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VENUE-BASED HEARING CONSERVATION STRATEGIES: REDUCING THE RISK OF MUSIC INDUCED HEARING LOSS.

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Declaration

I, Katherine Sally Horrell, hereby declare that this research report is my own work except as indicated in the references and acknowledgements. I am responsible for the content of this study and the conclusions presented. No part of this research report has been previously submitted for a degree at any other University/Institution.

Signed: Date:

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Abstract

Background: During live concerts attendees are exposed to excessive high intensity sounds for durations considered dangerous to the auditory system. Thus, regular live music concert attendees are at risk for developing Music Induced Hearing Loss (MIHL) due to their recreational habits. Although MIHL is preventable, current hearing conservation is limited at live music venues. As personal hearing protection is poor within this community, a need for alternative hearing conservation strategies is evident.

Method: The objectives of this multi-method quantitative research study was to determine whether venue-based hearing conservation strategies in live music venues are a plausible means of reducing the risk of music induced hearing loss. Four live rock and heavy metal music venues in Johannesburg (South Africa) were included in the study. The current venue-based hearing conservation strategies as well as the acoustic and structural characteristics of these venues are described. In addition, the Sound Pressure Levels (SPLs) were measured throughout the venues. The variance of the mean SPLs between different areas within these venues were then calculated and effects of the structural characteristics on the variance of the sound levels within the venues were determined.

Results: The results indicated that hearing conservation including awareness programs and availability of Hearing Protection Devices (HPDs) are not currently occurring in the music venues. Music venues further do not comply with the OHSA (2003) regulations nor are they compliant in terms of the acoustic and structural recommendations for reducing the intensity levels in music venues. Statistical analysis indicated at least one pair of significant differences in the mean SPLs recorded in the different areas in each venue. Results further indicated trends in the variance of intensity levels between different areas confirming a positive relationship between each of these five trends and the variance of sound levels. Thus,

this study indicates that venue-based hearing conservation strategies may be a plausible means for reducing the risk for MIHL in attendees at live music venues.

Implications: Implications of this study are discussed in relation to clinical and practice guidelines for both audiologists, and occupational health personnel, whilst the need for changes in legislation are highlighted.

Keywords*:* Music induced hearing loss, hearing conservation, recreational noise exposure, live music venues, venue-based hearing conservation, structural characteristics.

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List of acronyms and abbreviations

ADE	Acceptable Daily Exposure
dB	Decibels
dBA	Decibels (A weighted)
HCP	Hearing Conservation Program
HPD	Hearing Protection Device
LF	Lateral Fraction
NIHL	Noise Induced Hearing Loss
NIOD	Noise Induced Otologic Damage
MIHL	Music Induced Hearing Loss
ms	Milliseconds
PTS	Permanent Threshold Shift
RT	Reverberation Time
s	Seconds
SLM	Sound Level Meter
SPL	Sound Pressure Level
TTS	Temporary Threshold Shift
W	Watts
Min	Minimum
Max	Maximum

Chapter 1: Orientation

"This is not the end

This is not the beginning,

Just a voice like a riot

Rocking every revision

But you listen to the tone

And the violent rhythm

Though the words sound steady

Something empty's within 'em…"

(Bennington et. al. 2010, track 8)

The purpose of this chapter is to provide a brief discussion on the nature of live music venues and the risks of excessive recreational noise exposure in relation to the rationale of this study. This chapter further defines the contextual terms and provides an outline of the chapters which follow.

1.1 Background and rationale

Live music concerts are considered to be one of the loudest recreational noise exposure activities (Dillon, 2008; Vogel, Brug, Van der Ploeg, & Raat, 2010; Weichbold & Zorowka, 2007). It has been reported that the Sound Pressure Levels (SPLs) at live music concerts averages 90dB or more (Dillon, 2008;Williams & Burgess, 2007). Excessively loud and prolonged music exposure can result in Music Induced Hearing Loss (MIHL) (Morata, 2007).

MIHL is a term used for Noise Induced Hearing Loss (NIHL) caused as a result of excessively loud music exposure (Morata, 2007). Tinnitus, Temporary Threshold Shifts (TTS), hyperacusis and pain are common symptoms of auditory damage due to noise

exposure and thus are warning signs for the progression of a permanent threshold shift (PTS) (Bogoch, House, & Kudla, 2005; Chung, Des Roches, Meunier, & Eavey, 2005; Jokitulppo, Bjork, & Akaan-Penttila, 1997; Zhao, Manchaiah, French, & Price, 2010). MIHL may furthermore cause distortion of the music quality (Bogoch et al., 2005; Chesky, 2008; Chung et al., 2005; Zhao et al., 2010).

Research has found that 61% of music concert attendees suffered from TTS and/or tinnitus after recreational music exposure (Chesky, 2008). This is the result of exposure to excessively high intensity sounds for durations considered dangerous to the auditory system (Chesky, 2008). It is postulated that the increase in the prevalence of NIHL in children and young adults may be attributed to recreational noise exposure (Chung et al., 2005). The incidence of MIHL varies between genres (Einhorn, 2009). The incidence of hearing loss reported among Rock and Pop musicians range between 13% and 30%, whilst up to 58% of classical musicians may be affected. Sixteen percent of listeners exposed to rock music exceeding 110dB are estimated to suffer from permanent otologic damage (Einhorn, 2009). This supports claims that musicians as well as their audiences are classified as at-risk for MIHL. As MIHL is irreversible, prevention thereof is critical (Einhorn, 2009).

In South Africa, laws such as the Occupational Health and Safety Act (OHSA) of 1993 are in place to ensure evaluation of the work environment and medical surveillance (Jeebhay & Jacobs, 1999). Instruction 171 of the Compensation for Occupational Injuries and Diseases Act, promulgated in 2001, describes the protocol for the determination and compensation for work related permanent hearing loss in South Africa (Department of Labour, 2001). These legal obligations include but are not limited to the use of personal hearing protection in the workplace (Department of Labour, 2001).

Although studies indicate that awareness regarding Hearing Protection Devices (HPDs) and availability of HPDs will increase personal hearing protection (Bogoch et al., 2005), the implementation of such strategies is not currently evident in live music venues (Chung et al., 2005). Alternate forms of hearing conservation strategies and their application is therefore critical for reducing the risk of MIHL for audiences and musicians of live music concerts.

One such strategy is acoustic design within venues (Gastmeier, 2009). Poor acoustic design in music venues increases noise exposure for employees and attendees of such venues (Peters et al., 2005). According to the Health and Safety Executive (HSE) (2008) another strategy is the use of structural changes in live music venues to reduce the risk of MIHL. The following broad research questions were therefore formulated for this study:

i) What hearing conservation strategies are currently adopted in live music venues in South Africa?

ii) What are the current acoustic and structural characteristics within these venues?

iii) What are the current intensity levels within these venues?

iv) What structural characteristics can effectively reduce the risk for MIHL in live music venues?

In terms of audiological practice, this indicates a need for strategies that do not rely on individual compliance that may be adopted as an effective hearing conservation program within the South African music industry. The purpose of this research is to describe the current hearing conservation practices within live music venues, as well as the strategies that can be implemented to improve recreational hearing conservation.

1.2 Chapter outlines

An outline and description of the sections in this study are discussed in Table 1.

Table 1 *Chapter outlines*

Outline	Description
Chapter 1	The first chapter provides a background on MIHL and hearing conservation within the music industry in order to outline the purpose of this study. Furthermore, it outlines the chapters of this study.
Chapter 2	The literature review chapter presents a discussion on MIHL as a recreational health risk and presents the current practices in recreational hearing conservation within the music industry.
Chapter 3	The methodology chapter of this study details the research design and presents the theoretical framework for the data analysis methods used in this study. Furthermore, this chapter presents the participant selection criteria as well as the data collection tools and procedures used.
Chapter 4	The results chapter presents the data collected and discusses the results of analysis. The current hearing conservation practices in the music venues are presented, followed by the intensity levels measured within the venues. This chapter presents the variance of SPLs between the different areas within each venue. Furthermore, the relationship between the variance of SPLs and the structural characteristics of the venues are explored.
Chapter 5	The discussion chapter evaluates the results presented in chapter 4 in relation to findings in current literature. This chapter also discusses the relevance of these findings to the music industry and hearing conservation.
Chapter 6	The conclusion chapter presents a summary of the main findings of this study as well as presenting a critical evaluation of the study. This chapter further discusses the implications of this research as well as the need for future research.
Appendices	The appendices supply important information for the understanding of the data collection and analysis procedures, and thus the replication of the study.

1.3 Summary

This chapter briefly outlines MIHL and the need for venue-based hearing conservation strategies, providing the rationale for conducting the current study. Furthermore, this chapter provides an outline of the chapters of this study that further describes the aims and execution of the study.

Chapter 2: Literature review

"…We say Yeah!
With fists flying up in the air
Like we're holding onto something
That's invisible there
'Cause we're living at the mercy of
The pain and the fear
Until we dead it, Forget it,
Let it all disappear…"
(Bennington et. al. 2010, track 8)

This chapter provides a contextual background for this study. It further provides a critical discussion on noise, MIHL, the current regulations and practices in hearing conservation programs in the music industry. Furthermore this chapter discusses the need for venue-based hearing conservation in live music venues.

2.1 Noise exposure and the auditory system

2.1.1 Noise induced hearing loss and the effects of noise on the auditory system

NIHL, an acquired hearing loss, results from damage to or death of the inner hair cells of the cochlea due to excessive noise exposure (Einhorn, 2009; Schulz, 2008). Excessive noise exposure may cause a threshold shift which may be either permanent or temporary (Rappaport & Provencal, 2002). TTS occur when the inner hair cells are damaged but the severity is not great enough to result in cell death. A shift in threshold is thus noted until the hair cells recover and hearing sensitivity returns. A Permanent Threshold Shift (PTS),

however, occurs due to cell death on the inner hair cells within the cochlea (Chasin, 2009; Rappaport & Provencal, 2002).

NIHL may be a sudden permanent hearing loss due to a once off high intensity exposure or it may present gradually due to recurrent exposures to dangerously loud intensity levels resulting in repeated TTS. (Schulz, 2008). TTS, as well as tinnitus and pain, are common symptoms of auditory damage due to noise exposure and thus are warning signs for the progression of a PTS (Bogoch et al., 2005; Chung et al., 2005; Jokitulppo et al., 1997).

When NIHL is due to exposure to loud music it is referred to as MIHL (Einhorn, 2009), thus indicating that Noise Induced Otologic Damage (NIOD) may result not only from excessive noise exposure, but also music.

2.1.2 Music induced hearing loss

MIHL is a term used for NIHL caused as a result of on-going excessive exposure to music at dangerously high intensity levels for prolonged periods of time (Morata, 2007). Both MIHL and NIHL progress proportionately to the exposure of such conditions. The risk of developing MIHL due to overexposure to high intensity music is dependant both on the average SPL and the length of exposure in time (Chesky, 2008). The greater the intensity of the sound the shorter the time period is before damage is incurred (Chesky, 2008).

This time weighted exposure limit begins with an eight hour limit for an average intensity of 85dBA, with each 3dBA increase in intensity the exposure time is halved. One may thus be exposed to music at 80dBA for extended periods without risking damage to the

auditory system. However, one may for example, only be safely exposed to 85dBA for eight hours, 88dBA for four hours and 91dBA for two hours (Chesky, 2008, p.36).

This time weighted exposure limit was used to develop a measure of noise exposure, known as an Allowable Daily Exposure (ADE). The limit of exposure for one day (or one ADE) is thus 85dB for eight hours, or 94dB for one hour (Dillon, 2008, p. 6). ADEs are used to predict the risk for NIHL based on the average intensity levels and length of exposure. As these averages were calculated for work-related noise exposure, and the working week is five days, the allowable noise exposure for one week is five ADEs, similarly the noise exposure for a year is thus limited to 220 ADEs (Dillon, 2008, p. 6).

Music venue-attendees are unlikely to be exposed to excessive noise on a daily basis. However, the 220 ADE yearly limit may be exceeded therefore placing them at risk for MIHL (Dillon, 2008, p.6). For example, an individual may attend a live music concert for an average of five hours where the intensity levels average at 100dBA. According to the time weighted exposure limit, one may safely be exposed to 100dBA for only 15 minutes, as 15 minutes exposure at 100dBA is equivalent to one ADE. The hypothesised attendee was thus exposed to 100dBAs for five hours, equivalent to 20 ADEs, or one month's exposure allowance. Similarly, as shown in a study conducted in night clubs, an attendee frequenting a club 0.9 times a week over a course of 10 years of their lifespan will reach 60% of their lifetime allowable exposure from this activity alone (Williams, Beach, & Gilliver, 2010, p. 156). This study used dosimeters to calculate the attendee's total noise exposure in an average night of clubbing. Ten measurements were collected in total at eight different venues. Although the sample size is small, the study provides a clear idea of the noise levels attendees are exposed to as well as the average length of a clubbing session. The average noise levels

were 97.9dB and ranged from 90.7-105.7dB. The mean attendance time was calculated at five hours per week (Williams et al., 2010, p. 156).

Despite the fact that such attendees are at risk for MIHL by exposing themselves to dangerously high intensities, they may be unaware of the possible adverse effects as they may not consider music to be noise and thus potentially dangerous. In many aspects, music cannot be considered noise. Although the spectral shape and peak intensity measures of noise and music are similar, their intensity, dynamic ranges and temporal characteristics differ significantly (Chasin, 2009). Industrial noise tends to continue for sustained high intensity periods whereas music alternates between periods of relative quiet and greater intensity (Chasin, 2009). In addition, noise is perceived as unwanted sounds, whilst music is created intentionally (Morata, 2007). This implies that prevention techniques will differ. For noise, the prevention techniques initially aim to reduce or remove the sound, whereas for music the same prevention techniques cannot be implemented (Morata, 2007). The excessive exposure to high intensity noise or music may result in NIOD, however, the perception of music affects both the length of exposure to the source as well as limits hearing conservation techniques (Everton, 2004).

2.1.3 Music exposure and the risk of hearing loss

According to Schmidt, Vershuure and Brocaar (1994), the correlation between extensive music exposure and the risk for hearing loss has not yet been confirmed, as studies indicate conflicting results. It was found that the hearing thresholds of non-professional musicians (n = 42) with at least five years frequent music exposure were significantly higher than the thresholds of a control group. The hearing loss was more evident in specifically the 3

– 8 kHz range (Schmuziger, et al., 2006, p. 324). A large proportion of participants also suffered from symptoms of auditory damage; 26% of the participants complained of hyperacusis (indicating a reduced dynamic range) while 17% suffered from tinnitus (Schmuziger et al., 2006, p. 325). In a similar study, the hearing thresholds of newly graduated musicians (n = 79) were compared to a control group that consisted of medical students (Schmidt, et al., 1994, p.188). It was found that although the musicians demonstrated more significant high frequency hearing loss, especially in the extended high-frequency range, the incidence and degree of hearing loss was matched by the control group of medical students. This study concluded that frequent music exposure does not necessarily result in MIHL (Schmidt, et al., 1994, p. 190). The limitations of this study are however that (i) the recreational noise exposure habits of the control group were not examined; and (ii) as the participant mean age was 25 years, a permanent threshold shift may not have resulted yet.

Due to conflicting research results and insufficient audiometric evidence, disagreement and speculation remain regarding music as a sole cause of hearing loss (Zhao et al., 2010). It is postulated that this speculation may be affecting the implementation of adequate hearing conservation strategies to prevent MIHL, which in turn may lead to the current rise in MIHL.

2.1.4 Current rise in recreational MIHL

Intensity levels in live music venues have been recorded as dangerously loud (Bogoch et al., 2005; Chasin, 2009; Dillon, 2008; Schmuziger et al., 2006). With SPLs recorded at an average of 92dB, attending such concerts is considered one of the loudest recreational activities (Dillon, 2008, p. 8). This is confirmed by Sadhra, Jackson, Ryder, and Brown

(2002) who found that the average noise exposure in entertainment venues were 90dBA with peak levels up to 124dBA. Despite the small sample size (*n*=14), the study further indicated that 29% of the participants demonstrated a PTS of 30dB or greater in the post-test assessments (Sadhra, et al., 2002, p. 460). Likewise a study conducted in Australia found that SPLs recorded in music venues averaged at 97.9dB with intensity levels ranging from 90.7 to 105.7dB (Williams et al., 2010, p.56). The study, which recorded attendees noise exposure over the course of an evening (using dosimeters) in eight music venues, further indicated that the SPLs with in the venue increased as time progressed (Williams et al., 2010, p. 56). Another study indicated that over 50% of the adolescent participants were exposed to detrimental noise levels during recreational activities and noted a correlation between increased noise exposure and hearing symptoms (Jokitulppo et al., 1997). Seventy percent of the adolescent participants in this survey study reported tinnitus and 45% reported TTS due to recreational noise exposure (Jokitulppo et al., 1997, p. 260-261).

Shouting in order to be heard at a distance of one metre is a strong indicator that the intensity level is dangerous. Attendees of live music venues reported that they ‘always’ or ‘often’ have to shout to be heard (Dillon, 2008, p.2). It is postulated that the rise in recreational MIHL as a result of attending these activities are related to the limited hearing conservation programmes at these venues (Chung et al., 2005; Dillon, 2008). This indicates a need to enforce hearing conservation strategies in entertainment venues.

In South Africa, the OHSA of 1993 promotes the evaluation of the work environment and medical surveillance (Jeebhay, & Jacobs, 1999). These regulations regulate the implementation of hearing conservation programs in industries such as mines and factories where employees are exposed to dangerous noise levels. In South Africa, Instruction 171 was

implemented in May 2001 to regulate work place noise in South African industry (Department of Labour, 2001).

The implementation of these guidelines should reduce the prevalence of MIHL. However, professionals are reporting a rise in young adults and adolescents presenting with symptoms of NIHL despite a lack of occupational noise exposure (Chung et al., 2005; Dillon, 2008). This could be attributed to the fact that young adults are often exposed to dangerously loud intensity levels for on average five hours per night during their recreational activities (Williams et al., 2010, p.56). The study conducted in Australia calculated that frequent club attendees could reach 60% of their allowable noise exposure for their lifetime in 10 years of clubbing an average of 0.9 evenings per week (Williams et al., 2010, p.56). This highlights the possibility of a rising risk for MIHL in adolescents and young adults as a result of recreational noise exposure. Although MIHL is preventable, precautionary measures to prevent MIHL are not often followed by individuals or implemented in the entertainment venues.

2.2. Current hearing protection practices for MIHL

2.2 Strategies to prevent MIHL

Strategies for the prevention of MIHL at rock concerts should include (i) acoustic design and engineering control, (ii) health promotion, (iii) education and (iv) personal protection (Bogoch et al., 2005).

2.2.1.1 Acoustic design and engineering control

Room acoustics can affect both the intensity levels and the perceived quality of the

sound by the listener (Gastmeier, 2009). Room acoustics can be divided into four categories which may affect the perceived quality and intensity; these include (i) adequate sound levels with low background noise, (ii) sound reflections, (iii) sound distribution, and finally (iv) reverberation characteristics (Gastmeier, 2009).

The first aspect, *adequate sound intensity*, may be affected by the volume of the venue, the amount of absorptive materials, the distance from the source to the listener and the number of attendees. These factors are inversely proportional to the perceived loudness of the music (Gastmeier, 2009). The structural characteristics such as room size, building design and materials can significantly affect the intensity levels in a venue (HSE, 2008). Thus the intensity levels do not need to be increased to compensate for poor sound quality.

Thin walling (less than one inch) or dry walling is discouraged in music venues as low frequency absorption results in a reduction in the perceived loudness. Thus intensity levels are often increased to counterbalance the absorption (Gastmeier, 2009). This is confirmed by a study that suggests wooden flooring absorbs the base sounds and thus intensity levels are increased to overcome the perceived reduction in loudness (Chasin & Chong, 1995). The types of materials used within venues should also be considered; hard, reflective surfaces may increase the SPLs whilst soft, absorptive materials with reduce SPLs (HSE, 2008).

In contrast to this, the ‘seat-dip effect’ needs to be considered. The seat-dip effect is caused by the over-presence of absorptive materials, usually as a result of seating in the venue. This results in an energy reduction in the 100-400 Hz range (Gastmeier, 2009). This factor is important in venue acoustics as the overuse of absorptive materials result in

compensatory increased intensity levels to increase the perceived loudness. Similarly it is suggested that there should be at least two meters of unobstructed space between the performers and attendees, as bodies are absorptive (Chasin & Chong, 1995). The perceived loudness in a small tiled venue with few attendees would thus be higher than in a large venue with carpeted areas and a large audience.

Another factor which affects the intensity levels in music venues is the background sound levels. It is postulated that by decreasing background noise (e.g. air conditioners and road traffic noise) and optimising acoustic isolation of the venue, the overall intensity levels can be reduced without deducting from the perceived loudness of the music (Gastmeier, 2009).

The second aspect, *sound reflections*, also plays an important role in the intensity levels in music venues (Gastmeier, 2009; HSE, 2008). The ideal texture of sound is achieved when the initial reflection reaches the listener before 22ms and is followed by a large number of equally spaced reflections before 80ms (Gastmeier, 2009). The quality of the music is perceived as intimate when the initial time delay gap is less than 20-22ms after the first sound reflection reaches the listener after the direct sound. An echo occurs when a strong reflection reaches the listener 80ms or longer after the direct sound; this is an unwanted phenomenon in live music venues. Lateral reflections are also important as the ears are in the horizontal plane and the listener uses interaural cues to determine the location and width of the source. Thus, the binaural quality index is an important indicator of sound quality as it measures the early laterally deflected sound energy (Gastmeier, 2009). Lateral Fraction (LF) is the ratio between early lateral and vertical reflections and is also a measure of sound quality. Furthermore, sound waves traverse 7m in 20ms thus listeners positioned 7m or more from a wall or

reflective surface may perceive the sound to be less intimate (Gastmeier, 2009). Excessive reflections may cause the sound quality to be perceived as ‘loud and confusing’ (HSE, 2008). When the perceived sound quality is sufficiently loud with an intimate quality and a good texture, intensity levels are less likely to be increased to counterbalance poor sound quality. Thus, sufficient early sound reflections, an even sound distribution and appropriate sound reverberation are beneficial to both the musicians as well as attendees (Gastmeier, 2009).

Evenly distributed sound is the third aspect to be considered and is vital for venue acoustics. However, a number of acoustic defects may cause an interference with the even distribution of sound (Gastmeier, 2009). The first acoustic defect that needs to be considered in venue acoustics are standing waves which are caused by constructive and destructive interference of the incident and reflected waves caused by parallel surfaces in small venues (Gastmeier, 2009). Another acoustic defect is referred to as a flutter echo and is defined as a series of closely spaced echoes as the initial impulse repeatedly passes the listener (Gastmeier, 2009). Furthermore, large flat surfaces can cause acoustical glare and source shift in the venue which results in poor room acoustics as well as large SPL differences within a relatively small space (Gastmeier, 2009). This is supported in the venue regulations that state that reflective surfaces should be minimised as they increase the SPLs in a venue (HSE, 2008). These above defects demonstrate that parallel, poorly spaced or excessive reflective surfaces in music venues may adversely affect the room acoustics leading to greater intensity levels. Fortunately, these acoustic defects can be easily identified within the music venues and treated with absorptive or materials. However, such treatments should be used with care as overuse may adversely affect the natural reverberation of the venue (Gastmeier, 2009). Thus soft, absorptive materials should be used to eliminate reflected and reverberated sounds (HSE, 2008). Providing a sufficiently diffuse sound field can be achieved by the presence of

irregular surfaces which diffuse the sound evenly in an omnidirectional manner on reflection (Gastmeier, 2009). This can aid in the reduction of acoustic glare and increase the surface diffusibility index. This provides the perception of spaciousness as well as listener envelopment (Gastmeier, 2009).

The final important acoustic consideration in music venues is *Reverberation Time (RT)*. RT is defined as the length of time in seconds (s) for a sound to decay by 60dB and is proportional to the volume of the hall while inversely proportional to the total absorption (Gastmeier, 2009). A large volume space with minimal absorption or occupancy will have a long RT while sound-treated rooms or libraries will have a short RT. The RT has been standardised for international use in the ISO 3382 of 1997 (Gastmeier, 2009). Desired RT for modern music is 1.1-1.7s (Gastmeier, 2009). Reverberation degrades speech perception and thus the shorter the RT the better the sound quality (Crandell & Smaldino, 2002).

Computer programs can be used to aid in design techniques as they allow for the virtual design of the venues and the acoustics to be calculated (Gastmeier, 2009). Ray acoustics may be used during design to determine the orientation of reflective surfaces. Ray acoustics are based on the law of reflection which states that the angle of reflection is equal to the angle of incidence. Thus high frequency sound paths can be predicted with optics and aid in the design of music venues (Gastmeier 2009).

The above characteristics refer to the acoustic design of venues and should be used in conjunction with hearing conservation programs to reduce the risk for MIHL in live music venues (Gastmeier, 2009).

2.2.1.2 Personal hearing protection

The most common type of personal protection for music exposure is HPDs. Studies indicate that although the majority of rock concert attendees do not make use of HPDs, knowledge and awareness regarding HPDs and the adverse effects of noise on the auditory system may increase compliance with HPD use (Bogoch et al., 2005; Horrell, 2009). Furthermore, attendees of rock concerts reported they would be more likely to make use of HPDs if they were available at the music venues (Bogoch et al., 2005). HPDs have proven to reduce the temporary threshold shifts associated with over-exposure to noise for both blast and continuous noise, thus indicating HPD use is an effective means of preventing NIHL (Duvdevany & Furst, 2007). A recent study (*n*=1086) indicated that although adolescent attendees recognised the effects of noise exposure as severe, they did not recognise the usefulness of HPDs during loud music exposure and did not intend to change their current music exposure habits (Vogel, Brug, Van der Ploeg, & Raat, 2010. p. 742). Thus, as HPDs are an effective preventative means to reducing the risk of MIHL, the educational and awareness campaigns needed to promote their use are critical.

2.2.1.3 Health promotion

Health promotion refers to the provision of health awareness regarding the effects of loud sounds on the auditory system (Bogoch et al., 2005; Chesky, 2008). Characterising hearing loss for students may be an effective hearing conservation strategy (Chesky, 2008). In a web-based survey (*n* = 9 693), 66% of the participants stated they would be more likely to make use of HPDs had they been made aware of the risk of permanent hearing damage, whilst 59% stated they would make use of HPDs if they were advised by a medical professional (Chung et al., 2005, p. 864). This correlates to a study which reported that awareness regarding

hearing conservation strategies and their long term benefits have shown to increase personal protection in live music attendees (Bogoch et al., 2005). In a web-based survey (*n* = 9693), a mere 16% of respondents reported to receive any type of education regarding hearing health (Chung et al., 2005, p. 864). This low percentage is confirmed in a study conducted by Bogoch et al. (2005) that hearing health education is not currently occurring.

Music teachers are encouraged to educate students on the risk of hearing loss, how to prevent hearing loss and how to reduce the risk of hearing loss (Chesky, 2008). An education program was proposed that centred around three goals namely; promoting hearing health, preventing hearing loss and teaching risk reduction. NIHL should be characterised in the education program, including the acquisition of NIHL, audiological evaluations and the role of HPDs. The education program should describe and demonstrate safe SPLs for learners to conceptualise dangerous intensity levels (Chesky, 2008). Finally, students should be informed of the warning signs of hearing loss and should be encouraged to obtain baseline audiograms (Chesky, 2008).

A study that assessed recreational noise exposure and hearing conservation habits of high school students pre- and post a hearing awareness campaign, found that the hearing awareness campaign made no significant changes to hearing conservation habits (Weichbold & Zorowka, 2007). The study concluded that expecting behaviour changes due to educational campaigns alone is optimistic (Weichbold & Zorowka, 2007). This suggests that although educational campaigns alone may not be a strong enough technique, they should be included in a battery of strategies to improve personal hearing conservation. Hearing Conservation Programs (HCP) by its very nature advocates a combination of pillar application and approaches for maximising its efficacy (WWA Commission, 2003).

It is thus evident that although hearing conservation strategies are recommended to reduce the risk of MIHL in live music venues, literature indicates that these strategies are not being implemented or promoted in such venues (Chung et al., 2005).

2.3 The Occupational Health and Safety Act and the music industry

In terms of the OHSA of 1993 an employer is the person whom the employee is under a contract of employment. In the entertainment industry the employer may be the venue owner, the licensee of the premises, the venue management or anyone who employs another individual under a contract (WWA Commission, 2003).

In live music venues there may be a number of employers due to contractual relationships. For example the venue management may employ bar and kitchen staff while the event organiser contracts the bands and sound engineer. Under section 19(4) of the OHSA 1984, the principal employer is deemed responsible for any contractor, and the contractor's employees, when the contractor is signed for employment (WWA Commission, 2003). Thus in the music industry, should the venue management contract an event organiser the principle employer is the venue management, who is then responsible for the event organiser, the band members and the sound engineer (WWA Commission, 2003). All areas of the entertainment industry are required to adhere to these regulations (Barlow & Castilla-Sanchez, 2012).

The employee is considered an individual who works under a contract of employment. In the music industry this may include event organisers, concert promoters, bar, security and maintenance staff. Freelance workers, musicians and sound engineers are also

covered in these terms (Barlow & Castilla-Sanchez, 2012; WWA Commission, 2003).

A self-employed person may be at times an employer or employee and at times may be self-employed. According to the WWA commission (2003), under section 21 of the OHSA (1984) such persons should be responsible for their own health and safety and to ensure that the health and safety of others is not affected by their or their employees' work. However, freelance workers are usually covered in the terms of the OHSA regulations (Barlow & Castilla-Sanchez, 2012). Thus in the music industry individuals such as event organisers, bands, door staff and sound engineers may be considered self-employed if not under a contract of employment, in which case the principle employer is no longer responsible for their health and safety (WWA Commission, 2003).

The OHSA (1993) stipulates that the following regulations shall be enforced by any employer at a workplace where the SPLs exceed 85dBA:

1. No employer will allow an employee to work in an environment where the ambient noise exceeds 85dBA. Subject to the provisions:
    a. The employer shall reduce the SPLs to below 85dBA or in cases where this is not possible the employer shall reduce the intensity levels as far as possible and take all possible steps to isolate the source of the sound.
    b. Where the SPLs cannot be reduced to below 85dBA (as stipulated above), the employer shall i) demarcate noise zones by placing conspicuous warning posters at all entrances and exits to the noise zone. ii) Prohibit any person from entering the noise zone without HPDs.

2. In premises where warning posters cannot be implemented as stipulated in 1.b. above, the notices shall be placed at all entrances and exits to the premises or as close to the workplace as possible.
3. In the event that an inspector is of the opinion that the employer has failed to reduce the SPLs as far as possible, he may in writing request the employer take further steps.
4. The employer shall provide HPDs with no charge to any employee working in or permitted to enter a noise zone where SPLs exceed 85dBA.
5. The HPDs provided shall be:
    a. For the sole use of a specific individual. Except in cases where the employer has taken adequate measures to ensure the common use of HPDs will not result in the spread of infectious diseases.
    b. Maintained in a hygienic condition by the employer.
    c. Stored in a dust free container when not in use, as provided by the employer.
6. The employer shall provide training on the correct use of HPDs and instruct employees as to which areas within the work place require the compulsory use of the HPDs.
7. Furthermore, the employer is responsible to ensure:
    a. That each employee employed to work in a noise zone is subjected to audiometric examinations.
    b. Keep records of the audiometric examinations.
    c. Keep these records for at least 30 years after termination of employment.
8. In compliance with the above regulations the employer shall obtain the

services of an inspection authority.

2.4 Current hearing conservation program for the music industry

Although literature worldwide has indicated the importance of hearing conservation in the music industry, codes of practice for implementing hearing conservation could be found for two countries (HSE, 2008; WWA Commission, 2003) In Western Australia the code of practice has been developed and implemented as of 2002 to control noise in the music industry (Guo & Gunn, 2005; WWA Commission, 2003). This code was developed to ascertain that the OHSA regulations are met within the workplace of live and recorded music venues (Guo & Gunn, 2005; WWA Commission, 2003). The code provides strategies for venue owners, venue designers or builders, venue operators and managers, employers of service staff, suppliers of sound equipment, technical and service staff, performers and entertainers as well as promoters (WWA Commission, 2003). This indicates that current hearing conservation programs focus solely on employers of music venues and do not include strategies for attendees.

Currently there are a few suggestions regarding the venue layout and set up as a means to reduce the risk of MIHL. As structural characteristics such as design and layout may significantly affect the intensity levels in venues, the following strategies have been recommended (HSE, 2008). Firstly, the band should face the majority of the attendees but should not be directed at the bar or any other work area. If possible the speakers should be positioned up high on the walls or on stands, to avoid excessive exposure to individuals in close proximity. Reflection and reverberation should be minimised by using absorptive materials (HSE, 2008). Furthermore, on installation of sound equipment, loud speakers

should be placed with an orientation that minimises the sound directed to employee locations and in a manner that restricts access to areas likely to reach peaks of 140dB (WWA Commission, 2003).

A study conducted in Australia compared entertainment venue compliance with hearing conservation programs, comparing the compliance in the year 2000 to the compliance when the study was conducted in 2005. The Australian study reports that the awareness of responsibility in entertainment venues has increased over the five year period (Guo & Gunn, 2005). In 2005, 23% of the venues evaluated had completed a full noise assessment whereas in 2000, none of the venues had. In 2000, 8% and currently 18% of the venues had implemented a noise control policy including providing training and HPDs to their employees (Guo & Gunn, 2005, p. 213-214). Although this indicates that compliance is still low, it demonstrates that compliance is increasing in Australia.

In this review of current literature, similar studies and policies have not been found for the South African context. This may indicate that although legislation has changed to include the entertainment industry, policies and follow up studies may be required before compliance occurs.

2.5 Need for venue based strategies

Current literature is rich with evidence of the adverse effects of noise [and music] on the auditory system (Bogoch et al., 2005; Chasin, 2009; Chung et al., 2005; Dillon, 2008; Einhorn, 2009; Jokitulppo et al., 1997; Morata, 2007; Schmuziger et al., 2006; Schulz, 2008; Zhao et al., 2010). The lack of hearing conservation programmes in music venues places

attendees at these venues at risk for MIHL (Bogoch et al., 2005; Chung et al., 2005). Attendees at live rock concerts are unlikely to make use of hearing protection despite frequenting concerts where intensity levels place attendees at risk for MIHL (Bogoch et al., 2005). The majority of attendees do not strongly believe that the music exposure may damage the auditory system, despite them reporting tinnitus and TTS which indicate damage to the auditory system (Bogoch et al., 2005; Chung et al., 2005). Although studies indicate that awareness regarding HPDs and availability of HPDs will increase personal hearing protection (Bogoch et al., 2005), the implementation of such strategies is not currently evident in live music venues (Chung et al., 2005). The need for venue-based hearing conservation is further supported by a study, whose findings indicate that adolescent discothèque attendees did not indicate an intention to start complying with personal protection recommendations (Vogel et al., 2010).

It is thus critical to implement an alternate form of hearing conservation to reduce the risk of MIHL at live music concerts. The benefits of such strategies would be that once the strategies are implemented within the venues, the intensity levels and exposure times would automatically be reduced thus protecting attendees, musicians and staffs' hearing.

The purpose of this study is therefore to determine whether venue based-hearing conservation strategies could be an effective means of reducing the risk for music induced hearing loss in live rock and heavy metal music venues. The study was guided by the following research questions: (i) What are the current venue-based hearing conservation strategies implemented in amateur live rock and heavy metal venues? (ii) What are the acoustic and structural characteristics of these venues? (iii) What are the current sound pressure levels in these venues? (iv) Is there a relationship between the structural

characteristics of the venue and the sound levels within the venue?

Chapter 3: Methodology

"…Waiting for the end to come

Wishing I had strength to stand

This is not what I had planned

It's out of my control...."

(Bennington et. al. 2010, track 8)

The purpose of this chapter is to discuss the research design used, as well as the data collection tools and procedures used in this study. Furthermore this chapter discusses the participant selection criteria, the ethical considerations as well as the data analysis methods employed by the study.

3.1 Aims

3.1.1 Main aim

This study aims to determine whether venue-based hearing conservation strategies in amateur live rock and heavy metal venues are a plausible means of reducing the risk of MIHL.

3.1.2 Sub-Aims

In order to achieve the above mentioned aim, the following sub-aims were employed.

- To describe the venue-based hearing conservation strategies currently implemented in amateur live rock and heavy metal music venues in Johannesburg, South Africa.
- To describe the acoustic and structural characteristics of amateur live rock and heavy metal music venues in Johannesburg, South Africa.
- To measure the intensity levels in amateur live rock and heavy metal music venues.

- To determine the significance of variance between the intensity levels in the different areas within a venue.
- To determine the relationship between the structural characteristics of the venues and the difference in intensity levels of the different areas within the venue.

3.2 Hypothesis

The null hypothesis (H_0) is used in research to test theory and to eliminate bias from the hypothesis (Irwin, Pannbacker, & Lass, 2008). There were two hypotheses tested in this study. The first H_0 is that there is no statistically significant difference in variance between the intensity levels in each area of the different venues, whilst the alternate hypothesis (H_1) is that there is a statistically significant difference in variance between the intensity levels in each area of the different venues.

The second H_0 is that there is no statistically significant relationship between the structural characteristics of a venue and the difference in intensity levels within the different areas of the venue. The H_1 is that a statistically significant relationship exists between the structural characteristics of a venue and the difference in intensity levels within the different areas of the venue.

3.3 Research Design

Research design is the way in which the study plans to answer the research questions by testing the research hypothesis (Irwin et al., 2008). This study employed a quantitative research approach, which refers to a research design that organises and integrates the data collected as per mathematical procedures for statistical analyses (Irwin, Pannbacker, & Lass,

2008).

This study employed a multi-method research design in order to determine whether venue-based hearing conservation strategies in amateur live rock and heavy metal venues are a plausible means of reducing the risk of MIHL. A multi-method design is used when the different sub-aims investigated are researched in isolation (Morse, 2003). The results are then combined to test the hypothesis and provide an answer to the main research aim (Morse, 2003).

A non-experimental, descriptive research design was employed to describe the current venue-based hearing conservation strategies and the acoustic and structural characteristics of the live music venues, as well as to measure the intensity levels within these venues. Non-experimental, descriptive research designs summarise the characteristics and frequency of the observed phenomena of the study, and are thus used to systemically describe the phenomenon as it occurs naturally at that point in time (Irwin et al., 2008). Although non-experimental designs are considered the weakest of the quantitative designs (due to the lack of randomisation, manipulation or control), non-manipulation of variables within the current study allow for a better understanding of current practices in situ (Irwin et al., 2008). As this study aims to describe the current hearing conservation practices, acoustic characteristics, structural characteristics and intensity levels within live music venues as they naturally occur, non-manipulation of the environment is of utmost importance.

An exploratory, correlational repeated measure research design was employed to determine the relationship between the structural characteristics of a venue and the intensity levels within the venue. Exploratory research is used to investigate how one factor relates to

other factors (Irwin et al., 2008). This study specifically adopted a correlational design in that it aimed to determine the relationship between variable factors without any active intervention (Irwin et al., 2008). The variables being examined in the current study were the structural characteristics and the intensity levels within live music venues. This study made use of a repeated-measure design to ensure statistical validity. Repeated measures refers to the test situation where one subject, or in the case of this study, one dosimeter is exposed to a multitude of conditions in random order (Irwin et al., 2008). An advantage of this design for this study is that measurements were taken in a naturally occurring environment and thus carry over is ensured (Irwin et al., 2008). A disadvantage of this design for this study is that the analysis is thus limited to intra-venue analysis as the extraneous variables between venues such as equipment and performing band cannot be controlled.

3.4 Research Phases

The research comprised three major phases as outlined in Table 2.

Table 2 *Research phases*

Research Phase		
Developmental Phase	**Pilot Study**	**Main Study**
This phase was aimed at developing appropriate measuring instruments to be used in the study, namely the checklist for current hearing conservation practices and venue acoustics (Appendix A) and Research assistant record form (Appendix B).	The pilot study aimed to finalize the data collection measurements, procedures and equipment needs.	During this phase, the venues appropriate for the study were identified and all measuring instruments applied.

3.5 Pilot study

3.5.1 Objectives

Two pilot studies were conducted. The objectives of the pilot studies were (i) To determine the feasibility of the research; (ii) To finalise the measuring instruments; (iii) To determine whether the required information will be obtained with the measuring instruments; (iv) To determine the suitability of the equipment used in the data collection. The objectives are detailed in Table 3 overleaf.

3.5.2 Procedures

Once ethical clearance had been obtained (Refer to appendix C) the researcher contacted a venue that met the same selection criteria as for the main study. Once permission was obtained the researcher visited the venue to conduct the questionnaire via interview with the venue owner (Appendix A), and conduct the observations within the venue to determine the current hearing conservation practices and describe the venue acoustics. Furthermore during the visit, the researcher and research assistant recorded the SPLs within the venue. Once the equipment for the study had been secured, a second pilot study was conducted to determine the suitability of the equipment. The equipment was calibrated and set to record recorded music for 35 minutes and the researcher completed the research assistant record form (Appendix B).

3.5.3 Results and recommendations

The objectives, materials and equipment, procedures, results and recommendations made after the completion of the pilot studies are outlined in Table 3 overleaf.

Table 3 *Objectives, materials, procedures, results and recommendations from pilot studies*

Objectives	Materials & equipment	Procedures	Results	Recommendations
To determine the feasibility of the research	Selection criteria The current hearing conservation and venue acoustic form (Appendix A)	Following ethical clearance the researcher used the same venue selection criteria as in the main study. Once a venue had been identified the researcher conducted the questionnaire and observation.	Completion of the interview and questionnaire was effective and thus this phase of the research proved feasible.	As the pilot study indicated this phase of the study to be feasible it was included in the main study.
	Two Quest 210 sound level meters	The researcher and a single research assistant (Audiologist) visited the venue and recorded the SPLs within the venues. The research assistant was given a demonstration of the equipment.	The SPLs throughout the venue indicated large discrepancies between the area of the venue and the sound levels recorded.	It was thus determined that these significant variances of SPLs within the venue should be investigated further and included in the research aims.
	A band A sound engineer 100 participants Participant rating scale form	Initially this study envisaged to evaluate different speaker placements on attendee's perception of the intensity and quality on the music. It was proposed that a live music event be simulated with different speaker placements. At least 100 individuals would be required to rate each speaker placement on a sliding scale. The use of 100 participants was proposed to ensure statistical reliability.	On two occasions the event simulation was planned and prepared for. On the initial trial the band cancelled and on the second the sound engineer cancelled. On both attempts, finding the 100 participants proved difficult.	Based on the results it was deemed that this section of the study was not feasible due to logistical complications.
To determine whether required information will be obtained with the measuring instruments selected.	The current hearing conservation and venue acoustic form (Appendix A)	All data was encoded and analysed using basic descriptive statistical procedures.	The questionnaire and observations were successful in obtaining the required information and thus proved the measures to be valid and reliable.	The current hearing conservation and venue acoustic form is an effective tool and thus viable for use in the main study. A second form: Research assistant record form (Appendix B) was developed.

Objectives	Materials & equipment	Procedures	Results	Recommendations
To determine the length of time required to complete the data collection process.	The current hearing conservation and venue acoustic form (Appendix A) Research assistant record form (Appendix B) 7 Dosimeters	In the initial pilot study the current hearing conservation and venue acoustic form was completed. In the second pilot study, a test run with the equipment and research assistant record form was performed.	The questionnaire and observations could be completed over one evening within each venue. In order to collect the sound pressure levels within the venue two sets of 35minutes of recording was required. The pilot study indicated that both sets could be collected for one venue in a single evening.	Based on the results it was determined that the data collection period would require one evening per venue. As the data collection was required to occur over weekend evenings, the total data collection period was estimated at two to four weeks.
To determine the suitability of the equipment used in the data collection.	7 Dosimeters 1 Calibrator	In the second pilot study, a test run with the equipment and research assistant record form was performed.	The equipment proved suitable.	Based on the results the equipment was deemed suitable for use in the main study

3.6 Main study

3.6.1 Participants

3.6.1.1 Participant Sampling Strategy

A non-probability, purposive, maximum variation sampling strategy was used to identify the four amateur live rock and heavy metal music venues used in the study. Non-probability sampling refers to a sampling strategy that does not involve random sampling (Irwin et al., 2008). Purposive sampling was used as the study aimed to observe, describe and evaluate venues with regard to the current hearing conservation strategies employed. Maximum variation sampling allowed the researcher to evaluate venues with a wide range of variations (Patton, 2001). In the current study, these variations included structure, layout and size of the venues. This allowed for the provision of more in-depth information regarding hearing conservation and the acoustic characteristics of venues in Johannesburg. A disadvantage of this sampling strategy is that due to the limited number of amateur live rock and heavy metal music venues in Johannesburg random sampling could not be used despite the fact that random sampling aids in strengthening the reliability of the study (Irwin et al., 2008).

3.6.1.2 Participant Selection Criteria

The venues selected for the study were required to meet the following selection criteria:

- Located in the Gauteng area.
    - This study was limited to the Gauteng area due to the scope of the study.
- Have a valid entertainment licence.
    - Venues require an entertainment licence to host live music performances.
- Be structurally different from each other with regard to size and layout.

- Structural differences were required in order to allow for maximum variation.

- Host live music performances, specifically rock and heavy metal bands.
  - The venues were required to host live music venues as this study aims to investigate hearing conservation strategies with live music venues.

3.6.1.3 Participant (venue) description

Four amateur live rock and heavy metal music venues with valid entertainment licenses located in Gauteng were used in this study. On the evening of data collection there were live music performances by local bands in all four venues. Refer to Table 4 for a full description of each of the venues.

Table 4 *Description of venues*

	Venue 1	**Venue 2**	**Venue 3**	**Venue 4**
Location	Johannesburg	Johannesburg	Johannesburg	Johannesburg
Main function of venue on weekdays	Pool bar	Bar, diner as well as private function venue	Local bar and pizzeria	Bar, diner as well as private function venue
Type of music played on week days	Recorded music	Live bands or recorded music	Live bands or recorded music	Recorded music
Type of live music venue	Hard rock and heavy metal bands	Rock and heavy metal bands	Rock bands	South African bands from all genres
Type of live music played during data collection	Set 1: Heavy metal	Set 1: Light rock	Set 1:Mixed rock	Set 1:Rock
	Set 2: Heavy metal	Set 2: Rock	Set 2: Mixed rock	Set 2: Rock
Permanent speaker system available	Yes	Yes	No	Yes

3.6.2 Measures and Equipment

3.6.2.1 Equipment

The following equipment was utilized during the data collection procedure:

- Quest NoisePro DLX Dosimeters: Seven recently calibrated dosimeters (July 2012) obtained from the Council for Scientific and Industrial Research (CSIR) were used to simultaneously record the intensity levels at the venues. It is common practice to use a Sound Level Meter (SLM) for static recordings of sound levels, whereas, dosimeters are used to record and determine personal noise exposure over an extended period of time. As the researcher could not procure more than two SLMs for simultaneous recordings throughout the venues during data collection, the most appropriate alternative were the use of dosimeters. In this study, the dosimeters were used for static measurements recorded at one minute intervals by the research assistants (Figure 1).The measurement sets of 35 minutes were decided on based on the statistical requirements of at least 30 repeated recordings per set in each venue. Simultaneous recordings were required to compensate for the extraneous variables such as different music and the varied number of people in the venue. Various functions of the dosimeters (e.g. recording of SPL over a short period of time to estimate the projected time weighted average) where therefore not used during data collection. It should be noted that the dosimeters were set with a minimum limit of 65dB, therefore during the recordings, intensity levels lower than the minimum limit were recorded as 65dB.



Figure 1 Quest NoisePro DLX dosimeter.

- Quest sound calibrator: The calibrator was used to calibrate each dosimeter on each test day prior to use to ensure accurate readings and therefore enhance the validity of the study.
- Batteries: AA batteries were used to power the dosimeters and a 9 volt rectangular battery for the calibrator.
- HPDs: Formable HPDs were used by the researcher and research assistants to protect them from possible NIOD.
- Clipboards and pens: The research assistants were each provided with a clipboard and pen in order to record the intensity levels measured on the relevant data collection form.
- Timers: The timers on the dosimeters were used by the research assistants to record

the measurements at one minute intervals.

3.6.2.2 Measures

Two measures were developed for the purpose of this study.

3.6.2.2.1 Observation checklist: Current hearing conservation practices and venue acoustics.

This checklist was developed by the researcher to record the current venue-based hearing conservation strategies and acoustic characteristics of the venues (Appendix A). This checklist included three sections and included both open- and closed-ended questions. Demographic information included the venue number as well as the job description of the person with whom the checklist was completed. A description of the content and the rationale for the inclusion of the items are presented in Tables 5 and 6.

Table 5 *Description of self-developed checklist*

Sections	Sub-sections	No. of questions	Rationale
Owner/Managers' attitude towards venue-based hearing conservation strategies	HPDs	4	Strategies for the prevention of MIHL at rock concerts should include health promotions, engineering control, education, personal protection and frequent hearing screenings (Bogoch et al., 2005). Although MIHL is permanent and irreversible, many rock concert attendees are not concerned about causing damage to the auditory system as hearing loss is not immediate (Chung et al., 2005), thus venue-based strategies are important.
	Awareness posters/pamphlets	8	
	Low intensity areas	6	
Current hearing conservation strategies implemented in the venue	HPDs	5	Although studies indicate that awareness regarding HPDs and availability of HPDs will increase personal hearing protection (Bogoch et al., 2005), the implementation of such strategies is not currently evident in live music venues (Chung et al., 2005).
	Awareness posters	2	
Acoustic and structural characteristics of the venue	Acoustic characteristics of the venue	7	Acoustic characteristics such as venue layout (including physical obstructions such as walls and pillars), materials used and controlling speaker output can be used to reduce the risk of hearing loss (Bogoch et al., 2005). Furthermore speaker placements during live music concerts may affect the intensity levels in the venues (Chasin & Chong, 1995).
	Distribution of sound	2	
	Structural characteristics of the venue	8	

VENUE-BASED HEARING CONSERVATION STRATEGIES

As literature indicates that certain acoustic and structural characteristics may be used to reduce the intensity levels within music venues (Bogoch et al., 2005; Gastmeier, 2009; Guo & Gunn, 2005), the section on the acoustic and structural characteristics in the checklist are important. The limited literature regarding structural characteristics as a means to reducing the risk of MIHL highlights the need for obtaining information regarding the current practices in acoustic and structural characteristics in live music venues. The description of specific characteristics included in the checklist is outlined in Table 6 overleaf.

Table 6 *Description of acoustic and structural characteristics*

Characteristics		Rationale
Acoustic	Presence of dry walling and wooden flooring	The use of dry walling or wooden flooring in music venues is discouraged as the materials used absorbs the sound waves, specifically low frequency waves. This results in the music being further amplified by the sound engineer as to increase the perceived loudness of the music (Gastmeier, 2009).
	Presence of seating in the main entertainment area	The seat-dip effect should be avoided, this effect is caused by the over-presence of absorptive materials, usually as a result of seating in the venue, and results in an energy deduction in the 100-400 Hz range (Gastmeier, 2009).
	Distance between speakers and audience	Two metres of unobstructed space between the speakers and attendees is recommended as bodies are absorptive, and thus the perceived intensity levels will be reduced (Chasin & Chong, 1995)
	Speaker placement	If possible the speakers should be positioned up high, on the walls or on stands to avoid excessive exposure to individuals in close proximity (HSE, 2008). Furthermore placing speakers on the floor may result in absorption of the low frequencies (Chasin & Chong, 1995)
	Presence of background noise	Background noise such as air conditioning or road traffic noise may result in increased intensity levels in venues and should thus be avoided (Gastmeier, 2009).
	Presence of reflective surfaces	The over use of hard reflective surfaces is discouraged in music venues as this results in increased intensity levels and a poor sound quality (HSE, 2008).
Structural	This section includes information of the structural characteristics of the venue as it relates to the layout (See Appendix A).	There is currently limited literature to support the notion that structural characteristics may affect the intensity levels in live music venues. The current recommendations encourage a small venue or sectioned off entertainment area to reduce the RT within the entertainment space, as well as excluding work areas from the entertainment area (Gastmeier, 2009; HSE, 2008).

3.6.2.2.2. Research Assistant Record Form.

The second measuring instrument was used by the research assistants to manually record the sound level measurement readings (Appendix B). This record form included descriptive information (e.g. assistant code, location within venue, date of recording and test/set number) as well as the time of the recording (in one minute intervals) and the SPL reading corresponding with the time.

3.6.3 Procedures

The following procedures were employed in order to collect, record and analyse the data obtained:

- Ethical clearance was obtained from the University of the Witwatersrand's Medical Research Ethics Committee (Clearance certificate M110846) (See Appendix C).
- Potential venues were identified and the owners/managers approached and invited to participate in the study.
- Informed consent was obtained from each venue (See Appendix D).
- Two pilot studies were conducted to assess the feasibility of the study, to ensure the data collection methods were reliable and to estimate the length of data collection.
- Appointments to visit the venues were made at times indicated as convenient for the venue staff and the questionnaire (Appendix A) was administered to the venue owner/manager. The checklist (Appendix A) completed by the researcher through structured observations. The Owner/Manager was then provided with the information sheet (Appendix E)
- On each evening that the data collection took place, each dosimeter was calibrated before use.

VENUE-BASED HEARING CONSERVATION STRATEGIES

- Prior to recording and performance, seven areas within the venues were pre-marked by the researcher at recording sites. These areas included:
    a. One metre from the midpoint of the main sound output source.
    b. One metre from the back of the main entertainment area.
    c. At the centre of the visitor's side of the bar, unless the bar is at the back of the entertainment area, in which case the measurements were taken at the upper seating area if available.
    d. At the entrance to the venue.
    e. At any available seating area.
    f. One meter from the door of any available outside area.
    g. Midpoint between the doorways to the male and female bathrooms

These seven areas were selected as they are functional areas within the venues, which are commonly used by attendees.

- On each evening the research assistants were instructed on the use of the dosimeters. They were instructed on the aims of the study and the rationales for the procedures. Precautions and requirements were discussed.
- The SPLs were then recorded by the researcher and six research assistants during live music performances in each venue at times indicated as convenient by the venue staff. The recordings were performed during a typical weekend evening with a live band playing and attendees present. The data collection occurred over four evenings, one evening per venue. Over the course of each evening, two sets of measurements were recorded, within the venue being investigated. The research assistants recorded 70 measures for each venue, for two sets of 35 readings at one minute intervals.
- Each research assistant held a dosimeter and recorded the SPLs at one minute

intervals. The dosimeters were started by the assistants simultaneously and ran for 35 minutes, providing 35 readings for each position within the venue

- The second set of readings was then recorded at each venue where the assistants recorded a further 35 minutes of simultaneous recordings.
- Each set of SPL recordings were indicated by the research assistants at one minute intervals on the Research assistant record form (Appendix B).

3.7 Ethical Considerations

The World Medical Association (WMA) developed the Helsinki ethical principles to ensure the rights, safety and respect of all human participants in medical research (WMA, 2008). Although human participants were not used in this study, the managers/owners were involved in sections of this study. Furthermore, research assistants were used throughout the data collection period. It is vital that the health of the participants are always the main priority and that the researcher always acts in the participants' best interest. This research will now be discussed in terms of the four principles of ethics, which include autonomy, beneficence, non-maleficence and justice (Boylan, 2000).

The principle of *autonomy* refers to the individual's self-determination (Boylan, 2000). Autonomy was achieved in this study via informed consent. Written permission was obtained from the owners and/or managers of the live music venues using an introductory letter with informed consent (Appendix D). The venue owners or managers were informed in writing about the goals and importance of the study, the procedures involved the risks and benefits involved, and measures taken to ensure confidentiality. The informed consent letter

also stated their right to withdraw from the study at any point without any negative consequence.

The principle of *beneficence* refers to actions that lead to the wellbeing of others (Frankena, 1973). The venue owner/manager received ear and hearing care education in the form of a self-developed hearing awareness pamphlet (Appendix E) which discussed the effects of high intensity sounds on the auditory system and personal hearing conservation strategies that may be used to reduce the risk of MIHL.

Non-maleficence is the principle that states above all to do no harm (Boylan, 2000). Ethical clearance was obtained from the University of the Witwatersrand Human Ethics Committee (Appendix C). In accordance with the Helsinki principles, all research involving human participants should be written and submitted in the form of a research proposal for ethical clearance (MWA, 2008). The venue owner/manager and staff (including the band and sound engineer) were not exposed to any excess intensity levels outside of their regular work practices, and were thus not placed at additional risk that is not a part of their regular life activities. The research assistants were exposed to excessive intensity levels outside their regular work practices and thus were provided with HPDs with no charge.

Justice refers to the distribution of good and evil (Frankena, 1973). The dangers involved in participating in the study included exposure to potentially dangerous intensity levels. However, this exposure was either within their regular life activities or they were provided with HPDs. The potential benefits of the study thus outweighed the risks involved as the venue-based hearing conservation strategies being explored may provide long-term protection against the risk of MIHL in live music venues.

Confidentiality was ensured as each of the venues involved were assigned a venue number that was used on all forms and documentation. Only the researcher has the knowledge of each venue's name. Furthermore, the records are stored in a locked cupboard for five years or two years after publication in the Speech and Hearing department at the University of the Witwatersrand, after which they will be destroyed.

3.8 Reliability and Validity

3.8.1 Reliability

Reliability refers to the consistency of measurements or the correlation between repeated measures (Irwin et al., 2008). Reliability is important in research as it ensures dependability, credibility and stability of the results (Irwin et al., 2008). This study made use of a test-retest method of reliability as in each venue two sets of data were recorded on the same evening. Inter-rater reliability was also used in the initial pilot study. The researcher and a research assistant recorded the SPLs in the venue simultaneously to ensure reliability of the findings. The Inter-rater correlation proved to be good as the marked differences in SPLs within the venue was evident in both sets of measurements. Furthermore the equipment used was professionally calibrated (as in accordance with the SABS standards) within six months of use for this study to ensure reliable readings. The equipment further underwent daily calibration on each day prior to use.

3.8.2 Validity

The validity of a study refers to the extent to which the data collected is able to

answer the research question. (Irwin et al, 2008). Internal validity is used to determine if the manipulation of the experiment affected the dependent variable (Irwin et al., 2008). As this study was not a true experimental design and did not manipulate variables, internal validity was not preformed. External validity refers to the sensitivity and generalizability of the study (Irwin et al, 2008). External validity was achieved by means of construct validity. Construct validity refers to the ability of a measure to represent the variable being measured (Irwin et al, 2008). In the first pilot study conducted the current hearing conservation practices and venue acoustics checklist was administered. The hypothesised answers were obtained and thus the checklist deemed valid in obtaining the required information.

3.9 Data analysis and statistical procedures

The data was documented on all the relevant measuring instruments and encoded for data analysis. All the data was computerized for statistical analysis on a Microsoft Excel spreadsheet, using the add-in data analysis function. The results were then analysed using a variety of statistical procedures, listed in Table 7 and displayed in tables and figures.

Table 7 *Description of data analysis*

Statistical procedures	Rationale
Descriptive statistics	Descriptive statistics are used in research to describe quantitative data (Irwin et al., 2008). Central tendency and variability descriptive statistics were used in this study as the mean and range of the SPLs recorded were used for analysis.
Analysis of variance (ANOVA)	Inferential statistics are used to determine whether relationships observed in the sample are likely to occur in the larger population (Irwin et al., 2008). The hypothesis testing approach, a one-way ANOVA, is used to determine if a relationship between the variables exists (Irwin et al., 2008). In this study, the effect of the acoustic characteristics of live music venues on intensity levels was determined using a one-way ANOVA.
Bonferroni *t*-test of variance	Post-hoc analysis of results was performed where results were found to be significant. The Bonferroni *t*-test of variance were performed to determine which areas within the venues indicated significant differences between the means of the recorded SPLs (Howell, 2002)
Chi-square test	Based on the results of the Bonferroni *t*-test, the frequency of observations of significant variance for the different structural characteristics was analysed using the Chi-square test. This analysis aimed to determine if a relationship exists between each structural characteristic and the difference in SPLs between areas with the venue. The Chi square test is valid for this analysis as it is used when the data being analysed refers to the frequency of occurrence (Irwin et al., 2008)

3.10 Summary

This chapter discussed the aims of this study as well as the research design employed. The equipment, procedures and participants of the study were also outlined in this chapter. Furthermore this chapter detailed the ethical issues that governed the study as well as the data analysis procedures used.

Chapter 4: Results

"…Flying at the speed of light

Thoughts were spinning in my head

So many things were left unsaid

It's hard to let you go..."

(Bennington et. al. 2010, track 8)

The results of the study are presented in relation to the aims of the study. This chapter commences with a description of the venue-based hearing conservation strategies currently implemented in amateur live rock and heavy metal music venues in Johannesburg, South Africa. Thereafter, the acoustic and structural characteristics of the venues are discussed. The SPLs recorded in each venue are presented and the significance of variance between the SPLs in the different areas within a venue are analysed. Lastly, the relationship between the structural characteristics of the venues and the variance of the SPLs are discussed. Data was organized, analysed and interpreted with a view on drawing conclusions regarding the plausibility of venue-based hearing conservation strategies as a means of reducing the risk for MIHL.

4.1 Hearing conservation practices in live rock and heavy metal music venues

The current venue-based hearing conservation practices within each of the venues were discussed with the owners and/or managers and then confirmed through observation with and without attendees. The results of these observations are presented in Table 8 overleaf.

Table 8 *Current hearing conservation practices within live music venues*

Type of hearing conservation	Venue 1	Venue 2	Venue 3	Venue 4
HPDs available for sale	No	No	No	No
Attendees observed using HPDs	2	0	0	0
Staff observed using HPDs	0	0	0	0
Musicians observed using HPDs	3	2	2	1
Hearing conservation posters available	No	No	No	No
Hearing conservations pamphlets available	No	No	No	No

The results indicate that no hearing conservation strategies were observed to be implemented in any of the venues. Venues therefore did not sell HPDs nor had relevant posters and pamphlets available on hearing, hearing loss and MIHL. Although no staff and only a limited number of attendees (2) were observed using HPDs during the live music performances, a number of musicians (8) were using HPDs.

The owners and managers of the venues were asked about the implementation of hearing conservation programmes within the venues. The results demonstrate a willingness of all individuals interviewed to implement hearing conservation programmes in their venues. All the venue managers stated that if provided with HPDs they would supply them to attendees and display hearing awareness pamphlets. Only one of the four venues (Venue 4) indicated that they will not display hearing awareness posters.

4.2 Acoustic and structural characteristics of live rock and heavy metal music venues

The acoustic and structural characteristics of each venue were observed by the researcher and recorded on the Observation Checklist (Appendix A).

4.2.1 Acoustic characteristics of venues

The acoustic characteristics of each venue were observed and recorded in terms of the current recommendations for acoustics in live music venues. The current acoustic characteristics as observed in each venue are outlined in Table 9 overleaf.

Table 9 *Acoustic characteristics of live music venue*

Acoustic characteristics	Venue 1	Venue 2	Venue 3	Venue 4
Dry walls	Behind main entertainment area and by the entrance	None	None	None
Wooden floors	On the deck (outside area)	In the bar area	The upstairs area	The upstairs area
Reflective surfaces in the main entertainment area	Glass panels at the back of the main area	Glass windows along the back and one side of the main area	Glass windows in the main area as well as 5cm square mirrors on the wall as decor	None
Distance between stage and audience (in metres)	None	None	None	None
Speakers placed on floor	Two 15 inch 1000 watt (W) speakers	Two 18 inch 1000W speakers Two 15 inch 1000W speakers	Four 18 inch 1000W speakers Four 12 inch 1000W speakers (provided by musicians)	Four dual 18 inch subwoofers
Speakers suspended from ceiling	None	Two 12 inch 1000W speakers	None	Six 15 inch 500W speakers
Placement of speakers	One speaker on either side of the stage, facing the audience.	12 inch speakers suspended with one on each side of the stage facing the audience. The 18 inch speakers were placed on the floor, one on each side of the stage facing the audience. Each of the 18 inch speakers had a 15 inch speaker placed on top of it.	On each side of the stage, facing the audience, two of the 18 inch speakers were stacked on top of each other with a 12 inch speaker placed on top. Next to each of these stacks was another 12 inch speaker on a stand.	The 15 inch speakers were suspended from the ceiling with three on either side of the stage. The Subwoofers were placed on the floor with two placed on top of each other on each side of the stage.
Speakers permanently in the venue	Yes	Yes	No, speakers brought in and set up by performers	Yes
Seating in the main entertainment area	None	Wooden tables with wooden benches placed throughout the main area	Small cocktail tables with metal legged chairs. Placed away from the stage to allow room for audience	Wooden tables with wooden chairs placed throughout the main area
Background noise (in quiet venue)	None	None	None	None
Venue location	Free standing in industrial area	Shopping centre in residential area	Free standing on the outskirts of a residential area	Shopping centre in residential area

4.2.2 Structural characteristics of venues

The layout and floor plan (although not scaled to size) are presented and discussed for each of the venues. The points of measurements are also indicated on the floor plans as discussed in Section 3.6.3. A summary of the structural characteristics is presented in table 10 on page 56.

Venue 1

Venue 1 is open plan as the areas of the venue were not structurally separated from each other (See Figure 2). The main entertainment area opened up to the bar and inside seating area via a single step. The bar then led to the entrance as well as through an open door to an outside seating area. The inside seating area also contained pool tables. The pool tables were sectioned off from the stage with a large piece of dry walling. The bathrooms were connected by an open corridor to the inside seating area.

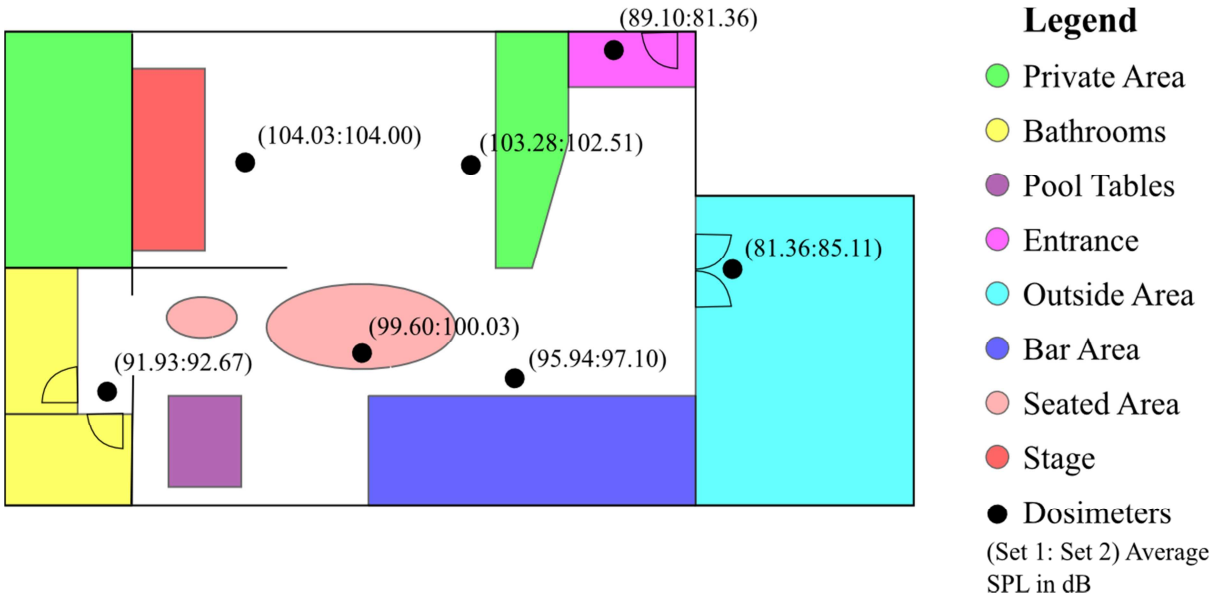

Figure 2 Structural layout of Venue 1 (not drawn to scale)

Venue 2

This is one of the two venues that were not open plan (See Figure 3). The main entertainment area was sectioned off from the rest of the venue with walls and windows. The bathrooms were connected to the main entertainment area by a short open corridor. Two doors connected the main entertainement area to the inside seating areas. The door closest to the entrance was observed to remain closed while the door closest to the bar was kept open. The bar was situated in the inside seating area. The inside seating area led down to the entrance via a few stairs. The outside area contained wooden tables and benches and was connected to the inside seating area through a door next to the bar. This door remained open throughout the observations.

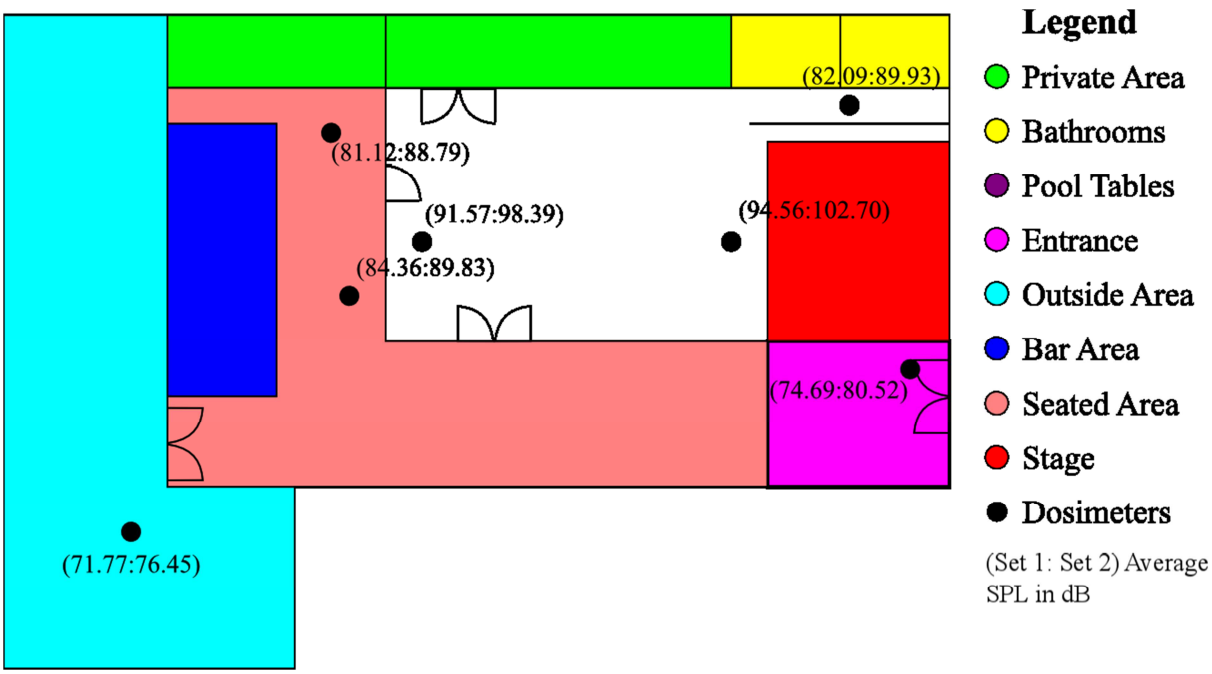

Figure 3 Structural layout of Venue 2 (not drawn to scale)

Venue 3

This venue has two levels. It was noted that the main entertainment area was sectioned off from other areas (See Figure 4). However, the bar was in the main entertainment area, as well as the upper seating area. The inside seating area was attached to the main entertainment area via a door and a set of stairs. Bathrooms were set within this inside seating area. The main entertainment area had two doors leading outside. The first door remained closed and opened up to an outside seating area and outside bathrooms. The second door remained open and led to the entrance of the venue as well as further seating areas. The upper seating area contained an inside and outside seating section. The inside section was within the main entertainment area and was open to view the stage.

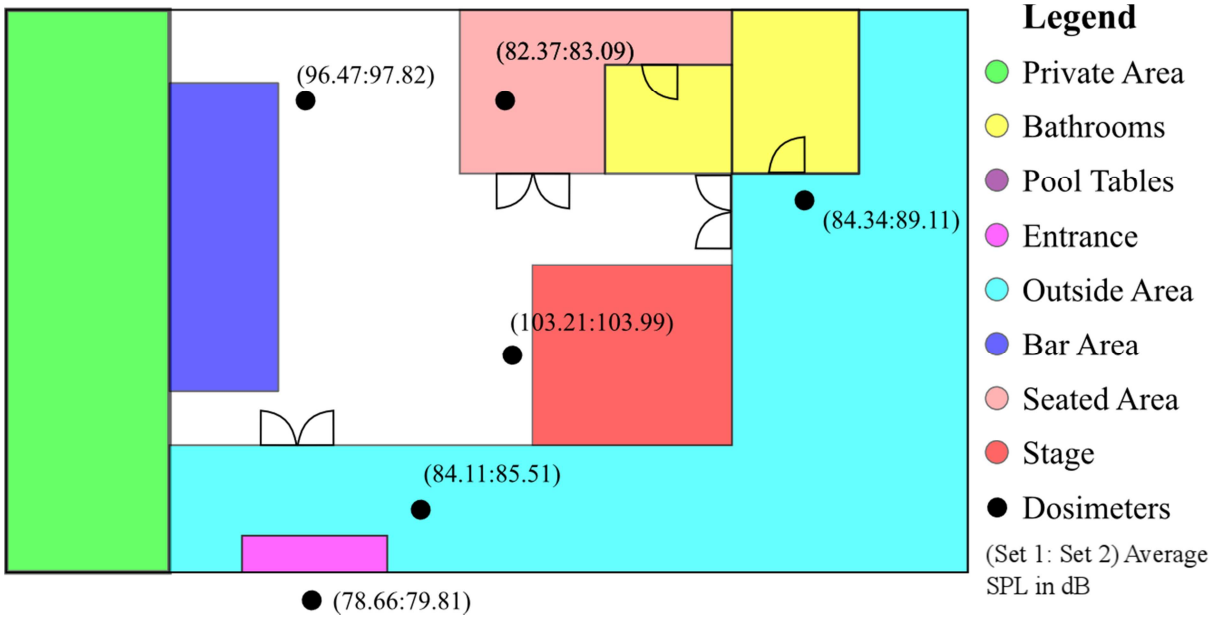

Figure 4 Structural layout of Venue 3 lower level (not drawn to scale)

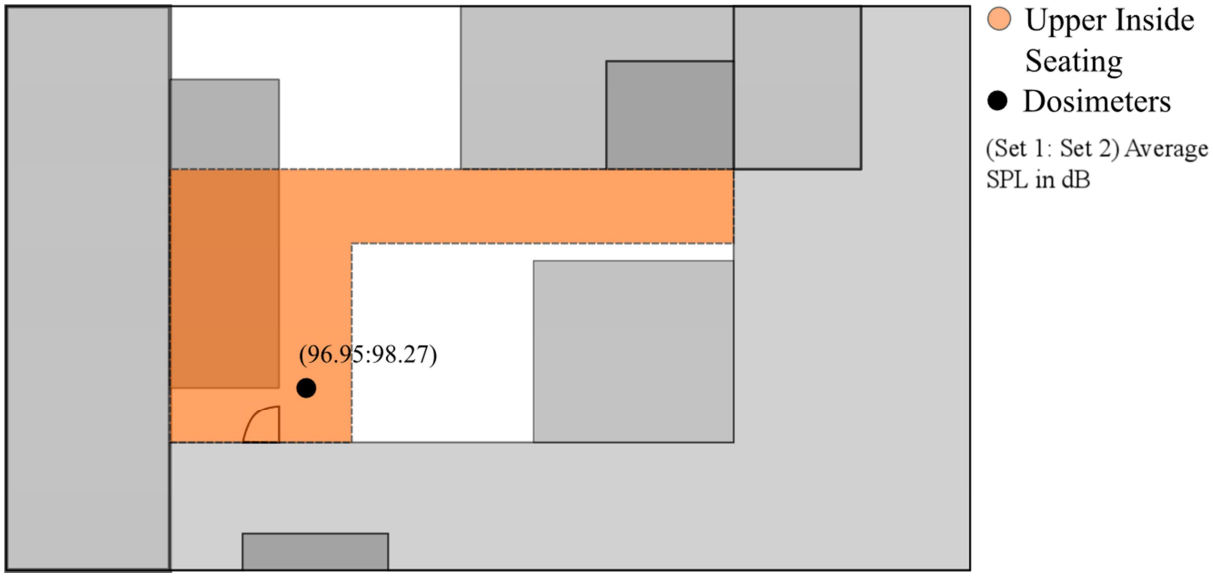

Figure 5 Structural layout of Venue 3 upper level (not drawn to scale)

Venue 4

This venue is open plan (See Figure 6). The main entertainment area contained the bar at the back with the upper seating area above. The bathrooms and entrance led off the main entertainment area. The inside seating area was in the main entertainment area as well as adjacent to this area. The bar at the back of the entertainment area opened to an outside balcony through a large open door.

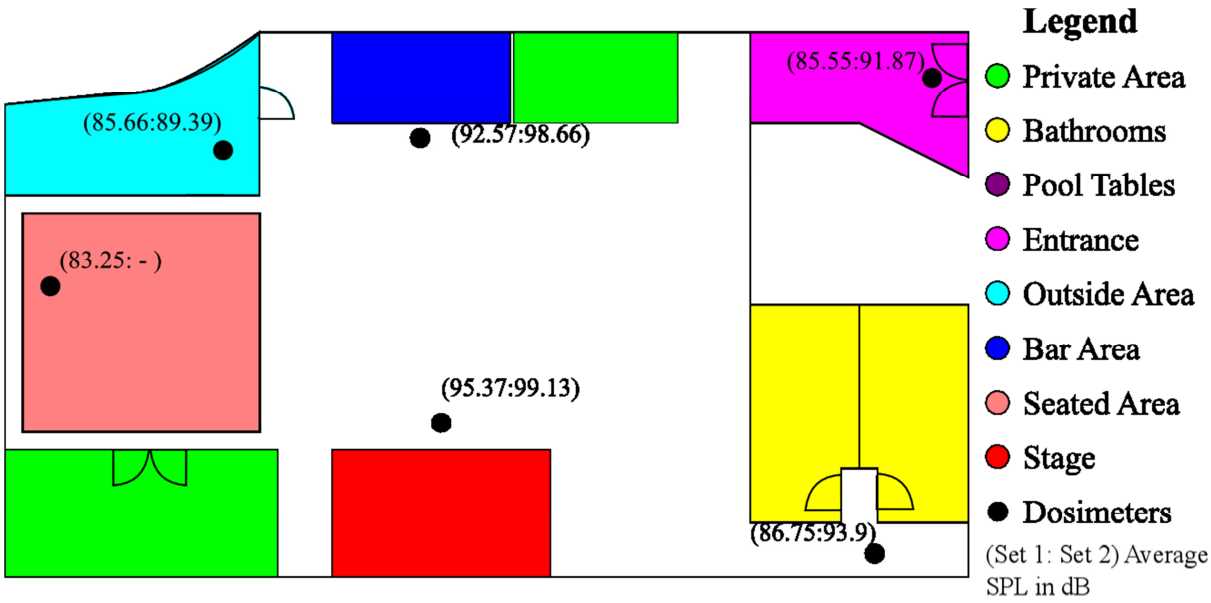

Figure 6 Structural layout of Venue 4 lower level (not drawn to scale)



Figure 7 Structural layout of Venue 4 upper level (not drawn to scale)

Table 10 *Structural characteristics of live music venue*

Structural characteristics	Venue 1	Venue 2	Venue 3	Venue 4
Main entertainment area	Venue open plan	Main entertainment area sectioned off by means of walls with windows and access through two doors.	Main entertainment area sectioned off by means of walls with windows and access through two doors.	Venue open plan
Bar area	Bar area separate from the main entertainment area but not structurally separated.	Bar structurally separated from main entertainment area by walls with windows.	Bar at the back of the main entertainment area.	Bar at the back of the main entertainment area
Outside seating area	Opens to venue via a door in the bar area. Door remains open.	Opens to venue via a door in the inside seating area, next to the bar. Door remains open.	The outside area separates the main entertainment area from the entrance. The main entertainment area has two doors that lead to the outside area. The door that leads to the entrance remains open whilst the door leading to the outside bathroom area remains closed	Opens to venue via a door in the bar area. Door remains open.
Upper inside seating area	None	None	Upper seating area is a balcony in the main entertainment area. It is open to this area and looks down onto the stage. The area is accessed through an outside stairway near the entrance to the venue.	Upper seating area is a balcony in the main entertainment area. It is open to this area and looks down onto the stage. The area is accessed via a stairway next to the stage.
Inside seating area	Positioned away from the main entertainment area but not structurally separated.	Structurally separated from the main entertainment area by walls with windows. Two doors join the areas; one remains open whilst the other remains closed.	Inside seating area structurally separated from the main entertainment area by walls. The areas are joined by a single door which remains closed.	Positioned away from the main entertainment area but not structurally separated.

Structural characteristics	Venue 1	Venue 2	Venue 3	Venue 4
Entrance	The entrance is separated from the main entertainment area and bar area by dry walling.	The entrance opens to the inside seating area via a few steps.	The main entrance is a gate outside. Attendees must enter the venue and pass through part of the outside seating area to enter the main building	The entrance is on the ground floor. Attendees enter the venue and must then walk up a flight of stairs to reach the entertainment areas.
Bathrooms	Bathrooms are attached to the inside seating area via a short open corridor.	Bathrooms lead off from the main entertainment area via a short open corridor	This venue has two sets of bathrooms. The one set is accessed through the outside seating area whilst the other set are positioned in the inside seating area.	Bathrooms lead off from the main entertainment area via a short open corridor

4.3 Recorded sound pressure levels

The SPLs were recorded in each of the venues. The research assistants were placed at the seven predetermined points within each venue, as discussed in Section 3.6.3.

In venue 1 the bands played heavy metal music during both sets of recordings. In venue 2 the first band played light rock music whilst the second played harder rock. In venue 3 one band played throughout both sets of recordings and their music ranged from light to heavy rock music. Both bands recorded in venue 4 were playing rock music on the evening the data was collected.

The results indicating the recorded SPLs in each of the venues (two sets of recorded data) are presented in Table 11. It should be noted that weighting has not been used on these averages.

Table 11 *Recorded sound pressure levels*

Venue	Set	SPL (in dB)	Position of recording (SPL measured in dB)							
			In front of stage (midpoint between speakers)	Back of entertain-ment area (parallel to 1st dosimeter)	Inside seating area	Upper inside seating area	Bar	Bathrooms	Entrance	Outside areas
1	1	Range	84.9 – 110.6	91.1-110.3	70.8-110.0	N/A	83.4-102.2	74.3-100.1	70.5-98.2	66.4-88.9
		Ave	104.03	103.28	99.60	N/A	95.94	91.93	89.1	81.36
	2	Range	82.4 – 112.4	70.3-110.2	83.8-106.9	N/A	85.9-102.9	73.6-99.3	76.4-97.6	74.3-92.0
		Ave	104	102.51	100.03	N/A	97.10	92.67	89.35	85.11
2	1	Range	71.4-115.1	71.6-108.2	73.5-98.1	N/A	71.8-92.4	65.0-95.4	65.0-84.1	65.0-84.8
		Ave	94.56	91.57	84.36	N/A	81.12	82.09	74.69	71.77
	2	Range	82.3-112.4	78.6-111.1	75.4-97.9	N/A	79.4-98.1	72.2-99.7	69.2-90.0	65.3-87.7
		Ave	102.7	98.39	89.83	N/A	88.79	89.93	80.52	76.45
3	1	Range	86.9-112.0	83.4-103.9	68.8-91.0	84.9-105.8	N/A	70.2-93.5	68.6-85.6	72.5-93.6
		Ave	103.21	96.47	82.37	96.95	N/A	84.34	78.66	84.11
	2	Range	90.1-115.4	86.6-103.8	69.6-89.2	89.6-103.6	N/A	73.8-99.2	69.8-87.2	75.3-91.4
		Ave	103.99	97.82	83.09	98.27	N/A	89.11	79.81	85.51
4	1	Range	76.1-109.6	77.5-104.3	65.0-97.1	69.0-106.5	N/A	69.9-100.8	69.2-98.4	73.4-95.3
		Ave	95.37	92.57	83.25	93.10	N/A	86.75	85.55	85.66
	2	Range	79.3-110.8	82.1-108.1	-	85.1-109.2	N/A	72.3-105.2	71.4-98.6	67.7-97.3
		Ave	99.13	98.66	-	100.03	N/A	93.9	91.87	89.39

VENUE-BASED HEARING CONSERVATION STRATEGIES

Based on the average SPLs, it is evident that the loudest point in each venue was at the front of the main entertainment area. In the venues without an upper inside seating area (Venues 1 and 2), the back of the main entertainment area indicated the next highest SPLs. However, in the venues with an upper inside seating area overlooking the stage (Venues 3 and 4), the SPLs upstairs indicated a higher intensity than the SPLs at the back of the entertainment area. In all the venues with the exception of Venue 3, the outside seating area presented the lowest SPLs in the venue and the entrance to the venue indicating the next lowest intensities. In Venue 3, the SPLs at the entrance were lower than in the outside seating area; this can be attributed to the structural design of the entrance to the venue being an outside gate rather than at the entrance to the building. In Venue 1 and 2, where the bar was not at the back of the main entertainment area, the bar area indicated SPLs of a lower intensity that the SPLs in the inside seating area. Whereas in Venue 3 and 4, where the bar was positioned at the back of the main entertainment area, the SPLs at the bar were higher in intensity that those recorded at the inside seating area.

Based on the range of SPLs recorded in each position in each venue it is evident that the difference between recorded SPLs can be as high as 35dB within the same position in the same venue during the same set of live entertainment. This large variance within the positions can be attributed to the performers. During a set, the entertainer will often interact with the attendees. Speech projected through the speaker systems, resulted in a peak in the SPLs, often reaching up to 115dB. Similarly there were often breaks between songs, lasting for a few seconds, which produced a lull in the SPLs. During these lulls, the only noise present is the noise of the attendees and thus a reduction in the SPLs recorded was observed. These levels were as low as 70dB in the main entertainment area and below 65dB in further removed

areas, indicating the need for time weighting. It should be noted that the dosimeters were set with a minimum limit of 65dB, therefore during the recordings, intensity levels lower than the minimum limit were recorded as 65dB.

4.3.1 Analysis of variance

The data from each set at each venue was analysed using the one-way analysis of variance (ANOVA) to determine if a significant variance existed between at least one pair of mean SPLs recorded in the venue. The null hypothesis (H_0) being tested was that there is not a significant difference in variance between the SPLs in each area of the venue. The alternate hypothesis (H_1) being that there is a significant difference in variance of the SPLs in each area of the venue. A confidence level of 95% (α =0.05) was utilized. A *p*-value less than the α-value thus indicated a significant variance and the null hypothesis was rejected.

The results of the ANOVA for each venue (two sets of recorded data) are displayed in Table 12. When the ANOVA indicated a significant variance and the null hypothesis was rejected, post hoc tests were run by means of the Bonferroni *t*-test (Dunn, 1961). The post hoc tests were run to determine the significance of variance between the mean SPLs of each position in each venue in comparison to the SPLs of the other positions within that venue. A critical value of t = 3.02 (Dunn, 1961) was selected and thus *t*-values > 3.02 were deemed significant and the null hypothesis was rejected. It should be noted that two sets of data were recorded per venue to ensure reliability of the results. Thus, results presenting as significant in one set of data but with results that were not repeatable (insignificant variance in one set of data), are marked in the table and are considered insignificant for analyses purposes.

Table 12 *Summary of ANOVA results (Recorded SPLs)*

Venue	Set	Source of variation	*df*	*MS*	*F*	*P*
1	Set 1	Between groups	6	2348.13	65.62	< .001*
		Within groups	238	35.75	-	-
	Set 2	Between groups	6	1736.78	53.43	< .001*
		Within groups	237	32.51	-	-
2	Set 1	Between groups	6	2381.93	37.17	< .001*
		Within groups	237	64.08	-	-
	Set 2	Between groups	6	2944.38	58.37	< .001*
		Within groups	237	50.44	-	-
3	Set 1	Between groups	6	2980.06	85.57	< .001*
		Within groups	237	34.83	-	-
	Set 2	Between groups	6	2828.28	163.64	< .001*
		Within groups	237	17.28	-	-
4	Set 1	Between groups	6	762.73	8.04	< .001*
		Within groups	236	94.90	-	-
	Set 2	Between groups	5	676.63	10.61	< .001*
		Within groups	204	63.80	-	-

*statistically significant

Venue 1

The ANOVA showed that the difference between the SPLs measured at the different positions within venue 1 was significant for both sets (Set 1, $F(6,238) = 65.62$, $p < .001$; Set 2, $F(6,237) = 53.43$, $p < .001$). Post hoc analyses were performed using the Bonferroni *t*-test for significance to determine the difference in variance of each position in relation to each other for both sets. The critical value of $t > 3.02$ was deemed to be significant and the H_1 hypothesis, that there is a significant difference in variance of the SPLs in each area of the venue, accepted. The results are presented in Tables 13 and 14 overleaf.

Table 13 *t-test results for Venue 1 Set 1*

Position of recording	In front of stage	Back of entertainment area	Bar	Bathrooms	Entrance	Outside area	Inside seated area
In front of stage	-	0.53	5.66*	8.47*	10.44*	15.86*	3.10*^
Back of entertainment area	-	-	5.14*	7.94*	9.91*	15.33*	2.57
Bar	-	-	-	2.81^	4.78*	10.19*	-2.56
Bathrooms	-	-	-	-	1.97	7.39*	5.37*
Entrance	-	-	-	-	-	5.42*	7.34*
Outside areas	-	-	-	-	-	-	12.76*
Inside seated area	-	-	-	-	-	-	-

*Critical value: $t > 3.02$ indicates statistical significance
^Significance varies between sets indicating poor repeatability

Table 14 *t-test results for Venue 1 Set 2*

Position of recording	In front of stage	Back of entertainment area	Bar	Bathrooms	Entrance	Outside area	Inside seated area
In front of stage	-	1.1	5.07*	8.32*	10.76*	13.87*	2.92^
Back of entertainment area	-	-	3.97*	7.28*	9.66*	12.77*	1.82
Bar	-	-	-	3.25*^	5.69*	8.80*	-2.15
Bathrooms	-	-	-	-	2.44	5.55*	-5.40*
Entrance	-	-	-	-	-	3.11*	-7.84*
Outside areas	-	-	-	-	-	-	-10.95*
Inside seated area	-	-	-	-	-	-	-

*Critical value: $t > 3.02$ indicates statistical significance
^Significance varies between sets indicating poor repeatability

The results of Venue 1 are represented graphically in Figure 8. The lines that overlap indicate the areas that were not significantly different from each other, whilst separated lines indicate a significant variance of SPLs.

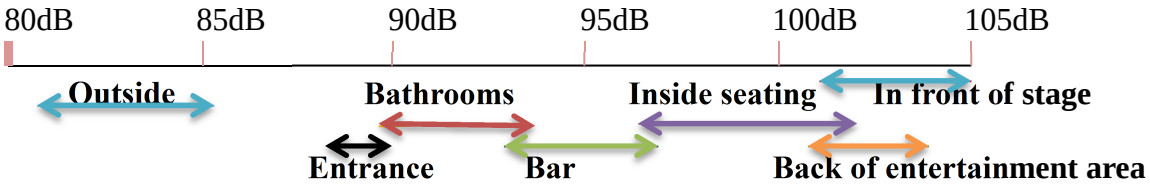

Figure 8 Variance of SPLs in Venue 1

In Venue 1, it is evident that there is no significant difference of the mean SPLs recorded in front of the stage to those recorded in the inside seating area or at the back of the entertainment area. Likewise, a non-significant difference in the mean SPLs was noted between the inside seating area and the bar, the bar and the bathrooms, the bathroom and the entrance. If the layout and structural characteristics of Venue 1 are recalled, it is evident that the sole reason for a significant difference in the mean SPLs between areas is the distance between the areas. Venue 1 is open plan in design; the only area structurally separated from the others is the outside area which was separated via a wall of the building. The outside area indicated a significant difference in the mean SPLs to all other areas in the venue.

Venue 2

The ANOVA results indicated the difference between the mean SPLs measured at the different positions within Venue 2 was significant for set 1, $F(6,237) = 37.17$, $p < .001$ and set 2, $F(6,237) = 58.37$, $p < .001$. Post hoc analyses were performed using the Bonferroni *t*-test for significance to determine the difference in variance of each position in relation to each other for both sets. A critical value of $t > 3.02$ was used to indicate significance and the H_1

hypothesis accepted. The results are presented in Tables 15 and 16.

Table 15 *t-test results for Venue 2 Set 1*

Position of recording	In front of stage	Back of entertainment area	Bar	Bathrooms	Entrance	Outside area	Inside seated area
In front of stage	-	1.56	7.028*	6.52*	10.38*	11.91*	5.33*
Back of entertainment area	-	-	5.46*	4.96*	8.82*	10.35*	3.77*
Bar	-	-	-	0.5	3.36*	4.89*	1.69
Bathrooms	-	-	-	-	3.87*	5.39*	1.19
Entrance	-	-	-	-	-	1.52	5.05*
Outside areas	-	-	-	-	-	-	6.58*
Inside seated area	-	-	-	-	-	-	-

*Critical value: t > 3.02 indicates statistical significance

Table 16 *t-test results for Venue 2 Set 2*

Position of recording	In front of stage	Back of entertainment area	Bar	Bathrooms	Entrance	Outside area	Inside seated area
In front of stage	-	2.54	8.19*	7.52*	13.06*	15.46*	7.58*
Back of entertainment area	-	-	5.65*	4.98*	10.52*	12.92*	5.04*
Bar	-	-	-	0.67	4.87*	7.27*	0.61
Bathrooms	-	-	-	-	5.54*	7.94*	0.06
Entrance	-	-	-	-	-	2.4	5.48*
Outside areas	-	-	-	-	-	-	7.78*
Inside seated area	-	-	-	-	-	-	-

*Critical value: t > 3.02 indicates statistical significance

The results of Venue 2 are represented graphically in Figure 9. The overlapping lines in this figure represent an insignificant variance of the mean SPLs between areas.

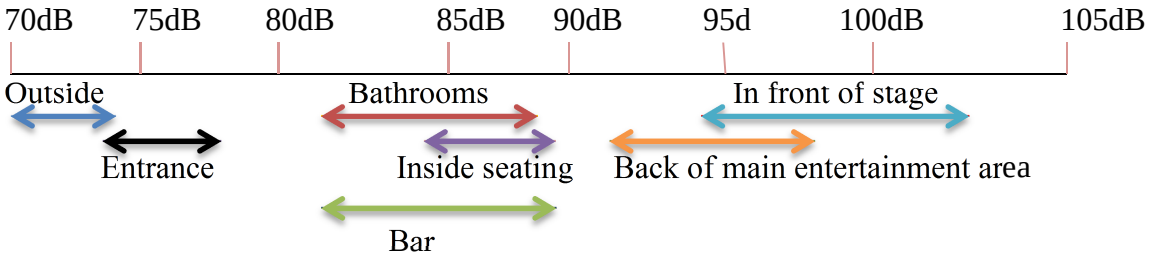

Figure 9 Variance of SPLs in venue 2

Figure 9 indicates that the mean SPLs within Venue 2 fall into three ranges. The mean SPLs recorded within the main entertainment area are not significantly different from each other but are significantly different to all the mean SPLs recorded outside the main entertainment area. The bathrooms, inside seating area and bar have non-significant mean different SPLs from each other, but all have a significant mean difference in SPLs to those recorded in the main entertainment area, the outside seating area and the entrance. Lastly, the outside seating area and entrance area indicate non-significant mean differences of recorded SPLs to each other, but both have significantly different mean SPLs to every other area in the venue.

Venue 3

The analysis of variance results indicated the difference between the mean SPLs measured at the different positions within Venue 3 were significant for set 1, $F(6,237) = 85.57$, $p < .001$ and set 2, $F(6,237) = 163.64$, $p < .001$. Post hoc analyses were performed using the Bonferroni *t-test* for significance to determine the difference in variance of each position in relation to each other for both sets. A critical value of $t > 3.02$ was used to

indicate significance and the H_1 hypothesis accepted. The results are presented in Tables 17 and 18.

Table 17 *t-test results for Venue 3 Set 1*

Position of recording	In front of stage	Back of entertainment area/ Bar	Upper seating area	Bathrooms	Entrance	Outside area	Inside seated area
In front of stage	-	4.78*	4.44*	13.38*	17.41*	13.54*	14.78*
Back of entertainment area/ Bar	-	-	-0.34	8.60*	12.63*	8.76*	10.00*
Upper seating area	-	-	-	8.94*	12.97*	9.11*	10.34*
Bathrooms	-	-	-	-	4.03*	0.17^	1.40^
Entrance	-	-	-	-	-	-3.86*	-2.63^
Outside areas	-	-	-	-	-	-	1.24
Inside seated area	-	-	-	-	-	-	-

*Critical value: $t > 3.02$ indicates statistical significance
^Significance varies between sets indicating poor repeatability

Table 18 *t-test results for Venue 3 Set 2*

Position of recording	In front of stage	Back of entertainment area/ Bar	Upper seating area	Bathrooms	Entrance	Outside area	Inside seated area
In front of stage	-	6.21*	5.75*	14.97*	24.33*	18.60*	21.03*
Back of entertainment area/ Bar	-	-	-0.46	8.76*	18.12*	12.39*	14.82*
Upper seating area	-	-	-	9.22*	18.58*	12.85*	15.28*
Bathrooms	-	-	-	-	9.36*	3.63*^	6.06*^
Entrance	-	-	-	-	-	-5.73*	-3.30*^
Outside areas	-	-	-	-	-	-	2.43
Inside seated area	-	-	-	-	-	-	-

*Critical value: $t > 3.02$ indicates statistical significance
^Significance varies between sets indicating poor repeatability

The results of Venue 3 are visually presented in Figure 10.

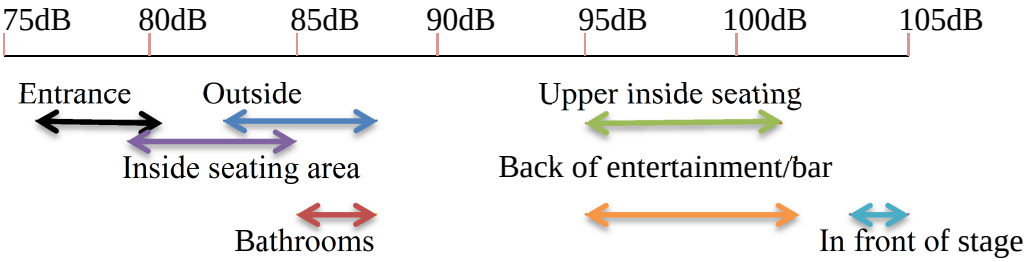

Figure 10 Variance of SPLs in venue 3

In Venue 3, the mean SPLs recorded at the front of the stage were significantly different from the mean SPLs recorded in all other areas of the venue, including those recorded in the main entertainment area.

Venue 4

The ANOVA showed the difference between the mean SPLs measured at the different positions within Venue 4 were significant for set 1, $F(6,236) = 8.04$, $p < .001$ and set 2, $F(5,204) = 10.61$, $p < .001$. Post hoc analyses were performed using the Bonferroni *t*-test for significance to determine the difference in variance of each position in relation to each other for both sets. A critical value of $t > 3.02$ was used to indicate significance and the H_1 hypothesis accepted. The results are presented in Tables 19 and 20 overleaf. It should be noted that the dosimeter used to record the SPLs in the inside seating area malfunctioned and thus the SPLs for the second set could not be obtained for the inside seating area

Table 19 *t-test results for Venue 4 Set 1*

Position of recording	In front of stage	Back of entertainment area/ Bar	Upper seating area	Bathrooms	Entrance	Outside area	Inside seated area
In front of stage	-	1.20	0.98	3.70*^	4.22*	4.17*	5.20*
Back of entertainment area/ Bar	-	-	0.23	2.50	3.01^	2.97^	4.00*
Upper seating area	-	-	-	2.73^	3.24*	3.19*	4.23*
Bathrooms	-	-	-	-	0.51	0.47	1.50
Entrance	-	-	-	-	-	-0.05	0.99
Outside areas	-	-	-	-	-	-	1.03
Inside seated area	-	-	-	-	-	-	-

*Critical value: $t > 3.02$ indicates statistical significance
^Significance varies between sets indicating poor repeatability

Table 20 *t-test results for Venue 4 Set 2*

Position of recording	In front of stage	Back of entertainment area/ Bar	Upper seating area	Bathrooms	Entrance	Outside area	Inside seated area
In front of stage	-	0.25	-0.47	2.74^	3.80*	5.10*	Unavailable
Back of entertainment area/ Bar	-	-	-0.72	2.49	3.56*^	4.85*^	Unavailable
Upper seating area	-	-	-	3.21*^	4.27*	5.57*	Unavailable
Bathrooms	-	-	-	-	1.06	2.36	Unavailable
Entrance	-	-	-	-	-	1.30	Unavailable
Outside areas	-	-	-	-	-	-	Unavailable
Inside seated area	-	-	-	-	-	-	-

*Critical value: $t > 3.02$ indicates statistical significance
^Significance varies between sets indicating poor repeatability

The variance of the recorded mean SPLs between the areas in Venue 4 are represented in Figure 11.

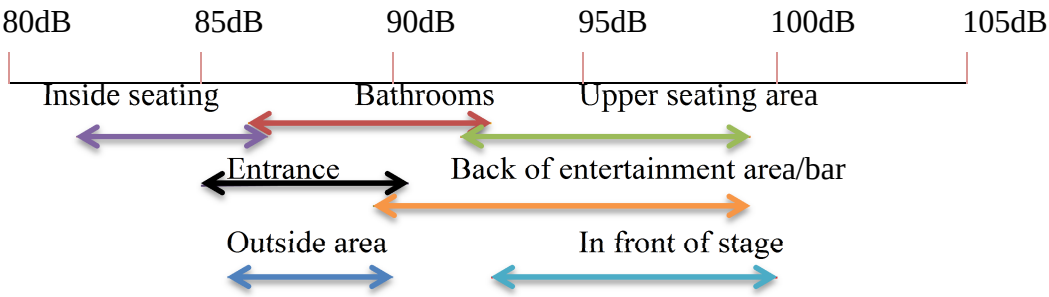

Figure 11 Variance of SPLs in venue 4

Figure 11 above demonstrates that venues with an open plan are not ideal for creating a variance in intensity levels between areas. Venue 4 is similar in design to Venue 1 in that none of the areas in the venue are structurally separate with the exception of the outside area

It is evident from the results above that the majority of the comparisons between areas within the venues indicated a significant variance in recorded SPLs. It was noted that the open plan venues (Venues 1 and 4) indicated fewer areas with significant differences in SPLs compared to the venues with structurally separated areas (Venues 2 and 3). Furthermore it was noted that in the venues that structurally isolated the main entertainment area (Venues 2 and 3) consistently indicated a significant variance of SPLs between the areas within the main entertainment area to those separated from the area. The final trend noted was that in all the venues, the outside area was significantly different to all other areas within the venues.

4.4 Relationship between the structural characteristics and the sound pressure levels in venues

The data from each set at each venue was analysed using the ANOVA to determine if a significant variance existed between at least one pair of mean SPLs recorded in the venue. The null hypothesis (H_0) being tested was that there is not a statistically significant relationship between the structural characteristics of a venue and the difference in SPLs within the different areas of the venues. The alternate hypothesis (H_1) being that there is a significant relationship exists between the structural characteristics of a venue and the difference in SPLs within the different areas of the venues. The Chi-square test (X^2) was used to determine if the relationship between the structural characteristics and the variance in the mean SPLs were significant. A confidence level of 95% ($\alpha = 0.05$) was utilized. A *p*-value less than the α-value thus indicated a direct relationship between the structural characteristic and the variance in the mean SPLs.

For each structural characteristic observed the results of the Bonferroni *t*-test of variance for each venue were used to calculate the frequency of significant and insignificant variance of the different positions within the venue. The positions compared were based on the structural characteristic being investigated. It should be noted that when significance of variance was not repeatable between the first and second set of recordings in a venue they were deemed to have a non-significant variance due to poor reliability.

Each structural characteristic is discussed below in order to, as per the main aim of the study, determine if each characteristic may be an effective venue-based hearing conservation strategy.

4.4.1 Main entertainment area

In venues 1 and 4 the main entertainment areas were not sectioned off from the rest of the venue, whereas venues 2 and 3 were structured that the main entertainment areas was closed off from the other areas of the venue.

Using the results of the *t*-tests, the frequency of significant and insignificant variance for the different structural characteristics was recorded. In each venue the main entertainment area (front and back) was compared to all other areas recorded in the venue (bar or the upper seating area, the bathroom, the entrance, the outside area and the inside seating area). Thus for each venue, the significance of variance between both positions in the main entertainment area and five positions were recorded, giving a total of 40 observations (Table 21).

Table 21 *Frequency of significant variance in different main entertainment areas*

Structure of the main entertainment area	Venues	Number of observations of significant variance	Number of observations of insignificant variance/ unrepeatable significance
Main entertainment area sectioned off	2 and 3	19	1
Main entertainment area not sectioned off	1 and 4	12	8

The results of the Chi-square test indicate a *p*-value of 0.008037545 (*df*=1) thus using a critical value of 0.05, the null hypothesis can be rejected. This indicates that there is a significant relationship between the structural characteristic of sectioning off the main entertainment area and increasing the variance of the SPLs recorded within and outside the main entertainment area.

4.4.2 Bar area

The bar area in Venue 3 and Venue 4 was positioned at the back of the entertainment area. Whereas the bar area in Venue 1 and Venue 2 are not within the main entertainment area. The frequency of significance of variance between the bar and the main entertainment areas were observed and can be seen in Table 22. A total of eight observations were analysed, specifically between the bar area and in front of the stage as well as at the back of the entertainment area for venues 1 and 2. In venues 3 and 4 the observations included the variance between the bar and in front of the stage as well as in the upper inside seating area.

Table 22 *Frequency of significant variance in the bar areas.*

Structure of the bar area	Venues	Number of observations of significant variance	Number of observations of insignificant variance
Bar in main entertainment area	3 and 4	1	3
Bar area outside the main entertainment area	1 and 2	4	0

The results of the Chi-square test indicate the *p*-value calculated at 0.02845973 (*df*=1) thus using a critical value of 0.05, the null hypothesis can be rejected. This indicates a significant relationship between the structural characteristics of the bar area in a venue and the difference in intensity levels between the bar and the main entertainment area. As a significant reduction in intensity levels was noted in both venues with the bar area outside of the main entertainment area, it can be stated that this structural characteristic may be used a venue-based hearing conservation strategy to reduce the risk of MIHL.

4.4.3 Outside area

All the venues in this study had an available outside seating area. In all four venues it

was determined that SPL in the outside area was significantly lower than in the main entertainment area. Firstly, this indicates that all outside areas are beneficial as a structural means to reduce the risk of MIHL. Furthermore, this suggests that the structural characteristics of the outside area do not affect the reduction in SPLs.

4.4.4 Upper inside seating area

Two of the venues (Venue 3 and 4) had an upper inside seating area available where attendees could sit and view the band. Both of these venues positioned the upper seating areas within the main entertainment area, structured as a loft. These areas were therefore open to the main entertainment area and attendees could view the stage from these areas. The *t*-tests above for both venues indicate a non-significant variance of SPLs between the back of the entertainment area and the upper seating area. In Venue 3, the *t*-test above indicates a significant difference in SPLs between the upper seating area and the front of the main entertainment area, whereas, in Venue 4 a non-significant variance was indicated between areas. These results suggest that as the intensity levels in the main entertainment area and in the upper seating area are similar, an upper seating area may not be considered a venue-based hearing conservation strategy.

4.4.5 Inside seating area

In venue 1 and 4 the inside seating areas were not sectioned off from the main entertainment area, whereas in Venue 2 and 3 the two areas were structurally separated.

The Bonferroni *t*-test of variance results between the inside seating area to the front of the main entertainment area and to the back of the entertainment area were used to determine

if separating the seating area from the main entertainment area could reduce the risk of hearing loss for attendees. The frequency of observations of significance is presented in Table 23. In venues 2, 3, and 4, all six comparisons indicated a significant variance, whereas in Venue 1 it was indicated that there was a non-significant variance between the positions.

Table 23 *Frequency of significant variance in the inside seating areas.*

Structure of the inside seating area	Venues	Number of observations of significant variance	Number of observations of insignificant variance
Inside seating area separated from main entertainment area	2 and 3	4	0
Inside seating area not separated from main entertainment area	1 and 4	2	2

The results of the Chi-square test indicate a *p*-value of 0.102470435 (*df*=1). A critical value of 0.05 was adopted and thus the results indicate an insignificant frequency of observations, suggesting the null hypothesis should be accepted. As the null hypothesis is accepted it can be stated that the structural characteristics of the inside seating areas in live music venues do not directly affect the difference of intensity levels between areas. Therefore the structural characteristics of the inside seating areas should not be used in attempting to reduce the risk of MIHL in venues.

4.4.6 Entrance

In all the venues it was indicated that the SPLs at the entrance were significantly lower than the SPLs recorded at the front and back of the main entertainment area. These results indicate that, the entrance areas of venues act as a structural characteristic that could reduce the risk of MIHL if made use of by the attendees. It also indicates that the structural

characteristics of the entrance to the venue do not effect the reduction of SPLs at the entrance.

4.4.7 Bathrooms

In three of the venues the bathrooms were not separated structurally from the main entertainment area. In venue 3, the entrance to the bathrooms was in the outside seating area. Thus attendees were required to leave the main entertainment area, walk through a section of the outside seating area and then enter the bathrooms. Using the *t*-test results, the frequency of significance of variance of the SPLs between the bathrooms and the front and back of the main entertainment area were recorded (Table 24). In venue 1, 2 and 3 the *t*-test results indicated a significant variance between the SPLs recorded in the bathrooms and those recorded in the main entertainment area. In Venue 4 the results indicated a non-significant variance between the SPLs of these areas.

Table 24 *Frequency of significant variance in different bathroom positions*

Structure of the bathrooms	Venues	Number of observations of significant variance	Number of observations of insignificant variance
Bathrooms not separated from main entertainment area	1, 2 and 4	4	2
Bathrooms separated from main entertainment area	3	2	0

The results of the Chi-square test indicate the *p*-value was 0.345778586 (*df*=1), the critical value adopted in this study is 0.05 and thus the results indicate a non-significant relationship between the position of the bathrooms and the difference in intensity levels. Based on the calculation the null hypothesis was accepted and thus the position of the bathroom within the venue may not be considered a venue-based hearing conservation

strategy.

4.5 Summary

This chapter aimed to discuss the results of the study regarding the plausibility of venue-based hearing conservation strategies as a means of reducing the risk for MIHL. The results indicated that currently venue-based hearing conservation strategies have not been implemented in live Rock and Heavy metal music venues in Johannesburg. The results further indicated that the managers and/or owners interviewed would be willing to implement such strategies in their venue. These results suggest that certain structural and acoustic characteristics of music venues may be used as plausible venue-based hearing conservation strategies.

Chapter 5: Discussion

"…Sitting in an empty room

Trying to forget the past

This was never meant to last,

I wish it wasn't so...

(Oh!) I know what it takes to move on,

I know how it feels to lie,

All I wanna do

Is trade this life for something new

Holding on to what I haven't got…"

(Bennington et. al. 2010, track 8)

This chapter summarizes the results of the study and includes a discussion of these results in relation to the literature. Data is interpreted so that conclusions can be drawn regarding the plausibility of venue-based hearing conservation strategies as a means of reducing the risk for MIHL.

5.1 Hearing conservation practices in live rock and heavy metal music venues

It is evident from the results of this study that hearing conservation programs are not being implemented in the participating live music venues. The discussions held with the venue owners and managers clearly indicate a low level of awareness of legislation, such as the OSHA of 1993, specifically as it relates to the responsibilities of employers in terms of noise. This is supported by findings in the current study that no staff members were provided with HPDs despite SPLs exceeding 85dB in most areas within the venues. The OSHA of 1993 clearly states that no employee shall be permitted to work in an environment with ambient SPLs exceeding 85dB without hearing protection.

These findings are in contrast to research conducted in Australia (Guo & Gunn, 2005; WWA Commission, 2003). Research has found that in the entertainment industry, employers' awareness of responsibility of employers in terms of noise had increased between the years 2000-2005 (Guo & Gunn, 2005). This may be contributed to the release and promotion of noise policies such as 'The code of practice: Noise control in the music entertainment industry' in Australian entertainment venues (WWA Commission, 2003). Research studies are also conducted to determine whether this legislation is adhered to (Guo & Gunn, 2005). There is no evidence that similar legislation on noise are being promoted or enforced in the South African music industry. This may contribute to the lack of hearing conservation programmes within the music venues investigated in the current study.

Despite the fact that hearing conservation programmes promote hearing awareness and education (Bogoch et al., 2005), none of the venues displayed posters or pamphlets highlighting the risk of noise and the benefits of protection. These results are supported by previous research that found that hearing awareness and education regarding the risks of music exposure is limited (Bogoch et al., 2005; Chung et al., 2005).

The limited use of HPDs by attendees of the venues included in this study, highlight the need for the implementation hearing awareness campaigns in live music venues in South Africa. Research has confirmed that knowledge and awareness of HPDs and the adverse effects of noise on the auditory system may increase compliance with HPD use (Bogoch et al., 2005; Horrell, 2009), Hearing awareness and education within live music venues may therefore prove to be a useful venue-based hearing conservation strategy. Specifically, as all

the managers and owners interviewed in the current study indicated that they would be willing to implement hearing conservation programmes. This willingness to comply with an awareness program was on condition that the HPDs and materials (posters and pamphlets) were provided to the venues.

It is encouraging to note that some musicians performing at the venues in the current study were using HPDS. This indicates that musicians are aware of the benefits of proactive hearing prevention despite the lack of hearing awareness campaigns and legislation in South Africa. This correlates to a previous study conducted in the South African music industry which indicated that 62.5% of the musicians in that study made use of HPDs (Horrell, 2009).

Although hearing awareness campaigns are one of the available venue-based hearing conservation strategies, it should not be used in isolation. Hearing conservation programmes should ideally incorporate a combination of strategies to maximise efficiency (WWA Commission, 2003). This is especially relevant as it has been reported that relying on awareness programs in isolation to increase personal protection compliance is not effective (Weichbold & Zorowka, 2007).

5.2 Acoustic and structural characteristics of live rock and heavy metal music venues

5.2.1 Acoustic characteristics

Six acoustic characteristics have been outlined in literature as effective in reducing the intensity levels in the venue. Each of these aspects will be discussed in terms of the recommendations as well as the frequency of compliance within the venues investigated in this study.

5.2.1.1 Dry walling

Dry walling was used in only one of the four venues (Venue 1). In this venue, dry walling was used to separate the entrance from the main entertainment area. The SPLs recorded within this venue in front of the stage and at the back of the main entrance area were excessively high when compared to the other venues (See Table 11). The use of the dry walling in this position may adversely affect the SPLs in the venue as it is positioned in the main entertainment area where the sound quality and perceived loudness are of maximum importance. This is supported by the intensity levels recorded within this venue. The SPLs in front of the stage averaged 104.03dB and 104.00dB for the first and second set of recordings respectively. The SPLs recorded at the back of the main entertainment area averaged 103.28dB and 102.51dBs. These intensity levels are excessively high and an attendee may safely stand in front of the stage for 7.5 minutes before being considered at risk of NIOD.

The use of dry walling in music venues is not encouraged. It has been found that the material used to construct dry walls absorbs low frequency sound waves (Gastmeier, 2009). Although the use of absorptive materials, such as cloth, panelling and posters, are encouraged to reduce the SPLs in venues, low frequency specific absorptive materials are not. Research indicates that these materials reduced the perceived loudness without actually reducing the SPLs (Gastmeier, 2009). Music is therefore often further amplified as to increase the perceived loudness of the music (Gastmeier, 2009).

5.2.1.2 Wooden flooring

All four of the venues in this study contained wooden flooring in at least one section of the venue. In Venue 1 the wooden flooring was present in the outside seating area and in

Venue 2 the wooden flooring was in the bar area, which was structurally separated from the main entertainment area. As the wooden flooring was not within the main entertainment area for these venues it can be assumed they will not adversely affect the SPLs within the venue. In venues 3 and 4 the wooden flooring is within the main entertainment area, specifically the upper seating areas. As the wooden flooring is within the main entertainment area, the SPLs may adversely be affected, specifically in Venue 4 where the sound engineers were positioned in the upper seating area.

Similarly to dry walling, wooden flooring is discouraged in music venues as this material also absorbs the low frequency waves. As discussed above, the SPLs in the venue are thus increased to counterbalance the perceived reduction in intensity levels (Chasin & Chong, 1995).

5.2.1.3 Reflective surfaces

In venues 1, 2 and 3, large reflective surfaces where present in the main entertainment area specifically glass panels and windows, indicating that the majority of the music venues in South Africa are not currently considering such acoustic characteristics in their venue design.

The over use of hard, reflective surfaces is discouraged in music venues (HSE, 2008). Although some well-placed reflective surfaces may improve the reflections and reverberations in the room (Gastmeier, 2009), the overuse of these surface may result in excessive intensity levels as well as a poor sound quality within the room (Gastmeier, 2009; HSE, 2008). When the perceived sound quality is sufficiently loud with an intimate quality

and a good texture, intensity levels are less likely to be increased to counterbalance poor sound quality. Thus, sufficient early sound reflections, an even sound distribution and appropriate sound reverberation are beneficial to both the musicians as well as attendees (Gastmeier, 2009). Other adverse effects of large flat reflective surfaces include acoustical glare and source shift which further results in a poor sound quality (Gastmeier, 2009).

5.2.1.4 Speakers

In all four venues, speakers were placed on the floor without allowing an unobstructed space between the speakers and the attendees. Venues 2 and 4 had speakers suspended above the audience as well as the speakers placed on the floor. In venue 3, two speakers were placed on stands in conjunction with the speakers positioned on the floor. These results again indicate that the live music venues are not consistently considering the acoustic characteristics during the venue design and set up.

With regards to the speakers in live music venues, there are two factors that need to be considered. The first is the placement of the speakers and the second is the distance between the speakers and attendees. If possible the speakers should be positioned up high, on the walls or on stands to avoid excessive exposure to individuals in close proximity (HSE, 2008). This characteristic is not used to improve the sound quality but to increase the distance and thus reduce the intensity of the sound as it reaches the attendees. Secondly, it is suggested that there is at least two metres of unobstructed space between the performers and attendees, as bodies are absorptive, and thus the perceived intensity levels will be reduced (Chasin & Chong, 1995).

5.2.1.5 Seating in the main entertainment area

In Venue 1, there was no seating in the main entertainment area. However, in venues 2 and 4, there was an abundance of wooden tables and seating in the entertainment area. Although small cocktail tables were present in Venue 3, they were made of metal and thus would not absorb the sound waves. Furthermore, the cocktail tables were placed away from the stage, closer to the bar. These results confirm that the recommendations regarding seating in the main entertainment were not consistently evident in the venues.

The seat-dip effect needs to be considered in live music venues. This effect is caused by the over-presence of absorptive materials, usually as a result of seating in the venue. This may result in an energy reduction in the 100-400 Hz range (Gastmeier, 2009). This factor is important in venue acoustics as overuse of absorptive materials result in compensatory increased intensity levels to increase the perceived loudness.

In venues 1, 2 and 4, the SPLs at the front and back of the main entertainment area were not significantly different from each other. However, in Venue 3, a significant difference was noted between the recording obtained in front of the stage to those obtained at the back of the entertainment area. This unexpected phenomenon can also be attributed to the seat-dip effect. The seat-dip effect results when there is excessive absorptive materials (usually seating) in the entertainment area which results in a reduction of intensity levels, this is usually caused by seating in the entertainment area (Gastmeier, 2009). This effect is usually avoided as the intensity levels are often increased to counteract the sound absorption, which results in higher SPLs in the room (HSE, 2008). However, in this venue, the seat-dip effect was not caused by seating in the entertainment area but by a large audience. People act as

absorptive materials and thus, as in this case, in a room filled with people, the SPLs may be significantly different in the front of the room to those in the back of the room. This example of the seat-dip effect proves to be beneficial as the attendees in the upper seating area and at the back of the entertainment area where exposed to significantly lower intensity levels than those in front of the stage. This does not correlate to the previously mentioned literature that discourages excessive absorptive materials in the main entertainment area (Gastmeier, 2009; HSE, 2008). A possible reason for the difference in findings is that seating and other permanent absorptive materials are present during the pre-performance sound check, where the intensity levels are adjusted to produce a loud but comfortable listening environment. In the case of Venue 3 where the seat-dip effect was caused by bodies, the absorptive materials were not present during the sound check and thus overcompensation did not occur.

5.2.1.6 Background noise

All four venues were removed from road traffic noise and did not contain noisy ventilation systems. Furthermore, by comparing the sound levels recorded at the entrances to the venues to the SPLs in the main entertainment area it can be deduced that the venues effectively isolated the noise to within the venue.

Background noise such as air conditioners or road traffic noise can affect the intensity levels in music venues. The overall intensity levels can be reduced optimising the acoustic isolation of the source of noise within the venue and decreasing the background noise without deducting from the perceived loudness of the music, (Gastmeier, 2009).

5.2.2 Structural characteristics

Currently, internationally there are very few recommendations in terms of specific structural characteristics being used to reduce the risk of MIHL in music venues (Crandell & Smaldino, 2002; Gastmeier, 2009; HSE, 2008).

In venues 2 and 3 the entertainment area was sectioned off. Venue 2 was more successful in this regard in that the entertainment area was used solely for the purpose for the attendees to enjoy the live performance. In venue 3, other areas were incorporated in the entertainment area such as the bar at the back of the venue and the upper seating area. It is evident that in the current study two of the venues (venue 1 and 4) were open plan in layout. Having a venue open in this way is not recommended due the effects on the RT in the venue. This is consistent with previous literature that recommends that other functional areas, such as the bar, should not be positioned directly opposite from the stage (HSE, 2008). This recommendation was not adhered to in venues 3 and 4, both of which positioned the bar at the back of the entertainment area. In addition, in all four venues the sound engineer was positioned within the main entertainment area. This further demonstrates the trend that South African music venues are currently not consistently adhering to recommendations that aim to increase the auditory safety of a venue.

In literature the current recommendations refer to the venue size and RT. It is postulated that the smaller the venue, the better the sound quality of the music. This can be explained as a large volume space with minimal absorption or occupancy will have a long RT (Gastmeier, 2009) Reverberation degrades speech perception and thus the shorter the RT the better the sound quality (Crandell & Smaldino, 2002). Based on these recommendations, it

can be advised that if venues section off the main entertainment area, the sound quality within that area will improve. When there is good sound quality in a room the intensity levels are not unnecessarily increased.

The structural characteristic of a separate entertainment area is supported by the HSE (2008) which recommends that the band should face the majority of the attendees but should not be directed at the bar or any other work area. This suggests that other work areas should not be in the entertainment area.

It is evident from the findings above that the current trends in the acoustic and structural characteristics of South African music venues do not comply with the safety regulations stipulated in legislation and hearing protection protocols. This indicates that the OSHA (1993) guidelines are currently not being enforced in the venues included in this study. This further highlights the need for extending hearing conservation and awareness programmes to venue owners and managers as they are currently not aware of the current legislation and hearing safety protocols for music venues. These findings indicate a need for the recommendations pertaining to the acoustic and structural characteristics of music venues to be included in legislation and policies in order for these protocols to be successfully implemented in venues. Studies in Australia have indicated an increase in venue awareness, responsibility and compliance over time due to the Australian government implementing, promoting and inspecting health and safety regulations and hearing protection policies (WWA Commission, 2003).

5.3 Recorded sound pressure levels

Intensity levels recorded in live music venues had been reported as dangerously loud (Bogoch et al., 2005; Chasin, 2009; Dillon, 2008; Schmuziger et al., 2006). It has also been described as one of the loudest recreational activities (Dillon, 2008). Previous studies have provided evidence of the average SPLs recorded in music venues (Jokitulppo et al., 1997; Sadhra et al., 2002; Williams et al., 2010), but has not provided insight into the different SPLs in different areas within a venue. It is postulated that this information could prove important as if practical means could be found to reduce the SPLs in functional areas of music venues, the attendees overall noise exposure would be reduced. The mean SPLs for seven areas of the four venues are discussed below.

5.3.1 In front of the stage

In all but one venue (1, 2 and 3), the highest mean SPLs were recorded in front of the stage. The exception was the second set of recordings in venue 4 where the mean SPL recording in the upper seating area exceeded the mean SPL recorded in front of the stage. The mean SPLs recorded in front of the stage ranged from 94.56dB- 104.03dB. The results of the current study correlate with the findings of Williams et al. (2010) which found that the intensity levels in music venues averaged at 97.9dB. This is however in contrast to a study conducted by Sadhra et al. (2002) which recorded average SPLs of 90dB.

Although risk predictions cannot be made on these averages (mainly due to the limited length of the recordings in the current study) the time weighted equivalent can be provided based on the ADE limits as discussed by Dillon (2008). The ADE limits for each venue are presented in Table 25 based on the measurements recorded in front of the stage.

Table 25 *ADE limits based on SPLs recorded in front of the stage*

Venue	Set	ADE limit
1	1	7.5 mins
	2	7.5 mins
2	`1	60 mins
	2	15 mins
3	1	7.5 mins
	2	7.5 mins
4	1	60 mins
	2	30 mins

Interestingly, although the recorded mean SPLs between sets were similar for venues 1 (104.03dB; 104.00dB) and 3 (103.21dB; 103.99dB), in the other two venues (Venue 2 and 4) a noticeable difference was recorded between sets. In audiological terms a noticeable difference can be assigned to differences exceeding 3dB as this will transcend to a difference in the time weighted exposure limit (Dillon, 2008). In venue 2, the mean SPL for the first set of recordings was 94.56dB whereas the average for the second set was 102.70, indicating an 8.14dB difference between sets. The only change that occurred between the sets was the band playing. In the first set, the band played light rock music whereas in the second set a heavy rock band was playing. Likewise in venue 4, during the initial set a lighter rock band was playing and the mean SPL was recorded to be 95.37dB whereas in the second set the intensity levels averaged at 99,13dB indicating a 3.76dB difference. Again, the only change in the venue between recordings was the band. This indicates that the band playing and the type of music played largely influences the SPLs within the venues. This correlates to current literature which states that the incidence of MIHL varies between genres (Einhorn, 2009).

5.3.2 Upper inside seating area

Two of the four venues (Venue 3 and 4) contained an upper inside seating area. In both of these venues the upper seating area was positioned within the main entertainment area. Both areas contained wooden flooring and both areas were loft-like in nature. In both of these venues the mean SPLs recorded in the upper seating area were the second loudest recordings in the venue, with the exception of the mean SPL in the second set of venue 4. In venue 4, the mean SPL recorded in the upper seating area exceeded the mean SPL recorded in front of the stage for that set. This unexpected result may be contributed to the majority of the speakers being suspended above the stage which resulted in them being physically closer to the attendees in the upper seating area than those in front of the stage.

The mean SPLs recorded in these upper seating areas ranged from 93.10dB-100.03dB. In terms of time weighted equivalents (Dillon, 2008), an attendee in Venue 3, would be exposed to the mean SPLs in the upper seating area for the first set of readings for 1 hour, but based on the second set of readings the ADE would be met after 30 minutes. In Venue 4 the time weighted equivalent for the first set of readings is two hours but only 15 minutes for the second set of readings.

The variations in these time weighted exposure limits highlight three important considerations. The first is that these differences in the mean SPLs recorded in the same position in the same evening in the same venue clearly demonstrate the importance of a prolonged noise assessment when the results will be used for risk management. The second consideration reiterates the effect the band and the music genre has on the mean SPLs recorded in the venue. The final consideration is that venues, with a significant difference in

the mean SPLs recorded between sets, the louder set is consistently later in the evening. This correlates to the results of a study that the intensity levels within music venues consistently increased as time progressed (Williams et al., 2010).

5.3.3 Back of the entertainment area

In the venues with an upper seating area (Venues 3 and 4), the mean SPLs recorded at the back of the main entertainment area where quieter than the upper seating area. In both venues without an upper seating area (Venues 1 and 2), the back of the entertainment area was consistently the second loudest area in the venue. The mean SPLs recorded at the back of the entertainment areas in all four venues ranged from 91.57dB - 103.28dB. The ADE limits based on the mean SPL for each venue are presented in table 26.

Table 26 *ADE limits based on SPLs recorded at the back of the main entertainment area*

Venue	Set	ADE limit
1	1	7.5 mins
	2	15 mins
2	`1	120 mins
	2	30 mins
3	1	60 mins
	2	30 mins
4	1	120 mins
	2	30 mins

The mean SPLs between sets in venue 1 and 3 did not significantly differ. However, the differences between sets in venue 2 and 4 were 6.82dB and 6.09dB respectively. As discussed in section 5.3.1.1, incidence of MIHL varies between genres (Einhorn, 2009). The audiologically significant difference (>3dB) observed in venues 2 and 4 can be contributed to

the genre being played. In venues 1 and 3 the same genre was played throughout the evening. In venue one two heavy metal bands played, whilst in venue 3, the same band played across both sets of recordings. In venue 2, the first band played light rock music and the second played harder rock. Similarly, in venue 4, two different rock bands played during the first and second sets of recordings.

5.3.4 Inside seating area

All the venues had an inside seating area that was not in the main entertainment area. In venue 1 and 4 the seating area was separated from the entertainment area by distance but not structurally separated. In venue 2 and venue 3 the inside seating area was structurally separated from the entertainment area. The mean SPLs recorded in the inside seating areas across the venues ranged from 82.37dB to 103.28dB. In venue 1, the time weighted equivalents were 30 minutes and 15 minutes for the first and second set respectively. During the first set of readings in Venue 2, the mean SPLs recorded indicated that the inside seating area was acoustically safe for extended periods of time as the average was less than 85dB, however, the second set of data indicated an exposure allowance of 4 hours in venue 2.

The mean SPLs recorded in the seating area of venue 3 and 4 also indicated no exposure limit due to averages below 85dB. Intensity levels below 85dB are deemed low risk because the risk of developing MIHL due to overexposure to high intensity music is dependant both on the average SPL and the length of exposure in time (Chesky, 2008).

5.3.5 Bar

In venue 1 and 2 the bar areas were separate from the main entertainment area, in venue 1 by distance and in venue 2 by structural means. In venue 3 and 4 the bar areas were

positioned at the back of the entertainment area and the intensity levels were thus discussed in section 5.4.1.3 above. The mean SPLs recorded in the bar areas across all four venues ranged from 81.12dB to 97.10dB.

As per the time weighted equivalents (Dillon, 2008), the ADE limits for venue 1 and 2 are presented in table 27.

Table 27 *ADE limits based on SPLs recorded in the bar area*

Venue	Set	ADE limit
1	1	30 mins
	2	60 mins
2	1	No limit
	2	4 hours

The difference of the mean SPLs recorded in the bar compared to in front of the stage in venue 1 was 8.09dB in set 1 and 6.90dB in set 2. In venue 2 the difference was 13.44dB in set 1 and 13.91dB for set 2. Although both venues indicate an audiological significant difference in SPLs (>3dB), it is evident that the difference is significantly larger in venue 2, where the separation of areas is structural. This indicates that structurally isolating functional areas is an effective means of a venue-based hearing conservation strategy. This correlates to previous recommendations promoting segregation between functional areas of venues and the main sound source (HSE, 2008).

5.3.6 Bathrooms

In venues 1, 2 and 4 the bathrooms were not structurally separated from the other areas. In these three venues a small open corridor joined the bathrooms to the rest of the venue. In

venue 3 the bathrooms were structurally separated from the venue as they were accessed through the outside seating area. The mean SPLs recorded equidistant between the entrance to the male and female bathrooms in all four venues ranged from 82.09dB to 93.39dB. The time weighted equivalents for each of the mean SPLs were calculated to be 2 hours in venue 1. In venue 2 and 3, the first set indicated an average SPL of below 85dB, thus the time allowance is not limited. However, in set two an attendee could safely be exposed to the mean SPL for 4 hours. In venue 4 the exposure limits were 8 hours and 2 hours for the first and second set respectively.

5.3.7 Entrance

In all the venues except venue 3, the entrance to the venue was at the entrance to the building. In venue 1 and 2 the entrance is on the same level as the venue. In venue 4, the entrance is on the ground floor with a stairwell leading to the rest of the venue on the first floor. In venue 3 the entrance to the venue was outside and opened to the outside seating area, which then lead to the main building. The mean SPLs at the entrances ranged from 74.69dB to 91.87dB. The time weighted equivalent in venue 1 was four hours, in venue 2 and 3 there is no time limit as the mean SPLs are below 85dB and in venue 4 the recommended limit was eight hours for the first set and four hours for the second set. In all the venues the mean SPLs recorded at the entrances to the venues indicated a significant difference to the mean SPLs recorded in the entertainment areas.

5.3.8 Outside area

All four venues had an outside area with seating. In venue one the outside area opened to the bar area, in venue 2 it opened to the inside seating area, in venue three the outside area was

accessed through the main entertainment area and in venue 4 through the bar area. The mean SPLs ranged from 71.77dB to 89.39dB. In all the sets for each venue with the exception of the second set in venue 4, the time weighted equivalents were either for eight hours or were not restricted. This thus indicates that the outside areas for all the venues are acoustically safe for at least eight hours of exposure. The exception was the mean SPL in the second set in venue 4 which indicated a time weighted exposure limit of four hours.

5.4 Relationship between the structural characteristics and the sound pressure levels in venues

As MIHL is on the rise (Chung et al., 2005) and music attendees do not report the intention to change their music exposure habits (Vogel et al., 2010), the use of structural characteristics to limit noise exposure in music venues is important. Despite research indicating that structural characteristics (e.g. design and layout) may significantly affect the intensity levels in venues, recommendations regarding the structural characteristics of venues are limited (HSE, 2008).

The structural characteristics of each position of the venues are discussed in terms of the relationship between the different structural characteristics found in each venue and the SPLs recorded.

5.4.1 Main entertainment area

In venues 1 and 4 the main entertainment areas were open to all other areas within the venue. In venue 3, the main entertainment area was isolated from some of the functional areas such as the bathrooms and the inside seating area, but not to others (bar, upper inside

seating area). In venue 2, the main entertainment area was isolated from all the other functional areas of the venue. It was noted that when the main entertainment area is segregated from all other areas of the venue, the following hearing protection strategies are automatically adhered to:

- A small area will be utilised for the performance, which minimises the RT and improves the sound quality thus reducing the SPL (Gastmeier, 2009).
- The speakers will not be positioned directly facing other functional areas such as the bar (HSE, 2008).
- Speaker placement will minimise the sound directed to employee locations (WWA Commission, 2003).

5.4.2 Bar area

In venue 1 and 2, the bar area was separated from the main entertainment area. In venue 1 the bar was separate from the entertainment solely through distance, in that an attendee would be required to walk away from the stage, past the inside seating area and then reach the bar. The attendee would not need to pass through a passage or door to reach the bar. In venue 2, the bar was structurally separated from the entertainment area by walls with glass windows. The wall separating the two areas formed an L, with a door on either side. Thus, an attendee would be required to exit the main entertainment area via either of the doors and then pass through the inside seating area in order to reach the bar. In venue 3 and 4 the bar area was situated in the main entertainment, directly across from the stage. Literature discourages that speakers be placed directed towards functional areas, especially areas with employees (HSE, 2008; WWA Commission, 2003). The results of this study based on the variance of SPLs within different areas of the venues indicated a significantly lower mean SPL in the bar areas

that were separated from the main entertainment area. This study indicates a significant relationship between the venue-based hearing conservation strategy of separating the bar area from the main entertainment area and the variance of SPLs between these areas. If venues were to comply with this strategy not only would they reduce the exposure levels of employees such as bartenders but they would also provide attendees with an 'auditory break' when the attendees leave the entertainment area to purchase beverages. Adhering to this venue-based strategy would simultaneously cause the venue to adhere to the following recommendations:

- The speakers will not be positioned directly facing other functional areas such as the bar (HSE, 2008).
- Speaker placement will minimise the sound directed to employee locations (WWA Commission, 2003).

5.4.3 Outside area

All four venues in this study had an outside seating area available. During the literature review reference could not be found to using an outside area as a means to reduce the attendees high intensity sound exposure. In all four of the venues in this study the mean SPLs recorded in the outside areas where significantly lower than the mean SPLs recorded in the main entertainment area, regardless of the size, position or acoustic characteristics of the outside area. This indicates that providing an outside area for attendees is an effective venue-based hearing protection strategy.

5.4.4 Upper inside seating area

Venue 3 and 4 contained an upper seating area. In both venues this seating area was

within the main entertainment area and open plan in design, in that it looked down to the stage. In venue 3 the area was accessed via a staircase in the outside seating area, whilst in venue 4 via a staircase next to the stage. In the variance analysis above, inconsistent results were found between the upper seating area and in front of the stage. In venue 3, the mean SPLs recorded in the upper seating area were significantly lower than those recorded in front of the stage. As discussed in section 5.2.1.5 above, this significant variance is thought to be due to the seat-dip effect caused by a large crowd in front of the speakers. In venue 4, a non-significant variance was found between the mean SPLs recorded in each area. In both venues the variance between the mean SPLs recorded in the upper seating area and the back of the main entertainment area proved insignificant. Due to the mean SPLs in the upper seating area indicating majorly a non-significant difference to the SPLs recorded in the other areas of the entertainment area, the upper seating area should not be considered a structural means to reducing the attendees' noise exposure in live music venues.

5.4.5 Inside seating area

All four venues had an inside seating area. In venue 2 and 3, the seating areas were structurally separate from the main entertainment area. In venue 2 the inside seating area was L-shaped and was separated from the entertainment area by walls with glass windows. Two doors joined the two areas. In venue 3 the seating area was separated from the entertainment area with solid walls and a single door. The results indicated that the mean SPLs recorded in the inside seating area were significantly lower than the mean SPLs recorded in the main entertainment area in venues 2, 3, and 4. A non-significant variance in SPLs between areas was found in venue 1. This study indicates that a relationship between the characteristics of the inside seating area and the variance of sound pressure levels between areas does not exist.

This does not correlate to previous findings, as research indicated that positioning functional areas away from the speakers is a functional hearing protection strategy (HSE, 2008).

5.4.6 Entrance

Similarly to the outside areas, the mean SPLs recorded at the entrances to all the venues proved to be significantly lower than those recorded in the main entertainment area. As this significant difference in SPLs was evident in all the venues, it suggests the size, position and characteristics of the entrance area do not affect the mean variance in SPLs between the entrance and the entertainment area. There is a dearth of information on the entrance to venues as a potential venue-based hearing protection strategy. For this strategy to be practical the attendees would need to make use of the entrance areas to venues. This could be achieved by positioning a functional area such as a seating area, the bar or the bathrooms close to the entrance of the venue. Alternatively, this could be achieved by positioning activities such as pool tables or darts near to the entrance area.

5.4.6 Bathrooms

In venues 1, 2, and 4 the bathrooms were situated inside the main building of the venue and were separated from the entertainment area via a short passage. Venue 3 contained two sets of bathrooms, one set was within the inside seating area which was structurally separated from the main entertainment area. The second set of bathrooms was accessed from the outside seating area and was thus also structurally separated from the main entertainment area. In venue 1, 2 and 3 the mean SPLs recorded at the entrance to the bathrooms proved to be significantly lower than the mean SPLs recorded in the main entertainment area. The results in venue 4 did not correlate to these findings. This study indicated that the positioning

of the bathrooms within the venue does not have a direct relationship with the variance of SPLs between areas.

5.5 Summary

Based on the discussion above, it is evident that the results from the current study highlight five structural characteristics that may be useful tools in reducing the risk for MIHL in live music venues. These characteristics include:

1. Increasing the distance between the speakers and functional areas such as the bar, seating areas and bathrooms.
2. Positioning the bar outside of the main entertainment area.
3. Structurally isolating the main entertainment area from the other areas of the venue.
4. Providing attendees with an outside seating area
5. Maximising attendees' use of the entrance area which consistently presents as a 'low intensity' area in live music venues.

Furthermore, the findings of the current study indicate that venue-based hearing conservation strategies in live Rock and Heavy metal music venues are a plausible means of reducing the risk of MIHL. This specifically relates to increasing compliance with personal hearing protection, educational campaigns and compliance with the acoustic recommendations in music venues (Table 28). This study further indicates that specific structural practices can be used to reduce the risk of MIHL for attendees (Table 29).

Table 28 *Proposed recommendations for HCP and Acoustic characteristics of live music venues*

Recommendations from literature		**Findings from the current study**	**Recommendations based on findings of current study to improve compliance**
Hearing conservation programmes	Education and awareness (Bogoch et al., 2005; Chung et al., 2005).	Not observed in venues	Implement awareness programs in live music venues by means of pamphlets and posters. The findings from this study indicate the venues would implement such a program if the means were provided.
	Availability of HPDs(Bogoch et al., 2005).	Not observed in venues	Live music venues should be provided with HPDs so that they may be easily accessible for attendees and employees.
Acoustic	Absence of dry walling (Gastmeier, 2009).	Compliance in three of the four venues	Venue owners and managers need to be informed of the current legislation and recommendations currently in place. Current legislation and hearing conservation recommendations should be promoted in live music venues. Regular follow up inspections need to be conducted by the department of labour to ensure adherence to the legislation and hearing protection recommendations.
	Absence of wooden flooring(Chasin & Chong, 1995).	Non-compliance in all venues investigated	
	Minimal use of reflective surfaces (Gastmeier, 2009; HSE, 2008).	Compliance in one of the four venues	
	Placement of speakers (Chasin & Chong, 1995; HSE, 2008).	Inconsistent compliance	
	Absence of seating in the main entertainment area(Gastmeier, 2009).	Non-compliance in three of the four venues	
	Absence of background noise (Gastmeier, 2009).	Compliance in all venues	
	Speakers facing away from work areas (HSE, 2008; WWA Commission, 2003).	Compliance in one venue	
	Employees not exposed to SPLs exceeding 85dB without the provision of HPDs (OHSA, 1993).	Non-compliance in all venues investigated	
	Warning posters at all exits and entrances to noise zones (OHSA, 1993).	Non-compliance in all venues investigated	

Table 29 *Additional venue-based strategies*

Venue-based strategy as indicated by this study	Recommendations based on each strategy	Suggested implementation technique
Increasing the distance between the speakers and functional areas such as the bar, seating areas and bathrooms.	When structural separation between areas is not plausible, venues are advised to position functional areas as far from the entertainment area as possible.	As these venue-based hearing conservation strategies all effect the structural design of the venue, implementation into current live music venues may be challenging. However, as live music venues are required to obtain a business licence (Business Act 1991), these strategies could be implemented, by the department of labour, into the legislation requirements for venues to obtain the licence.
Positioning the bar outside of the main entertainment area.	It is recommended that live music venues structurally separate the bar from the main entertainment area. When structural separation is not plausible, separating the areas is recommended. It is not advised that venues position the bar within the main entertainment area.	
Structurally isolating the main entertainment area from the other areas of the venue.	The main entertainment area should be structurally separated from the other functional areas of a venue. Ideally the separating structure should be a solid wall. Dry walling is not recommended.	
Providing attendees with an outside seating area	Venues should attempt to maximise the attendees' use of the outside area. Suggestions include, providing cover in case of rain, heating in winter and easy access to other areas such as the bar or bathrooms without entering the main entertainment area.	
Maximising attendees' use of the entrance area which consistently presents as a 'low intensity' area in live music venues.	Venues should also maximise the attendees' use of the entrance area. This can be achieved by positioning functional areas, such as the bar, near the entrance. Alternatively, other forms of entertainment can be positioned near the entrance, such as pool tables or dart boards.	

Chapter 6: Conclusion

"What was left when that fire was gone?
I thought it felt right but that right was wrong
All caught up in the eye of the storm
And trying to figure out what it's like moving on
And I don't even know what kind of things I've said
My mouth kept moving and my mind went dead
So, picking up the pieces, now where to begin?
The hardest part of ending
Is starting again!!"
(Bennington et. al. 2010, track 8)

.

This study aimed to determine if venue-based hearing conservation strategies in amateur live rock and heavy metal venues are a plausible means of reducing the risk of MIHL. This chapter summarizes the findings of the study. Thereafter, it focuses on the strengths and limitations of this study, the recommendations for future research and the implications of the results.

6.1 Summary of the results

This study indicates that currently there are no hearing conservation programs implemented in live rock and heavy metal music venues in Johannesburg, South Africa. Results also confirm that managers of these live music venues would be willing to implement hearing conservation programs including awareness programs, education programs and by increasing the availability of HPDs in the venues.

The SPLs were recorded throughout the venues and statistical analysis was used to determine if the mean SPLs in each area of the venues were significantly different from each

other. In all four venues the ANOVA analysis indicated a definite significance of variance between at least one pair of mean SPLs recorded in the venue. Thus, in all the venues the null hypothesis was rejected and therefore it can be stated that there is a significant difference in variance of the mean SPLs between different areas in a venue.

The structural characteristics of the venues were analysed to determine if a relationship between each characteristics and the differences in mean SPLs exist. The structural characteristics that proved to indicate a relationship with the differences in SPLs within the venues included: i) separating the main entertainment area from the other areas in the venue, ii) the position of the bar area, iii) the presence of an outside area and iv) the entrance area.

Thus this study has found evidence to support venue-based hearing conservation strategies as a plausible means to reducing the risk of MIHL in live music venues. Furthermore, evidence from this study indicates that in addition to traditional hearing conservation strategies (e.g. awareness programs and personal hearing protection), structural characteristics and layout of the building can be used as venue-based hearing conservations strategies as well as traditional hearing conservation strategies.

6.2 Critical evaluation of the study

6.2.1 Strengths of the study

The strengths of this study lie in the setting of the research as well as the exploratory nature of the design. As this study was conducted in live music venues, during typical weekend performances, the results provide insight into the current practices within the venues. Furthermore, as this study did not manipulate the environment, the results provide a

true indication of the SPLs occurring within live music venues. The exploratory nature of the study allowed the pre-existing conditions within these venues to be evaluated in terms of trends within the venues which may be used to aid hearing conservation. This ensures that future recommendations regarding the structural requirements of venues are realistic and goals will be obtainable.

6.2.2 Limitations

Whilst this study has provided valuable information regarding current and future hearing conservation strategies in the music industry, the limitations of this study need to be taken into account:

- This study was limited by research design in that it did not include a true experimental phase whereby the relationships discovered between the variance in sound pressure levels in the venues and the structural characteristics could be examined for a true cause-effect relationship.
- This study was further limited by the type of equipment used. As dosimeters were used in the study, the SPLs in each area of the venue were recorded manually at one minute intervals by the research assistants which allows for human error. Ideally, advanced sound levels meters capable of automatically recording and storing the SPLs at minute intervals should have been used.
- A further short-coming of this research was the length of the measurements. The measurement sets of 35 minutes were decided on based on the statistical requirements of at least 30 repeated recordings per set in each venue. However, audiological requirements for risk assessments require longer sets of recordings, ideally eight hours per set. For this reason, this study did not relate the SPLs recorded in the venues to risk predictions.

6.3 Recommendations for future research

The results revealed a variety of interesting trends. Preliminary answers and many more questions were raised that will need to be answered in the following type of future research:

- It is recommended that further studies are conducted to consolidate the findings of this research. It is further recommended that experimental studies are conducted to investigate the functional use of the hearing protection techniques suggested by this study.
- It is also recommended that this study be replicated in venues where the floor plans and actual measurements of the venues are available. Not only will this allow for the repeatability of this study to be evaluated, but will also allow the researcher to calculate the expected SPLs in each area based on physical distance and structural obstructions. This information will be important for architects and engineers when doing prediction based calculations in music venues.
- Another study that would provide valuable information would be to record attendees' noise exposure over the course of a typical evening in the different venues, to determine if the structural differences within the venues affect the attendees' overall noise exposure.

6.4 Implications of this study

The implications of this study include clinical, educational policy, and practice, factors.

A clinical implication is that the audiological community should be required to include music venues in hearing awareness campaigns and promotions.

In terms of educational implications, music venue owners and managers require education in terms of the health and safety regulations adopted in South Africa as well as education in terms of allowable daily exposure limits for employees.

The development of policies is required to ensure the hearing protection recommendations, designed to reduce the risk of MIHL in music venues, are correctly implemented. This study also highlights the need for policy development with regard to the acoustic and structural recommendations to reduce the intensity levels in music venues and thus reduce the risk of employees and attendees within the venues.

This study indicates the need for investigations by the South African department of labour to ensure music venues are complying with the OHSA regulations. The final implication of this study highlights the need for follow up investigations by the department of labour to ensure the on-going compliance with the above mentioned policies.

“When you were standing in the wake of devastation

When you were waiting on the edge of the unknown

And with the cataclysm raining down

Insides crying “Save me now”

You were there impossibly alone…

…And in a burst of light that blinded every angel

As if the sky had blown the heavens into stars

You felt the gravity of tempered grace

Falling into empty space

No one there to catch you in their arms…”

(Bennington et. al. 2010a, track 12)

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Appendix A: Current hearing conservation and venue acoustics

Part A: Owner/Manager Interview to be presented verbally by the investigator

Current hearing conservation

Initials:_____

Job Description: Owner/Manager

HPDs (HPDs)

1. Are HPDs available at your venue? Y/N

2. Why?: _____

_____

_____

3. If no, would you be willing to sell HPDs at your venue? Y/N

4. Motivate your answer:

_____

_____

Awareness posters/pamphlets

1. Are there hearing conservation posters at the venue? Y/N

2. Would it be possible to have hearing conservation posters at the venue? Y/N

3. Why? _____

_____

4. If Yes: Where? _____

_____

5. Are there hearing conservation pamphlets at the venue? Y/N

6. Would it be possible to have hearing conservation pamphlets at the venue? Y/N

7. Why? _____

_____

8. If Yes: Where? _____

Low intensity areas

1. Does the venue have some areas that are quieter than others? Y/N

2. If yes: Where? _____

3. If yes: What percentage of attendees make use of the areas? ____

4. If yes: Are these areas:

Always empty

Mostly empty

Quite full

Very full

Usually packed

5. If no: Would it be possible to try create a quieter section of the venue? Y/N

6. Why?_____

_____

Part B: Observations

Evaluation of Current Venue Based Hearing Conservation Strategies to be filled out by investigator

HPDs

1. Are HPDs available in the venue? Y/N

2. If yes: Provide type and cost

	Type	Cost
1.		
2.		
3.		
4.		

3. Where attendees observed making use of HPDs? Y/N

4. Where staff members observed making use of HPDs? Y/N

5. Where band Members observed making use of HPD? Y/N

Awareness posters

1. Are there any Hearing conservation awareness posters/pamphlets in the venue? Y/N

2. If yes: Provide Type, sponsor and brief description of the poster/pamphlet

	Poster/Pamphlet	Sponsor	Description
1.			

2.			
3.			

Acoustic characteristics of live rock and heavy metal venues in South Africa

Acoustic characteristics	Notes
Size of venue in m2	
Presence of dry walling or thin walling (less than 1 inch)	
Wooden flooring	
Seating in the main entertainment area	
Distance between the speakers and the audience	
Presence of background noise	
Presence of reflective surfaces	

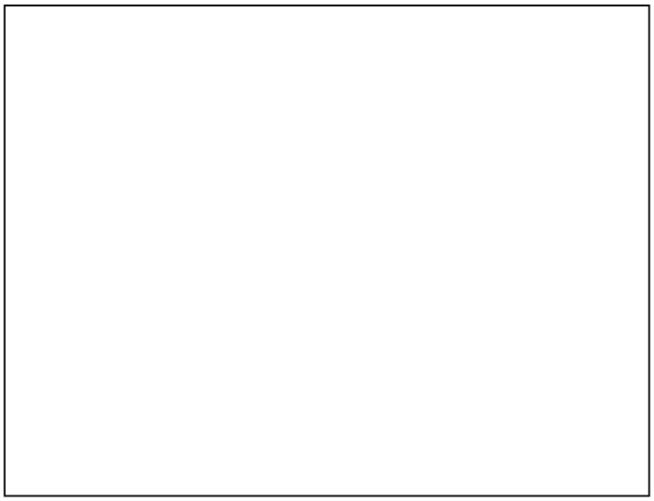
Distribution of sound

Speaker specifications

Type of speaker	Number	Size	Output	Manufacturer

The placement of the speakers in relation to the stage:

Sketch stage and speaker placement in block below



Structural characteristics of the venue	***Notes***
Main entertainment area sectioned off	
Bar at the back of the main entertainment area	
bar sectioned off from main entertainment area	
outside seated area available	
Inside seating area sectioned off from main entertainment area	
Bathrooms separate from main entertainment area	
Bathrooms outside	
upper inside area in main entertainment area	

Appendix B: Research assistant record form

Assistant code: _____ Area: _____

Date: _____ Test number: ____

Time hh:mm	**Reading**	**Time** hh:mm	**Reading**
00:01		00:19	
00:02		00:20	
00:03		00:21	
00:04		00:22	
00:05		00:23	
00:06		00:24	
00:07		00:25	
00:08		00:26	
00:09		00:27	
00:10		00:28	
00:11		00:29	
00:12		00:30	
00:13		00:31	
00:14		00:32	
00:15		00:33	
00:16		00:34	
00:17		00:35	
00:18			

Appendix C: Medical ethics clearance certificate

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG
Division of the Deputy Registrar (Research)

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
R14/49 Ms Katherie Horrell

CLEARANCE CERTIFICATE	M110846
PROJECT	Venue-Based Hearing Conservation Strategies: Reducing the Risk for Music Induced Hearing Loss
INVESTIGATORS	Ms Katherie Horrell
DEPARTMENT	Speech Pathology & Audiology
DATE CONSIDERED	26/08/2011
M1108460DECISION OF THE COMMITTEE*	Approved unconditionally

Unless otherwise specified this ethical clearance is valid for 5 years and may be renewed upon application.

DATE 24/10/2011 **CHAIRPERSON** .....
(Professor PE Cleaton-Jones)

*Guidelines for written 'informed consent' attached where applicable
cc: Supervisor : Dr Karin Joubert

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10004, 10th Floor, Senate House, University.
I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. **I agree to a completion of a yearly progress report.**
PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

Appendix D: Venue information leaflet and informed consent

Introduction

Hello. My name is Katherine Horrell, I am currently completing my Masters degree in Audiology at the University of the Witwatersrand. In accordance with requirements for the degree, I am conducting a research project. This research aims to provide the audiological community with information regarding the current hearing conservation (protection) strategies implemented in live music venues in Johannesburg as well as the acoustic characteristics of such venues. Furthermore, this research aims to determine if structural characteristics directly affect the sound levels within music venues.

This consent form may contain words that you do not understand. Please ask me to explain any words or information that you do not clearly understand.

You are invited to consider participating in this research study. Your participation in this study is entirely voluntary.

1. Before agreeing to participate, it is important that you read and understand the following explanation of the purpose of the study, the study procedures, benefits, risks, discomfort and precautions as well as the alternative procedures that are available to you, and your right to withdraw from the study.
2. This information leaflet is to help you decide if you would like to participate. You should fully understand what is involved before you agree to take part in this study.
3. If you have any questions, do not hesitate to ask me.
4. You should not agree to take part unless you are satisfied about all the procedures involved.
5. If you decide to take part in this study, you will be asked to sign this document to confirm that you understand the study. You will also be given a copy to keep.
6. You will be given written and oral feedback regarding the results found within your venue which may help you in complying with the occupational health and safety act (OHSA) regulations for workplace noise.

VENUE-BASED HEARING CONSERVATION STRATEGIES

Length of study

The aim is to determine the current practices of live music venues and thus your involvement will include:

The total amount of time required for your individual participation is approximated at less than half an hour, which will include discussing the hearing conservation strategies at your venue. The researcher will also require access to the venue over the course of one evening in order to take intensity measurements during a live music performance.

Terms of agreement

If you agree to take part in this study: the researcher will ask you 21 questions regarding the venue, hearing conservation and speaker configurations, and you allow the researcher and research assistants access to the venue on one evening during a live music concert to record the intensity levels using dosimeters and to record and analyse the acoustic characteristics of the venue.

Risks of procedures

There are no risks involved in participating in this study

Benefits of procedures

Benefits of the study include education and awareness on ear and hearing care as well as the effects of noise on the auditory system by means of an awareness pamphlet.

Rights as a participant in this study

1. Your participation in this study is entirely voluntary.
2. You can decline to participate, or stop at any time, without stating any reason without any negative consequences
3. I will provide you with any additional information that becomes available during the study, which may affect your willingness to continue the study.

Confidentiality

1. All information obtained during the course of this study including personal data and research data will be kept strictly confidential. Data that may be reported in scientific journals will not include any information that identifies you or the venue as a participant in this study.
2. The information may also be inspected by the University of the Witwatersrand Human Research Ethics Committee (HREC). Therefore, you hereby authorise me to release your data to the University of the Witwatersrand Human Research Ethics Committee (HREC).
3. These records will be utilised by them only in connection with carrying out their obligations relating to this study.
4. The raw data collected in this study will be stored in a locked cupboard within the University and will be destroyed after a period of five years.

Thank you, if you need any further information you are welcome to contact me at any time on 074 065 1010 or kat.horrell@gmail.com. Should you have any questions or concerns you may contact the University of the Witwatersrand research office on 011 717 1234 or anisa.keshav@wits.ac.za.

Yours sincerely,
Katherine Horrell

Venue Informed consent

1. I have received, read and understood the above written information (participant information leaflet and informed consent) regarding this study.
2. I am aware that the results of the study will be anonymously processed into a dissertation.
3. I may, at any stage, without prejudice, withdraw my consent and participation in the study without any negative consequences
4. I have had sufficient opportunity to ask questions and (of my own free will) declare myself prepared to participate in this study.

Participant

_____	_____	_____
Printed Name	Signature	Date

Investigator

I, Katherine Horrell, here within confirm that the above participant has been fully informed about the nature, conduct and risks of the above study.

_____	_____	_____
Printed name	Signature	Date

Appendix E: Information sheet

Adapted from Horrell (2009)

This information sheet aims to provide you with information with regard to HPDs (HPDs) as well as noise and music as a health risk. If you have any queries or concerns with regard to the following information, please feel free to contact me on 082 497 5570.

Definition

HPDs (HPDs) can be defined as instruments used to reduce the intensity of the sound entering the ear. HPDs are used as a preventative measure against Noise Induced Hearing Loss (NIHL), including Music Induced Hearing Loss (MIHL), and are important in hearing conservation where individuals (including musicians) are exposed to noise levels considered dangerous and cannot be reduced by engineering or administrative controls.

Why should I use HPDs?

Exposure to loud sounds can cause a Noise induced hearing loss (NIHL). NIHL can be traumatic, where the individual may have experienced a once off high intensity (loudness) exposure that results in a sudden permanent hearing loss. Alternatively NIHL can be gradual, caused by recurrent exposure to noise at or above 85dB. In the case of a typical gradual NIHL, initially the individual will experience a temporary hearing loss that can be described as having a blocked sensation in the ears and/or ringing in the ears (tinnitus) that persist only for a period of time after the noise exposure. This is known as a temporary threshold shift. However, repeated exposure may result in a permanent threshold shift. Once an individual has acquired a permanent threshold shift the damage is permanent and irreversible.

The impact of NIHL, including MIHL, on an individual may include an emotional effect and stress as a result of communication difficulties. Noise exposure is linked to an increase of serum cortisol levels in the blood; serum cortisol is a sign of stress and is linked to insomnia, high blood pressure and irritability.

NIHL may affect an individual's ability to monitor loudness, thus one may perceive a sound to be louder or quieter than it actually is. NIHL may also affect an individual's ability to

locate sounds in the environment, thus one may think a sound is coming from one direction while in fact it is coming from another. Further more NIHL may distort sounds including high frequency sounds and vowel sounds which are critical for understanding speech. All of the above factors may affect an individual's ability to accurately play and create music.

When should I use HPDs (HPDs)?

You should wear HPDs when exposed to sounds that are 85dB in intensity (loudness), especially if you are exposed to the sound for eight hours or longer. 85dB can be likened to a telephone ringing or a hair dryer. As the sound's intensity increases, the period of time that exposure is considered safe decreases. You can work out the time considered safe by this simple calculation. For every 3dB increase in intensity, the time considered safe is halved.

Time that is safe at different intensities.	**Examples of different sound intensities.**
85dB: 8 hours or less is considered safe. 88dB: 4 hours or less is considered safe. 91dB: 2 hours or less is considered safe. 94dB: 1 hour or less is considered safe. 97dB: 30 minutes or less is considered safe. 100dB: 15 minutes or less is considered safe. At 112dB a minute is considered unsafe. At 130-140dB a second is considered unsafe. (National Institute for Occupational Safety and Health (NIOSH) publication No. 98-126)	30dB: whisper 35-40dB: country residence 60dB: average conversation 70-85dB: average street noise 85-90dB: hair dryer or telephone 90- 110dB: Disco 100- 110dB: motorcycle 105- 115dB: power lawn mower 120dB: thunder clap 150-170dB: jet engine (Feuerstein, 2002).

How does this relate to me?

Studies have indicated that live amplified music can reach levels that are considered dangerous even for short periods of time; Rock concerts can reach up to 140dB.

A good way to determine how loud your environment is is to use this rule-of-thumb. At 90dB you have to raise your voice to talk to someone a meter away, at 100dB you have to raise your voice to talk to someone right next to you, at 110dB you have to shout in their ear and at 120dB you can't hear yourself shout.

Types of HPDs

The three types of general HPDs include ear plugs, ear muffs and canal caps.

Ear plugs



Premoulded ear plugs



Formable earplugs



Custom ear plugs

Ear plugs are the most popular type of HPD; they are inserted into the ear canal and form a seal against the canal walls. Three types of ear plugs are available, namely Premoulded, formable and custom earplugs.

Premoulded: Premoulded ear plugs are made of vinyl, silicone or other flexible material. They come in different set sizes that fit most individuals and may come in single or triple flange styles. Premoulded ear plugs are re-usable as they may be washed, however they should be replaced periodically due to deterioration. These can be found at your local hardware shop or pharmacy.

Formable: Formable ear plugs are made of soft, expandable foam or fiberglass. These ear plugs come in one size; they are compressed and inserted into the ear canal, where they expand to the shape of the canal and create a seal. Formable ear plugs are disposable in nature; however, they may be washed and re-used for 3weeks or until optimal seal no longer results. These can be found at your local hardware shop or pharmacy, for as little as R5 a pair.

Custom: Custom ear plugs are made specifically for your ear and your hearing needs; due to this they provide the most protection. Custom ear plugs have one unique feature, they can be designed to filter certain frequencies, and thus they provide the required protection but do not distort the musical signal and may also allow for the wearer to hear speech without removing the ear plug. However, these ear plugs are expensive and the individual must be referred to the audiologist for ear impressions to be taken.

Audiologists in your area can be found by visiting the following websites:

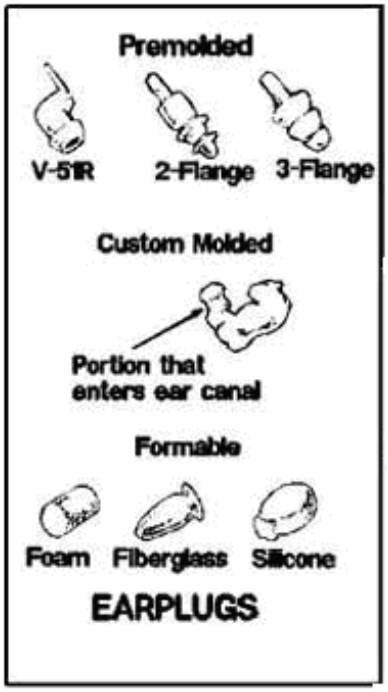
www.audiologysa.co.za

www.saslha.co.za

VENUE-BASED HEARING CONSERVATION STRATEGIES

Ear muffs and canal caps

Earmuffs and canal caps are rarely used in the musical industry; they are intended for use in other occupational settings such as mines and factories.



Thank you for participating in this study and taking the time to read this leaflet.

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