Description and Evaluation of a Hearing Conservation Program in Use in a Professional Symphony Orchestra

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ABSTRACT
Professional orchestral musicians risk permanent hearing loss while playing their instruments. Protecting the hearing of these musicians in the workplace is critical to their ongoing ability to play their instruments, but typical workplace hearing conservation measures can have very damaging effects on the product (music) and the musicians’ abilities to hear one another sufficiently. To enable effective intervention, orchestras as employers must encourage engagement with hearing protection programs and implement controls while preserving the integrity of the music. To achieve this, typical approaches used in other industries must be redesigned to suit this unique workplace. In response to these challenges, the Queensland Symphony Orchestra (Brisbane, Australia) introduced a comprehensive hearing conservation strategy in 2005 based upon best practice at the time. This strategy—which has been regularly refined—continues to be implemented on a daily basis. This investigation aimed to assess the successes, difficulties, and practical viability of the program. To achieve this a process evaluation was carried out, incorporating archival analyses, player and management focus groups, and an interview with the program’s administrator. Results show the program has successfully become integrated into the orchestra’s and the musicians’ daily operations and significantly contributes to managing the risk of hearing loss in this population. While there is room for improvement in the orchestra’s approach—particularly regarding usable personal protective devices and improved education and training, results are encouraging. This study provides a basis for those wishing to implement or evaluate similar paradigms.

KEYWORDS: hearing; damage; musicians; music; orchestra; sound; exposure

INTRODUCTION
It is well established that professional orchestras can create sound levels at durations sufficient to risk damage to the hearing of their musicians. The impact this exposure has upon the hearing health of orchestral musicians after years in the industry has also been well documented, with research indicating increased incidence of hearing damage due to excessive sound exposure in this population. Although music (generally considered desirable sound) is clearly not ‘noise’ (usually undesirable sound), the risk of damage to the auditory system from exposure to music is considered the same as this risk due to exposure to noise. As such the resulting damage—whether from noise, music or
other sound source—is usually referred to using the term ‘noise-induced hearing loss’ (NIHL), and this term is used throughout the manuscript.

In Australia, which has workplace health and safety (WH&S) legislation regarding sound exposure similar to that seen elsewhere in the world (Safe Work Australia, 2011), managing the risk of NIHL is usually carried out according to a program incorporating a series of control measures delivered in a specific hierarchical order.

In an orchestra, which is subject to this legislation, using primary control measures such as the isolation or removal of the louder instruments cannot be achieved without very damaging effects on the very art the musicians are creating. Further to this, the remaining engineered, administrative, and personal controls such as orchestra layout, rostering according to exposure, or the use of earplugs are all capable of significantly interfering with the musicians’ abilities to carry out their job effectively. Such challenges require a carefully balanced approach to hearing conservation that preserves the sound and excitement of the orchestra without interfering with the musicians’ abilities to perform to a professional standard.

Published studies such as those by Schmidt et al. (2011) and O’Brien et al. (2008) which illustrate orchestral musicians are routinely exposed to potentially hazardous sound exposure in the orchestra are relatively abundant. While some researchers such as Kähäri et al. (2001) and Obeling and Poulsen (1999) have previously failed to find evidence of hearing loss among working musicians, there are many more investigations that do show increased incidence of NIHL in this population. Notably, Royster et al. (1991) found widespread evidence of NIHL in the Chicago Symphony Orchestra, while most recently Schink et al. (2014) found that orchestral musicians were four times more likely than the general population to suffer a hearing injury. Researchers such as Jansen et al. (2009) and Pawlaczyk-Łuszczyńska et al. (2009) have also observed high rates of associated noise-related pathologies such as tinnitus and hyperacusis among orchestral musicians. Concurrently, there have been several investigations into the effectiveness of exposure control measures such as acoustic screens studies by Williams and Stewart (2011) and Libera and Mace (2010) as well as the uptake and efficacy of musicians’ earplugs (Laitinen, 2005; Zander et al., 2008) although there is very little information regarding the implementation and design of hearing conservation programs for professional orchestras in the literature.

One exception to this is seen in the UK. Commissioned by The Association of British Orchestras (ABO), Wright-Reid (1999) developed an exposure management report suggesting a strategic approach to hearing conservation. This included recommendations to form a group within all orchestras made up of players, management and artistic staff tasked with overseeing, implementing, and managing exposure control on an ongoing basis. A follow-up report (Wright-Reid and Holland, 2008) also contained educational material for players and managers, a noise monitoring methodology and suggestions for more effective education and audiometric assessment. This document included a case study of orchestras who had been attempting to implement these recommendations and concluded that despite significant progress, the industry was yet to achieve effective implementation of the suggested strategies. Subsequently, the British Broadcasting Commission (BBC) produced a similar guide directed at both players and management staff (Hansford, 2011). This document recommends a range of control measures aimed at incrementally reducing exposure over time and relies heavily upon behavioral change from the musicians—such as not playing loudly during orchestral breaks—encouraged through ongoing educational programs.

As part of a 5-year occupational health study into Australian orchestras, the current authors found a range of approaches and attitudes to hearing loss prevention within Australia’s orchestras (O’Brien et al., 2012, 2014). One orchestra in particular—the Queensland Symphony Orchestra (QSO)—was maintaining a long-running strategy incorporating elements of the ABO’s 1999 report. It was found musicians in this ensemble were more likely to be aware of noise hazards and were significantly more likely to take preventive action—such as using earplugs—than musicians in other orchestras, both in Australia and when compared internationally.

The QSO’s original hearing conservation strategy was developed following preliminary sound level surveys in 2003, prior to which the orchestra had only limited articulated strategies or policies regarding hearing
conservation. Following a formative evaluation process incorporating industry experience as well as literature and product reviews, a strategy was devised in consultation with players and staff which aimed to achieve reasonable compliance with legislation and manage the risk of NIHL developing in the musicians.

This strategy incorporated an ongoing exposure assessment program, a range of control measures, education programs, and annual audiological management, with all elements of the strategy managed by a central committee. The key elements of this strategy were as follows:

1. Maintain an ongoing noise exposure monitoring program
2. Regularly review data and plot accurate noise maps for each key venue
3. Supply of the highest quality hearing protection devices (earplugs), designed for use by musicians
4. Continuous investigation and refinement of engineered controls, including orchestral the set-up/layout of the orchestra, use of risers and use of acoustic screens of various types
5. Formation of a noise committee
6. Rostering and seat rotation according to exposure where feasible, and other administrative controls
7. Ongoing evaluation of the artistic impact of controls through involvement of musicians and representatives of the orchestra’s artistic department on the noise committee
8. Maintain an up-to-date hearing evaluation program
9. Develop an ongoing education package for the musicians (including casuals) and management
10. Ongoing research into available technological solutions.

Upon launching the strategy in 2005 a 3-year longitudinal evaluation of orchestral sound exposure on a seat-by-seat basis was carried out (O’Brien et al., 2008). At the time of this inquiry, the program had been operational for over 9 years and had evolved to its current iteration through multiple revisions.

As there is currently no literature reporting on the practicalities surrounding the ongoing management of orchestral hearing conservation strategies and little is known regarding the engagement of musicians and other orchestral staff with such strategies, the current investigation was devised to evaluate an existing orchestral hearing conservation program in order to provide a foundation for those wishing to implement or design similar strategies. The lead author of this investigation—a musician with the QSO and a practicing audiologist—devised the strategy and assists in its delivery and development.

METHODS
The QSO is a professional Australian ensemble that carries out playing activities year-round in various venues, from symphonic concerts on the concert hall platform to opera and ballet seasons in the orchestra pit. There are 88 musicians employed full-time, supported by a team of over 20 ancillary managers and operational staff. The QSO’s hearing conservation program (referred to as ‘the program’) is considered by many in the industry to be one of the most comprehensive in Australia.

This investigation took place over a 4-week period from March to April, 2014. It adopted established process-evaluation techniques as a method for evaluating the hearing conservation program as described by Dehar et al. (1993) and subsequently by Saunders (2005), with specific questions and associated methodologies detailed in Table 1. These questions will be addressed in the Discussion, with gathered data presented in the Results section of this article.

Data gathering took place in two stages. Stage 1 (Program description and delivery) was intended to describe the program’s structure, implementation, components, and delivery systems (Table 2, column 1). These records were gathered from QSO’s archives and collated chronologically. A themes-based analysis was undertaken on the committee minutes and a comparative analysis undertaken on the strategy revisions.

Stage 2 (Program Delivery) aimed to explore issues surrounding the program’s delivery, contextual factors relating to its implementation, perceptions of the program’s participants, and engagement by musicians and staff (Table 2, column 2).

The interview and focus group data was also subjected to a themes-based analysis and subsequently...
analyzed using data triangulation methods as described by Guion et al. (2011) to validate the findings and draw out the common themes between the three transcripts.

The hearing conservation management committee focus group consisted of five of the regular committee members, while the players’ focus group was made up of four musicians selected using a separate random draw for each instrument section (strings, brass, woodwind, and percussion). Players who were new to the orchestra (employed within the last 3 years) were excluded from the random draw group in order to allow historical context to be explored.

Generic data on earplug usage and type was gathered from the orchestra’s latest report as supplied by QSO’s audiological consultant, who requests this information from each player as part of their compulsory annual audiological assessment.

In an effort to avoid bias, all interviews were conducted and facilitated through a neutral mediator—an experienced audiologist familiar with hearing conservation strategies. The interviewer used open-ended questions centered loosely on the process evaluation questions. The authors were not present during the interview or focus groups, with responses and discussions recorded, and subsequently transcribed for later

Table 1. Process evaluation questions and methodology

<table>
<thead>
<tr>
<th>Process evaluation questions</th>
<th>Methodology</th>
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<tbody>
<tr>
<td>How is the program implemented?</td>
<td>Interview program coordinator; observation; noise policy and procedure</td>
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<td>Is the program delivered as planned regularly and time appropriately?</td>
<td>Review minutes from hearing conservation management committee meetings; interview Program Coordinator and committee members</td>
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<tr>
<td>What changes have been made to the program and what is the rationale behind these changes?</td>
<td>Compare current program with initial program; interview Program Coordinator; review minutes from hearing conservation management committee meetings</td>
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<tr>
<td>Is the program evolving appropriately over time?</td>
<td>Compare current program with initial program; interview Program Coordinator; focus groups.</td>
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<tr>
<td>How is the program received by musicians and operational staff?</td>
<td>Focus groups; hearing conservation management committee minutes; assess hearing protector usage — frequency and type</td>
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<td>What are the barriers/facilitators to the delivery of the program?</td>
<td>All sources</td>
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Table 2. Data gathering methods

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<tr>
<th>Data gathering stage 1: program description and delivery</th>
<th>Data gathering stage 2: program reception</th>
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<td>1. Analysis of QSO policy documents and archival records surrounding program design and development</td>
<td>1. Interview with the Program Coordinator</td>
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<td>2. Comparison of the original strategy and five subsequent strategy revisions</td>
<td>2. Focus group with members of the hearing conservation management committee</td>
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<td>3. Themes-based analysis of 23 records of minutes of hearing conservation management committee meetings since program inception</td>
<td>3. Focus group made up of randomly selected musicians in the orchestra representing each instrumental section</td>
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<td>4. Review of generic data on hearing protector usage and type as reported at latest review</td>
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Two investigators undertook independent analyses of the interview data, with results compared for inconsistencies. Gathered data was imported into NVivo 10 Research software (QSR International, Burlington MA) for analysis and triangulation.

This investigation was granted ethical approval by the University of Sydney's Human Research Ethics Committee (#2013/1007).

RESULTS

Stage 1: program description and delivery

Figure 1 details the current elements and structure of the QSO's hearing conservation program. It is delivered via the hearing conservation management committee working with staff in each of the committee members’ areas of the organization. This committee meets quarterly (more frequently if required) and consists of the WH&S Coordinator (also the Program Coordinator), the Director of Orchestra Management, the Production Manager, two musicians, and the orchestra’s Artistic Coordinator. The Program Coordinator is responsible for general oversight of the strategy, organization of audiological testing, management of the noise monitoring program and the budget as well as liaison with musicians, operational, and administrative staff. These duties are but one part of this employee’s wider duties as a fully trained WH&S Coordinator. This individual was initially a musician with QSO and moved to their current role in 2007.

Exposure monitoring is undertaken using personal noise dosimeters either worn by the musicians or positioned on stands at the ear of the musicians, providing individual exposure data. The dosimeters are set up and their data collected by trained operational staff, with results transferred to a database for analysis and
archiving. Audiological assessment occurs annually, with testing mandatory for the musicians.

Awareness of risk is reinforced weekly to orchestra members through the roster, with annual education sessions given by a specialist consultant. In addition, activities such as annual audiological screening and the presence of ongoing sound level monitoring serve to reinforce awareness. Education also extends beyond the orchestra to visiting artists and hiring companies through liaison and dialogue with conductors, hiring companies and artistic staff, particularly for performances and seasons in the orchestra pit.

While exposure controls are devised, planned, and assessed by the committee, delivery occurs on several levels. Engineered controls are delivered by orchestral operations (orchestral setup, acoustic screens, and acoustic treatments); administrative controls (rostering, scheduling, and seat rotation) are overseen by orchestra management; while the use, maintenance and provision of personal controls (musicians’ earplugs) is managed by the Program Coordinator. All musicians are provided with custom moulded musicians’ earplugs, level-dependent electronic musicians’ earplugs (with custom fitting if required), or generic fitting musicians’ earplugs. Usage of these devices and the devices themselves are checked annually during audiological assessment and remade if necessary.

Analysis of strategy iterations
Examination of the almost annual revisions of the strategy showed that the basic 10-point strategy had been maintained, although it had progressed from a ‘stand-alone’ strategy to be housed within a broader Policy document in 2007. This Policy document more directly references Australia’s WH&S (Noise) Code of Practice (Safe Work Australia, 2011) and details how the embedded strategy facilitates QSO’s compliance with relevant legislation.

There have been two significant alterations to the strategy itself during its operation. The first of these aimed to reduce the obligation to carry out sound level monitoring from ‘every performance and rehearsal’ to ‘selected performances and rehearsals’. This change occurred in 2008 following the establishment of QSO’s sound level database, which in 2007 held in excess of 1800 full rehearsal and performance records from across the orchestra and was significantly larger at the time of this investigation.

The second development occurred in the area of education and training and involved the introduction of a program-by-program communication via the orchestra’s printed roster (Fig. 2). Each upcoming program is assigned a ‘Noise Risk Level’ on a scale of one (least risk) to three (highest risk) based upon the orchestra’s existing noise exposure database. The roster is accompanied by a graphical chart of exposure risk by position which details both advised and required actions by the musicians specific to each individual’s position within the orchestra. Such actions include the use of earplugs and personal acoustic screens.

Analysis of committee meeting minutes
Analysis of the collected minutes revealed the following broad themes:

- Controls—administrative and engineered
- Education and training
- Monitoring
- Program administration

Table 3 (column 2) details the incidence of these themes as areas of discussion during these meetings. The Committee records show attention to all areas of the strategy, but particularly to its practical implementation. Topics of high incidence include planning of administrative controls, determination of orchestra set-up, acoustic screens to be deployed, sound level monitoring, and education and training—discussed at nearly all meetings.

Stage 2: program reception
The interview and focus groups consisted of wide-ranging discussions, with themes revealed that were very similar to those observed in analysis of the minutes of the hearing conservation management committee meetings. Each, however, gave weight to different elements of the strategy. The incidence of these themes and subthemes is detailed in Table 3.

Program coordinator interview
The Program Coordinator interview reflects upon this employee’s primary areas of responsibility outlined above, with the most frequent themes emerging being both human and financial resources and the limiting nature of finite resources on elements

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of the program, particularly the noise monitoring program (Table 3, column 3). Another major theme of this interview was in the area of organizational engagement, namely the coordinator’s negotiations with the orchestra’s upper management and directors. Exploration of these themes demonstrated engagement and commitment from the executive towards the ongoing conservation of the musicians’ hearing while highlighting concerns at the highest levels of the organization that the program facilitated compliance with legal obligations. Themes that were absent from the Program Coordinator interview were administrative controls, orchestra set-up, and hearing tests.

Hearing conservation management committee focus group

The most prevalent themes within this focus group were in the areas of education and awareness and organizational engagement (Table 3, column 4). The discussion surrounding education was often directed towards the need for improved flow of information to the musicians regarding the implementation of control measures. However, discussions also highlighted the belief that there was much greater awareness amongst the players since the commencement of the program. Several committee members stated they believed a level of ‘cultural change’ may have occurred amongst sections of the orchestra regarding hearing conservation. Similar to the analysis of the committee meeting minutes, all areas of the program were considered at this focus group.

Musicians’ focus group

A great deal of discussion during the musicians’ focus group centered upon difficulties playing while using earplugs and the prevalence of earplug use (Table 3, column 5). This was often discussed in conjunction with topics surrounding education and awareness of the members of the orchestra and visiting conductors. Discussed in detail were: increased awareness arising from the sound level monitoring program; information delivery via the weekly and annual roster; and annual hearing tests and earplug verification by the audiologist. It seemed clear to the musicians that there were multiple aspects to the hearing
conservation program and that a lack of resources restricted greater control measures, particularly regarding administrative controls such as personnel rostering according to exposure levels. One area not mentioned at all by the musicians was the structure of the noise committee.

**Common themes**
Themes which were shared between the three transcripts were resourcing, education and awareness, and organizational engagement. These themes were explored in similar ways by the three groups, with resourcing highlighted as being a limiting factor to greater effectiveness of the program; education and awareness identified by all groups as being fundamental to the program’s acceptance and engagement by management and musicians; and organizational engagement being mentioned as critical to the initial implementation and ongoing maintenance of the program.

**Hearing protector use in the orchestra**
Use of any style of hearing protector by QSO musicians as reported at their most recent annual audiological assessment is shown in Fig. 3. The predominant earplug type used were custom-molded musicians earplugs (67%), with fifteen percent using newly developed electronic musicians’ earplugs.

**DISCUSSION**
In order to describe and assess an orchestral hearing conservation strategy, a process evaluation was carried out on a strategy that has been in use at a symphony orchestra in excess of 9 years. Investigations involved archival analyses, interviews, and focus groups. The discussion will address questions posed at the commencement of the investigation.
How is the program implemented?
The program is principally implemented through the committee led by the Program Coordinator. The make-up of the committee aims to promote awareness of the strategy throughout the organization and ensure its practical and efficient delivery, as initially suggested by Wright-Reid (1999). Problems or potential problems arising from the implementation of elements of the strategy (whether artistic, practical, legal, or otherwise) are assessed and considered by the committee with direct input from the relevant area of the organization.

Is the program delivered as planned, regularly and time appropriately?
The program appears to be mostly delivered as planned, with some restriction of planned activities such as noise monitoring and greater administrative controls evident due to limited resources. According to the Program Coordinator, monitoring does not always occur when required due to staffing resources and pressures from other activities. There has also been difficulty scheduling annual group education sessions as planned due to limited company meeting time, and this is seen as a significant problem within the program.

Administration and practical delivery of the program appears to be regular, with meetings of the committee usually occurring quarterly and the Program Coordinator also administering practical elements of the program in an ongoing fashion.

Exposure controls—which vary from program to program—appear to have become part of standard procedure for the orchestra unless the committee recommends a change.

What changes have been made to the program and what is the rationale behind these changes?
Changes to the program have been limited. Sound level monitoring has become less frequent since the establishing a database that provides historical data relevant to many upcoming programs. Exposure monitoring is now largely used to assess the impact of significant changes to orchestral set-up, unknown repertoire or to spot-check selected points which may have been reported as problematic by musicians or staff. The introduction of written warnings and an information system has enabled the effective communication of risk. Additionally, the external provider of audiological services has changed several times for a variety of reasons, although longitudinal files for the musicians are maintained.

Engineered controls constantly change according to level of risk, repertoire, and venue. Occasionally newly designed controls such as acoustic screens are trialed and specific control measures are constantly evolving based upon monitoring results and recent developments in the field. The program has seen the adoption and increased use of wrap-around absorptive screens [as described by Williams and Stewart (2011)] some sectional screens in the orchestra pit and the development of a series of moveable diffusive panels for treating poor acoustic spaces if necessary.

If appropriate, new technology is introduced as and when it becomes available, with electronic earplugs now being used by many in the brass and woodwind sections, however frequency of use remains an issue with the players due to practical difficulties with earplugs (discussed below).

The housing of the hearing conservation management committee—whether as a subset of the broader WH&S committee or as its own entity—has also changed several times over the life of the strategy, mostly due to logistical issues surrounding availability of staff. At the time of this investigation the committee
met immediately prior to the broader WH&S committee, with overlapping issues discussed at a joint sitting of these committees.

How is the program received by musicians and operational staff?
The program appears to be very well received by both musicians and ancillary staff, and there appears to have been a shift in attitudes towards hearing conservation issues. This is summarized by a comment from one of the musicians on the hearing conservation management committee: ‘...even when there are issues of noise the anger isn’t there as much in the orchestra as it used to be because the orchestra know now that management care... But there’s not this underlying thing, oh here we go, I’m sick and tired of this, and this used to be very strong in the orchestra... a lot of that underlying anger has gone.’

This sentiment was echoed in the musicians’ focus group, as was evidence of a change in behavior and awareness: ‘...we just used to merely put up with noise and not try and avoid it because it was part of the job so it’s been great in the awareness stakes and, particularly good in making us feel comfortable to take the protection and use it...’

All musicians in the focus groups highlighted the difficulties surrounding the use of earplugs, whether custom-molded musicians’ earplugs, electronic musicians earplugs, or both. Some players were able to use these plugs most of the time, as one trombonist stated: ‘...I could just never take them out, I mean, solos that’s it, that’s the only time they come out.’ However, the musician tempered this statement with an acknowledgment that wearing earplugs impacted upon his playing abilities. Other players had tried several times and failed to adapt to earplug use such as this bassoon player: ‘I just find it so uncomfortable to wear earplugs that I very rarely do...’ or felt the artistic compromise was simply too great: ‘I just lose too much contact with the front of the orchestra because I’m at the back... I really have to keep that connection visually and through hearing what’s happening at the front so I can play my part effectively and still do the job that I need to do in that position.’

The variety of views expressed by the players highlighted a strong awareness that earplugs were ultimately necessary at least some of the time together with a frustration that they made it difficult to play with them in. The musicians also appeared to have a natural understanding of the place of earplugs in the range of control measures: ‘You can’t really play properly with [the plugs in] so the other things are in reality probably more important.’

Earplug use at QSO and the use of appropriate styles of attenuators is significantly higher than that seen in other Australian orchestras as reported by O’Brien et al. (2014) and also as reported in orchestras in other countries where up to 70% have been reported to seldom or never use hearing protection while playing in the orchestra (Laitinen and Poulsen, 2008). The high profile of hearing conservation measures and regular education sessions—including with annual contact with an audiologist—is clearly contributing to this positive outcome at QSO.

What are barriers/facilitators to the delivery of the program?
While the work of interested and well-informed staff members clearly facilitates the delivery of this program, there are two key barriers to its successful delivery. Firstly, finite human and financial resources will continue to be a critical issue as the traditional struggle for resources in the Arts sector continue and competing concerns prevent orchestra management from devoting more resources to the issue.

The second barrier is technological. In spite of a shift in the attitudes and the actions of the QSO musicians there still appears to be no broadly accepted personal protective device available for use at this level. This leaves orchestras who are confronting the issue of mandating the use of personal hearing protection unable to supply a device that will not cause unacceptable compromises in playing ability. This is an ongoing problem awaiting a solution and will be the focus of future research by the authors.

CONCLUSIONS
This investigation has shown that, although there are practical and resource-based problems to be overcome and further improvements in education and training are possible, the strategy in place at QSO is both functional and effective at protecting the hearing of these musicians. With awareness of risk and the use of earplugs much more prevalent in this orchestra than that reported in similar ensembles, it is clear that QSO’s
hearing conservation program is largely responsible for this.

This investigation was limited by several factors. Due to the nature of the investigation only a small number of musicians were interviewed as part of the focus group, with results relying upon reports from this group combined with historical data. As such there may be other factors or variables that were not accounted for in assessing the engagement of the musicians with the program described, such as age, gender, and instrument type, although this has been discussed more fully in previous investigations by the authors (O’Brien et al., 2014). In addition, as only one orchestra has been investigated, further research is required to confirm the effectiveness of the program described here when transferred to other orchestras, however it is believed the strategy in place at QSO is broadly applicable to similar ensembles.

The problem of hearing conservation for orchestral musicians will be present as long as orchestras continue in their current form. A strategy such as the one described here should be considered as part of standard operating procedure for all full-time professional ensembles.

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**REFERENCES**


