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The Contribution of Leisure Noise to Overall Noise Exposure

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ABSTRACT

Maximum acceptable noise exposure levels are well established for the workplace. For example, Australian occupational health and safety regulations mandate a maximum acceptable daily workplace noise exposure level (LAeq,8h) of 85 dB (INCE: 1997). However, a person's day extends beyond the 8 hours spent at work, and thus noise exposure during non-working hours (leisure time) also contributes to a person's overall noise exposure. To investigate the levels of noise experienced during leisure activities, a long term study (Study 1) is under way. Measurements are being undertaken in 7 main categories: attendance at entertainment venues, attendance at sports venues, active recreation and sport, arts and cultural activities, travel, domestic activities, and other activities. In conjunction with these measurements of individual activities, a second study is also under way to measure individuals' noise exposure levels over an extended period. Participants wear personal noise dosimeters which measure their personal noise exposure levels over a 4- or 5-day period, including work days and weekend (leisure) days. Data collected thus far reveals that, while many leisure activities are below the acceptable noise levels and are thus 'safe', there are other leisure activities which, if engaged in regularly over a long period of time, have the potential to shift a person's noise exposure beyond acceptable limits and thus increase the risk of acquiring a hearing loss at a relatively early age.

Increasingly, noise researchers are appreciating that noise exposure and the associated risk of noise-induced hearing loss (NIHL) is a whole-of-life issue [1]. There is a growing trend towards treating occupational and leisure-related noise exposure not as separate issues, but as two sides of the same coin. This approach acknowledges that all sources of noise, wanted and unwanted, have equal potential to cause damage to a person's hearing health, regardless of whether heard at work or play.

Being mindful of this new approach to noise research, we are conducting two studies concurrently. In Study 1, levels of noise during leisure activities are being measured to create a database of typical noise levels for a wide range of recreational pursuits. Measurements are being collected at entertainment venues, sports venues, during active recreation and sport, arts and cultural activities, travel, domestic and other activities. Reported here is a subset of measurements collected thus far in two categories: entertainment venues and arts and cultural activities.

In Study 2, participants wear personal noise dosimeters which measure their personal noise exposure levels over a 4- or 5-day period, including work days and weekend (leisure) days. The aim is to assess each individual's overall noise exposure and determine how work and leisure noise combine to form a person's overall noise dose.

STUDY 1

METHOD

144 measurements were collected by volunteers who visited entertainment venues (nightclubs, pubs, bar, and restaurants) and arts and cultural activities (movies, music concerts, festivals and outdoor events, drama, dance, and theatre performances) as part of their personal social agenda. Volunteers carried calibrated CEL-350 dBadge personal sound exposure meters in accordance with the relevant measurement standards [2]. Dosimeters were worn at the lapel or as near as possible to the ear, and participants were advised to use their discretion to ensure the dosimeters were unobtrusive so as not to attract attention. The dosimeters logged sound levels (L_{Aeq}) at 1-minute intervals and the data were later downloaded using supplied software with ISO protocols [3].

RESULTS AND DISCUSSION

Table 1 shows noise levels (L_{Aeq}) of entertainment venues and arts and cultural activities. The events are listed from highest to lowest in terms of noise level.

Table 1. Mean noise levels at selected entertainment venues and arts and cultural events

	L_{Aeq} (dBA)				
Event /activity	*n*	*Mean*	*StDev*	*Min*	*Max*
nightclub	12	**97.3**	5.1	88.9	105.7
popular music concert	10	**95.9**	6.4	84.7	104.7
bar / pub with live music	5	**93.4**	7.1	85.5	101.8
music festival / outdoor concert	13	**91.1**	5.8	79.6	98.3
classical music concert	11	**84.7**	3.7	76.3	90.3
bar / pub – no live music	30	**83.8**	6.5	71.2	96.3
street parade / outdoor event	3	**82.4**	2.3	80.4	84.9
dance performance	8	**80.2**	5.2	73.6	85.4
theatre	9	**79.0**	2.9	72.7	82.7
restaurant	31	**78.6**	6.3	67.2	88.9
movie	12	**74.9**	4.3	67.7	79.7

High noise levels

Nightclubs, popular music concerts, live music at bars and pubs, and music festivals yielded high average noise levels (above 91 dB). All sampled nightclubs and live music events at pubs and bars had an L_{Aeq} above 85 dB. Of the 10 popular music concerts, 9 had an L_{Aeq} above 85 dB and 12 of the 13 music festivals/outdoor concerts had an L_{Aeq} above 85 dB. These noise levels are consistent with those reported elsewhere [4-7].

Mid-range noise levels

The mean noise levels at classical music concerts, and bars and pubs where there was no live music were below 85 dB. However, there were several instances of events in these categories at which the L_{Aeq} exceeded 85 dB: 4 of 11 classical concerts and 13 of 30 pubs/bars had an L_{Aeq} above 85 dB. Again, similar levels have been reported elsewhere [8, 9].

Lower noise levels

The mean L_{Aeq} for dance and theatre performances, street parades, restaurants, and movies was less than 85 dB. Only 1 dance performance and 4 restaurants reached an L_{Aeq} of 85 dB or more. Noise levels for these activities are rarely reported in the literature, although movies have previously been measured with L_{Aeq}s between 75.5 and 84.5 dB [10, 11].

A number of conclusions can be drawn from these data. First, some leisure activities do not generate harmful noise levels. Although the community may regard movies as potentially harmful to hearing health [12, 13], the measurements presented here suggest that movies rarely generate sufficient noise to pose a risk to hearing. Similarly, most restaurants, theatre and dance performances emit safe noise levels.

At the other end of the scale, many nightclubs, popular music concerts, pubs and bars with live music and music festivals/outdoor concerts do emit noise levels that may be harmful to hearing health. Knowing the typical noise level of particular types of leisure activities is useful because this information can be used to educate patrons to exercise caution and take steps to protect their hearing while engaged in these activities. However, before we can draw conclusions about how these activities might affect one's overall noise exposure, we need further information about the length of time spent at these activities and how the leisure noise levels compare with noise exposure at work.

STUDY 2

The aim of Study 2 is to obtain snapshots of individuals' overall noise exposure over a period of 4 or 5 days to determine how work and leisure noise combine to form a person's overall noise dose. Although the study aims to enrol up to 100 participants, to date only 11 participants have completed the study. Thus the results presented here should be regarded as preliminary and perhaps providing some indication of what might be expected from a larger sample.

METHOD

Eleven volunteers (3 males, 8 females) participated in the study. They were aged between 18 and 35 (mean age: 29.9 years, SD: 3.11) and all worked in quiet office settings. Participants wore dosimeters during all waking hours over a 4- or 5-day test period, which included Friday, Saturday and Sunday. Eight participants measured a 4-day period and 3 participants measured a 5-day period. Across the 11 participants, a total of 47 days of noise exposure was measured: 14 days weekdays (Monday – Thursday) and 33 weekend days (Friday – Sunday).

Throughout the test period participants kept a diary of all activities. They were asked to record the type of activity undertaken, duration of the activity, location, and approximate number of people in the vicinity.

As in Study 1, participants carried calibrated CEL-350 dBadge dosimeters as per the relevant measurement standards [2]. During waking hours, dosimeters were worn at the lapel or as near as possible to the ear. When engaged in vigorous activity such as exercise, participants were advised to place the dosimeter on a non-reverbaratory surface and as close by as practicable. At night when participants slept, dosimeters were turned off and recharged ready for use the next morning. The dosimeters logged sound levels (L_{Aeq}) at 1-minute intervals and at the end of the test period, the data were downloaded using supplied software with ISO protocols [3].

The data were analysed in a 3-step process. First, the daily A-weighted noise exposure level ($E_{A,T}$) was calculated for each of the 47 days. Exposure level, expressed in Pascal squared hours (Pa^2h), is a measure of noise level (L_{Aeq}) over time (T) and is calculated using the formula:

$$E_{A,T} = 4\ T\ 10^{\ 0.1(LAeq\ -\ 100)} \qquad (1)[2]$$

Second, the daily noise exposure levels were compared to workplace noise exposure levels using the method described by Williams et al [14]. The aim of this method is to compare a person's daily (work + leisure) noise exposure to the maximum workplace noise level that society will accept as producing minimum harm. Australia's maximum workplace noise level is one of the most commonly used: a daily exposure level ($L_{Aeq,8h}$) of 85 dB [15]. Although this level does not guarantee no hearing loss in the population, it is considered to represent an 'acceptable' level of risk by legislators and regulators [16]. Conveniently, an $L_{Aeq,8h}$ of 85 dB is equivalent to 1 Pa^2h and hence this exposure level will be referred to as 1 'acceptable daily exposure' (or 1 ADE) [14].

Finally, the noise exposure data were examined to determine if there were any activities or events with an L_{Aeq} greater than 85 dB. The noise sources for these activities and events were

identified by comparing the time-stamped L_{Aeq} data with participants' diaries.

RESULTS AND DISCUSSION

As shown in Table 2, noise exposure on the majority of days (36 out of 47) was less than 1 ADE and there were no events exceeding 85 dB. Noise exposure on a further 5 days was less than 1 ADE, but participants experienced at least one event with an L_{Aeq} greater than 85 dB. Only 6 days yielded noise exposure levels that exceeded 1 ADE and all of these were Fridays, Saturdays or Sundays. Mondays, Tuesdays, Wednesdays and Thursdays were uniformly under 1 ADE.

Table 2. Number of days during which daily noise exposure was greater than or less than 1 ADE

No.	Number of Days				
	< 1ADE 0 events > 85 dB	**< 1 ADE** at least 1 event > 85 dB	**> 1 ADE** (equivalent ADEs)		Σ
1 (M)	3	0	1	(13)	4
2	3	0	1	(12.2)	4
3 (M)	2	1	1	(9)	4
4	2	1	1	(9)	4
5	4	0	1	(7.5)	5
6 (M)	2	1	1	(3.2)	4
7	4	1	0		5
8	3	1	0		4
9	4	0	0		4
10	4	0	0		4
11	5	0	0		5
Σ	**36**	**5**	**6**		**47**

Although there were only 6 instances of days exceeding 1 ADE, most of these days were well in excess of a working week's acceptable noise exposure (i.e., 5 ADE). The highest recorded ADE was 13 which is equivalent to almost 3 weeks acceptable occupational noise exposure. This level of leisure noise exposure, if repeated regularly over several years, would accumulate to a level that one might expect to see in someone who has been exposed to significant sustained workplace noise over a lifetime. This is despite the fact that this particular person has very low levels of occupational noise (his weekday ADEs were 0.09 and 0.07 respectively).

Interestingly, although there were only 3 males in the study, all of them recorded an ADE greater than 1. Obviously, the participant numbers reported here are too small to draw conclusions, but it may be worthwhile to consider the effect of gender on a larger sample size to determine whether excessive noise exposure is more prevalent among young males.

Sources of Noise

Comparing the noise data with the diary records revealed 11 days during which there was an event greater than 85 dB. Five participants experienced 1 event greater than 85 dB and 3 experienced 2 or more events greater than 85 dB. Examination of diaries showed that pubs, a cafe, a street parade, music festival and dragon boats were responsible for these noise levels. See Table 3.

Dragon boats had not previously been considered as a noisy activity and were therefore not included in Study 1 so it is not possible to say whether the level obtained here is typical or not. Furthermore, at the time of recording, the dosimeter was located close to the coach, who was yelling, so this noise level may be artificially high. The other noisy activities: pubs with and without live music, a cafe, street parade and music festival were included in Study 1 and hence it was possible to compare the actual L_{Aeq} measures obtained in Study 2 with the mean levels of Study 1.

Music festivals and pubs with live music fall in the High noise category in Study 1 and therefore it was not surprising to find that these 2 activities featured in the group of 85+ dB activities. The music festival attended by participant 2 had an L_{Aeq} of 96.7 dB which was at the upper end of the range reported in Study 1. Similarly, participant 4's night at a pub with a live band was at 90.2 dB, which compares well with the mean level reported in Study 1 (93.4 dB).

Although we might have expected that all events greater than 85 dB would be drawn from the High noise group, 3 activities from the Mid- and Low-range noise groups also featured, i.e., street parade, pubs without live music, and a cafe. The street parade attended by participant 1 had an L_{Aeq} of 99.7 dB. This level is considerably higher than the 3 street parades measured in Study 1 (range: 80.4 – 84.9 dB). The street parade attended by participant 1 was the Sydney Gay and Lesbian Mardi Gras, a major international event, comprising around 10,000 participants, and 135 floats, most of which play amplified music [17]. Therefore, it is most likely one of the noisiest street parades staged in Australia each year.

Table 3. Activities and events with a noise level > 85 dB

No.	Sources of Noise			
	Event > 85 dB (< 1 ADE)	L_{Aeq} (hr:min)	Event > 85 dB (> 1 ADE)	L_{Aeq} (hr:min)
1 (M)	-	-	street parade	99.7 (3:00)
2	-	-	music festival	96.7 (6:29)
3 (M)	cafe	87.5 (1:40)	pub 1	102.2 (1:45)
			pub 2	88 (3:07)
4	live band at pub	90.2 (0:23)	live band at pub	97.6 (3:53)
5	-	-	dragon boats	99.2 (2:14)
6 (M)	pub	85.7 (5:41)	pub	94.8 (2:18)
7	bar	86.8 (1:23)	-	-
8	pub	91.7 (0:52)	-	-

There were 6 instances of pubs or bars without live music that reached levels greater than 85 dB. Although in Study 1 this activity was classified as Mid-range, with a mean L_{Aeq} of 83.8 dB and a range of 71.2 – 96.3 dB, in Study 2 pub and bar noise was close to and beyond the upper limit on 2 occasions: participant 6: 94.8 dB and participant 3: 102.2 dB. Both of these measurements occurred on weekends late at night (11:46pm and 11:13pm respectively). This suggests that noise levels vary according to both day and time. If a database of 'typical' exposures is to be useful, noise levels for certain activites may need to be categorised in terms of day of week and time of day. To test the effect of weekday versus weekend, we decided to re-examine the noise levels measured for pubs in Study 1. The measurements were split into 2 groups: those recorded between Monday and Thursday (weekdays) and those recorded on Friday, Saturday or Sun-

day (weekends). We found that the average noise level for pubs on weekdays was 79.9 dB whereas the average noise level on weekends was 85.2 dB. Furthermore, the 5 highest L_{Aeq} pub measurements in the Study 1 database (ranging from 90.8 to 96.3 dB) were recorded on a Friday, Saturday or Sunday.

To test the effect of time of day, we categorised the measurements for pubs into 2 groups: those that started before 9pm and those that started after 9pm. We found that the pre-9pm noise levels at pubs averaged 82.5 dB and the post-9pm levels averaged 90.2 dB. In addition, 3 of the 5 highest L_{Aeq} pub measurements were recorded after 9pm. Thus, both day and time affect noise exposure levels at pubs and these factors should be taken into account when determining typical noise levels for this activity.

Duration of Noise Exposure

An interesting feature of the results listed in Table 3 is how they can be used to illustrate that risk from noise exposure is a combination of both duration *and* noise level. For example, consider participant 6. He was at a pub for almost 6 hours where the L_{Aeq} was 85.7 dB and yet, his ADE for that day did not exceed 1. Participant 8 was at a pub with a much higher noise level (91.7 dB) but was there for less than an hour and her ADE was also less than 1. However, when both the noise level and duration are high, then the overall noise exposure is pushed beyond 1 ADE, sometimes significantly so. For example, participant 1 at the street parade (99.7 dB for 3 hours) received 13 ADEs as a result of this activity. Similarly, participant 2 at the music festival (96.7 dB for 2.5 hours) received 12.2 ADEs. Thus, rather than focussing solely on noise levels, it is important to refer to both noise level and duration when assessing the potential risk from noise exposure.

FUTURE DIRECTIONS

Both studies reported here are ongoing. In Study 1, more event measurements are planned with the aim of collecting noise readings from less well-known leisure activities, such as dragon boat racing, which may pose a hearing health risk. We also aim to broaden the range of measurements for popular activities such as pubs, to ensure that the averages extracted from the database are representative of weekend versus weekday exposure, and different times of day.

For Study 2, more participants will be recruited to complete 5-day noise exposure measurements. Once this data set is complete, statistical analyses will be undertaken to ascertain if age, gender, occupation or other factors significantly influence a person's noise exposure.

A further extension of this work will be the development of lifetime noise profiles. That is, how many people undertake noisy activities, how often, and for how many years? This participation data is critical because it will provide information about how people's noise exposure changes over time, and it will allow us to predict whether this accumulated exposure will be sufficient to affect hearing health later in life. Some information about leisure participation is available from (mostly government-sponsored) time-use surveys. For example, we know that in Australia in 2002-2003, there were 91 music festivals of at least three days duration, attended by 748,000 people [18]. In 2005/2006, around 4 million Australians attended at least one pop concert, while 1.5 million attended at least one classical music concert [19]. On the other hand, there is little publicly available data regarding nightclub and pub patronage. Thus, a comprehensive survey of leisure time activities and how these change through the lifetime is needed.

CONCLUSIONS

The preliminary results of these 2 studies provide an insight into leisure noise levels and their potential to impact upon overall noise exposure. Study 1 shows that although some leisure activities can be regarded as safe, others must be considered to pose a potential risk to hearing health. In particular, many nightclubs, popular music concerts, live music events at bars and pubs, and music festivals, emit high noise levels. These events are similar in that they all involve music, almost always involve dancing; and certainly the vast majority, if not all, patrons would attend these events expecting to hear loud music.

Study 2 shows that if leisure activities are loud enough and undertaken for long enough, they can generate noise exposure levels many times higher than the accepted daily workplace noise limit. Thus, for some young people, their weekend leisure noise may produce just as much risk as occupational noise does for others.

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