

**The NOISE (Non-Occupational Incidents Situations and Events) Database:**

**A new research tool**

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## **ABSTRACT**

This paper describes the development of the NOISE (Non-Occupational Incidents Situations and Events) Database. The NOISE database currently contains 536 separate leisure activities and events, including noise level measurements, ( $L_{Aeq}$  and  $L_{Cpeak}$ ), and detailed information about the circumstances of each event. The data are organised into seven categories, in which high-noise events and activities can be identified. Thirty-five percent of events in the database were over 85 dB (the level at which noise is considered a risk according to workplace standards) and 3% were over 100 dB. Fourteen percent of events exceeded the acceptable workplace noise exposure limit of  $1.01 \text{ Pa}^2\text{h}$ . The noise exposure levels recorded in the database can be used to identify high-risk leisure activities and to estimate individuals' leisure noise exposures and make comparisons between leisure and workplace noise exposures.

Over the past 20-30 years, leisure (or non-occupational) noise has emerged as one of the key focus areas for noise exposure and hearing loss prevention research. The National Acoustic Laboratories (NAL), in Sydney, Australia and other research centres have been investigating the relative contribution of leisure noise to overall noise exposure to determine the risks afforded by this noise either in conjunction with, or independently of, occupational sources of noise (Beach et al. 2013b; Clark, 1991; Diaz and Pedrero, 2006; Jokitulppo et al. 1997; Williams et al. 2010). These studies suggest that noise exposure from certain leisure activities poses a significant threat to the hearing of a proportion of the population, with some groups showing particularly high risk levels (e.g., young adults, recreational shooters) because their overall noise exposure exceeds accepted workplace noise levels. In Australia and many other countries the acceptable workplace noise level is 85 dB continuous equivalent noise level ( $L_{Aeq}$ ) over 8 hours, with an “exchange rate” of 3 dB. The exchange rate means that for every 3 dB increase in  $L_{Aeq}$ , time of exposure must be halved (i.e., for 88 dB  $L_{Aeq}$ , the maximum exposure time is 4 hours etc) (Standards Australia 2005). Workers exposed to noise that exceeds this standard are at risk of hearing loss and employers are obliged to mitigate the risk by reducing noise levels time spent in noisy environments, or providing hearing protection.

Noise-related hearing loss results in a wide range of difficulties for the sufferer, including reduced overall audibility, inability to hear particular speech sounds, reduced dynamic range impaired sound localisation, and difficulty separating sounds. These problems make it particularly difficult for people with hearing loss to hear in noise, which can have negative impacts on their social relationships, learning and employment outcomes. In addition to the risk of hearing loss and its associated effects, high noise exposure levels have a range of other effects on human health and wellbeing. Negative effects include sleep disturbance, raised blood pressure, and increased stress levels (Fyhri and Aasvang, 2010; Babisch, 2000). But loud noise, particularly music, can also be a source of arousal, pleasure, and motivation

(Blessner, 2007; Karageorghis and Terry, 1997). Such effects are of particular relevance to leisure studies because they can significantly influence participation in leisure activities. For example, if patrons feel motivated by the high noise level experienced during a fitness class, they may be more likely to attend such classes in the future. However, if other patrons find these same noise levels annoying or stressful, then enjoyment and future participation is less likely (Edworthy and Waring, 2006). Similarly, noise levels in entertainment venues can either enhance or impede individuals' enjoyment of leisure events, and in turn, influence the amount of time (and money) spent in those environments. Thus, leisure-related noise levels are of interest, not only to researchers in the field of hearing, but also leisure.

Studies of leisure noise exposure often report noise levels for specific types of events and activities, such as motor racing events (Kardou and Morata, 2010); nightclubs (Goggin et al. 2008); and hockey games (Hodgetts and Liu, 2006). Many of these noise levels have been collected into a database known as the Noise Navigator<sup>TM</sup> database (Berger et al. 2010). Noise Navigator<sup>TM</sup>, compiled in 2007 and updated regularly since then, draws together more than 1700 occupational and non-occupational noise levels. Some of its noise levels are from published sources (some from as early as 1971), and others are the authors' own measurements. While this is undoubtedly a valuable resource, the amount of detail varies considerably between entries and there is substantial variation in the measurement methods and reported noise parameters for each entry. This lack of uniformity makes it difficult to make comparisons and draw conclusions about the relative noise levels of the different activities.

To address the need for a large, consistent dataset of current noise measurements from non-occupational settings, NAL has developed a database of leisure noise measurements. The purpose of the database is to i) collect examples of non-occupational activities and events, and identify which of these pose a risk to hearing health, and ii) provide reliable average

measures for a wide range of leisure activities which could subsequently be used to estimate individuals' noise exposures in the absence of actual noise measurements (obtained using dosimeters and sound levels meters), and to explore the relationship between noise exposure and leisure participation patterns. This article describes the development of the database, its content, and organisational structure.

## **METHOD**

### **Participants**

Since 2008 noise measurements have been undertaken by the three authors and numerous other volunteers, employed by or associated with NAL or NAL's parent body, Australian Hearing. Most measurements have occurred in Sydney, Australia, although a small number have occurred in other parts of Australia and abroad.

### **Materials**

For each measurement, participants wore calibrated CEL-350 dBadge personal sound exposure meters (Casella-CEL, Bedford, United Kingdom), in accordance with the relevant measurement standards (Standards Australia 2005). Dosimeters were positioned at the lapel or as near as possible to the ear and participants used their discretion to ensure the dosimeters were unobtrusive so as not to attract attention. The dosimeters logged the average A-weighted<sup>1</sup> sound levels ( $L_{Aeq}$ ) and the maximum C-weighted<sup>2</sup> peak sound level ( $L_{Cpeak}$ ) between 65 and 140 dB at one-minute intervals over the measurement period. The data were later downloaded for analysis using software complying with international standards and protocols (ISO 1999, 1990).

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<sup>1</sup> The A-weighting on a sound level measurement applies a 'human' listening characteristic to the instrument taking the measurement

<sup>2</sup> The C-weighting on a sound level measurement applies a relatively flat frequency response across the frequency spectrum, and therefore includes more low-frequency information than A-weighted measurements.

## Procedure

When each measurement was downloaded, the  $L_{Aeq}$  output chart was assigned a record identification number and annotated with a set of standardised relevant details, such as noise sources, and the location of the wearer/dosimeter. For example, the output graph shown in Figure 1, shows an individual's noise exposure at a football match, including travel to and from the venue, waiting for entry and entertainment by a band. In many cases, additional written information about the circumstances of the measurement was provided by the participant and these records were retained under the relevant record identification number.

----- **Insert Figure 1 about here** -----

Each measurement was then entered into a custom-designed Microsoft Access database by the first author. For each measurement the following standard details were recorded: record identification number; serial number of dosimeter; date of measurement; day of week; the start and end times; wearer's name, age, gender, and postcode (where available); the file location of the original data download; overall  $L_{Aeq}$ ; and a short description of the measurement.

Some measurements contained a single event only (e.g., a music concert from start to finish) whereas other measurements contained multiple events (e.g., a train trip, followed by dinner at a restaurant, followed by a movie). To manage this situation, each measurement was linked to one or more 'events' depending on the number of events contained within the measurement period.

Events were defined according to seven broad categories: attendance at entertainment venues; arts and cultural activities; attendance at sports venues; active recreation and sport; travel; domestic activities; and other. Each event was then also allocated an appropriate subcategory from a defined list (as shown in Table 1). Where possible, the sub-categories were sourced

from existing lists used by Australian government agencies in large-scale research surveys and compilation of national statistics. For category two, twelve of the 18 sub-categories were from the Arts and Culture classifications developed by the Australian Bureau of Statistics (2009). For categories three and four, all but six of the sub-categories were from the *Exercise, Recreation and Sport Survey* developed by the Australian Sports Commission (2010). For category five, all sub-categories were from a list developed by the Bureau of Infrastructure, Transport and Regional Economics (2009). For categories one, six and seven, there were no suitable lists available so the sub-categories were compiled by the authors to accommodate the noise measurements collected thus far.

As an example, for the multiple-event measurement described above, three events were recorded and allocated the following categories and sub-categories:

1. Train trip (category five: travel / sub-category: rail);
2. Restaurant (category one: attendance at entertainment venues / sub-category: restaurants);
3. Movie (category two: arts and cultural activities / sub-category: movies, cinemas).

**----- Insert Table 1 about here -----**

For each event, the following details were recorded: Start and end time, duration,  $L_{Aeq}$ , and  $L_{Cpeak}$ . These parameters were measured directly from the graphed results by positioning cursors at the start and end of the particular event. The event's location (city, regional or rural), whether it was inside or outside; its degree of completeness (complete, partial or sample); the venue size; the wearer's distance from the noise source; the estimated or actual crowd size; furnishings (soft, hard, or mixed); seat location (where relevant); number of band members (where applicable); and the source of any recorded music (if known) were also recorded. In addition, each event was coded according to whether: the event involved live or

recorded music; the live music was acoustic or amplified; there was a DJ; the event was child-oriented; and the participant had worn earplugs.

Depending on the category of each event, additional information was recorded as shown in Table 2. Any further information about events not covered by the fields described above was recorded under a miscellaneous ‘Notes’ field.

----- **Insert Table 2 about here** -----

To calculate the noise exposure for each event, the formula,  $\text{Exposure} = E_{A,T} = 4 \times T \times 10^{0.1(L_{Aeq}-100)} \text{ Pa}^2\text{h}$ , (Standards Australia, 2005) was used to automatically calculate the Pascal squared hours ( $\text{Pa}^2\text{h}$ ) of each event and this figure was stored with the event details. The acceptable daily noise exposure limit of 85 dB over 8 hours is equivalent to 1.01  $\text{Pa}^2\text{h}$ . Similarly, 88 dB over 4 hours = 1.01  $\text{Pa}^2\text{h}$ , 91 dB over 2 hours = 1.01  $\text{Pa}^2\text{h}$  and so on. Thus, any exposures exceeding the workplace noise limit could be easily identified.

A reporting function was developed to allow the user to extract data according to category, sub-category, date, dosimeter wearer, or dosimeter serial number. The data records can then be sorted and/or exported to a spreadsheet program for further analysis.

## **RESULTS**

To date, the NOISE database contains 436 measurements, comprising 536 individual events. A summary of the main noise parameters of the 536 events is shown in Table 3. The loudest activities were from categories one and two: attendance at entertainment venues, and arts and cultural activities. Category three, attendance at sports events, recorded the highest average noise level (89.3 dB), and category five, travel, the lowest (77.4 dB).

----- **Insert Table 3 about here** -----



Overall, 35% of the events were over 85 dB and 3% were over 100 dB. The activities with noise levels greater than 100 dB were mostly music-related: nightclubs, popular music concerts, live gigs, and performing music. A rugby league football match also exceeded 100 dB. Details of the events in each category and the noise exposure associated with the events are provided below.

### **Category 1: Attendance at Entertainment Venues.**

The most common sub-category was *pubs and bars* (n=43). *Restaurants* (n=32); *community events*, such as street parades and markets (n=18); and *nightclubs* (n=14) were also well represented. There were four sub-categories with average noise levels greater than 85 dB: *nightclubs* (mean: 95.7 dB); *discos* (mean = 90.7 dB); *parties* (mean = 89.5 dB); and *dinner dance events* (mean = 89 dB). The two events which yielded the highest exposures were visits to inner-city nightclubs late at night where the noise levels were 105.7 dB for 31 minutes, and 104 dB for 36 minutes. Although the duration of the events was quite short, the high noise levels resulted in very high exposure doses of 6.2 Pa<sup>2</sup>h and 7.9 Pa<sup>2</sup>h respectively.

### **Category 2: Arts and Cultural Activities**

The most common event types were *popular music concerts* (n=21); *performing - instrumental or voice* (n=19); and *movies, cinemas* (n=15). The noisiest sub-categories (all averaging greater than 85 dB) were *gigs, live music performances* (mean = 95.5 dB); *performing - instrumental or voice* (mean = 94.5 dB); *popular music concerts* (mean = 94.4 dB); *music festivals* (mean = 91.8 dB); and *other performing arts* such as comedy, variety etc (mean = 89.8 dB). There were three events which yielded exceedingly high exposures. These were all 'heavy metal' concerts of between 119 and 139 minutes duration. One concert was

held indoors and delivered a noise exposure dose of 22.7 Pa<sup>2</sup>h. The other two were held at a large football stadium and the doses were 23.4 and 26.8 Pa<sup>2</sup>h respectively.

### **Category 3: Attendance at Sports Venues**

The most common event type was *Australian Rules football* matches (n=8), and most sub-categories averaged above 85 dB. In order of noise level, these were: *motor sports* (mean = 92.6 dB); *rugby league* (mean = 96.9 dB); *soccer* (mean = 88.3 dB); *Australian Rules football* (mean = 87.8 dB); *rugby union* (mean = 87.4 dB); and *cricket* (mean = 86.9 dB). Not surprisingly, the two events which yielded the highest exposures were a MotoGP event at 96.2 dB over 275 minutes (7.6 Pa<sup>2</sup>h) and a rugby league football match at 100.2 dB over 126 minutes (8.8 Pa<sup>2</sup>h).

### **Category 4: Active recreation and sport**

*Aerobics/fitness* was the most common activity (n=17). It was also the noisiest activity (mean = 86.2 dB), and the activity with the highest noise exposures. ‘Spin’ classes at different fitness studios were measured at 97.1 dB for 49 minutes and 92.4 dB for 51 minutes which exposed the participants to a noise dose of 1.7 Pa<sup>2</sup>h and .6 Pa<sup>2</sup>h respectively. Also included in Category 4 was the activity *shooting sports*, which is a particularly loud recreational pursuit. Because shooting firearms produces impulse rather than continuous noise, it is inappropriate to measure noise exposure while shooting in Pa<sup>2</sup>h. Instead, the L<sub>Cpeak</sub> parameter is examined to see whether this exceeds 140 dB, which is the workplace maximum for impulse noise. Of the four examples of shooting sports in the NOISE database, all exceeded the 140 dB maximum L<sub>Cpeak</sub> level.

### **Category 5: Travel**

The most common travel modes were *cars and light commercial vehicles* (n = 25) and *Air* (n = 24). The noisiest sub-category was *motorcycles* (mean = 87.3 dB). All other sub-categories averaged below 85 dB. There were two particularly noisy motorcycle trips: a 188-minute ride at 96.2 dB exposed the rider to 3.3 Pa<sup>2</sup>h and a 94-minute ride at 93.5 dB that exposed the rider to 1.4 Pa<sup>2</sup>h.

### **Category 6: Domestic Activities**

The most common domestic activities were *cleaning* (n = 5) and *yardwork* (n = 4). The noisiest sub-category was *yardwork* (mean = 89.3 dB). The other sub-categories averaged below 85 dB. The noisiest domestic activity was 30 minutes of chainsawing at 99.6 dB, exposing the operator to 1.8 Pa<sup>2</sup>h.

### **Category 7: Other**

*Church* was the most common activity (n = 10) and it was also the noisiest (mean = 80.8 dB). There were no notably noisy activities in Category 7 and no activities were above 85 dB.

## **DISCUSSION**

The NOISE database provides a detailed and standardised record of non-occupational leisure events. Of the 536 events in the database, 35% were over 85 dB and 3% were over 100 dB, and the majority of these were music-related events. Fourteen percent of events exceeded the acceptable workplace noise exposure limit of 1.01 Pa<sup>2</sup>h. The information contained in the database can be used by researchers to identify high-risk leisure activities and to estimate noise exposures from simple questions posed during leisure participation surveys. In fact, measurements from this database have already been used in studies as a means of estimating individual noise exposures from participation in particular leisure activities, such as nightclubs, sporting events, and fitness classes (Beach et al. 2013a; 2013b; Williams et al.

2010). These data were also used recently as part of a large, nationwide, online survey, Sound Check Australia (Australian Broadcasting Commission, 2012), to provide personalised estimates of noise exposure for survey respondents who provided information about their participation in a range of leisure activities.

Access to reliable noise exposure estimates will allow researchers to examine any correlation(s) that may exist between noise exposure levels and hearing health; incidence of hearing loss and tinnitus; or other general health effects such as sleep disturbance, raised blood pressure and increased stress (Department of Health and Ageing, 2004). Similarly, the NOISE database will provide leisure researchers with a current inventory of typical noise levels for a wide range of leisure activities, which can inform research into the effects of noise level on leisure participation patterns, individual performance during leisure activities, and attitudes of participants towards leisure activities.

### **Future Directions**

As further data is gathered the NOISE database will continue to grow. Gaps will be filled and additional measurements will be added in categories and sub-categories where data is sparse. Additional measurements which have been collected as part of other NAL studies will be added to the database. Other researchers will also be invited to contribute to the database by submitting information on activities and events which have been measured using the same procedures. Incorporating such additional data into the NOISE database has the potential to boost its international relevance and maximise its utility and up-to-the minute relevance for researchers in the field of hearing conservation.

The authors intend to further develop the NOISE database as a searchable online resource for members of the public and other researchers to interrogate in order to obtain average measurements. Until this occurs, researchers will be able to request noise level measurements

from specific categories or sub-categories via email, and a detailed spreadsheet containing the requested data will be provided.

The data contained in the NOISE database has the potential to be used in educational and hearing loss prevention material. For example, the noise data could be used in smartphone apps or online tools whose aim is to provide users with ‘real’ information about potentially risky high-noise activities and events. Users could provide details of their participation in certain leisure activities and receive a ‘risk score’ or ‘noise dose’ derived from the noise levels contained in the NOISE database.

## **Conclusion**

The NOISE database is a valuable new resource for hearing and leisure researchers and health promotion professionals who require an up-to-date realistic estimation of the noise exposure experienced at non-work and leisure activities. Members of the public seeking ‘real’ information about noise levels of leisure events and activities can also be directed to this database. In future, expansion of the database and electronic availability will ensure the database’s ongoing utility and relevance for all who use it.

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**Table 1: Database categories and subcategories.**

	Category	No. of subcategories	Subcategories
1	Attendance at entertainment venues	15	cafes, coffee shops; casinos; community events; dinner dance events; food courts; karaoke venues; nightclubs or dance clubs; parties; pubs and bars; registered clubs; restaurants; shopping centres; theme parks; video arcades; discos.
2	Arts and cultural activities	18	art galleries; botanic gardens; classical music concerts; dance performances; gigs, live music performances; libraries; movies, cinemas; museums; musicals and operas; other performing arts; popular music concerts; theatre performances; zoos or aquariums; music festival; amateur performing arts: live music; amateur performing arts: no live music; performing - instrumental or voice; performing – other.
3	Attendance at sports venues	53	aerobics/fitness; aquarobics; athletics/track and field; Australian Rules football; badminton; baseball; basketball; boxing; canoeing/kayaking; carpet bowls; cricket (indoor); cricket (outdoor); cycling; dancing; darts; equestrian activities; fishing; golf; hockey (indoor); hockey (outdoor); ice/snow sports; lawn bowls; martial arts; motor sports; netball; rock climbing; roller sports; rowing; rugby league; rugby union; running;

			sailing; scuba diving; shooting sports; soccer (indoor); soccer (outdoor); softball; squash/racquetball; surf sports; swimming; table tennis; tennis; tenpin bowling; touch football; triathlons; volleyball (indoor); volleyball (beach); walking (bush); walking (other); water skiing/powerboating; weight training; yoga; opening/closing ceremony.
4	Active recreation and sport	55	aerobics/fitness; aquarobics; athletics/track and field; Australian Rules football; badminton; baseball; basketball; boxing; canoeing/kayaking; carpet bowls; cricket (indoor); cricket (outdoor); cycling; dancing; darts; equestrian activities; fishing; golf; hang-gliding; hockey (indoor); hockey (outdoor); ice/snow sports; lawn bowls; martial arts; motor sports; netball; parachuting; rock climbing; roller sports; rowing; rugby league; rugby union; running; sailing; scuba diving; shooting sports; soccer (indoor); soccer (outdoor); softball; squash/racquetball; surf sports; swimming; table tennis; tennis; tenpin bowling; touch football; triathlons; volleyball (indoor); volleyball (beach); walking (bush); walking (other); waterskiing/powerboating; weight training; playground, indoor or outdoor.
5	Travel	10	cars and light commercial vehicles; trucks; motorcycles; bicycles; light rail; rail; bus; ferry; pedestrian; air

6	Domestic activities	12	power tools; yardwork; cleaning; cooking; personal hygiene; indoor craft, hobbies; home-based gaming; TV; music, radio; general; resting; study.
7	Other	8	conferences and meetings; church; childcare; health & personal hygiene; school events; picnic; school or college (TAFE); youth group activities.

**Table 2: Additional information relating to each category.**

Category	Additional information
1&2	<ul style="list-style-type: none"><li>- Venue</li><li>- Event</li><li>- Performers</li></ul>
3&4	<ul style="list-style-type: none"><li>- Venue</li><li>- Level (amateur or professional)</li><li>- Score</li><li>- Home team win?</li></ul>
5	<ul style="list-style-type: none"><li>- From? and To?</li><li>- Vehicle type</li></ul>
6 & 7	<ul style="list-style-type: none"><li>- Activity</li><li>- Location</li></ul>

**Table 3: Summary of the main noise parameters of the 536 leisure events.**

Category	No. of events	>85 dB	>100 dB	>1.01 Pa <sup>2</sup> h	No. of subcategories	Min L <sub>Aeq</sub> (dB)	Max L <sub>Aeq</sub> (dB)	Median L <sub>Aeq</sub> (dB)	Mean L <sub>Aeq</sub> (dB)
1. Attendance at entertainment venues	165	64	4	21	14/15	66.1	105.7	82.2	83.1
2. Arts and cultural activities	132	72	11	37	16/18	64*	106.6	85.9	86.4
3. Attendance at sports venues	25	20	1	9	8/53	75	100.2	89	89.3
4. Active recreation and sport	59	19	0	5	24/55	64*	99.7	78	79.2
5. Travel	114	8	0	2	9/10	65.1	96.2	76.5	77.4
6. Domestic activities	24	5	0	1	9/12	64*	99.6	79.5	80.1
7. Other	17	0	0	0	6/8	71.6	84.9	79.8	79.5
Total	536	188	16	75					

\*64 dB = baseline value of instrument

**Figure 1: Typical dosimeter output from an evening of activities from 5:26pm to 10:13pm.** The lower trace represents the average noise level ( $L_{Aeq}$ ) at one minute intervals, while the upper trace provides the maximum C-weighted peak level ( $L_{Cpeak}$ ) that occurred during the measurement period.

