FACE THE MUSIC: A 20 YEAR PLAN

S Dance Acoustics Group, School of Architecture and Built Environment, London South Bank University, London, UK
G Zepidou AECOM Ltd, Croydon, London, UK

1 INTRODUCTION

The Control of Noise at Work Regulations 2005 (CoNAWR2005) [1] were introduced to protect employees from health risks associated with noise. The 2005 regulations replaced the 1989 Noise at Work Regulations and introduced new, stricter requirements for action to be taken by employers. These include action to protect workers at levels of sound 5 dB(A) lower than those in the 1989 regulations, as well as health surveillance for employees regularly exposed to sound levels above 85 dB(A). The CoNAWR2005 were enforced in 2006 for all sectors other than the entertainment sector which was allowed a 2-year transitional period.

It is known that excessive sound exposure can result in Noise Induced Hearing Loss (NIHL) typically occurring at 4 kHz [2]. Approximately half of NIHL occurs within the first 3 years of excessive sound exposure with the remaining NIHL occurring over the following 42 years based on analysis of ISO 1999 [3]. Therefore, it is critically important to protect new employees or university students at the earliest opportunity.

The other major cause of hearing loss is presbycusis, but this is minimal (< 1dBHL at any frequency) for 18-25 year olds [4]. The CoNAWR were developed based on research in the effects of occupational noise exposure on hearing health which was based on industrial environments and did not include effects of entertainment sound or music exposure. This was due to the absence of relevant data. Enforcing the regulations on the entertainment sector is particularly difficult due to the nature of their work and sound being a deliberate product rather than a byproduct of the work undertaken.

Since 2007, through a long-term collaboration with the Royal Academy of Music (RAM), approximately 330 students each year have been assessed using the standard Bekesy pure tone screening audiometric (PTA) test procedure as part of a hearing health surveillance programme [5]. It should be noted that, although the CoNAWR2005 do not apply to students, the management of RAM considering the welfare of their students as being of equal importance to that of their employees, has been taking proactively taking measures to reduce exposure to as low as reasonably practicable and protect the hearing of both employees and students without compromising the high levels of music studies and performance. A similar approach has been taken by St Paul's Cathedral regarding their choristers [6].

This paper will provide an update on the 2014 paper [7] including audiometric results and specifically when music has the same audiometric effect as noise. In addition, the long-term effect of a prolonged campaign to raise awareness to the risk of excessive sound exposure.

2 UPDATED RESEARCH RESULTS

Audiometric information, hearing health surveillance, has been collected over 17 years, every year except 2020 (COVID) using calibrated Amplivox CA850 Mark 4 instrumentation implementing the Bekesy test procedure. This has resulted in numerous findings detailed below.

2.1 Hearing Thresholds

Early data, from the first 1955 students tested, indicated a consistent reduction in hearing acuity of musicians at 6 kHz [8], see figure 2 and 3. Whereas a change in the hearing thresholds at 4 kHz is normally seen in cases of noise induce hearing loss [2].

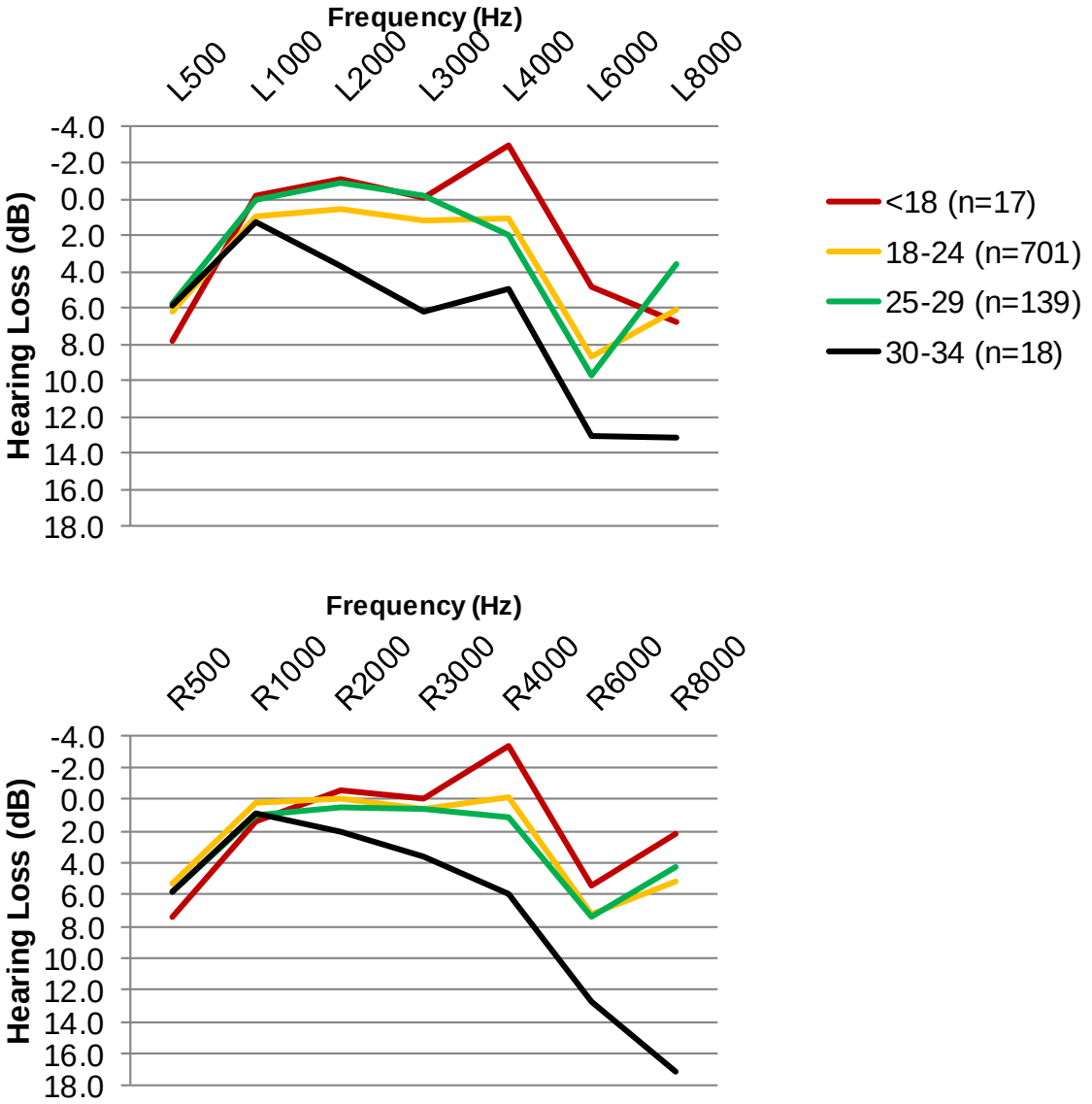

Figure 2. Hearing thresholds for male music students, n=875.

The study also found that, based on the Health and Safety Executive (HSE) categorisation scheme [9], 94% of students had “Normal” hearing (acceptable hearing ability), 4.5% presented “Warning” levels of hearing loss (mild hearing impairment) and 1.5% “Referral” levels of hearing (poor hearing) [8]. Note that according to the HSE categorisation scheme, typically 75% of population for each age band and gender would have hearing within normal limits, 20% would normally present a mild hearing impairment and 5% would need to be referred for further investigation.

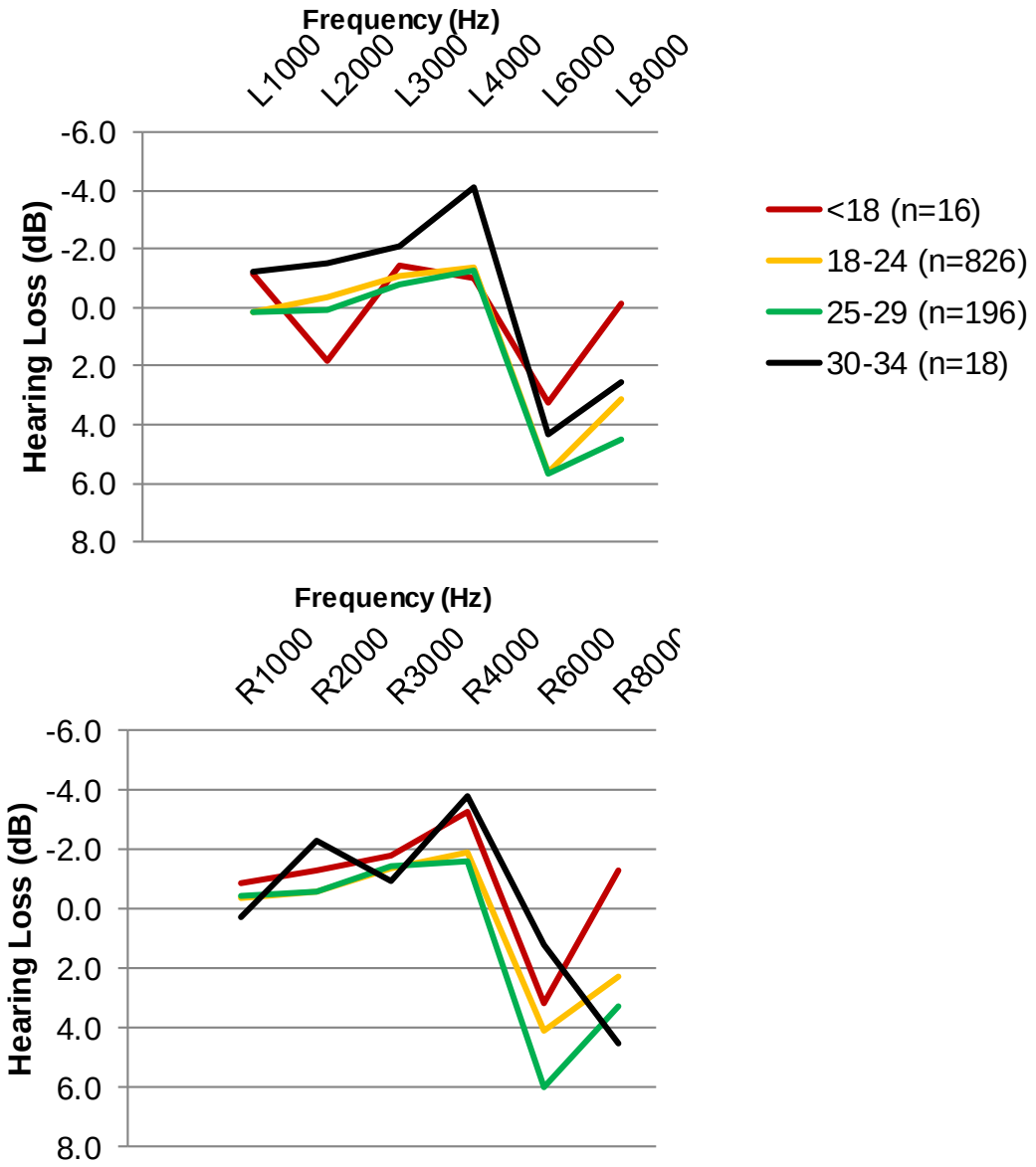

Figure 3. Hearing thresholds for female music students, n=1056.

2.2 Effects of Music and Noise on Hearing Thresholds

In 2017 a review of the audiometric dataset pulled out a comparison of Piano Accompanists, n=70 and Pianists, n=302 [10]. This demonstrated that the left ear of piano accompanists had identical hearing acuity as the pianists. However, the right ear had a significant reduction in hearing acuity in the right ear for the accompanists at 6 kHz, on average a 3 dBHL change in hearing threshold in 2 years of playing see figure 4.

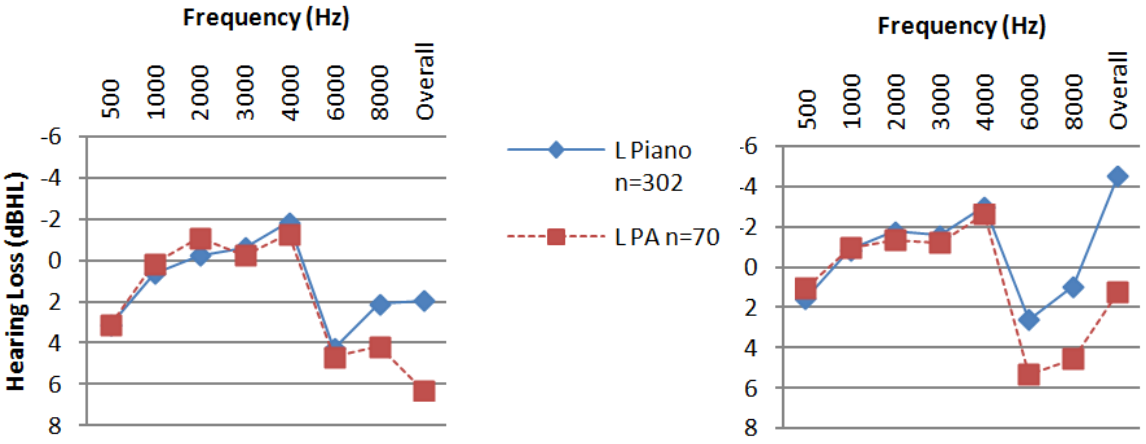

Figure 4. Hearing threshold of Pianist, n=302, compared to Piano Accompanists, n=70 (left/right)

The opera singers were found to have symmetric hearing thresholds, as did the pianists. This demonstrated that in a relatively short time the piano accompanists were exposed to high sound levels which affected their hearing, but did not affect the singer's acuity, specifically the exposed right ear, due to the piano lid position. The inference is that music created a different physiological response than noise, as to the piano accompanists the opera singer is more noise than music, whereas the pianist is making music as is the opera singer. It should be noted that some opera singers produce 100 dBA+ and they are replaced during practice by another singer each hour and the practice takes place in a small music room, approximately 50m^3 [10,11].

2.3 Hearing Thresholds by Cohort

Normal hearing for 18-25 year old is defined by 0 dBHL hearing thresholds. As such, the students summed hearing losses, should be zero for 50% of the population based on ISO 1999:2013 [3]. Analysis of the test data from 5300 students broken down into yearly cohorts of approximately 330 students has been undertaken. This allowed the authors to track the relative effectiveness of the on-going 17 year awareness campaign, see figure 5.

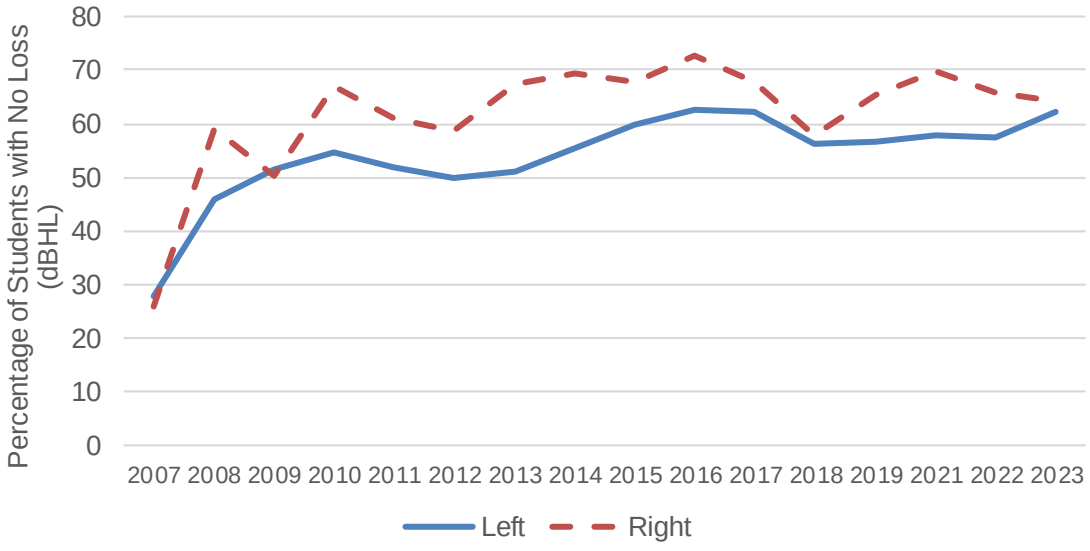

Figure 5. Annual cohort percentage with zero or negative hearing thresholds (dBHL).

As can be seen from figure 5 that after the first year of the programme the 50% threshold has been exceeded consistently. Currently, in 2023, it sits at 62% of the students with an overall zero or negative hearing loss (dBHL). It should also be noted that across the years the right ear had consistently greater hearing acuity. This has also been found in a study by Fearn [12]. It should also be noted that in the RAM study the right ear was consistently the second ear tested, whilst normally it is the first ear to be tested.

3 CONCLUSIONS

O'Brian *et al* concluded in their 2008 paper that the nature of orchestral music was complex [13]. The past 17 years has taken the subject of music and acoustics forward by working together to understand the issues and find solutions. This also explains why it took the assistance of five PhD students, (Georgia, Ben, Doug, Eric and Ruben) to start to address the problems and challenges set out in the original project.

Results have found that music students have excellent hearing and they have been listening to the advice that there is a risk associated with excessive sound exposure. It has definitely helped that technology has become highly popular which has allowed new awareness raising tools (iPhone) and campaign materials (WHO Make Listening Safe) have become available and are given away freely by leading companies.

Advances have recently been made in hearing health surveillance methodologies such as otoacoustic emissions these were suggested by Lutman *et al* in 2008 [14] and are now commercially available and recommended [15]. In addition, sound monitoring instrumentation that is more conducive for use by musicians has been developed. Further advances in room acoustics could help mitigate the sound exposure of musicians such as metadiffusers [16,17] in orchestra pits, a current research project. There is more work to do. Musicians are the most talented people, and they deserve to have a better working environment so that music can be enjoyed by all.

4 REFERENCES

1. The Control of Noise at Work Regulations, Health and Safety Executive, (2005).
2. Alberti P. W. *Noise and the ear*. In: *Scott-Brown's Otolaryngology*, Volume 2, Adult Audiology, D. Stephens (ed.). Oxford: Butterworth-Heinemann, (1997).
3. BS EN ISO 1999: 2013 Acoustics — Estimation of noise-induced hearing loss, Geneva, Switzerland, (2013).
4. BS EN ISO 7029: 2017. Acoustics. Statistical distribution of hearing thresholds as a function of age, Geneva, Switzerland, (2000).
5. Dance S., Zepidou G., Shearer D. Face the Music: A 12 year study of the sound of performance and hearing of classical music students, *Proc International Congress on Acoustics*, Aachen, (2019)
6. Dance S., Zepidou G. Sound exposure of choristers, Noise and Health, 21(98), (2019) DOI:10.4103/nah.NAH_40_19
7. S. Dance, Conservatoires - Acoustics and Music working together, *Proc. Institute of Acoustics*, Birmingham, (2014)
8. Health and Safety Executive. *The control of noise at work regulations* 2005, Guidance on Regulations L108 3rd Edition (2021).
9. G. Zepidou, S. Dance, Hearing loss amongst classical music students, Proc 11th International Congress on the Noise as a Public Health Problem (ICBEN), London 2011
10. Dance S., Dymock B. Sound exposure and the hearing of musicians, *Proc. Euronoise 2015*, Maastricht, (2015)

11. Okten G. The effect of room acoustics on the vocal loading of Opera Singers, PhD Thesis, London South Bank University, 2016
12. Fearn F.W. Hearing loss in musicians, *Journal of Sound and Vibration*, **163**, (1993) 372.
13. O'Brien I., Wilson W., Bradley A. Nature of orchestral music, Journal of the Acoustical Society of America, 124, p926-939, (2008).
14. Lutman M., Davis A., Ferguson A. Epidemiological evidence for the effectiveness of the noise at work regulations RR669, Health and Safety Executive, (2008).
15. Shepard R., Ryan F., Checkley P., Cordeaux C. Hearing Conservation for Performers: Best Practice Guidance, British Association for Performance Arts Medicine, (2020).
16. Ballestero E., Jiménez N., Groby J-P., Dance S., Aygun H., Romero-García V. Metadiffusers for Quasi-Perfect and Broadband Sound Diffusion, Applied Physical Letter, **119(4)**, 2021; https://doi.org/10.1063/5.0053413
17. Ballestero E., Hamilton B., Jiménez N., Groby J-P., Dance S., Romero-García V. Simulating Acoustic Subwavelength Metamaterials in Large 3D Finite-Difference Time-Domain Volumes Using Impedance Filtering, Applied Science, 11, 8084, 2021, doi: 10.3390/app11178084