STUDY OF DAILY NOISE EXPOSURE TO AVOID HEARING LOSS IN MUSICIANS

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To my parents and my sister

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ABSTRACT

Excessive noise exposure damages hearing and affects directly to quality of life, but it is something that people usually don't take too much into account. Sometimes this noise is too high and short and you can't avoid it, but other times, this noise is softer (but dangerous too) and people assume that exposure without knowing that it will damage their hearing system and produce noise-induced hearing loss (NIHL). This second profile is much related with musicians hearing problems, because musicians are exposed in orchestras and other ensembles to excessive sound pressure level and their hearing is being damaged without their knowledge until they notice they listen much worse. In this project, 10 musicians have been measured while they were practicing and playing their instruments to analyse the noise levels each instrument produces. Some questionnaires have been filled for other musicians to analyse their daily activities and if those activities will aggravate their hearing loss risk. It has been computed that musicians are really in risk of NIHL and if they would like to avoid it without any protection, they should play very short periods of time every day (for example, violinists should be exposed only 72 minutes, saxophonists 30 minutes and flutists just 35 seconds).

RESUMEN

Una exposición excesiva a ruido es la principal causa de pérdida de audición y es algo que afecta directamente a la calidad de vida de las personas. Pese a ello, no es algo que la gente suela tener muy en cuenta. A veces, dicha exposición al ruido es muy alta pero durante un periodo corto de tiempo y es imposible evitarla, pero otras veces, el ruido es de una intensidad mucho menor (pero dañina igualmente) y la gente lo asume como algo normal sin saber que dañará su sistema de audición y que les producirá una pérdida de audición producida por el ruido (NIHL, noise-induced hearing loss). Este segundo perfil está muy relacionado con los problemas auditivos que padecen los músicos, pues están muy a menudo expuestos en orquestas y otros conjuntos instrumentales a altos niveles de presión sonora y su sistema auditivo se ve afectado sin que se den cuenta, hasta el punto que notan que ya oyen mucho peor. En este proyecto, diez músicos han sido medidos mientras tocaban sus instrumentos para analizar la cantidad de ruido que cada tipo de instrumento produce. Además, un seguido de cuestionarios han sido respondidos por una treintena de músicos con la finalidad de analizar sus actividades diarias y saber si dichas actividades agravarían el riesgo de sufrir pérdida auditiva. Se ha concluido con los resultados obtenidos que los músicos están muy en riesgo de sufrir pérdidas auditivas y que si quisieran evitar dicho riesgo sin el uso de protecciones, deberían practicar sus instrumentos y estar expuestos a sus actividades un periodo de tiempo diario muy corto (por ejemplo, los violinistas deberían estar expuestos alrededor de 72 minutos al día, los saxofonistas apenas 30 minutos y los flautistas simplemente 35 segundos al día).

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1 INTRODUCTION

1.1- Goal of the investigation

The main goal of this project is to study the hearing loss risk of musicians when they play and listen to music. For that, we propose indexes that allow musicians to estimate their hearing loss based on the noise level they are exposed. We also propose the inclusion of a variability index to estimate the reliability of the proposed exposure index, depending on many studied factors.

That index could be used to give information to the musicians about how many hours could he / she expend playing music alone or inside an ensemble. When you play alone, the sound impact you receive is your own music plus all the reverberations that the place where the musician is produces. When the musician plays with an orchestra there are a lot of other acoustic impacts that his/her ear receive: all the sounds produced by the other musicians plus all the reverberation they create. It's not the same to be a violinist or a flute or a bass (in terms of this exposure): The violins are surrounded by other violins, which is not a very noisy environment, while flutes are surrounded by lots of metal wind instruments which produces very high music levels.

If they have this tool, created from their own characteristics as musicians, they will be able to organize their classes without being exposed to too much loud levels for too much time that could produce a non-recoverable hearing loss (that is usually known as NIHL: noise-induced hearing loss).

To achieve this goal, some partial objectives are proposed:

- Verification of the measured levels summarized in the State of the Art
- Design of the factors that may influence/alter the overall dose (going to concerts, discotheques, mp3…)
- Propose the indexes (exposure and reliability). The design of it will be based on the basis proposed by Enrica D'Aulas PhD thesis [39], and taking account the generic profile of each kind of musicians.

1.2- Problem propose

The hypothesis of this thesis is that musicians are exposed to higher noise levels than the permitted noise levels on workers and they are really in danger of being in hearing loss risk. Musicians should know their daily noise exposure and avoid that risk, playing less time their instruments or using some ear protections.

1.3- Motivation on the investigation

Since I started playing violin when I was a kid, I realized that I liked to compare noise levels. Ten years later, I investigate that there were tools to set values to sound levels and I decided to do my high school research project on the topic of acoustics of concert rooms. In this master thesis I wanted to do something related with that (in terms of methodology and theory) but focusing in the musicians. I found very interesting to focus on hearing loss of musicians because lots of my musician friends recognize they suffer that but don't knew why. That's the reason I wanted to investigate and try to develop something that could be useful for them in order to warn them. The state of the art on this topic is not very large, but some interesting articles have been found to introduce ourselves on the topic and create a background for this thesis

2 STATE OF THE ART

2.1- Introduction

Excessive noise exposure damages hearing and it is something that people usually don't take into account at work. Sometimes this noise is too high and you won't bear it (for example, the noise produced by an airplane). But other times, this noise is softer and you will assume your exposure without taking account it will damage your hearing and produce noise-induced hearing loss (NIHL). This second profile is quite related with musicians, who usually are exposed in orchestras and other ensembles to excessive sound pressure level and their hearing is being damaged without their knowledge.

In table 1, it is seen typical sound pressure levels of life [1]. People are not usually exposed to all of them, only to low-moderate ones and at some times at the high ones. The sound pressure level is expressed in decibels, defined as: $20 \log_{10}(p_1 / p_0)$ where p_1 correspond to the sound pressure level of a given sound, and p_0 is a reference value of 20μPa (lowest hearing threshold of the young, healthy ear). In the logarithmic scale the range of human ear's audible sounds is from 0 dB SPL (hearing threshold) to 120-140 dB SPL (pain threshold) as we can see below. A 10 dB change is a ten-fold change. A 3 dB change is a doubling or halving. In some cases, the unit used to represent the amount of sound pressure level is dBA, a variation of the explained dB which takes account of the particular sensitivity of the human ear [1].

Source	SPL (dB)	Subjective valuation
Radio studio	20	
Bedroom at night	30	Low
Living room	40	
Office, classroom	50	
Speech range	50-70	Moderate
Inside a car	70	
City street	80	
Heavy truck	90	High
pneumatic hammer	100	
Building in construction	110	
Jet Engine (60 feet away)	120	Very High

Table 2.1: Typical sound pressure levels

Then, at work people are exposed to different noise sources. These sources are in a wide variety and produce different pressure levels. For example, noise produced in workplaces like industries are higher than in offices, and as we have seen in table 1, the noise produced in an office will not present a high risk of hearing loss but they also can produce bad effects like physiological alterations, distractions [2].

Human hearing doesn't responds with the same form for all audible frequencies. According with that, a frequency threshold can be established between speech and music (figure 1 from [1]). That is a clear way to visualize how musicians are also exposed to high sound levels which can produce different forms of hearing loss on their auditory system.

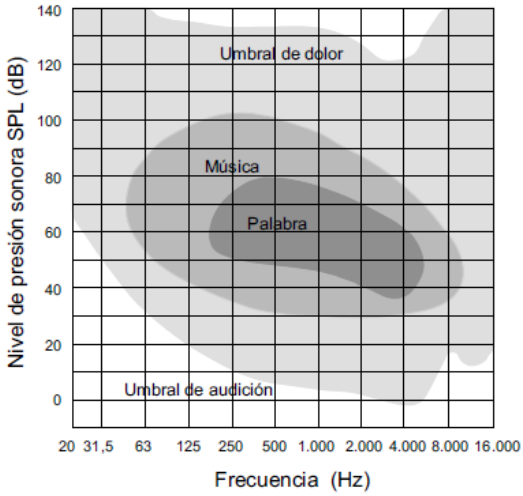

Figure 1: Differences on frequency and Sound pressure level on Music and Speech

2.2 Hearing Loss and Sound exposure of musicians

Criteria for the maximum amount of noise a worker can be exposed to noise without significantly increasing risk of hearing loss has been established, but sometimes differ from country to country. Generally it has been established that if a noise level is above 80 dBA, damage can occur (depending always on the duration of the exposure) and hearing loss can be produced [3][4]. That maximum of noise exposure is the mean of all 8-hours a worker is exposed to noise, not a peak value. The NIOSH criteria indicate that a Hearing Conservation Programme should be established which includes annual audiometric testing, education and training for employees in environments where they are exposed to 85 dBA or more over an 8-hour period [5]. In the case of a worker that is exposed a mean sound pressure level above 85 dB, he

should reduce the amount of minutes of exposure to that noise.

Musicians are exposed to music noise along the day. A part from the amount of hours of individual practice time and orchestral/ensemble rehearsals, they expend much time listening to music at home with loudspeakers, using personal music players with ear-speakers or listening live music in a concert or a disco. They are some examples of other measurable activities that must be taken account to measure hearing loss (see more in detail in chapter 1.5). The sum of all of those exposures has a repercussion in that music majors experience 12 dB more exposure on average compared to their non-music major peers [6]. There is not a central database with representative noise measurements for music, but from a range of measurements done in UK [7] many indicative player exposures are in table 2.

Indicative Player Exposures		
Leq	**Section**	**Piece**
75	Brass	Haydn
80	Conductor	Carmen; Elektra
80-90	Brass	Schnabel I
80-85	Strings	Mahler I - Sectional
85-90	Strings	Mahler I
85-90	Middle of orchestra	Turangalila
90-95	Brass	Bruckner 5
90-95	Brass	Rigoletto
92-94	Chorus	Opera
95-100	Brass	Mahler 9
100	Trumpet	Elektra
100	Piccolo	Nutcracker

Table 2.2: Indicative Player Exposures

In general, the brass section is the one with highest exposures and the fiddles the lowest. Brass players can reach an exposure of 100 dB in function of the piece (most of the contemporary pieces present hard participation of brass section). On the other hand, percussion is the section which has excessive peak exposures, but it is not known how much or how often. Sound pressure level is represented by the average level (Leq) because rarely a noise source produces a very sound level without fluctuations.

The importance of the ensemble where the different instruments play is something that has been studied [8], showing sound exposure values above 85 dBA on instruments like cellos. Following that example, it is measured that cellos registered a maximum daily exposure of 87.9 dBA, while trombone just measured 85.3 dBA (playing the same piece). The main reason was that cellist was seated in front of the brass section. Other results shown in that project are really similar than the presented in table 2.

In general, a player's own instrument dominates their exposure (table 3), demonstrated by Laitnen et al's project [9], although another near player might increase its overall playing intensity. It also depends on the place where the player is: pit is worse than a stage (around 3 dB), but the main critical factors are the repertoire and the style. Some instruments like woodwind spend much more time in personal practice than in performances, so its personal practice contribution will be louder. Table 4 shows the maximum spikes measured on different instrument positions (what doesn't mean they have produced that) in different pieces.

Personal Practice Average noise levels measured during one study	
Instrument	**Leq (dB)**
Double Bass	79
Violin	85
Viola	86
Cello	88
Harp	89
Other Woodwind	91
Other Brass	95
Flute and Piccolo	96
Trumpet	97
Percussion	99 + Peak Exposures

Table 2.3: Personal practice average noise levels measured during one study

Results on table 4 are really related with the maximum amount of noise exposure a worker can be exposed, commented at the beginning of this chapter. We can see how different instruments receive spikes (not always produced by them) which are very dangerous noise levels. [10] The spikes repetition influence in the temporary impairment: a low repetition rate gave less

temporary impairment than a higher repetition rate, although the total number of impacts was the same [11].

Spikes		
Piece	**Player**	**Spike**
Swan lake	Trombone	> 125
Mahler I	Double Bass	122
Mahler I	Brass	128
Beauty	Trumpet	139
Beauty	Viola	128
Beauty	Piccolo	145

Table 2.4: Spikes on different instruments

2.3 How affects this hearing loss in musicians

It has been accepted that excessive exposure to noise can produce several hearing symptoms, which can lead to a risk of permanent hearing loss. This potential risk has been studied in detail on several projects using musicians and people exposed to loud noise at work as study targets [12], each project with its own characteristics. In the 90's, the prevailing view was that susceptibility to NIHL could be related to relatively fixed factors, such as the length and resonant properties of the ear canal, the presence of melanin in the skin, and the effectiveness of the acoustic reflex. As a result of lots of experiments, it was demonstrated that individuals' susceptibility to NIHL can be influenced by their prior noise-exposure history, and that the amount of damage resulting from high-level noise exposure can be either increased or decreased by manipulating the ear's natural defense systems [13].

To study and measure that hearing damage, different ways are present in the literature. The most easily and studied form of hearing damage is "threshold shift", a change in the quietest noise a person can hear at a given frequency [14]. Figure 1 [3] show the age-related hearing loss and noise induced hearing loss in people, depending on the frequency and the age. We can see how hearing loss is more affected in high frequencies than in low frequencies when it is produced by age. The degradation of loss is more or less progressive. On the other hand, when hearing loss is produced by noise, the maximal loss is focused around 4 kHz, while in low and very high frequencies it is negligible. The problem is that age-related threshold shift and noise related threshold shift affect different parts of the internal ear: it means that a person can suffer both of them.

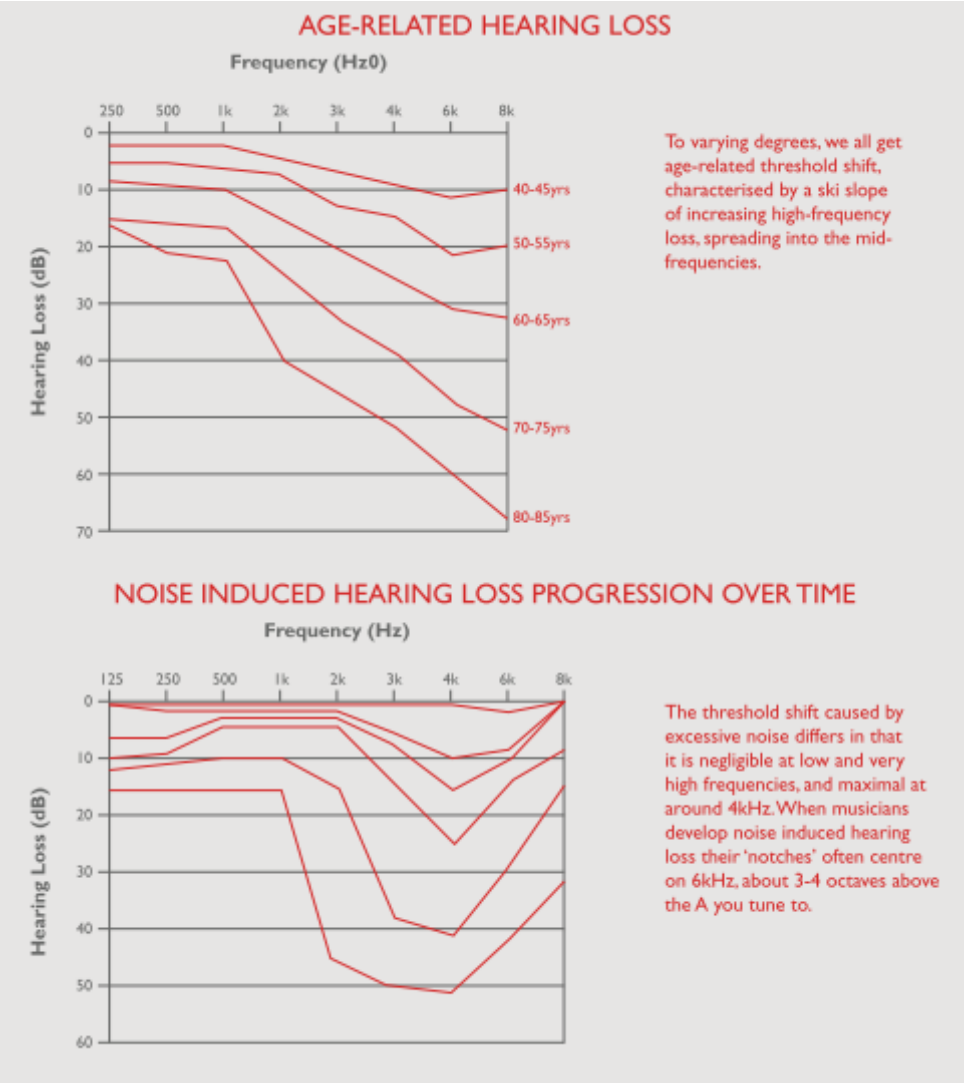

Figure 2: Age related vs noise induced hearing loss

Other forms of damage more significant for musicians are, for example:

- TINNITUS: it is the perception of sound in the absence of any corresponding external sound. This noise may be heard in one ear, in both ears or in the middle of the head or it may be difficult to pinpoint its exact location. The noise may be low, medium or high-pitched. There may be a single noise or two or more components. The noise may be continuous or it may come and go [15]. Around 35-40% of musicians have frequent or occasional tinnitus, with the woodwind being much more likely than other sections to report frequent tinnitus [3][16][17].

- HYPERACUSIS: Individuals with hyperacusis have difficulty tolerating sounds which do not seem loud to others [18]. Sounds as typical as the noise from running faucet water, riding in a car, walking on leaves, shuffling papers… Although all sounds may be perceived as too loud,

high frequency sounds may be particularly troublesome. The result of that is a quality of life greatly compromised because it is difficult and sometimes impossible to function in an everyday environment with all its ambient noise. Hyperacusis can contribute to social isolation, phonophobia (fear of normal sounds), and depression [19].

- RECRUITMENT: the consequence is that as a given noise level rises, the damaged ear hears from nothing, to too much increasingly

- COCTAIL PARTY EFFECT: occurs when hearing damage makes it difficult to distinguish a particular noise against high background noise levels. For musicians, it means that they cannot listen to particular instruments against the general sounds of the orchestra.

- DIPLACUSIS: results from ears having a significant difference in frequency selectivity. It produces clashing interpretations of the tonal contents of the noise.

There is not conclusion about if men or women are more susceptible to the exposed hearing problems, but Heili Laitinen [20] found some interesting results, presented in table 5. The median age at diagnosis with NIHL was 59 years in OSSA reports and 50 years in OPRA [21]. By using pure tone audiometry, Kahari [22] obtained the interesting (but not concluding) results that female musicians were shown to have significantly better hearing thresholds in the high-frequency area than did male musicians.

% of Respondents	Tinnitus	Hyperacusis	Distortion	Diplacusis
All	24	25	12	5
Women	18	31	14	6
Men	27	21	11	4

Table 2.5: Percentage of women and men with different hearing damage

2.4 Hearing Loss in Teachers

Not only music players are exposed to music noise. Teachers also are exposed a lot of hours to music which can damage their hearing. To explain that more precisely, two kinds of music teachers have been analysed: public school music teachers and professional music teachers. In contrast with hearing loss in musicians, there is no much literature that explains hearing loss in teachers or conductors (maybe because it’s difficult to define the distribution of activities a teacher does during a day or a week). Music teachers who work at school expend 8-hours each day doing different kind of music activities [23]. Each one

of these sources generates an amount of sound level very different, depending of the activity and the size of the group. For example, they teach the playing of an instrument and conduct bands and choirs. The mentioned project proposes an alternative measure of noise exposure level to Leq seen before: the Lex. That new index is normalized over an 8-hour period assuming that during the rest of the day (the difference between the measurement duration and the 8-hour workday), the person remains in a quiet environment which for the purpose of that study had a sound level lower than 70 dBA (that means no hearing loss will occur). This project will be a good point to start with the index computing on this project, modifying that Lex. The definition of that Lex index is shown below.

$$L_{ex} = 10\mathrm{Log}_{10}\left(\sum_i \frac{x_i}{8} 10^{\frac{L_i}{10}}\right)$$

In Behar's project has been determinate that there are other factors that influence more to the total noise exposure level than the class size (in contrast the author expected). It's results determines that the kind of music being played, whether the students were learning or performing, and the duration of the time while performing and listening to examples showed by the teacher influences more. Table 6 shows the measured L_{eq}, the duration and the calculated 8-hour pondered Lex for 18 different teachers. That table presents the importance of pondering the L_{eq} taking account the amount of hours on each activity: while L_{eq} is higher than the maximum allowed value (85 dBA) in fourteen occasions, just seven are above that value using L_{ex}.

Leq and Lex of Music Teachers			
Teacher	**Leq (dBA)**	**Duration (h)**	**Calculated Lex (dBA)**
1	89	5	87
2	91	5	89
3	89	3	85
4	95	5	93
5	88	4	85
6	82	4	79
7	86	3	86
8	88	4	85
9	82	7	82
10	86	6	85
11	88	3	84
12	82	5	80
13	88	4	85
14	87	3	82
15	92	7	92
16	93	5	91
17	85	4	82
18	87	4	84

Table 2.6: L_{eq} and Lex of Music Teachers

On the other hand, professional music teachers are usually exposed to the same sound pressure level the amount of hours they are teaching. For that reason, I think using L_{eq} only is a good approximation of their exposure. In [3] some resume values of that part are presented (shown in table 7). As it has been commented previously, instruments like Brass section and Percussion presents a higher sound values than Piano or singers, for example.

Music Teachers – Indicative Exposures	Leq
Brass, wind and percussion ensemble	94
Trombone	90
Flute	89
Singer	85
Piano	82
Percussion	92-95
Recorder group	87

Table 2.7: Music teachers – indicative exposures

2.5 Other factors

In previous sections, factors like own instrument and nearest instruments take account on noise exposure and hearing loss. But other factors should too. The environmental noise exposure seems something that should be taken really account, but Susan L. Phillips et al [24] demonstrate that exposure to outside noise does not appear to be a determining factor in who develops hearing loss. It is exposed that genetic predisposition is a likely risk factor and noise notches are seen in all instrument groups, including voice, and are seen more in the right ear than the left ear. The amount of hours the musician is exposed listening to music is important too. This section can be divided in two parts: live music concerts / discotheques and mp3 players.

Years ago, people used to use cassette players to listen to music and nowadays, MP3 player is the most used technology for that. These devices are connected to earphones, so the sound is directly received by listeners to their ears [25]. Usually listeners listen to music this way with a loud sound level, producing and excess of sound exposure. Different mp3 players have been studied in Levey project [26] and different output levels are obtained. As long as most of people usually fix its mp3 players volume around the 80% of the maximum volume (adolescents, especially male students, plays their MP3 players at maximum volume [27]), their exposure during their listening time is around 89 dBA (above the maximum value without risk of 85 dBA).

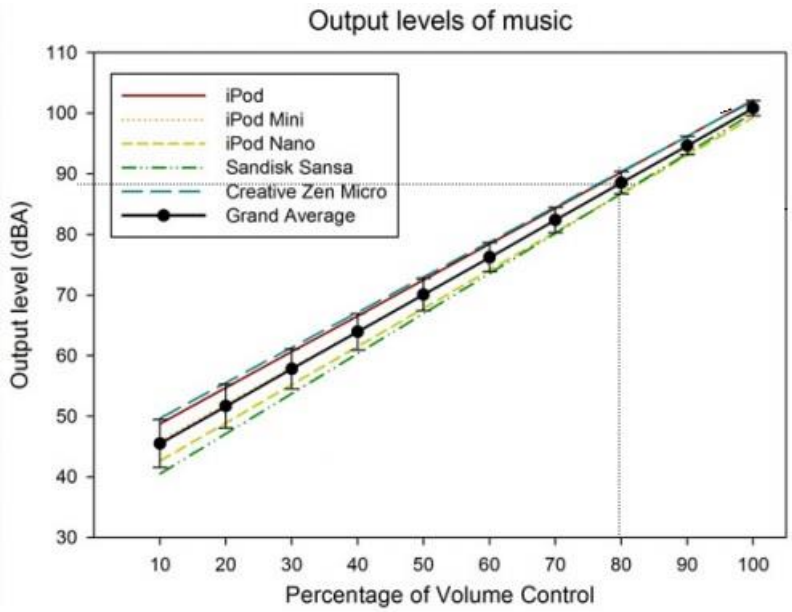

Figure 3: Output levels of mp3 players

On the other hand, musicians don't usually spend a lot of hours per week, so that factor will not take account a lot on their hearing loss. In spite of that, LT Lee [28] presents some results for discotheque employees, who are exposed every day to high sound levels: the range of exposure is always above 85 dBA for employees who work between 4 and 7 hours (mean of 5.1 hours). All the occupational groups are exposed to noise level of at least 89 dBA. It is also conclude that workers of 30 years old or more and who were working there for 1 year at least, suffer from hearing loss. The younger workers appeared to complain of tinnitus more.

Another factor that can be risky for hearing loss is the subway transport. This transport way presents the highest mean L_{eq} noise levels (80.4 dBA) and the highest individual measured L_{eq} (90.2 dBA on a subway platform) among the types of transit assessed in [29]. Subways also present the highest mean level (90.4 dBA) and the highest measured L_{max} (102.1 dBA on the subway platform) among the transit modes assessed. Seeing this results, this factor will be taken account in the questionnaire for the studied musicians in the current project.

2.6 Amount of hours a musician can play without risk of hearing loss

Using information from musicians of ESMUC (Escola superior de música de Catalunya), OPAM (Observatori de Prevenció Auditiva per a Músics) projects have estimated the amount of hours different musicians can be playing in a

orchestra without being in risk of hearing loss. Table 8 shows a summary of their results. This will be a starting point for the current project, where those values will be checked and modified if they are not properly accurate.

Instrument	Maximum amount of hours
Violin 1	10
Violin 2	3,2
Viola	2
Cellos	12,7
Bassoon	5
Flute	0,25
Trombone	0,5
Percussion	2,5
Harp	3,2
Director	2,5

Table 2.8: Results from OPAM

2.7 Conclusions of the State of the Art

Musicians are exposed to higher sound pressure levels than they usually imagine. Sometimes those levels are high enough to produce hearing loss in them. The musicians can also suffer some hearing diseases like hyperacusis or diploacusis. Depending on the instrument the musician plays or the instruments around him when he is playing in an ensamble, the sound levels varies a lot, so some instrument players have more risk of suffer hearing loss or hearing diseases. They also are exposed to other noisy activities related with the music, so a pondered average needs to be calculated to be more precise. It is important for them to know the levels they are exposed and try to avoid their risks of hearing loss.

3 METHODOLOGY

The first approach of this thesis has been the verification of the state of the art measurements on musicians. Before any mathematical calculation to compute the equations and weight system coefficients in musicians (see in chapter 5), ten different students have been measured while they were practicing or doing instrument class. All these musicians were ESMUC students who accepted to participate on this project selflessly.

3.1- Musicians

For this project, ten students who play different instruments (all of them with values on the state of the art) have been chosen. These instruments are: violin, viola, cello, double-bass, flute, clarinet, saxophone, trumpet, horn and marimba. All of them are students from ESMUC (Escola Superior de Música de Catalunya) and decided to participate selflessly.

3.2- Instrumentation

To carry on all the measurements, a personal audio analyser from the company Phonic has been used. The used model is the PAA3 and was provided by the Sonology Department of ESMUC. This sonometer is a highly accurate audio analyser with 31-band real-time spectrum analysis, Sound Pressure Level and dBu / dBV / line voltage measurement, EQ setting, phase checking and reverb time analyzation as main characteristics.

The main problem of this sonometer is that it isn't an integrator sonometer. An integrator sonometer allows a ponderation in time at the same time it does a ponderation in frequency. In section 2.3, the measurement procedure, it is explained how this handicap has been solved.

3.3- Measurement procedure

The procedure to measure the noise levels during the periods that musicians practice has been the same for all of them and their conditions have been the most similar as possible. Those conditions include the practice rooms, the distance between the noise source (that means the music instrument) and the sonometer.

Each instrument has been measured individually more than once. Ten different measures for each one has been done, separated in time approximately 1 minute, in order to do the time integration manually using all of these ten measures (all of them

in lineal scale, but afterwards the ponderations A and C have been applied).

The sonometer was situated approximately at 1 meter or 1.5 meters from the noise source in every situation to measure the direct pressure field without a large amount of reverberation field interferences.

3.4- Results and comparison with the State of the art

In table 2.1, the obtained results are resumed alongside some state of the art values. These values are from table 1.3 in chapter 1 and from SoundAdvice manual [30]. Not all the articles show the same results, so comparing the obtained values and several values from the state of the art will help to decide if the measured levels are properly obtained and correct or not. We can observe how all the obtained values are between the values proposed in SoundAdvice article, and approximately the same valued proposed in table 1.3.

Personal practice noise levels measured during one study vs State of the Art measures					
	PERSONAL MEASUREMENTS			STATE OF THE ART	
	Leq (dB)	Leq (dBA)	Leq (dBC)	1. SoundAdvice	2. Table 1.3
Violin	85,15	84,06	85,10	80-90	85
Viola	84,25	80,78	84,22	80-90	85
Cello	82,71	79,85	82,66	80-104	88
Double-Bass	86,15	72,86	85,68	70-94	79
Flute	89,76	90,43	89,68	92-105	96
Clarinet	88,76	87,84	88,74	68-82	91
Saxophone	93,85	90,77	93,82	75 - 110	91
Trumpet	94,18	93,60	94,14	88 - 108	97
Horn	101,00	97,55	101,00	92 - 104	95
Marimba	96,46	91,94	96,45	90 - 105	99 + Peak

Table 3.1. Personal practice noise levels measured during one study vs SOTA measures

Instruments like Violin or Viola presents values identically as the ones state of the art provides. Conditions were practically perfect for this task: good practice rooms and the distance between the musician and the sonometer was approximately 1 meter.

In the case of cello, we can observe how the obtained value is quite lower from the state of the art 2, but still between the values of 1. The main reason could be that the room where the cellist played was bigger than the others and the distance between the cello and the sonometer was approximately 2 meters. The direct pressure field is a bit attenuated by distance.

Double-Bass in our case presents a higher value than in 1.3 because the musician did class accompanied by its teacher playing sometimes the piano, so its noise level exposure is higher than a musician who does class alone.

The main problem of musicians like horn and marimba players is that they practice in small rooms in proportion with the amount of sound levels they generate with their instruments. That means their noise exposure is not only the amount of sound level they generate with their instruments (which is a really high value), it is the sum of that with the large number of sound reflections they receive in that kind of practice rooms.

4 ANALYSIS OF DATA

As it has been explained in previous chapters, musicians are exposed to high noise levels every day, but this noise is not only generated by its own music. Musicians are also exposed to daily activities that are really risky to suffer hearing loss.

In this chapter, it will be analysed the main activities that generates risky noise levels those who musicians are exposed. Some questionnaires have been done to different musicians of each instrument, where they have explained all the noisy activities they do every day of the week and how many time they are exposed. Each activity has been rated by a points system from SoundAdvice [30] in order to punctuate properly each activity and its impact in the musician.

In the following tables, the main activities that produce above 85 dB SPL are listed for some musicians. We can also compare for each musician how many hours they do that activities per day and how many days per week. Comparing with the noise level that their instruments produce when they are playing them, we can observe if their hearing loss risk is produced by the rest of activities or the combination of music and non-music activities.

After that, it has been analysed if any activity is done by all the musicians of the same instrument or if the difference of daily noise exposure presents no pattern by musicians.

VIOLIN

Measured at class: 85,15 dB

VIOLIN 1 – Week mean noise exposure 95 dB

Activities >85 dB	Time (week mean)	Level (dB)	Days per week
Dance floor	2	99	3
Headphones	1	94	5
Chamber music	2	85	1
Violin study	3	84	5
Bar staff	2	86	1
Amplified music	2	105	2

VIOLIN 2 – Week mean noise exposure 91 dB

Activities >85 dB	Time (week mean)	Level (dB)	Days per week
Orq. Simfònica	3	100	1
Headphones	1	94	7
Cambra	1	90	1

VIOLIN 3 – Week mean noise exposure 91 dB

Activities >85 dB	Time (week mean)	Level (dB)	Days per week
Ambient sounds	2	87	7
Swimming pool	0,6	90	3
Metro	0,5	90	1
Headphones	0,4	94	6
Orquestra	3	95	1
Party	2	100	1
Personal concert	1,5	90	1

VIOLIN 4 – Week mean noise exposure 87 dB

Activities >85 dB	Time (week mean)	Level (dB)	Days per week
Ràdio cotxe	1	85	7
Orchestra cocnert	2	95	1
Personal concert	2,5	90	2

VIOLIN 5 – Week mean noise exposure 88 dB

Activities >85 dB	Time (week mean)	Level (dB)	Days per week
Study	4,5	90	3
Study 2	2.5	87.8	6

The measurement of violin at class shows a 85 dB SPL, but the noise exposure level of violinists of the questionnaire is between 87 and 91 dB SPL, but one of them is exposed to 95 dB every day (daily mean per week). That exceptional case shows that higher value because he is used to do some amplified activities as dance floor or playing amplified music several times per week, two hours every day (that activities produces around 100 dB SPL of noise level).

Violinists also play in orchestras and chamber music groups. Orchestras present levels also around 95 and 100 dB SPL. Chamber groups where violin usually are inside are string quartets and other ensembles where the sound level is around 85 dB.

The using of headphones to listen to music is also a risky activity for hearing loss. People usually listen to music at high music levels, producing around 94 dB SPL directly to their ears. Most of the musicians of the questionnaire use that and several hours per week.

VIOLA

Measured at class: 84,25 dB

VIOLA 1 **– Week mean noise exposure 116 dB**

Activities >85 dB	Time (week mean)	Level (dB)	Days per week
Rock concert	1,5	130	1
Study	3	87.8	7
Opera concert	4	92	1
Cambra	1,5	90	1
Orquestra	4,5	87,1	2

VIOLA 2 **– Week mean noise exposure 85 dB**

Activities >85 dB	Time (week mean)	Level (dB)	Days per week
Any activity above 85 dB of noise exposure. No hearing loss risk			

VIOLA 3 **– Week mean noise exposure 110 dB**

Activities >85 dB	Time (week mean)	Level (dB)	Days per week
Symphonic orq	3	89	1
Cambra	3	85	4
Bar	2	95	1
Cinema	1,5	100	1
Discoteca	4	120	1
Concert cambra	1	90	1

Violists present one of the largest differences between the measured sound level while they are playing and the daily noise exposure. Two of the violists present 110 and 116 dB SPL each one, due they go one day per week to a Disco, Rock concert, cinema or they play to orchestras. The main difference with previous violinists analysed is that violist don't present any activity pattern: it seems that each one do some personal activities, but all of them with more or less same noise levels. The third of the violist don't present any activity above 85 dB and he is not in hearing loss risk because his week mean noise exposure is around 85 dB SPL.

In the case of cellos, we can see how all of them present a daily exposure more or less similar, because they are exposed between 90 and 92 dB, with the exception of one of them, who presents 87 dB. This person presents only two kinds of activities that produce hearing loss risk: listening to music with headphones and his individual practice of cello, but not so many hours per day.

On the other hand, the rest of cellist practice cello between 3 and 4 hours per week, which is a high noise exposure. They also play in orchestras and make concerts, a high noisy activity too, but thanks it is not every day. Chamber groups are usually the same as violins and violas, so the noise levels are not too high (around 85 dB). The other activities that produce the highest noise levels are listening to music with headphones, going to bars and discos (which mean to be exposed to 100 dB or higher levels) or assisting to jazz jams, where music arrives to 95 dB SPL.

CELLO

Measured at class: 82,71 dB

CELLO 1 **– Week mean noise exposure 91 dB**

Activities >85 dB	Time (week mean)	Level (dB)	Days per week
Individual practice	4	90	7
Disco	4	100	1
Esplai	4	86	1
Orchestra	2	86	1

CELLO 2 **– Week mean noise exposure 92 dB**

Activities >85 dB	Time (week mean)	Level (dB)	Days per week
Individual practice	4	90	6
Bar	4	95	1
Headphones	1	93	1
Orchestra	3	90	1
Concert	3	100	1

CELLO 3 **– Week mean noise exposure 90 dB**

Activities >85 dB	Time (week mean)	Level (dB)	Days per week
Individual practice	3	90	7
Dance	1,5	90	1
Cambra	2,5	85	3
Orchestra	2,5	94	1
Concert cambra	2	85	1
Disco	3	95	1

CELLO 4 **– Week mean noise exposure 92 dB**

Activities >85 dB	Time (week mean)	Level (dB)	Days per week
Individual practice	3,5	90	7
Headphones	0,8	94	3
Cambra	2	85	4
Class	1	88	1
Jazz Jam	1	95	1
Pub	3	99	1

CELLO 5 **– Week mean noise exposure 87 dB**

Activities >85 dB	Time (week mean)	Level (dB)	Days per week
Headphones	0,6	94	7
Individual practice	1,5	90	5

DOUBLE BASS

Measured at class: 86,15 dB

DOUBLE BASS 1 **– Week mean noise exposure 96 dB**

Activities >85 dB	Time (week mean)	Level (dB)	Days per week
Combo 1	2,5	95	2
Combo 2	2,5	98	2
Classes	1,5	92	5
Study DB	2	89	6
Study Elect. Bass	1	85	6
Concert	2	102	1
Orchestra	1	98	1
Jazz concert	2	98	1
Gospel	2	102	1

DOUBLE BASS 2 **– Week mean noise exposure 95 dB**

Activities >85 dB	Time (week mean)	Level (dB)	Days per week
Orchestra	4	94	3
Study DB	3	89	6
Pub	2,5	99	2
Combo 1	1	96	4

DOUBLE BASS 3 **– Week mean noise exposure 92 dB**

Activities >85 dB	Time (week mean)	Level (dB)	Days per week
Study DB	4,5	89	7
Combo	1,5	98	2
Listening to music	2	85	7
Jam session	2	95	2
Practice	2	95	1

DOUBLE BASS 4 **– Week mean noise exposure 94 dB**

Activities >85 dB	Time (week mean)	Level (dB)	Days per week
Study DB	3	89	7
Orchestra concert	2	98	1
Pub	2	99	2
Combo	1	96	4
Class	1,5	91	1
Orchestra class	3	94	1
Accoustics class	1	97	2

DOUBLE BASS 5 **– Week mean noise exposure 99 dB**

Activities >85 dB	Time (week mean)	Level (dB)	Days per week
Study DB	0,5	89	5
Study elec. Bass	4,5	100	5
Train travel	2,5	90	3
Combo	3,5	100	3
Orchestra practice	2	100	1
Rock practice	2	100	1
Concert	1	100	1

The measured value of double bass at class is above the critical value explained of 85 dB SPL. It was measured a mean of 86 dB. A double bass usually don't produce high noise levels, but they usually do classes accompanied by piano, so the sum of both levels is what the musician receives every class.

On their daily activities, we can find in all of them activities like participating in combo groups. That combo groups usually are composed by wind noisy instruments (like saxo, trumpet, trombones…) or amplified instruments (for example, electric bass or electric guitars). That kind of music groups produces between 95 and 98 dB, depending on the instruments. It is possible to observe that bassists also usually go to concerts (jazz, orchestra or live concerts, around 100 dB) and once or twice per week they go to the bar, which means a high exposure at 100 dB approximately during two hours (while they shuldn't be exposed to that levels more than 15

minuts…).

The other noisy activities the musicians explain they do are listening to music, singing in gospel chorus or attending classes where they use amplified devices for it (normal theory classes only creates noisy levels behind 80 dB, but in this case, levels around 97 dB are measured).

FLUTE

Measured at class: 93,85 dB

FLUTE 1 **– Week mean noise exposure 98 dB**

Activities >85 dB	Time (week mean)	Level (dB)	Days per week
Study flute	3	94	6
Study piccolo	0,5	104	5
Orchestra	3	98	1
Class flute	3	94	1

FLUTE 2 **– Week mean noise exposure 119 dB**

Activities >85 dB	Time (week mean)	Level (dB)	Days per week
Study flute	2	89	7
Headphones	1	94	3
Radio at car	1	85	6
Bar	2	95	2
Combo concert	3	101	1
Combo jam	3	101	1
Combo	2	98	2
Singing class	2	100	2
Concert	3	130	1
Cinema	3	100	1

FLUTE 3 **– Week mean noise exposure 95 dB**

Activities >85 dB	Time (week mean)	Level (dB)	Days per week
Running	1,5	85	1
Spinning	1	95	2
Cinema	2	100	1
Restaurant	2	90	1
Guàrdia pati	0,5	100	2
Classe carrillo	1	100	3
Singing class	1	105	1
Chorus class	2	86	2
Metro	0,15	90	1
Study flute	1	89	2

Flute players are the kind of musician in more danger of hearing loss. It has been measured that they produce around 93 dB at class when they are playing. They also play in orchestras (usually symphonic) and combo groups, where they receive the direct sound of metal instruments like trumpets. The flutists are exposed not only to their own damager sound but also the sound produced by others. Those activities produce noise levels between 98 and 102 dB SPL.

Some flutists also usually play piccolo. That instrument is a kind of flute but shorter and has a higher pitch, but the main problem (from hearing damages point of view) is that piccolo produces higher sound levels than flute. Usually those players use ear protection to avoid the levels around 104 dB, but not always and not during concerts.

The rest of the activities we can observe that flutists do every week produce values around 100 dB: we can see that some flutists go to the cinema once per week and do singing class. The other activities are more particular of each musician, like teaching different instruments or forming part of combo and jam groups, travelling by metro or listening to music in the car or with headphones.

HORN

Measured at class: 101 dB

HORN 1 – Week mean noise exposure 92 dB

Activities >85 dB	Time (week mean)	Level (dB)	Days per week
Band concert	2	95	1
Horn Study	2	90	6
Jam session	0,5	90	1
Classical concert	3	100	1
Disco	2	100	1
Headphones	1	94	1
Cinema	2	100	1
Orchestra	3	96	1

From the horn musician who participated in the questionnaire, it is possible to know that they are really in hearing loss danger. It was measured that at class, horn produces 101 dB SPL, noise level equal to other activities like going to a disco or playing in an orchestral classical music concert. Other really risky activities are playing in different kind of ensembles (jazz group, orchestras or playing with piano, for example), going to the cinema or listening to music with headphones.

TRUMPET

Measured at class: 94,18 dB

TRUMPET 1 **– Week mean noise exposure 96 dB**

Activities >85 dB	Time (week mean)	Level (dB)	Days per week
Headphones	2,25	95	3
Study trumpet	2,5	94	6
Combo 2	1,5	98	1
Music at car	1	85	1
Combo 3	1,5	101	1
Percussion class	1,5	100	2
Bar	1,5	90	1

TRUMPET 2 **– Week mean noise exposure 96 dB**

Activities >85 dB	Time (week mean)	Level (dB)	Days per week
Headphones	2	94	4
Quintet metal	1,5	97	2
Study trumpet	3	94	7
Orchestra	2,5	93	1

Trumpet players are exposed more or less daily at the same level their instrument produces when they practice. It was measured 94 dB at class while they are exposed to 96 dB per day. Both musicians in the questionnaire listen to music with headphones (that means 94 dB), study trumpet around 3 hours every day of the week and play in music groups that produces between 97 and 101 dB (usually that combo groups are metal wind groups, so high levels are produced in each training and concert). Other activities are assisting to bars at the weekend or listening to music quite high in the car.

SAXOPHONE

Measured at class: 93,85 dB

SAX 1 **– Week mean noise exposure 93 dB**

Activities >85 dB	Time (week mean)	Level (dB)	Days per week
Headphones	2	94	5
Study Saxo	1,5	98	5
Combo	1,5	96	1
Party	4	97	1

SAX 2 **– Week mean noise exposure 98 dB**

Activities >85 dB	Time (week mean)	Level (dB)	Days per week
Study saxo	2,5	98	5
Combo	2	100	5
Chorus	1,5	86	1
Rhythm class	2	100	1
Concert	2	100	2
Bar	3	90	1
Jazz concert	2	100	1

SAX 3 **– Week mean noise exposure 100 dB**

Activities >85 dB	Time (week mean)	Level (dB)	Days per week
Study saxo	4	98	7
Cambra	3	102	1
Saxo ensamble	1,5	105	1
Modern group	2	101	1
Concert	3	100	1

SAX 4 **– Week mean noise exposure 100 dB**

Activities >85 dB	Time (week mean)	Level (dB)	Days per week
Study saxo	4	98	7
Cambra	2	102	2
Saxo ensamble	1,5	105	1
Modern group	2	101	1
Concert	3	100	1

The last measured instrument was the saxophone. The sound level measured at class was around 94 dB SPL. We can observe how saxophonists are exposed every day around 100 dB. All of them practice sax many hours: two of them every day 4 hours and, the other two, 2 hours five days per week. We can see how all of them play inside a combo or chamber music group generating more than 100 dB every time they play. They also tend to assist to jazz concerts, which produces also around 100 dB (they tend to assist between 2 or 3 hours, but just one day per week).

5 RESULTS

5.1- Daily noise exposure computed

Once all the noisy activities all musicians do in a week and the amount of hours they practice them, the mean of all musicians that play the same instrument has been computed in order to visualize a virtual musician of each instrument and its daily noise exposure. In the following list, the amount of activities that musicians exposed they do are listed. Near the name of each activity, the sound pressure level that produces is annotated.

ACTIVITIES	Variable	ACTIVITIES	Variable	ACTIVITIES	Variable
Violin study (85,15)	x1	Orchestra Trumpet (96)	x20	Discoteque (120)	x39
Viola study (84,25)	x2	Orchestra Horn (96)	x21	Party (100)	x40
Cello study (82,71)	x3	Orchestra Sax (95)	x22	Pub (99)	x41
Double bass study (86,15)	x4	Amplified music (105)	x23	Bar (86)	x42
Flute study (93,85)	x5	Brass chamber 1 (95)	x24	Dance floor (99)	x43
Trumpet study (94,18)	x6	Brass chamber 2 (98)	x25	Headphones (94)	x44
Horn study (101)	x7	Combo 3 (100)	x26	Swimming pool (90)	x45
Sax study (93,85)	x8	Personal concert (100)	x27	Metro (90)	x46
Electric bass study (85)	x9	Rock group (100)	x28	Ambient sounds (87)	x47
Piccolo study (104)	x10	Chorus class (86)	x29	Radio car (85)	x48
Singing class (100)	x11	Saxo ensamble (105)	x30	Cinema (100)	x49
Carrillon class (100)	x12	Modern grup (101)	x31	Boyscout activities (86)	x50
Strings chamber (90)	x13	Rock concert (130)	x32	Music at home (85)	x51
Symphonic orchestra (100)	x14	Opera concert (92)	x33	Accoustics class (97)	x52
Orchestra violin (83)	x15	Jam Session Jazz (95)	x34	Train (90)	x53
Orchestra viola (89)	x16	Jazz concert (98)	x35	Running (85)	x54
Orchestra cello (83)	x17	Gospel concert (102)	x36	Spinning (95)	x55
Orchestra Double Bass (86)	x18	Classical concert (100)	x37	Restaurant (90)	x56
Orchestra Flute (101)	x19	Band concert (95)	x38	School vigilance (100)	x57

Table 5.1: Noisy activities of collaborative musicians

The proposal of this project was to compute the daily noise exposure on musicians in order to analyse if they are in hearing loss danger or not. In the following results (subdivided by sections) we can see how all of them are really in danger of hearing loss. Table 5.2 resumes the mean daily noise exposure, the mean amount of hours of exposure, the equivalent noise level exposure and the amount of time the musician should be exposed to those levels in order of not being in hearing loss danger.

Instrument	Daily exposure (mean) [dB]	Daily exposure (mean) [hours]	Recommended time exposure
Violin	93,8	4,53	72 minutes
Viola	112,9	4,88	56 seconds
Cello	106,4	4,70	3,75 minutes
Double Bass	93,7	6,31	72 minutes
Flute	114,9	4,39	35 seconds
Trumpet	94,7	4,43	60 minutes
Horn	109,6	3,79	1,88 minutes
Saxophone	97,5	4,79	30 minutes

Table 5.2: Resume of daily exposure on musicians (average)

Looking on the right column of table 5.1 is easy to conclude that all musicians are really in hearing loss risk. Taking the reference of that a worker can be exposed a maximum of 85 dB during the 8-hours period of work to avoid hearing losses, it has been demonstrated that musicians are far away from this minimum values of daily exposure. The minimum daily exposure of them is 93,7 dB, more or less 9 dB above the 85 dB of the minimum. It is remarkable that flute players are exposed to 114,9 dB every day: that sound level is equivalent to a building construction! To prevent hearing loss, flutists should be exposed only 35 seconds every day. That reflexion seems ridiculous, as long it has been analysed that flutists play every day around 2 or 3 hours alone. We can compare the results with McBride's work [31] who clearly obtained that wind musicians are more in danger than string musicians, but that's only true if we take account the noise produced by the instruments in their lives. We have demonstrated that it isn't completely true when all the daily noise activities are taken account.

But which kind of activities affect more in the daily noise exposure on a musician, the activities related with music (that includes playing along or in ensembles, so activities between x1 and x38 from table 5.1), or the activities they practice during their free time (so, activities between x39 and x57)? And what would be a bigger influence, playing alone or playing inside an ensemble? In table 5.3 the sound pressure level of different group of activities are resumed for each instrument and the time (hours per day) they dedicate to each activity.

Instrument	Music	Time	Individ	Time	Ensemble	Time	Free time	Time
Violin	92,20	3,16	81,75	2,14	91,79	1,01	88,67	1,37
Viola	111,83	4,52	82,05	3,00	111,82	1,52	106,09	0,36
Cello	86,55	3,96	81,21	3,11	85,05	0,84	106,32	0,74
Double Bass	92,35	5,14	82,88	3,24	91,83	1,90	87,89	1,17
Flute	114,88	3,21	91,98	1,88	114,86	1,33	89,09	1,17
Horn	98,99	2,93	97,91	1,86	92,41	1,07	108,83	0,86
Trumpet	93,65	3,18	91,64	2,57	89,35	0,61	87,94	1,25
Sax	96,82	4,18	91,54	2,71	95,29	1,46	86,94	0,61

Table 5.3: Classification on music related or non-music related activities

Observing the results that fills table 5.3, we can compare each profile of musician that its NIHL is mostly produced by the noise of its instrument and its colleagues when he plays inside an ensemble, or it is mostly produced by free time activities. We can see how all of them dedicate lot of more time to music activities (in general) than other kind of activities, but the SPL are not very different.

Violinists are exposed every day (mean value) to 92,20 dB SPL, while their free time activities are just 88,67 during 1,37h every day. The final shown in table 5.2 is really near to their music exposure because the difference between the two values is higher enough, more than 6 dB. The same happen with other instruments like viola, which daily exposure is really affected by their ensemble activities (most of it is their participation in orchestras) and their free time activities.

Cellists, on the other hand, are approximately inside the law with their music related daily exposure: 81 dB on their individual practice and 85 dB on their ensemble activities, what generates an 86 dB SPL of noise exposure produced by music. Their problem is on their free time activities. 45 minutes every day are exposed to 106 dB, level that should be exposed only 3 minutes to avoid the risk of NIHL. That huge total value that resumes their free time activities is mainly produced by discos, pubs and headphones.

Brass instruments like Horns, Trumpets and Saxs are exposed to very high values of music activities, so their risk of hearing loss is mainly produced by their own practice of the instrument and group music. They are not exposed much time to noisy activities (less than an hour per day) and the level difference is higher than 6 dB (except trumpets, whose free time activities are really noisy, around 106 dB SPL).

The most impacting case was the case of flutists, the musicians that were exposed to the highest total noise level. Their NIHL risk is totally produced by their music activities. Flute is a noisy instrument, 92 dB itself, but their problem is the sound level produced by the wind instruments around them in an orchestra or ensemble (usually brass instruments).

5.2- Lineal regression equations

After all the analysis of the available data, a lineal regression from it has been computed. A lineal regression is a mathematical method which models the relation between a dependent variable (Y) and some independent variables (Xi) and a random term ε [32]. Enrica d'Aula's method [33] creates a kind of equation for spaces comparable to that model, expressed in (5.1):

$$Y_t = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_p X_p + \varepsilon \qquad (5.1)$$

For this survey, the Y variable will be the daily noise exposure and the Xi variables the time each musician dedicates to the different activities. All the activities have been listed and named between x1 and x57 and using the following order. Near each of the activities there is the noise level of all of them.

In this survey, a first approximation of the equations for eight different instruments has been tried to compute, using the musicians proposed in chapter 4. As long as the coefficients of the regression matrix should be more accurate if we had had more available musicians for this investigation, the parameters can't be considered definitive. The system should be trained with lots of extra musician for each instrument until the coefficients won't be enough accurate versus the computational cost.

We have seen that most of the coefficients are zero for each kind of musician. That means that some kind of musicians tend to do some daily activities that others don't. For example, wind instrument musicians tend to assist to jazz concerts and jazz jam sessions, while string musicians don't (with the exception of some double bassists). Another example is that cellists usually use more headphones for listening to music than double bassists.

Violin

Y = 1,071381621*x1 + 0,055611416*x23 - 0,010826527*x27 + 0,036468406*x40 + 0,028220451*x44

Viola

Y = 1,011904762*x2 + 0,288502986*x32 + 0,25836232*x39

Cello

Y = 1,073255224*x3 + 0,002201806*x13 + 0,051233463*x37 + 0,03033155*x39 + 0,054768131*x41

Double Bass

Y= 1,100226568*x4 + 0,12783059*x18 + 0,111442559*x37 - 0,069540008*x41 - 0,016640908*x52

Flute

Y = 1,053879773*x5 + 0,066847041*x12 + 0,215826687*x32

The equations computed for Horns, Trumpets and Saxes had any kind of sense. In case of sax and trumpet because some of the coefficients computed were not for activities that these musicians does (the extreme case was when the trumpet equation was obtained and was observed that the first coefficient was x1 activity

instead of x6. trumpeters don't play the violin…). The case of horn is simpler: there are not enough musicians for a linear regression computing with some sense. With just one vector of data, lineal regression coefficients will be the same as time coefficients of the logarithmic sum.

These results lead us to find another kind of weight system less closed than an equation because the amount of variables on musicians activities don't guarantee the reliability level expected. A weight system based on the noise levels and the time of exposition to them has been created.

5.3- Weight system

The weight system allows musicians to know the amount of impact each of the activities they do generates more risk of hearing loss. In this chapter, the proposed weight system is shown and discussed. The activities have been grouped in three main blocks for an easier interpretation.

Instrument	Individual music	Collective music	Free time activities
Violin	0,47	0,23	0,30
Viola	0,63	0,31	0,06
Cello	0,67	0,18	0,15
Double Bass	0,5	0,30	0,20
Flute	0,43	0,30	0,27
Horn	0,5	0,28	0,22
Trumpet	0,58	0,14	0,28
Sax	0,57	0,31	0,22

Table 5.4: Coefficients of the weight system

In table 5.4, each musician can compare the impact coefficient of each kind of activity. The coefficients have been computed by taking account the sound level of each activity and the direct relation between the time each sort of activities is practised and total exposure time.

The computed coefficients are an easy tool for them to analyse which is the kind of activity that influence more on their noise induced hearing loss, combined with the noise levels computed on table 5.3. With that, each musician knows in which activities need more to take actions to protect their hearing system. We can see that for all of them, individual practice is the kind of music activity that produces more dose levels, but depending on the instrument, the amount of importance of that is higher than half of their dose exposition and others less. Then, it is important for them

to analyse if collective music has a big impact in their noise exposition or not much (relatively with the other activities) and they should apply prevention techniques for collective music playing (some of them, explained in chapter 6) or they should pay more attention in their noisy activities every day, avoiding some of them or just reducing their time exposure for them

6 FINAL DISCUSSION

In this project, it has been studied the daily noise exposure of different profile of musicians. It has been analysed the main activities each kind of musician do every week and the amount of noise it means (sound pressure level that activity generates). With the results obtained, musicians can easily be alert of which kind of activity affects more in their hearing and where they should improve their ear defense.

We have seen some patterns in musicians that play the same instrument. These patterns allow us to analyse and propose the final weigh coefficients that better explains the noise exposure on that kind of musician. The coefficients could be modified because for this kind of project, it will be needed more data from musicians to train the system properly. For this project it hasn't been available the amount of musicians that required so the final results will be improved and reloaded in the future with more participants.

The accuracy of the questionnaires should be better also. Some of the questionnaires were filled quite fast, without specifying properly the activities each musician does every day. Others filled some ceils of the questionnaire in blank so it was impossible to determine exactly at which kind of activity they were referring. It was also found that some musicians didn't specify the instrument they play, so it was not possible to use that questionnaire to train the system of each kind of musician profile. All of those problems are examples of bad answers for that project and have limited me to work with few musicians instead a great amount of them.

At the end of some measures, it was interesting to talk with the musicians to know if they were aware of the amount of noise they were exposed while they were playing. Some musicians knew their instruments generate a huge amount of decibels, but not all of them confessed the usage of hearing protectors. The reason that most of them said was that it is not comfortable to play while you are wearing ear plugs: you can't listen properly the sound you are producing, so it's impossible to control your instrument for every note. They prefer suffering hearing loss instead of using that protection stuff. Others explained that they were aware of health problems and injures depending on the way they play and they did some exercises and apply some techniques of body awareness and relaxation, but nothing related for their ear health [34].

6.1- POSSIBLE METHODS TO CONTROL HEARING LOSS

As long as musicians' most important part of their body is their ears, it is important that they take care of them the most as possible. It is important that musicians detect early signs of harm so that better-directed effort can prevent further damage. To detect these early signs, some hearing tests could be done to indicate the extent to

which a musician is successfully controlling risks, to identify people who have so much existing hearing loss that additional noise related damage would be serious or to identify people who seem to be especially sensitive to noise-induced damage and so need an extra protection than most of musicians [35]. There is an organization called Musicians Union that subsidises hearing tests for its members. This programme may be converted into a health surveillance scheme where information about each musician trend will give feed back to the Union.

Before the usage of any protection, it is important to have a training instruction, what means information that includes, for example, the noise exposure and the risk to hearing it creates, what you are doing to control the noise exposures, arrangements for health surveillance, symptoms to look out for, etc.

The part of training is really important because noise control will be a major change for musicians to convince them of the need, for their livelihood and pleasure. Musicians should be aware that noise control is not simple: they should understand the pros and contras of the various options available.

6.1.1- Options for controlling noise

As long as some musicians don't want to use any kind of protection while they are practicing, it is important to inform them that there are some control measures that will provide them some dose reduction. That no means that all of them could be apply always, but it is important to know about them and when it is possible, use the most as possible of them to decrease hearing loss risk [36].

- Play less loudly: it seems the easiest way to reduce hearing loss risk when a musician is playing, and sometimes musicians say that this sentence is much easier to say than to put in practice. But if we analyse a bit in deep we can find some clues to do it.
  - Sometimes the excitement can be increased but the exposures reduced by accentuating the quitter areas around very high power segments.
  - The usage of practice mutes or practice pads during personal practice is a good option while individual practice.
  - Keep piano lid down during personal practice
  - Avoid playing always together when you play in a group. Practice by sections reduces the time exposure to the highest noise exposure that the musician could be exposed.
  - Play loud only when it is needed, not always you see a forte in the score
- The usage of less powerful instruments: some modern brass instruments have different power ranges. Musicians usually play instruments that are quite powerful because they require less blowing force. The usage of that kind of

instruments in an orchestra generates a higher power of the rest of the orchestra. Avoiding this instruments while practicing, will reduce considerably the noise level.

- Use an appropriate space: avoid playing in rooms that generate large reverberations and echoes and don't present good conditions on absorption.
- Adjust playing stance: changing the disposition of some instruments in an orchestra helps and improve their projections to avoid some direct high levels to some musicians.
- Usage of sound screens around musicians exposed to noisy neighbours
- …

6.1.2- Usage of personal hearing protection

The problem of previous options to control the noise is that not always is possible to apply them and other times they are not enough to reduce enough noise impact. In that case, musicians must use personal hearing protection (especially mention of flutists [37]).

Workers, in general, when exposures exceed the upper levels, use that kind of protection to reduce the noise impact [38] and it's something that don't disturb them for the development of their task. But in the case of musicians, who need their ears at 100% to hear every single sound, their own sound and their colleagues' for the quality of the performance. The inner portion of our ear canal is lined with bone (as compared with the outer portion which is cartilage). This bone receives low frequency sound vibration directly from our jaw and mouth. That is, the boney wall of the ear canal vibrates like a speaker diaphragm and sound is generated in the ear canal. Normally, this sound energy goes out to the environment. If we plug up the ear canal with an earplug, the sound becomes trapped in the ear canal and goes inward through our hearing system. This is called the occlusion effect and accounts for the echoey and hollow sound of our voice whenever we plug our ears [35]. So it is important to avoid over-protection for musicians: basic protectors will eliminate tones that players need in order to play accurately and will not hear properly (or hear almost nothing) in quite passages where there are sudden changes in dynamic [39].

There exists some different kind of ear plugs, each one with its own properties and consequences for the musician's ear. The flanged industrial plugs are a variant of typical roll-up plugs that also over-protect when they are top fitted, but the flanged design allows the partial insertion in the ear to give less reduction. The main problem of them is that you can't know exactly how deep it should be placed. Another option is the usage of the bespoke ear plugs, which allow a more personal protection of the ear because are custom-moulded and can be constructed with swappable filters. They are recommended for bass players and cellists, who usually prefer a style of plug that allows them to hear their own instrument but reduce the treble from

neighbours. Level dependent protection is available in off-the-shelf flanged plugs, bespoke plugs and ear muffs [6].Ear muffs are another option and don't involve the problem of resonance in a blocked-up ear canal. They supply a controlled electronic version of the external sound field, but the problem is that sometimes it introduces a slight time delay. It could be a great solution but only if all the ensemble musicians wear them to avoid some of them were behind the beat.

All of those options are valid to avoid noise induced hearing loss in musicians, but not so much are put in practice nowadays in most of orchestras and music groups.

6.2- LIST OF FIGURES

6.3- LIST OF TABLES

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