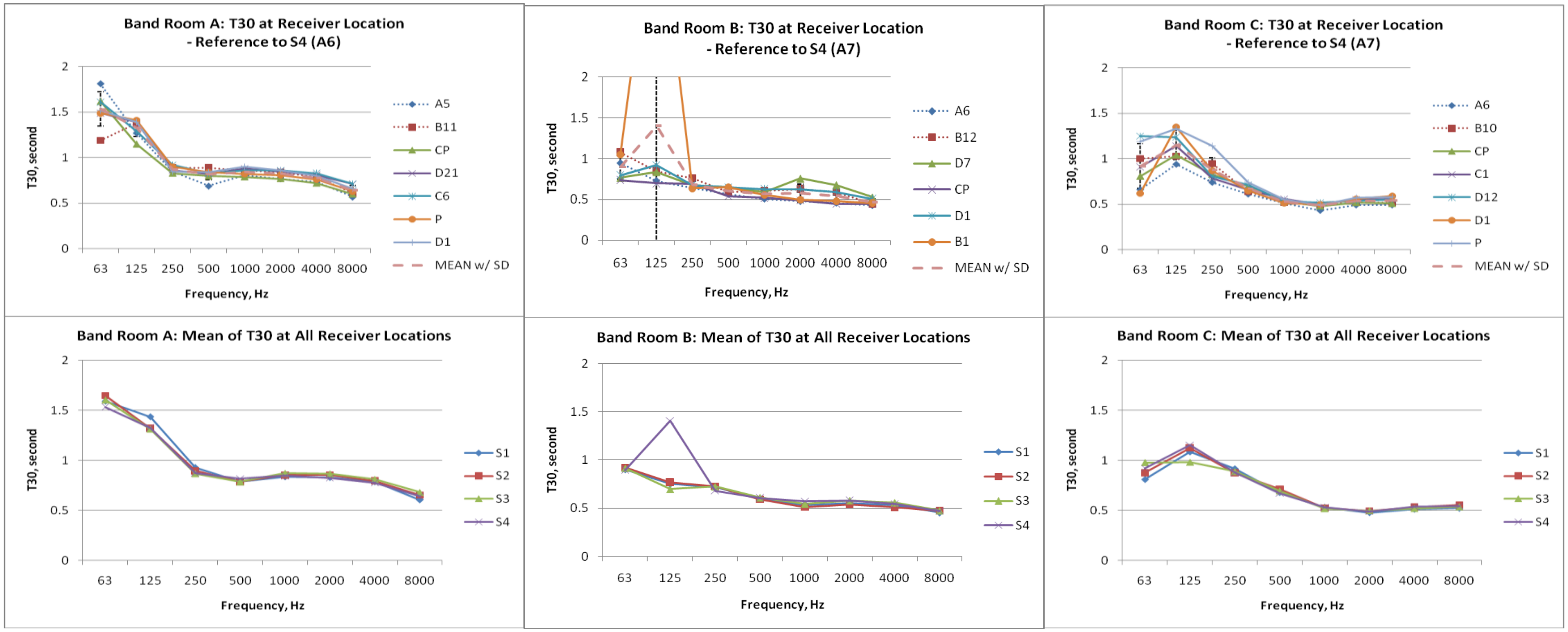


Figure B-2. Continued.

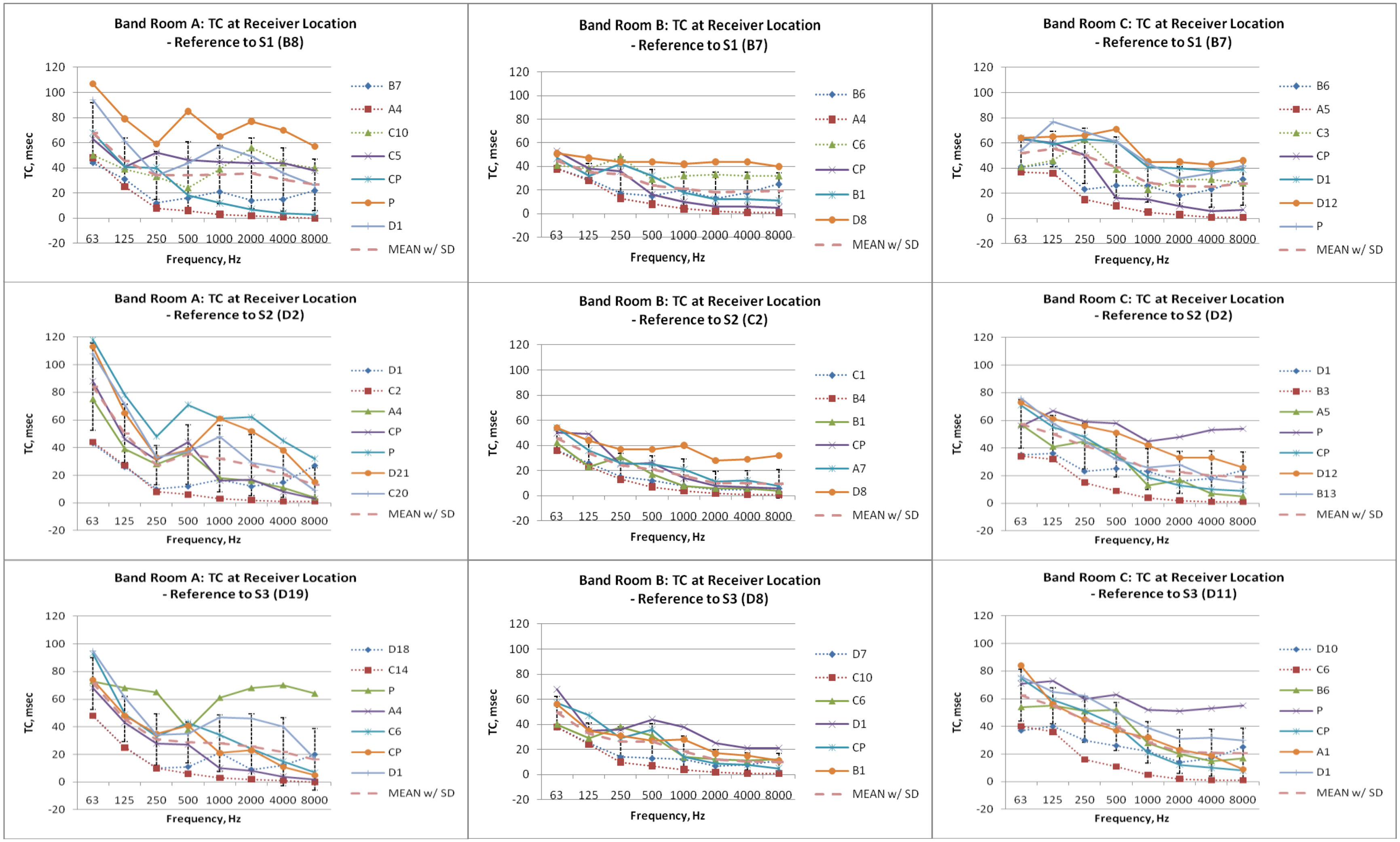


Figure B-3. Center Time (TC) in the three band rooms.

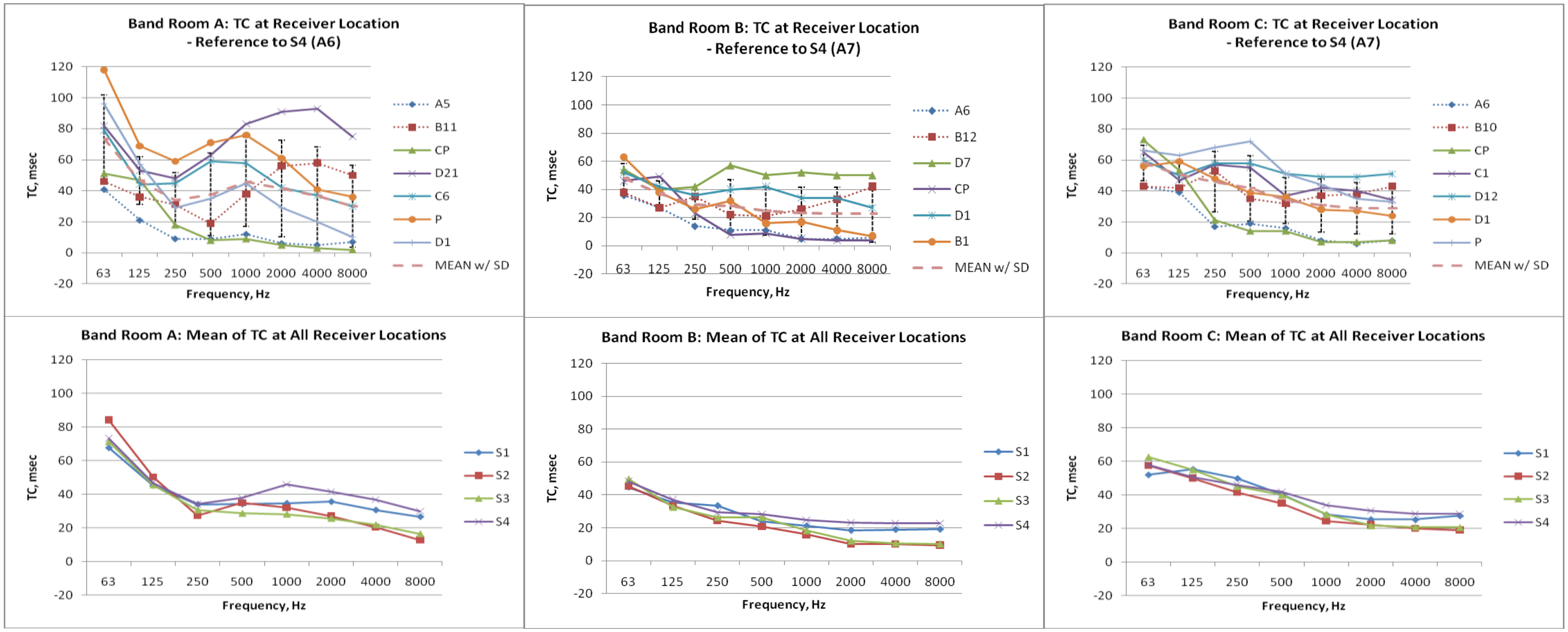


Figure B-3. Continued.

APPENDIX C
CORRELATIONS OF ACOUSTICAL RESPONSES AND LISTENING EVALUATION IN THREE BAND ROOMS

Background

The additional investigations to correlates tone quality and the results of the listening evaluation were necessary because tone quality was identified as one of the listening criteria by conductors during the rehearsal interviews. Tone quality was also not used in the student questionnaires. Since the overall impression from the listening evaluation was “about ease of playing as an ensemble”, this could be construed as to evaluate the ease of hearing each other during rehearsals. The correlations between the overall impressions to acoustical parameters are also included in this analysis. However, since different methods were used in the student questionnaire and listening evaluation, the correlated results could also be different. The playback of audio tracks during the listening evaluation used headphones that could not totally reproduce the sound field of the room. Hence, the correlated results of using the listening evaluation are only used to show the possible effects of acoustical parameters to tone quality and overall impression.

Method

Methods to conduct the acoustical measurement, listening evaluation, and statistical analysis are the same as stated in Chapters 6, 7 and 8. Hence, author will not repeat the methods used for the correlations of tone quality and overall impression to acoustical parameters here.

Results and Discussions

Results of Listening Evaluation on Tone Quality and Overall Impression

The scores of tone quality and overall impression in the three band rooms are shown in Figures C-1 and C-2. Figure C-1 shows that Band Room A has higher scores of hearing tone quality than Band Rooms B and C. Figure C-2 shows that Band Room A has higher scores of overall impression than Band Rooms B and C on all receiver condition and near receiver condition. However, Band Room B has higher scores of overall impression than Band Rooms A and C on far receiver condition. The possible reasons were discussed in chapter 7. The far receiver location of Band Room B is 10 feet closer than the far receiver location of Band Room A and the stronger direct sound and smooth decay slope of far receiver location of Band Room B gave it a better overall impression.

Results of Multiple Linear Regressions

The acoustical measurement data for the listening evaluation and statistical correlation analyses were based on one near and one far receiver location from each band room. Therefore, the correlations of the tone quality and overall impression with acoustical parameters were solely used to indicate the trends of the possible effect between these parameters.

Tone Quality – Overall Condition

Table C-1 shows five models that were derived from the overall receiver condition of the three band room data. Model 1 has an $r^2 = 0.805$. Model 2 has an $r^2 = 0.982$. Model 3, 4 and 5 have $r^2 = 1.000$. When $r^2 = 1.000$, it means the model has the best linear correlation of the predicted acoustical parameters and scores on tone quality. The best predicted parameters for clearly hearing tone quality regardless the receiver condition is the interaural cross correlation for late energy (IACC_L) at the average of 2000 to 8000 Hz and at 2000 Hz, early support (ST1) in the 63 Hz octave band, interaural cross correlation for overall energy (IACC_A) in 1000 Hz octave band and room constant at the average of 63 to 250 Hz octave bands. However, from Table C-1, the late energy (IACC_L) at the average of 2000 to 8000 Hz octave bands has changed r^2 = 0.805. This means that IACC_L at the average of 2000 to 8000 Hz octave bands has a significant percentage (80.5%) of predicting the linear relationship with scores of tone quality. Figure C-3 shows the Mean Plot of the IACC_L_HIGH versus scores of hearing tone quality in the three band rooms. Apparently, the trends of decreasing the values of IACC_L at the average of 2000 to 8000Hz octave bands result in better scoring for hearing tone quality clearly.

Overall Impression – Overall Condition

Table C-2 shows five models that were derived from the overall receiver condition of the three band room data. Model 1 has an r^2 = 0.716. Model 2 has an r^2 = 0.996. Model 3, 4 and 5 have r^2 = 1.000. When r^2 = 1.000, it means that the model has the best linear correlation of the predicted acoustical parameters and highest scores for overall impression. The best predicted parameters for overall impression about ease of playing as an ensemble regardless of the receiver condition is the average surface absorption coefficient in the 250 Hz octave band, interaural cross correlation for late energy (IACC_L) at the average of 500 to 1000 Hz octave bands, room constant at the average of 2000 to 8000 Hz octave bands, surface diffusivity index (SDI) multiply by the ceiling height (CLG) and the reverberation time (T20) in the 125 Hz octave band. However, from Table C-2, the average surface absorption coefficient in the 250 Hz octave band has r^2 change = 0.716. This means that the average surface absorption coefficient in the 250 Hz octave band has a significant percentage (71.6%) of predicting the linear relationship with scores of overall impression. Figure C-4 shows the Mean Plots of the predicted parameter versus scores of overall impression in the three band rooms. It is clear that the trends of increasing the Alpha_bar in the 250Hz octave band and the product of SDI to Ceiling Height result in better scores for overall impression.

Architectural Parameters versus Tone Quality and Overall Impression

Figures C5 (A to J) show the architectural elements versus the scores of tone quality and overall impression. From the figures, it is clear to see the positive relationship between scores of the tone quality to overall impression. As the scores of tone quality went up, the scores of the overall impression went up as well. It indicates that in order to design the rehearsal room with ease of hearing each other as an ensemble; tone quality must be considered as the primary musical attribute and design criterion.

In general, higher product of T30 versus room volume (T30_RV), higher product of surface diffusivity versus ceiling height (SDI_CLG), larger surface area, larger room volume, higher ceiling, larger mean free path (MFPath), less ratio of ceiling height to room volume (CLG_RV) and longer distance to ceiling (D_CLG) are shown as the key architectural elements to obtain the higher scores of tone quality. Therefore, these architectural elements could be used to achieve the optimized tone quality of the rehearsal rooms.

Table C-1. Multiple Linear Regression versus Tone Quality in the three band rooms.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics: R Square Change	F Change	df1	df2	Sig. F Change
1	.897[a]	.805	.756	.2132	.805	16.483	1	4	.015
2	.991[b]	.982	.969	.0758	.177	28.680	1	3	.013

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics: R Square Change	F Change	df1	df2	Sig. F Change
3	1.000[c]	1.000	.999	.0150	.018	74.276	1	2	.013
4	1.000[d]	1.000	1.000	.0000	.000	7.627E7	1	1	.000
5	1.000[e]	1.000	.	.	.000	.	1	0	.

a. Predictors: (Constant), IACC_L_HIGH

b. Predictors: (Constant), IACC_L_HIGH, ST1_63

c. Predictors: (Constant), IACC_L_HIGH, ST1_63, IACC_L_2K

d. Predictors: (Constant), IACC_L_HIGH, ST1_63, IACC_L_2K, IACC_A_1K

e. Predictors: (Constant), IACC_L_HIGH, ST1_63, IACC_L_2K, IACC_A_1K, RC_LOW

Coefficients[a]

Model		Unstandardized Coefficients: B	Std. Error	Standardized Coefficients: Beta	t	Sig.	Correlations: Zero-order	Partial	Part
1	(Constant)	6.480	.445		14.551	.000			
	IACC_L_HIGH	-16.623	4.094	-.897	-4.060	.015	-.897	-.897	-.897
2	(Constant)	7.374	.230		32.058	.000			
	IACC_L_HIGH	-23.429	1.932	-1.264	-12.128	.001	-.897	-.990	-.952
	ST1_63	-.090	.017	-.558	-5.355	.013	.274	-.951	-.420
3	(Constant)	7.418	.046		161.608	.000			
	IACC_L_HIGH	-25.846	.475	-1.395	-54.440	.000	-.897	-1.000	-.848
	ST1_63	-.095	.003	-.590	-28.096	.001	.274	-.999	-.437
	IACC_L_2K	2.064	.239	.175	8.618	.013	-.516	.987	.134

Table C-1. Continued.

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	Correlations Zero-order	Correlations Partial	Correlations Part
4	(Constant)	7.416	.000		997504.352	.000			
	IACC_L_HIGH	-25.515	.000	-1.377	-297724.545	.000	-.897	-1.000	-.751
	ST1_63	-.100	.000	-.621	-126065.845	.000	.274	-1.000	-.318
	IACC_L_2K	2.129	.000	.180	53912.647	.000	-.516	1.000	.136
	IACC_A_1K	-.056	.000	-.053	-8733.191	.000	-.530	-1.000	-.022
5	(Constant)	7.416	.000		.	.			
	IACC_L_HIGH	-25.517	.000	-1.377	.	.	-.897	-1.000	-.027
	ST1_63	-.100	.000	-.621	.	.	.274	-1.000	-.008
	IACC_L_2K	2.129	.000	.180	.	.	-.516	1.000	.021
	IACC_A_1K	-.057	.000	-.053	.	.	-.530	-1.000	-.002
	RC_LOW	-1.250E-8	.000	.000	.	.	.736	-1.000	.000

a. Dependent Variable: Tone_Quality

Table C-2. Multiple Linear Regression versus Overall Impression in the three band rooms.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics R Square Change	F Change	df1	df2	Sig. F Change
1	.846[a]	.716	.645	.2839	.716	10.100	1	4	.034
2	.998[b]	.996	.993	.0401	.279	197.394	1	3	.001
3	1.000[c]	1.000	1.000	.0029	.004	560.177	1	2	.002
4	1.000[d]	1.000	1.000	.0000	.000	113696.521	1	1	.002
5	1.000[e]	1.000	.	.	.000	.	1	0	.

a. Predictors: (Constant), Alpha_bar_250

b. Predictors: (Constant), Alpha_bar_250, IACC_L_MID

c. Predictors: (Constant), Alpha_bar_250, IACC_L_MID, RC_HIGH

d. Predictors: (Constant), Alpha_bar_250, IACC_L_MID, RC_HIGH, SDI_CLG

e. Predictors: (Constant), Alpha_bar_250, IACC_L_MID, RC_HIGH, SDI_CLG, T20_125

Table C-2. Continued.

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients			Correlations		
		B	Std. Error	Beta	t	Sig.	Zero-order	Partial	Part
1	(Constant)	3.752	.359		10.464	.000			
	Alpha_bar_250	3.125	.983	.846	3.178	.034	.846	.846	.846
2	(Constant)	2.096	.128		16.342	.000			
	Alpha_bar_250	4.330	.163	1.173	26.521	.000	.846	.998	.998
	IACC_L_MID	5.314	.378	.621	14.050	.001	.005	.992	.529
3	(Constant)	1.986	.010		189.909	.000			
	Alpha_bar_250	4.419	.013	1.197	353.470	.000	.846	1.000	.972
	IACC_L_MID	5.610	.030	.656	184.970	.000	.005	1.000	.508
	RC_HIGH	1.844E-6	.000	.072	23.668	.002	-.227	.998	.065
4	(Constant)	1.985	.000		45121.885	.000			
	Alpha_bar_250	4.398	.000	1.191	54571.459	.000	.846	1.000	.629
	IACC_L_MID	5.625	.000	.658	41683.427	.000	.005	1.000	.481
	RC_HIGH	1.879E-6	.000	.073	5479.544	.000	-.227	1.000	.063
	SDI_CLG	.001	.000	.008	337.189	.002	.643	1.000	.004
5	(Constant)	1.986	.000		.	.			
	Alpha_bar_250	4.397	.000	1.191	.	.	.846	1.000	.036
	IACC_L_MID	5.626	.000	.658	.	.	.005	1.000	.163
	RC_HIGH	1.878E-6	.000	.073	.	.	-.227	1.000	.024
	SDI_CLG	.001	.000	.009	.	.	.643	1.000	.000
	T20_125	-.001	.000	.000	.	.	.507	-1.000	.000

a. Dependent Variable: Overall_Impression

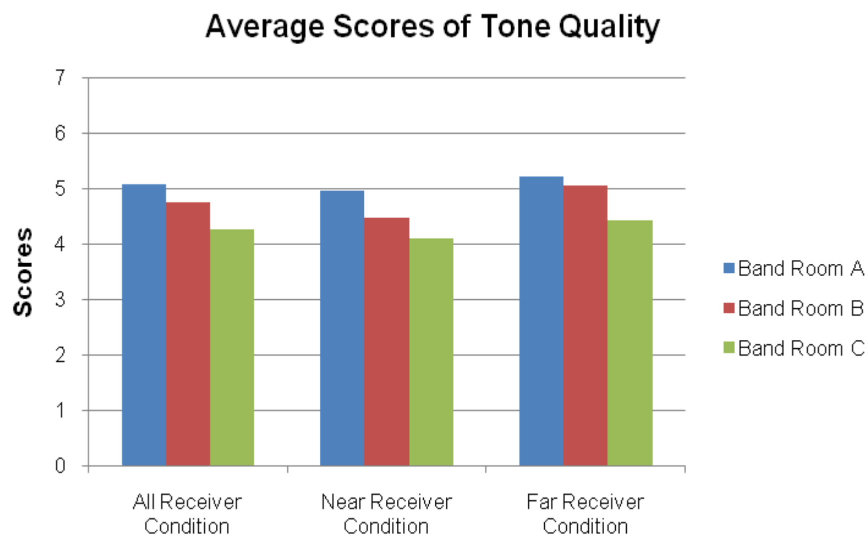


Figure C-1. Listening evaluation of tone quality scores in the three band rooms.

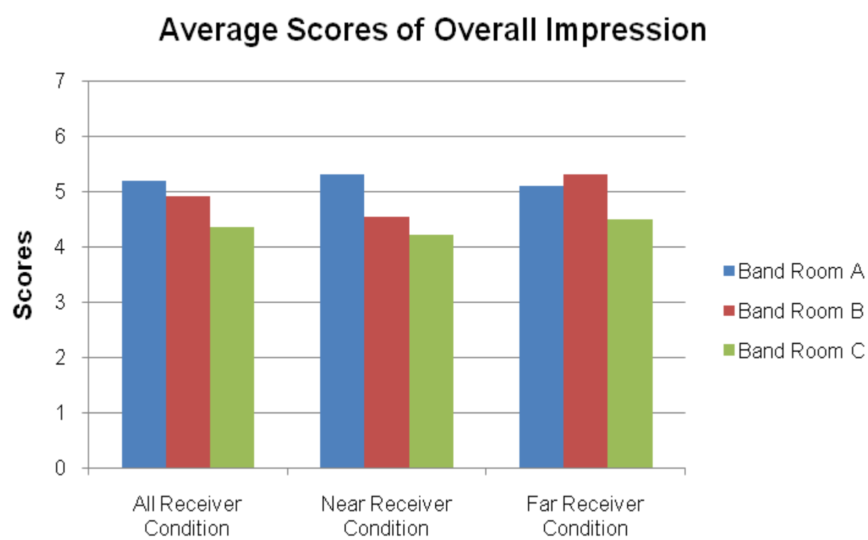


Figure C-2. Listening evaluation of overall impression scores in the three band rooms.

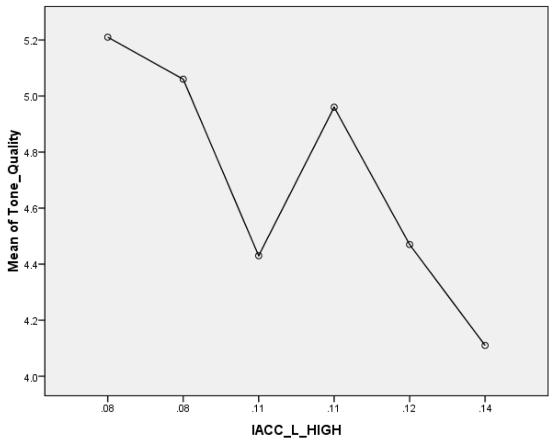
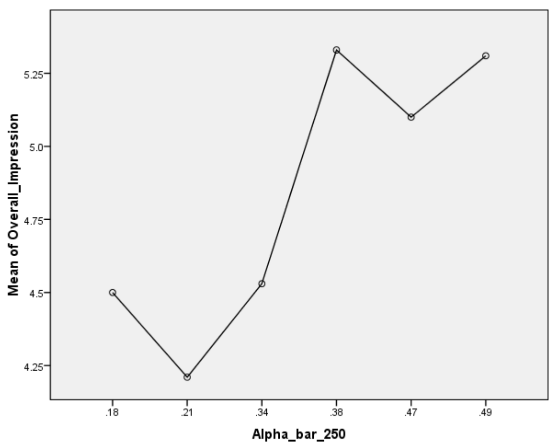


Figure C-3. Mean Plot of predict acoustical parameter (IACC_L_HIGH) versus scores of hearing tone quality in the three band rooms.



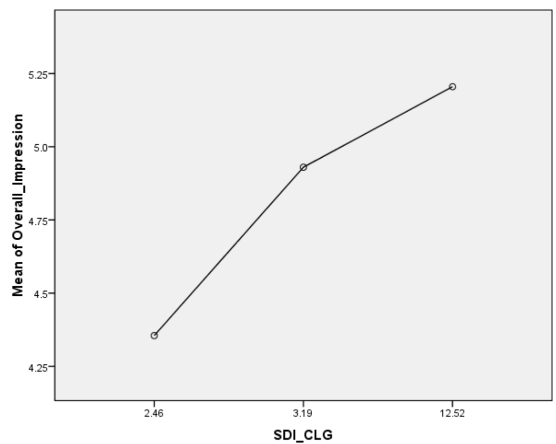
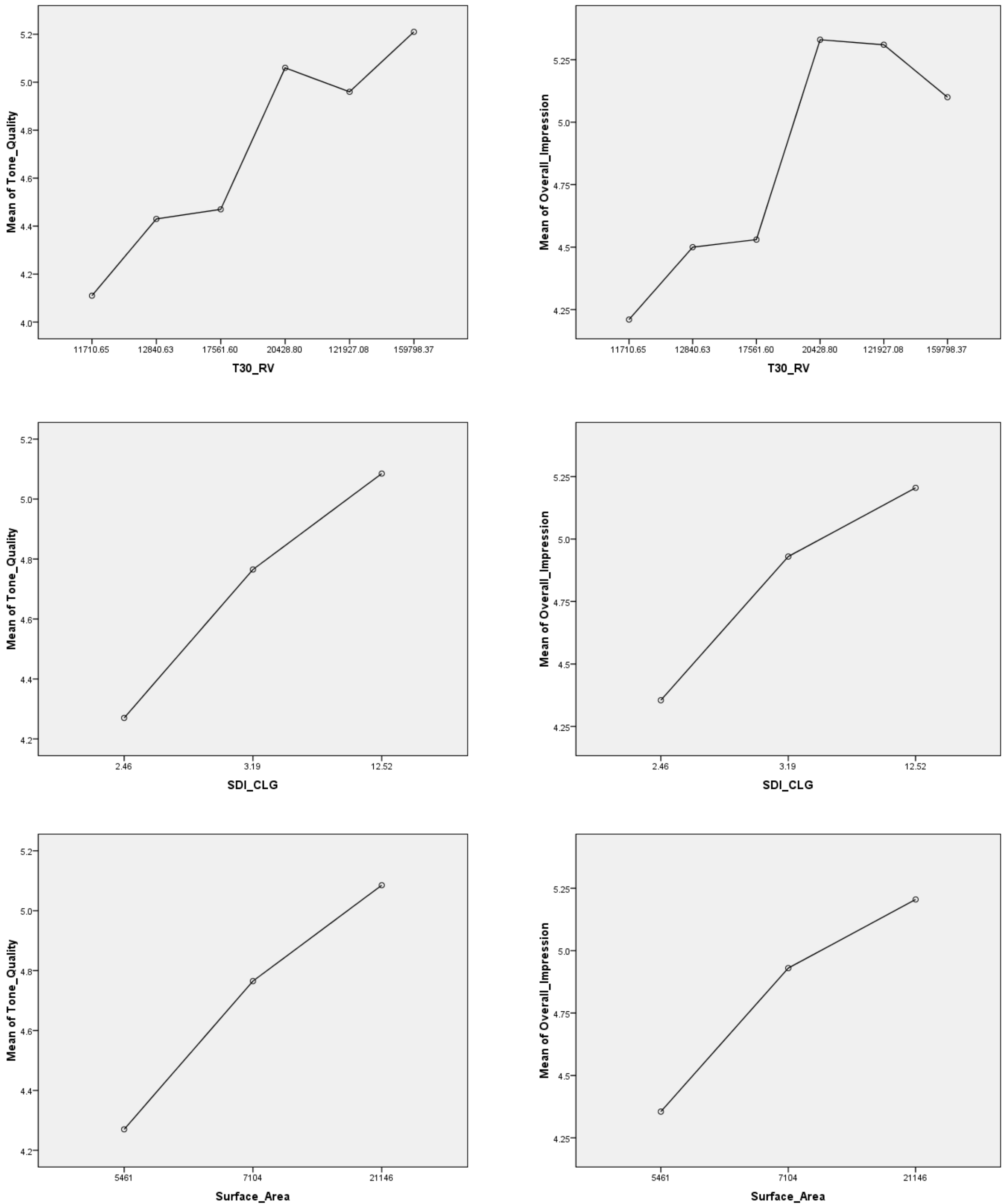
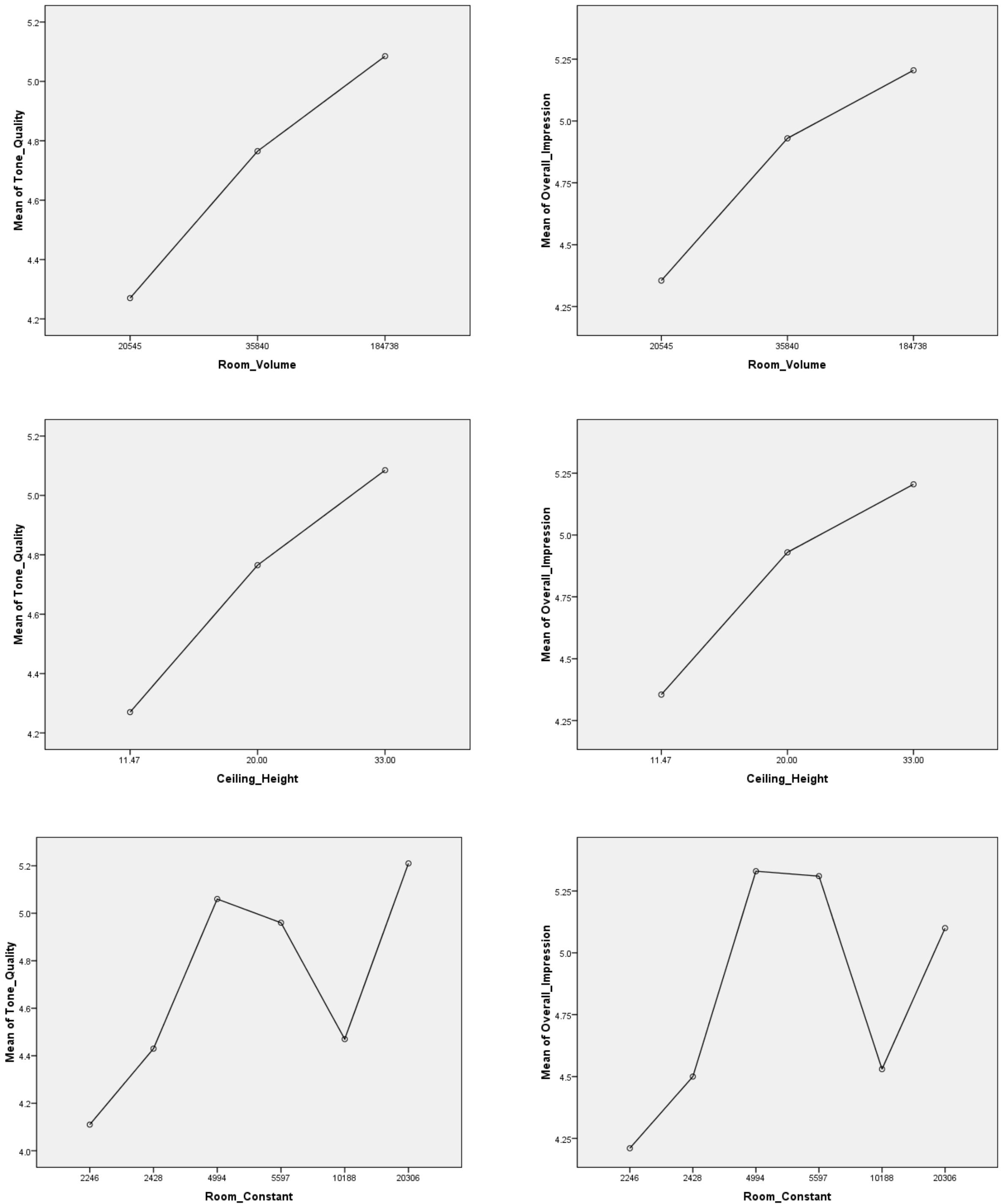


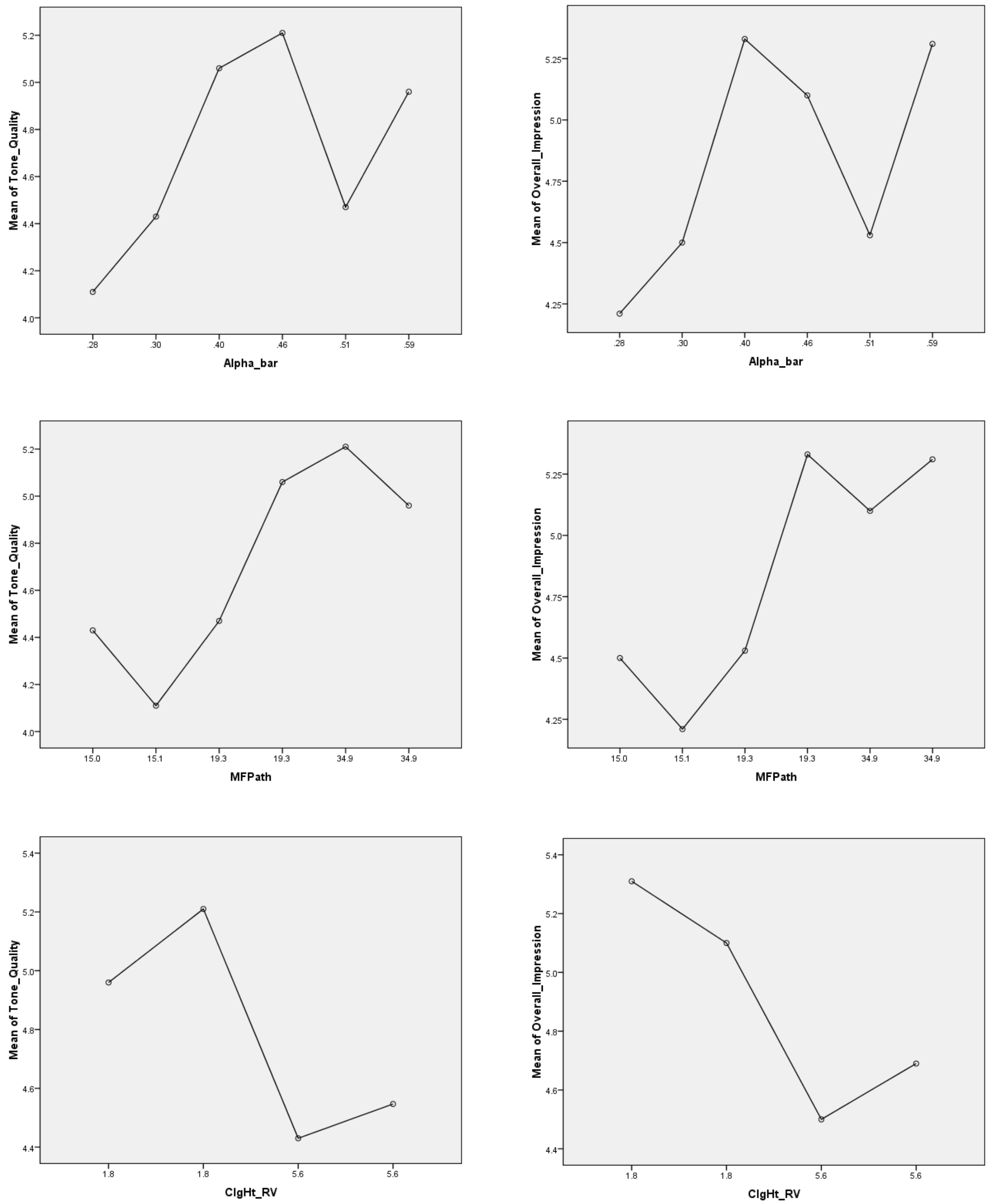
Figure C-4. Mean Plots of predict acoustical parameters versus scores of overall impression in the three band rooms.



Figures C-5 (A to C – top to bottom). Mean Plots of predict architectural elements versus scores of tone quality and overall impression in the three band rooms.



Figures C-5 (D to F – top to bottom). Continued.



Figures C-5 (G to I – top to bottom). Continued.

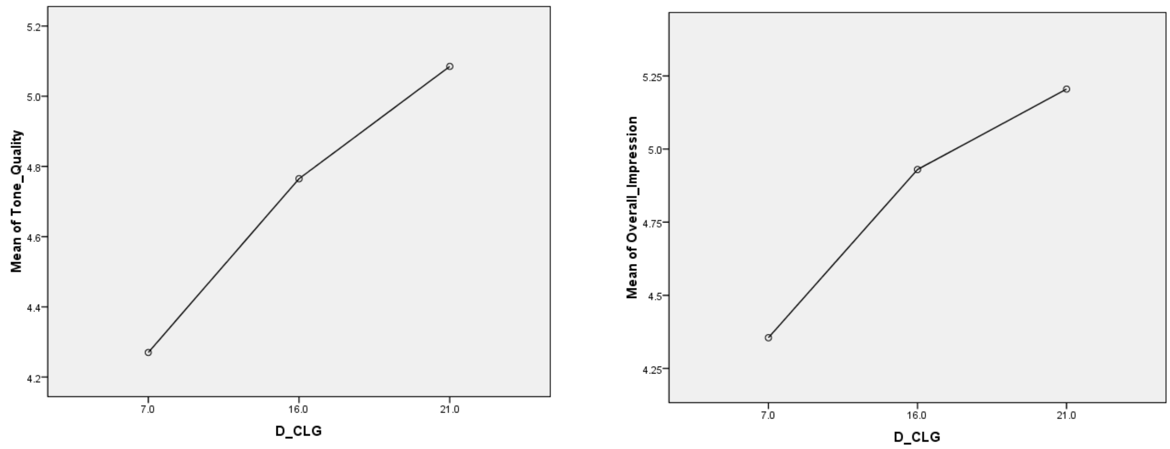


Figure C-5 (J). Continued.

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BIOGRAPHICAL SKETCH

Lucky is a native of Taiwan and received a Bachelor of Music in trombone performance (1996) and a Master of Arts in audio and acoustics (2003) from the Peabody Institute of The Johns Hopkins University. She is also a graduate of Manhattan School of Music and received a Master of Music in trombone performance (1998). Lucky has worked as an acoustical consultant for eight years (five years as full time, three years as part time). She is a member of the Acoustical Society of America (ASA), Technical Committee on Architectural Acoustics of ASA, Institute of Noise Control Engineering (INCE), Audio Engineering Society (AES) and National Band Association (NBA).

With her educational and professional background as a scholar, acoustical consultant and musician; her interests and passions about creating an optimum acoustical environment for musicians and ensembles to rehearsal in is undertaken. She believes that optimizing the acoustics of any musical or educational space is a primary factor that contributes to a better learning environment and more efficient musical education.