Investigating the use of sound level management software in live indoor music venues

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ABSTRACT

As part of a larger study of sound (pressure) levels in small and midsized live music venues, the effect of using sound level management software (10EaZy), on sound exposure levels of patrons and staff was investigated. Overall, no reduction in sound level exposure was observed, however, results suggest that use of 10EaZy led to significantly less time spent at higher volumes as measured for loud performances.
Introduction

Music-induced hearing injury (MIHI) is a preventable, yet prevalent form of injury caused by cumulative over-exposure to sound affecting both musicians and the listening public (Zhao et al., 2010). Symptoms commonly reported by exposed musicians include hearing loss, tinnitus, distortion and reduced sound tolerance (Kahari et al., 2003; Laitinen & Poulsen, 2008; Patel, 2008; El Dib et al., 2008). MIHI typically presents as a symmetrical sensorineural loss with a characteristic ‘notch’ centred on 4kHz, caused by the mechanical and metabolic destruction of fine inner ear structures (Nordmann et al., 2000). Temporary threshold shifts (TTS), can also occur immediately post-exposure, subjectively improving over 24-48 hours, yet increasing the risk of permanent damage and secondary symptoms, such as tinnitus and sound sensitivity (Nordman et al. 2000; Laitinen & Poulsen, 2008; Furman et al., 2013). Beyond this, MIHI can lead to functional changes, including decreased ability to discriminate speech in noise, impaired frequency resolution, and psychological symptoms of depression or social isolation (Mohamad et al., 2016; Eggermont 2017).

Despite the risks, the use of hearing protection to counter the potential harmful effects of excessive exposure to live music remains low. In a survey of over 9000 participants, 61% had experienced tinnitus or hearing impairment after a concert, yet only 14% had used earplugs in a place of live music. Furthermore, up to half of concert attendees reported they would view their peers negatively if they used hearing protectors, evidence that there is a degree of stigma associated with protective behaviours in music (Chung et al, 2005). Staff use of hearing protectors in music venues is also low, with issues such as comfort, discretion and distortion of speech and music commonly cited (Kelly et al., 2015; Jamieson, 2015).

At present, the best parameters we have for estimating the potential for hearing risk in music venues are derived from occupational health and safety standards. In Australia, these guidelines outline a daily noise dose of 85 dB L_{Aeq} for 8-h, and 140 L_{Cpeak}, with exposure time halved for every doubling of intensity (3dB; Standards Australia 2005). This means 8 hours at 85 dB L_{Aeq} carries the same risk as 88 dB L_{Aeq} for 4-h, or 91 dB L_{Aeq} for 2-h. By these standards, sound levels in music venues regularly exceed those deemed to be safe, with volumes of 100 dBA not uncommon (Goggin et al., 2008; Beach et al., 2013) To better manage the risks, several countries have introduced legislation which impose limits on the maximum sound levels permissible in music venues (Tronstad & Gelderblom, 2016).

10EaZy is a sound level management software system, designed to help venues and sound engineers adhere to sound level regulations. It does this by translating the time trade-off for high sound levels into a novel metaphor, known as ‘decibel-banking’ (Navne, 2015; for an in-depth description see Mulder, 2016). The interface displays each decibel above the target level in red, and each decibel below in green, continually informing the user as to how many decibels are ‘left in the bank’ as they aim for the set L_{Aeq,15min} target.

Systems like 10EaZy are commonly used for sound level management in music festivals and concerts, but at the time of this study, only anecdotal evidence for the efficacy of such a system in an indoor live music venue was available. The data reported here is part of a larger study examining the typical sound levels and hearing health of patrons and staff at indoor music venues. As a whole, the hypothesis was that access to the 10EaZy system, and implementation of a 15-minute maximum L_{Aeq} sound level, would result in lowered sound exposure of patrons and staff. Patrons were also canvassed as to their perceptions of any such change. This paper focuses on preliminary data from one of six venues, and presents initial findings from this study.

2 Methods

This study was conducted under the ethics approval and oversight of the Royal Victorian Eye & Ear Hospital’s Human Research Ethics Committee (project number 15/1225H).
Participants
Invitations to participate were emailed to seven small-to-medium sized live music venues within the Melbourne metropolitan area, and six agreed to participate. Data pertaining to one venue only were ready for analysis and these are reported here. A total of 61 patrons at the venue participated in the study (male = 30, female = 27, indeterminate = 4), ranging in age from 19 to 58 years ($M = 28.9, SD = 10.0$). Six staff members at the venue also participated (male = 1, female = 5), ranging in age from 22 to 35 years ($M = 27.7, SD = 4.9$).

Materials
A Class 2 recording system with a Dell Inspiron laptop (Regulatory Model P25T), pre-amp and MK216 microphone was installed in the venue, using Version 2.6 of 10EaZy (SG Software, Denmark; AS IEC 61672.1-2004). The set-up was placed at the sound desk, with the microphone left in a fixed location throughout the study, secured at ear level to the sound engineer. A log sheet for tracking band performance data and information on the mixing engineer was also supplied. Five calibrated Casella dBadge (CEL-350) noise dosimeters were used to measure $L_{Aeq}$ and $L_{Cpeak}$ sound levels.

Surveys
Two surveys were designed for this study using online survey platform SurveyGizmo (SurveyGizmo, Boulder, Colorado). One survey was for the staff and the other for patrons. The patron survey consisted of 10 closed items, covering hearing health and hearing protection use in a live music setting, as well as patrons’ satisfaction with the venue’s sound levels. The staff survey covered the topics of hearing health and hearing protection use, as well as listening wants and needs in a live-music workplace. Neither patrons, nor staff were incentivised or rewarded for their time completing these surveys. Responses were recorded anonymously, and as such, signed consent was not required.

Procedure
At initial contact, a statement outlining the study was supplied to the venue. This was followed up by an in-person meeting to discuss implementation of the protocol in the venue. Informed consent was obtained from the venue manager, with authority to sign on the venue’s behalf. Once the study had been agreed upon, the staff survey was emailed to the manager to pass onto all available staff to complete. No inducements or rewards were offered for participation; however, the venue was provided with the sound level measurements at the completion of the study.

The study was conducted in two phases. During Phase A, for each live music performance, the venue was asked to log the name, genre and performance time of each band, including if the mixer was an in-house or guest engineer. The venue was instructed to have the 10EaZy system recording for the duration of each performance, excluding DJ sets$^1$. The laptop screen was to be kept out of sight of the engineer in this phase, so as not to influence their management of the sound levels. The time weighting on the 10EaZy system was set to ‘fast’, and it logged sound levels at intervals of one minute ($L_{Aeq1min}$); 15 minutes ($L_{Aeq15min}$) and 60 minutes ($L_{Aeq60min}$). At the close of the system, an automated email was sent to the researchers, containing the night’s sound level log data and an audio recording of the night’s performance.

At the completion of Phase A, a report was sent to the venue outlining the sound levels recorded in their venue, along with instructions on how to use 10EaZy in Phase B. They were asked to discuss the Phase A measurements with their team and report back with a desired $L_{Aeq15min}$ to use in Phase B. Once set, Phase B commenced. The venue was re-instructed to use 10EaZy for each live music performance. This time, however, the laptop was positioned in view of the sound engineer, and they were encouraged to interact with the ‘Maximum Average Manager’ (MAM) of the system. The MAM provided the sound engineer with minute-by-minute updates of the venue’s sound levels, and how they compared to the target level, as set by the venue, thus updating them constantly on their

$^1$ The lack of backline sources (i.e. guitar amplifiers and drum sets) set DJ performances apart in term terms of sound level management.
‘decibel bank’ or ‘headroom’. At the close of the system, venue management and the head sound engineer also received an email summary of the night’s audio.

Dosimeter recordings were measured twice during the study: on the final night of each phase. The recordings were taken at five fixed locations; the sound desk, the ticket desk, the bar, on stage and central to the dancefloor (hung from the lighting rig roughly three metres above ground). The other dosimeters were placed as close to head height as possible, working within the allowable space and structure of the venue, avoiding any physical obstructions between dosimeters and speakers. Patrons were approached during these ‘dosimetry nights’ to participate in the sound level survey. Patrons were only engaged between performances, so as not to interfere with their musical experience.

**Data Management and Analysis**

To maintain consistency across the sound data, daytime recordings and any involving computer failure (and thus corrupt or incomplete data) were excluded. Furthermore, any sound captured prior to the onset of live music (i.e. the first band) and after the final performance was excluded. This resulted in the omission of five live-recording sessions, leaving a total of 4865 minutes of sound data captured over 27 nights in Phase A, and 3580 minutes over 21 nights in Phase B.

Descriptive statistics were used to analyse responses to the survey data. For between-phase comparisons, independent tests and analysis of variance were performed. A significance threshold of .05 was set for all analyses. Due to the small sample size, all patrons identifying as indeterminate were excluded from post-hoc analyses involving gender as an independent variable. For investigations involving age as a parameter, patrons were divided into two categories by the sample mean; adult (≥28 years) and young adult (≤27 years).

**3 Results**

*Patron Hearing Health*

Of the 61 patrons, 33 were surveyed in Phase A (male = 16, female = 13, indeterminate= 4), ranging from 20 to 58 years (M = 31.0, SD = 10.7), and 28 in Phase B (male = 14, female = 14), ranging from 19 to 56 years (M = 26.4, SD = 8.8).

Patrons were asked if they had experienced any of the following symptoms of hearing injury, either during, or directly after visit to a live music venue (see table 1). Tinnitus was the most commonly reported (57.4%; n = 35), followed by hearing dullness (26.2%; n = 16) and ‘not being able to hear as well the next day’ (18%; n = 11). Hearing distortion and a sensation of blocked ears were both reported by 9.8% (n = 6), while 32.8% (n = 20) reported they had not experienced any of the above symptoms.

**Table 1. The proportion of patrons and staff who had experienced hearing symptoms during or after attendance at a live music venue.**

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Patrons</th>
<th>Staff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tinnitus</td>
<td>57.4%</td>
<td>16.7%</td>
</tr>
<tr>
<td>Dullness</td>
<td>26.2%</td>
<td>16.7%</td>
</tr>
<tr>
<td>Distortion</td>
<td>9.8%</td>
<td>16.7%</td>
</tr>
<tr>
<td>Pain</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Blocked Ears</td>
<td>9.8%</td>
<td>33.3%</td>
</tr>
<tr>
<td>Reduced Hearing</td>
<td>18.0%</td>
<td>+</td>
</tr>
</tbody>
</table>

*Question not asked in staff survey*

Attendance at live music venues was high, with 34.4% (n = 21) of patrons attending at least once a fortnight, 32.8% (n = 20) on average once per month and 24.6% (n = 15) at least once every 2-3 months. A small percentage of surveyed patrons attended music venues less than twice per year (8.2%; n = 5). Hearing protection use was low, with 75.4% (n = 46) reporting that they rarely or never used protectors in a live music setting. Nine individuals had used them occasionally or sometimes (14.7%), with the remaining 9.8% (n = 6) reported wearing them often or always. Using Fishers exact test, frequency of live music attendance was found not to be related to the use of hearing protection, p = .34. A Pearson chi-square test found age (p = .20) was also unrelated, while gender was close to significance (p = .08), with females more likely to report never or rarely
wearing hearing (88.9%, n = 24) compared to (70%, n = 21).

**Patron Satisfaction**
Using a five-point Likert scale, patrons were asked to rate their satisfaction with the musical experience, ranging from very dissatisfied to very satisfied. Overall, patrons responded positively, with 93.4% (n = 57) being satisfied or very satisfied. Only one individual was very dissatisfied with their experience at the venue (1.6%) and 3 remained neutral, (4.9%) all of which were interviewed during Phase A. Using a two-sided Fisher’s Exact test, no significant difference was observed between satisfied (satisfied or very satisfied) patrons in Phase A (87.9%, n = 29) and those in Phase B (100%, n = 28), p = .08. The same analysis found age (p = .16) and sex (p = .35) to be unrelated to patron satisfaction.

As above, a 5-point Likert scale was used by patrons to rate their attitude towards the sound levels in the music venue, ranging from much too quiet to much too loud. During both phases, the majority felt the sound levels were just right in the venue (73.8%, n = 45). Four reported them as either much too quiet or a little too quiet (6.6%), while 21.3% found the sound to be a little too loud (n = 13). No patrons reported the volume as being much too loud. Pearson Chi-square analysis found phase (p = .17), age (p = .67) and sex (p = .46) to be unrelated to patron perception of the sound levels.

**Staff Hearing Health**
Staff were asked if, and to what degree, they had experienced tinnitus daily. Half the respondents reported hearing it sometimes (n = 3), and the remainder often or always. They were then asked which hearing injury symptoms they had experienced either during or after a work shift. Three reported no post-shift symptoms. Among the other three respondents, the most common of these was a sensation of blocked ears (n = 2), followed by tinnitus, hearing dullness and distortion, each reported by 1 person. No participants reported experiencing pain.

**Staff Hearing Protection**
Use of hearing protection by staff was low, with 4 never/rarely using them, and the remaining 2 staff using them occasionally. Two had used foam earplugs, and 1 individual had used filtered non-custom plugs. A further comment was made by one staff member that they had used a security communication earpiece as a form of hearing protection.

**Sound Measurements**
At the start of Phase B, the venue nominated to set the 10EaZy system at 102 L_{eq, 15min}. By the end of the first week, however, this limit had been reduced to 98, following feedback from the venue’s sound engineer that it was too high. It remained at this level for the rest of Phase B.

The sound level for each gig was calculated using the L_{eq, 1min} 10EaZy recordings from the start of the first band, to the end of the headliner’s performance (see Figures 1 and 2). Four evenings in Phase A were excluded as outliers, because they featured small folk bands or solo instrumentalists, and therefore recorded significantly lower sound levels compared to the other gigs (see black data points on Figure 1). This left 23 nights of recording in Phase A, and 21 nights in Phase B.

Across both phases, the mean sound level was 93 dB ($SD = 2.6$), with the minimum, 88 dB, recorded on a Tuesday night in Phase B, featuring a line-up of indie-pop, and the maximum, 98 dB, recorded on a Monday night in Phase A, featuring four Punk bands. In Phase A the mean sound level was 93 dB ($SD = 2.73$), and 94 dB in Phase B ($SD = 2.32$). A three-way analysis of variance was performed investigating the effect of the day of the week, (weekend [Friday/Saturday] or weekday), engineer (guest, in-house, a mixture of both) and phase (A or B). There was a significant main effect of engineer, $F(2,33) = 3.40, p < .05$, with the mean L_{eq} for in-house engineers ($M = 95, SD = 2.65$), louder than guest ($M = 93, SD = 2.32$) or a mixture of both ($M = 93, SD = 2.83$). Phase also yielded a significant effect, $F(1,33) = 4.41, p < .05$, with sound levels in Phase A ($M = 93, SD = 2.73$) softer than Phase B ($M = 94, SD = 2.32$). No significant effect of day of the week was noted, $F(1,33) = 1.38, p = .25$. 

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Dosimeter Recordings
The results of the dosimeter recordings showed a similar pattern in the level of sound recorded at each location (see table 2). For both nights, the highest sound levels, and equivalent daily noise dose, were recorded by the on-stage dosimeters. The second highest were recorded on the dance-floor, with the equivalent of 990% of a daily noise dose in Phase A, and 1381% in Phase B. These results were comparable with the sound levels recorded by the 10EaZy system, which measured an $L_{Aeq}$ of 95 and 96 at the sound desk for each phase, respectively.

Table 2. Dosimeter recorded sound levels and exposure by location

<table>
<thead>
<tr>
<th>Location</th>
<th>Phase A</th>
<th>Phase B</th>
<th>L$_{Aeq}$</th>
<th>L$_{Cpeak}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage</td>
<td>105 (3900%)</td>
<td>103 (2000%)</td>
<td>135</td>
<td>132</td>
</tr>
<tr>
<td>Dance floor</td>
<td>99 (1000%)</td>
<td>100 (1000%)</td>
<td>132</td>
<td>131</td>
</tr>
<tr>
<td>Bar</td>
<td>96 (500%)</td>
<td>97 (500%)</td>
<td>126</td>
<td>123</td>
</tr>
<tr>
<td>Sound desk</td>
<td>95 (400%)</td>
<td>96 (400%)</td>
<td>125</td>
<td>127</td>
</tr>
<tr>
<td>Ticket desk</td>
<td>86 (50%)</td>
<td>87 (50%)</td>
<td>120</td>
<td>118</td>
</tr>
</tbody>
</table>

Note: Percentage values show the daily noise exposure dose (rounded) as calculated per Australian occupational noise management standards (Standards Australia, 2005).

Punk vs Metal
To more closely examine the impact of 10EaZy on mixing behaviour during particularly loud performances, the loudest nights from each phase were selected for analysis. These consisted of a punk night in Phase A, with an $L_{Aeq}$ of 98, and a death metal night in Phase B, $L_{Aeq}$ of 97. The $L_{eq}$ values over the course of each gig can be seen in Figures 3 and 4.

An estimation of the data as it would have been seen by the sound engineer using the MAM of the 10EaZy system, was derived for each $L_{eq1min}$ recording. The $L_{eq1min}$ value was subtracted from the nominated target of 98 $L_{eq15min}$, for clarity all recordings outside 98 +/- 6dB were excluded, mirroring the restriction of the MAM interface.
showing at most 6 red or green boxes each representing 1 dB. We noted however that there were no $L_{eq1min}$ values over 104 dB recorded at this venue.

The plot of these derived MAM readings can be seen in Figures 5 and 6, showing the progression of cues the sound engineer would have received during the evening, with red (positive) values being above the target, and green (negative) at or below. In Phase A, the average MAM reading was -1.4 ($SD = 3.4$), and .08 ($SD = 1.9$) in Phase B. An independent t-test revealed the mean of the $L_{eq1min}$ values greater than 98 was significantly higher in Phase A ($M = 101.7; SD = 1.3$) than in Phase B ($M = 99.3; SD = 1.0$), $t(146) = 12.4, p < .05$. Using $L_{eq1min}$ recordings, time spent at or above the 10EaZy target of 98 dB was then compared between phases. A two-proportions z-test found there to be a significant difference, with 75% of $L_{eq1min}$ values ≥ 98 in Phase A, compared to only 49% in Phase B, $z = 5.2, p < .01$.

4 Discussion

The data presented in this paper confirms that patrons and staff in live music venues may be at risk of hearing injury due to high levels of sound exposure. The sound levels recorded on 44 evening performances ranged between 88 and 98 dB $L_{Aeq}$, averaging 93 dB $L_{Aeq}$ across the study period. Two-thirds of patrons (67%) reported experiencing a symptom of hearing injury during or after a gig, most commonly tinnitus, which was or had been experienced by 57% at least once after a show. Tinnitus rates were also found to be high amongst venue staff members – all six reported incidences of tinnitus at least sometimes, and for three employees, it was frequent or constant. These findings are consistent with previous research indicating higher rates of tinnitus in individuals with significant music-related exposures (Beach et al., 2010; Putter-Katz et al., 2015; Gilliver et al., 2015 Williams & Carter, 2017).

Despite the prevalence of symptoms of hearing injury, the use of hearing protection in the sample was low. In patrons, 75% had never or rarely used earplugs in a live music venue, a figure consistent with earlier studies (Bogoch et al., 2005, Cha et al., 2015). For staff, only two out of the six staff reported wearing earplugs occasionally during a shift. The reasons behind low earplug use were not explored in this study, however the literature suggests that issues relating to sound quality, comfort, and lack of awareness surrounding the
Goggin, or if the Aeq, the aperaintaining safe sound levels, such as France–15min, vol. 16, no. 2, Aeq–15min. For these environments, la, the sound levels measured at the venue in (102 dB L
European regulations and covenants lower than the limit set in 
(2018), this is higher. The Netherlands in this particular venue approached the limit set in 10EaZy as a ‘target’ rather than as a ‘limit’. Therefore, in this particular venue, the limit could have been set to a lower level, e.g. L\textsubscript{Aeq15min}=96dB, which would make it significantly lower than the upper limits cited in different European regulations and covenants, such as France (102 dB L\textsubscript{Aeq15min}) or The Netherlands (103 dB L\textsubscript{Aeq15min}). Additionally, the effect of using the ‘limit’ as a ‘target’ indicates that the instructions with regard to using 10EaZy given at the start of phase B needed to be more specific.

As noted, the data reported in this study are part of a larger investigation of six live music venues, and analysis of the entire data set may give an insight into whether the between-phase differences will be observed in a range of different venues, or if the venue discussed in this paper is an outlier in terms of staffing, acoustics and programming.

5 Conclusions

The data presented in this paper suggest that patrons and staff in live music venues are at risk of long-term hearing injury caused by exposure to music, and that more work is needed to promote the uptake of healthy hearing behaviours in the industry. Use of a monitoring system, such as 10EaZy, did assist with management of high sound levels, particularly in gigs where loud levels of music were expected. However, a single “systems-based” approach may not be fully effective for indoor venues in which sound levels vary considerably between different nights and bands. For these environments, greater flexibility in setting the target level may be required.

References


