Orchestral Sound Levels

and what can be done when it all gets too much

A Guide for Amateur Orchestra Players and Organisers

Martin Brown, clarinet with the Ku-ring-gai Philharmonic Orchestra, October, 2012

Overture

We all accept that if we want to be part of a full symphony orchestra, it's occasionally going to get LOUD. Bruckner pales into insignificance next to Hekla by Jon Leifs depicting the eruption of an Icelandic volcano which calls for 140 musicians including 19 percussionists and organ as well as a chorus, 1/2 ton bells, sirens, "musical rocks" being belted by hammers, cannons, and more.

After many, many rehearsals and concerts struggling to play as well as I can with earplugs in, I decided to do an investigation into orchestral sound levels and how other players and orchestras have dealt with it. This article is the result.

Disclaimer

Our orchestra has trumpets, trombones, piccolos, and a plethora of percussion instruments. This article is not an attack on those instruments and players, they are all vital components of any symphonic orchestra. Experiencing the “wall of sound” that the brass and percussion can produce in The Pines of Rome is something not to be missed.

I want to be constructive here so that everyone enjoys the experience of playing orchestral music more. The percussionist shouldn’t have to be worried that the third trumpet is getting an ear bashing from the bass drum or glockenspiel, and the back desk violins shouldn’t duck for cover whenever the piccolo player reaches for her instrument. Addressing people's concerns about volume levels can improve their enjoyment as well as removing ill-feelings between various players and sections of the orchestra. It can also help to protect their hearing.

I would also point out that I am not a trained acoustic engineer although this article is compiled from a range of sources written by such specialists.

Is There Really a Problem?

If a whole group of orchestral players are frequently unhappy about the sound being so loud that they can’t hear their own instrument or are prepared to put up with the soul destroying effects that ear plugs have on their playing, yes, there is definitely a problem. And it’s a problem that can be addressed. People should not be left with the view that that’s how it always has been and always will be, so don’t complain, pull your head in and put up with it.

In amateur orchestras, the enjoyment of playing is usually the primary reason for turning up every
week. Professional orchestras have to be conscious of the possibility of being sued if they don’t address excessive sound volumes that can permanently damage players’ hearing, but that’s not the topic of my article here. Generally speaking, amateur players are exposed to far fewer occurrences of high volume sound than professional players and there are no studies showing that amateur orchestral musicians have experienced hearing loss as a result of their pastime.

It is generally accepted that hearing loss is related to the actual sound level as well as to the period of time that the sound persists. A trumpet teacher sitting in a practice room with ten students passing through in a day is at risk of having hearing problems as a result of their work. Someone who has to put up with ten minutes of Star Wars in their ears each week for six weeks, not so much.

Many studies have been published on the risks of hearing loss in professional orchestral and rock musicians. Surprisingly, orchestral musicians seem to be more affected by hearing loss than rock musicians. I suggest that this could be because of the consistently high sound levels produced by rock music and the high level of awareness of the risk to hearing inherent in this kind of music. One of the main problems that orchestral musicians have with using hearing protection is the sporadic nature of the high volume levels.

All players of louder instruments should be made aware of the effects their playing can have on their own and other’s hearing from a very early stage. A young trumpet player can easily damage a mate’s hearing for life by blasting a high note at them from half a metre away as a prank.

The Raw Data

Perceived Sound Level

Sound volume or level is described in a number of different ways. The main one is decibels (dB). A decibel is a ratio of one measurement to a base measurement, modified so that higher ratios are reduced to give a more human friendly scale. In the case of sound, the following table is usually used as an example of decibel ratings:

<table>
<thead>
<tr>
<th>Example</th>
<th>Decibels (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Near total silence</td>
<td>0</td>
</tr>
<tr>
<td>A whisper</td>
<td>15</td>
</tr>
<tr>
<td>Normal conversation</td>
<td>60</td>
</tr>
<tr>
<td>A lawnmower</td>
<td>90</td>
</tr>
<tr>
<td>A car horn</td>
<td>110</td>
</tr>
<tr>
<td>A rock concert or jet engine</td>
<td>120</td>
</tr>
<tr>
<td>A gunshot or firecracker</td>
<td>140</td>
</tr>
</tbody>
</table>

A trumpet at 0.5m can produce a sound level of 130dB and a trombone up to 135db on some notes. Doubling the power of the sound adds 3dB to the decibel value - so a trombone can produce more than twice the sound power of a trumpet.

But this is only part of the picture. Human hearing is limited to a particular range of frequencies and we experience sound volumes differently to decibels. For this reason, sound volumes are usually represented as dB(A), weighted according to perceived loudness, not level.

Australian Standards

The Safe Work Australia Code of Practice for noise in the workplace[^9] specifies the following sound levels and exposure periods as being acceptable before sound protection is required:
Sound Frequencies

A new-born can generally hear sounds in the range 20Hz (E four octaves below middle C) to 20kHz (D# 10 octaves above middle C) but as we age, our high frequency limit reduces down to about 15kHz and we become far less sensitive to the higher frequency sounds. (Some societies of native Africans living in a natural environment all their lives, however seem to maintain their superb “20/20” hearing right through old age, so perhaps our loss of hearing with age is more related to our environment than age itself.)

The Effect of Distance

A natural reaction to hearing a loud sound is to move away from the source. This reaction actually has a very significant effect on reducing the impact of a loud sound. By doubling the distance from a sound source, you divide the sound intensity by 4. Humans perceive sound levels differently though (represented as $db(A)$) and to achieve a halving of the perceived sound level, the distance from the source has to increase by a factor of about 3 depending on the pitch of the sound.

![The effect of distance on reduced sound level](image)

Directional Effects

As the pitch produced by an instrument increases, the directionality of the sound increases. So the decrease in volume by moving away from the axis of the instrument is more noticeable at higher frequencies. The pictures below illustrate this.
Adding More Players

If you have two piccolos behind you instead of one, when they’re both playing, the sound intensity doubles as you would expect. That doesn’t exactly mean that the perceived sound level is double though - it will be a bit less than that. And if the piccolos are not both aiming directly at you then the off-axis effects will further reduce the perceived increase in sound level.

Supersonic Shock Waves

Believe it or not, trumpets and trombones can actually produce supersonic shock waves⁴. Here’s a picture of one being produced from a trumpet playing a fortissimo high G at 106 dB(A). The shock wave (the dark semi-circular line in front of the bell) disappears at distances beyond about 1m. (You can’t normally see a shock wave. Special techniques were used to show it in this photograph.)

Are Younger Players More Susceptible to Higher Sound Levels?

As you can imagine, performing experiments on this topic is quite difficult, but studies into rats and cats⁵,⁶ have shown that younger animals are more susceptible to hearing damage and that exposure to high sound levels when young can exacerbate hearing loss later in life.

The picture here shows an Australian youth orchestra with cymbals almost surrounding a trumpeter’s ears and the flutes less than a metre from the bell of some other trumpets and trombones.
What Can We Do About It?

Personal Sounds Shells

One of the most common types of person hearing protection devices are perspex head shields and perspex wall-like barriers. Numerous studies into these have been undertaken and the results generally show that they have little benefit overall, and can actually increase sound levels for the players being “protected” by reflecting sound from the front into the player’s ears. They especially increase sound levels for the players next to the shells and for the players facing the back of the shells.

An alternative to perspex shells has been developed by the Symphony Services International in collaboration with the Australian National Acoustic Laboratories. These are a similar shape to the perspex shells but are constructed of sound absorbing material. Sound reductions of between 7 and 8 dB have been measured in the normal use position\(^1\).

Using a sound barrier that absorbs sound usually implies that they absorb light and this is not going to be well received unless they can be placed strategically so as not to block the audience’s, players’, or conductor’s views.

The London Symphony Orchestra, West Australian Symphony Orchestra, SYO and AYO are among orchestras using these shields, available as the Goodear Acoustic Shield for around $300 each including the stand.
Earplugs

Another solution is for players in loud locations to use earplugs. While these may be suitable in some situations for some instruments, there are a few drawbacks:

1. They affect the sound that the player experiences from their own playing. Even $300 a pair, custom made musicians earplugs result in a clarinet sounding more like a kazoo to the player because of the direct transfer of the instrument vibrations to the ear via the upper jaw.

2. They can shift the instrument’s pitch as perceived by the player by favouring various harmonics.

3. They distort balance levels so that the player really has no idea how loud they are with respect to their colleagues.

4. Inserting them takes time. You need several bars rest in order to properly fit them in place.

These effects are recognised in several professional orchestra agreements. For example, from the Adelaide Symphony Orchestra agreement: 

“...it is recognised that the wearing of such devices [earplugs] may compromise the player’s best performance standard. It is also recognised that hearing protectors make playing in tune and with correct attention to balance more difficult...”

Custom made earplugs usually come with a few swappable attenuators 9 or 10dB, 15dB, and 25dB. I’ve found that 10dB is adequate for orchestral playing.

If you don’t want to shell out the $300 or so for custom earplugs, there are cheaper alternatives but these usually have an attenuation of around 30dB which is more than necessary and cut out far more high frequency sound than low frequency.

Quieter Pieces

Well, we can all choose to play chamber music if we want, but we’ve chosen to be part of symphony orchestra.
Quieter Playing

Most instruments these days are able to play significantly louder than their Classical period equivalents. So it is actually reasonable to ask the timpani player to use different sticks or the trombones to turn it down a bit from the ff marked by Beethoven or Mozart in order to get a more period-sensitive performance. But then, if the composer wanted it loud, and your orchestra has six desks of first violins, why not play an actual ff?

Player Positioning

A trombone at full tilt can produce a sound level of 113dB at a metre from the bell. If the bassoons are seated immediately in front of the trombones (as they often are), then this is at best uncomfortable and at worst, potentially damaging for any significant period. But by increasing the distance between the bassoons and the trombones from 1m to 3m, the sound level drops by 10dB - about the same effect as a set of musician’s earplugs.

The picture below is of the Sydney Symphony in the Opera House concert hall. You can see the extra separation between the brass and the winds. The brass are about 10m from the front of the orchestra with a gap of around 3m to the rear winds. The SSO also uses perspex sound shells to further reduce the effect of the brass on the rear wind players.

One problem with increasing these distances is that it will cause small delays in the overall orchestral sound arriving at the rear players and extra delays for their sound to reach the front of the stage. In fact, increasing the distance from the conductor to the brass, even by 5 metres, will not result in players, conductors, or audience being aware of any extra delay in the sound.

To put some figures on this, when playing a passage at 120 beats per minute, increasing a player’s distance from the front of the orchestra by 5 metres will delay the sound that gets to them (and from the player back to the conductor) by a quarter of a hemi-demi-semi-quaver (15 milliseconds). This is a minuscule, insignificant delay compared to the delays involved in physical reflexes and sound production. Studies have shown that a sound delay of at least 50ms is required before it is detectable by humans.

Most professional orchestras have brass and percussion players significantly further back than in amateur orchestras so it could be said that increasing this distance for amateur groups is good training for budding professional players.

Another aspect of player positioning is their vertical position. Often, the belief is that lifting the brass onto risers above the winds reduces the effect on the winds. The problem here is two-fold:
1. Trumpet and trombone players typically hold their instrument angled down at around 10-30 degrees. So raising the players may actually result in the heads of the winds being directly in the “firing line”.

2. Trumpets and trombones are more directional at their higher frequencies but even at four octaves above middle C, you would still need to be more than 15 degrees off axis to achieve any significant reduction in sound.

Less Reverberant Venues

A lot of the sound volume we hear is made up of reflections from the walls of the venue. When playing outdoors, the sound is obviously much quieter but there are the negative effects of losing touch with the rest of the orchestra. Each situation needs to be considered separately; whether adding more sound absorbing material is justified by the reduction in feedback to the players from the other areas of the orchestra or not.

Finale

So the main points are:

1. Being close to loud instruments has the potential to damage your hearing and continuous exposure can exceed the levels recommended by Australian and other health and safety organisations.

2. If possible, make sure there is adequate distance between loud instruments and players in front of them.

3. Tests show that Goodear Acoustic Shields are preferable to perspex shells.

4. If all else fails, invest in some custom made earplugs.

References


