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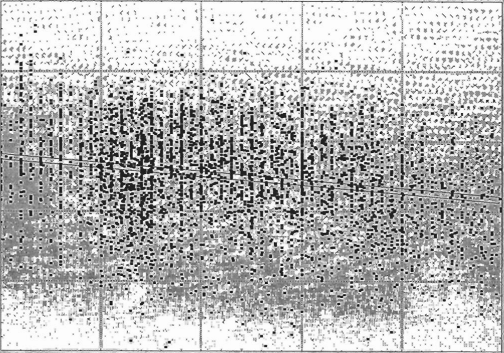

SPECIAL ISSUE: EFFECTS OF NOISE

- Community Reaction
- Effects in Families
- Hearing Loss
- Sleep Disturbance
- Oto-acoustic Emission
- Noise and Animals

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COVER ILLUSTRATION: Distribution of otoacoustic emission strengths over the population as a function of age. See paper by LePage.

From the President

There can be no doubt that noise is a major problem in our communities today. Adrian Davis, of the MRC Institute for Hearing Research, has estimated that in Britain around 15 percent of the population has some degree of hearing loss and, while much of that may be attributed to aging, certainly some significant fraction is due to noise exposure. The 7th International Congress on Noise as a Public Health Problem, being held in Sydney in October, will bring together international experts on many aspects of the problems which noise brings to modern life and the Australian Acoustical Society is proud to have been a supporter of this event. It is appropriate that we should have participated, for one of the roles of this Society is to promote awareness of the harmful effects of noise and to encourage research into methods of measuring, reducing and alleviating its effects.

Australia is a significant player in this research. We have a number of people working on various aspects of noise: its physical, biological and psychological effects, its control in the environment, the measurement and prevention of hearing loss and the basic physiology of hearing. And it is important that we continue such work, for, while some may argue that other countries will do the work if we don't, I argue that it is essential that we do our share. Apart from the direct responsibility of pulling our weight in the new 'globalised community', we gain direct benefits from participating. We need a pool of expertise in this country, a group of people who are well aware of the latest developments and who understand the implications and significance of the biological effects of noise, in order that we may lead the nation in implementing new policy and adopting new practices.

Acoustics Australia is encouraging such research in this special issue, by letting individual Australian researchers explain what they are doing and what impact their work might have in the future. I congratulate the Editorial Committee for their initiative in putting together such an issue and I urge all members of the Australian Acoustical Society to support Australian research by using every opportunity to point out to the public and to politicians just how this research benefits our country.

I also congratulate Dr Norman Carter, chair of the Congress organising committee, for his splendid achievement in bringing the Congress to Australia and for his skill in managing such a complex project.

Graeme Yates

From the Editor

Noise of all sorts – defined quite generally as unwanted information – is becoming increasingly a fact of life. Fortunately we can skip advertisement pages in the newspapers, turn off the television, and refuse to "surf the net." But it is much more difficult to avoid the noise of the neighbours' stereo system, the roar of overflying aircraft, or the relentless pounding of machinery in our workplaces. In a manner that people in other fields might consider parochial, we define noise to mean acoustic noise, and concentrate attention on this!

Most of the effects of noise, from our point of view, are broadly speaking "biological," and we devote this Special Issue of our journal to the Biological Effects of Noise, in recognition of the important ICBEN meeting, Noise Effects 98, to be held in Sydney in a few months' time.

Within the area of biology, we can recognise certain quite distinct types of problems associated with noise. The first class might be called physiological, because they produce effects that can be readily measured and related to changes in the bodies of the humans or animals involved. Some of these changes are directly anatomical, such as the damaging effect of continued extreme noise exposure on the outer hair cells of the cochlea, leading to impaired hearing. Some are indirect, like the complex neurophysiological mechanisms that cause raised blood pressure. In either case, however, those studying the problem have some hope of tracking down the physical chain of events and quantifying them.

Another class of problems belongs to the field of the social sciences. Noise causes sleep disturbance and irritability, and these in turn lead to problems in family and work relationships. The psychological factors involved are much more difficult to isolate, and the chain between cause and effect is much more individual.

Understanding what happens to humans, and indeed other animals, exposed to excessive noise levels is, however, only the first part of the problem. Much more difficult is to decide what can realistically be done about it. Here the clash is between science and economics, and therefore between science and politics. Ignoring the effects of noise is certainly the easy and cheap way to go in the short term, as we discover when we visit some of our developing neighbour countries, but in the long run this is no longer true. When we consider the social and personal costs for the country as a whole, then the reduction of noise should be a national economic priority.

This issue has space to touch upon only a few of these matters, and some of them will be taken up in subsequent issues. We hope that it will sharpen your appetite for more.

Neville Fletcher

COMMUNITY REACTION TO NOISE

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ABSTRACT: Community reaction to noise is an important effect of noise exposure which may harm health. Amelioration of community reaction requires that it be understood. We offer methodological recommendations in order to improve the validity and reliability of the reaction data upon which this understanding is based. Evidence is presented to indicate that reaction is influenced by features of the person hearing the noise and the situation in which the noise is heard, as well as features of the noise itself. Consistent with this claim, the relationship between noise and exposure is found to be stronger when based on grouped rather than individual data. Given the critical influence of human factors (including psychological variables) on whether a sound is perceived as noise, and on the reaction it produces, we argue that development of solutions to the noise problem should not be focused exclusively on noise abatement measures. Psychological approaches to overcoming the noise problem, as well as issues for future research are suggested.

1. INTRODUCTION

The global trends towards larger cities and reduced proportions of populations living in rural settings have concentrated people in more noisy areas. At the same time, industrialisation and transport mechanisation have created substantial increases in noise production. The confluence of these factors has resulted in a substantially increased proportion of the population being exposed to noise from outside sources while in or around their homes. The noise may arise from transportation (motor traffic, aircraft, trains, boats), factories, construction, mining, power plants or electrical transmission lines, wind turbines, music or television, air-conditioning units, or neighbours and their pets.

People may have a range of reactions to this noise, amongst them dissatisfaction, annoyance, anger, frustration, disappointment, and/or distress [1]. These responses to noise are generally known as community reaction. Community reaction is important for three reasons. First, it is one of the undisputed effects of noise generally, and is one of the two undisputed effects of residential noise in particular (the other being sleep disturbance [2,3,4]). Second, it is in its own right a significant factor in human quality of life and health. People who have their daily activities (eg. conversation, listening to music, watching television, reading, sleeping) disturbed, and who are dissatisfied and annoyed, clearly have reduced quality of life. Thus, community reaction constitutes a negative health factor within the World Health Organisation's definition of health (as well-being, not just the absence of disease). Third, community reaction may contribute to other putative effects of noise such as elevated blood pressure [5] and mental health problems such as anxiety and depression [6,7]. Indeed, several studies have identified reaction to noise as a better predictor of several noise-related health effects than is noise exposure itself (eg. anti hypertensive treatment [8]; psychosocial well-being [9]; nervous stomach [10]; and general health ratings [11,12]). While these studies were observational and so do not provide compelling evidence for causality, noise, via the reactions it generates, remains the most likely causal agent (for review see [4]).

This paper reviews socio-acoustic studies of community reaction to noise, focussing on the measurement of reaction to noise, and noise-, person- and situation-related factors which influence reaction. Unresolved issues are identified for future research.

2. THE MEASUREMENT OF REACTION

The measurement of community reaction inevitably relies upon subjective report. Residents must tell us about their reactions. This methodology has difficulties, including the possibility of inaccurate or incomplete recall, as well as response biases. However, since most socio-acoustic surveys refer to the recent past, memory is unlikely to present a problem. Psychological data suggests that people so not lie in surveys [13]. Further, whilst people may be motivated to give inaccurate reports of their reaction, this may be minimised with appropriate questionnaire construction (eg. see point 3 below), and by stressing the importance of accuracy to respondents. Many response biases can be also controlled with considered questionnaire construction. The quality of the data collected in studies of community reaction may be improved through a number of specific methodological refinements:

1. Ensuring random sampling of households and of residents within households, to provide an unbiased sample.
2. Minimising refusal rate through the use of experienced interviewers [14] and payment of incentives for participation [15, 16].
3. Not revealing the focus of the survey on reactions to noise until at least one critical reaction question has been asked, hidden among questions on other aspects of the neighbourhood [17,18,19,20].
4. Using several questions to assess reaction, rather than a single question, in order to improve reliability [14,21,22]. When several questions are used the measure is not as susceptible to random fluctuations in response and is thus more reliable.

5. Employing the best questions for a valid and reliable measure of reaction. Reaction to noise has typically been assessed in terms of "annoyance". However, there are many possible reactions to noise besides annoyance: for example, anxiety, distraction, exhaustion, anger, frustration, disappointment and fear. Empirical data indicate that overall reaction to noise is captured better by a general scale of reaction (involving questions such as "how much are you affected by [noise]" and "rate your dissatisfaction with [noise]") than by simple annoyance measures [23,1]. Thus, these general questions appear to be more valid measures of reaction. They have also been shown to be more reliable both with respect to internal consistency and stability. Internal consistency refers to the extent to which the questions within one measure tap the same underlying variable; responses to general reaction questions have been shown to be more consistent with each other than are responses to annoyance questions (for review see [24]). Stability (or test-retest reliability) refers to the extent to which questions tap the same variable from one measurement occasion to the next; responses to general reaction questions are more similar across time than are responses to annoyance questions [24]. Thus, socio-acoustic surveys would benefit from the measurement of general reaction to noise in addition to measurement specifically of annoyance with noise.

3. FACTORS WHICH INFLUENCE REACTION

Many factors have been identified as influencing reaction. It should be noted that often these factors have only been identified in observational (usually correlational) studies, which thus do not identify the direction of causality. However, in many instances some causal accounts can be eliminated. For example, because the weak relationship between gender and reaction could not arise from the noise influencing gender, it is taken to indicate that gender influences reported reaction, although the mechanism of such an effect is not obvious. In other instances, laboratory studies suggest the causal sequence [2,4] or the nature of the observational data suggest an interpretation [25].

Features of the noise itself which influence reaction to noise include: the noise energy level, with greater energy associated with greater reaction [21,26]; the number of events, with more events influencing reaction above and beyond total noise energy exposure [27,28]; the frequency distribution of the noise, with lower frequency leading to more reaction [29]; tonality, with more pure tone components causing more reaction [2]; impulsivity, with more impulsive noise causing considerably more reaction (an effect equal to 20-30dB [28]); changes in noise exposure, which yield the exaggerated changes of greatly reduced reaction when the noise exposure drops and over-reaction when the noise exposure increases [30,31].

Features of the person hearing the noise also influence reaction: more negative attitudes to the noise source are associated with more reaction [2,21]; more noise sensitive residents show more reaction [2,21]; those who own their own home show perhaps slightly more reaction [21]; expectations of the level of future noise influence reaction, with those expecting an increase in noise showing more reaction [32]. Personality influences reaction [2] often in a manner consistent with the health risks of different personality types

TABLE 1: Correlation (r) of noise and reaction based on individual (ind) versus grouped (grp) data for a range of noise sources studied in several countries.

STUDY	COUNTRY	NOISE SOURCE	SAMPLE SIZE	r (ind)	r (grp)
Baugham & Huddart (1993), NPHP	U.K.	Road			0.94
Bertoni et al (1993), NPHP	Italy	Road	908	0.67	
Bjorkman & Rylander (1993), NPHP	Sweden	Road	918		0.77
Borsky (1983), NPHP	U.S.A.	Aircraft	942	0.58	
Bottom (1971), JSV	U.K.	Aircraft/Road	315		0.96
Bradley (1992), JASA	Canada	Air-conditioner	550	0.19	0.99
Bradley (1983), Internoise	Canada	Neighbourhood	98	0.35	
Bradley (1978), NPHP	Canada	Road	1150	0.50	0.85
Bradley & Jonah (1979), JSV	Canada	Road	300	0.49	
Brown (1978), Aust. Road Research Board Rpt.	Australia	Road	818	0.27	0.79
Buchta (1990), JASA	Germany	Rifle range	392	0.44	0.90
Buchta (1990), JASA	Germany	Road	322	0.70	0.91
Bullen et al (1986), JSV					
Hede & Bullen (1982), NAL Rpt.	Australia	Aircraft	3575	0.36	0.84
Bullen et al (1991), NCE					
Job et al. (1991), Internoise	Australia	Artillery	1626	0.22	0.57
Cook et al (1994), NAL Rpt.	Australia	Artillery	231	0.44	
Cook et al (1994), NAL Rpt.	Australia	Artillery	54	0.66	
Cook et al (1994), NAL Rpt.	Australia	Artillery	56	0.72	
Cops et al (1978), Internoise	Belgium	Road	1800	0.86	
Dankittikul et al (1993), NPHP	Japan	Road	96	0.49	
Dankittikul et al (1993), NPHP	Thailand	Road	138	0.40	
Dankittikul et al (1993), NPHP	Thailand	Road	94	0.23	
Diamond & Walker (1986), Internoise	U.K.	Aircraft			0.82
Dixit & Reburn (1980), Internoise	Canada	Railyard	523		0.71
Fidell (1978), JASA	U.S.A	Urban	2037		0.70
Fidell et al (1983), JASA	U.S.A.	Quarry blast	992		0.66
Fields & Powell (1987), JASA	U.S.A.	Aircraft	330	0.20	0.95
Fields & Walker (1982), JSV	U.K.	Railway	1453	0.46	
Foreman et al (1974), JSV	Canada	Neighbourhood			0.91
Gambart (1981), Psychologia Belgica	Belgium	Road	617	0.48	

Gambart et al (1976), Applied Acoustics	Belgium	Road	247	0.61	0.94
Garcia (1983), Internoise	Spain	Road	430		0.56
Garcia et al (1993), JSV	Spain	Aircraft	1800	0.30	0.92
Gjestland et al (1990), Rpt. ST4 40 A90189	Norway	Aircraft	1554	0.37	
Graeven (1974), J. Health & Soc. Behav.	U.S.A.	Aircraft	552		0.40
Grandjean et al (1973), NPHP	Switzerland	Aircraft	3939	0.59	0.95
Grandjean et al (1973), NPHP	Switzerland	Road	944	0.43	
Griffiths & Langdon (1968), JSV	U.K.	Road	1000	0.29	0.88
Griffiths et al (1980), JSV	U.K.	Road	222	0.44	0.86
Groeneveld (1981), Internoise	Netherlands	Industrial	597	0.35	
Hall et al (1979) [book: McMaster University]	Canada	Aircraft (commercial)	673		0.68
Hall et al (1979) [book: McMaster University]	Canada	Aircraft (general)	292		0.84
Hall et al (1979) [book: McMaster University]	Canada	Road	292		0.56
Hall et al (1978) , Internoise	Canada	Road			0.89
Hall et al (1983), Internoise	Canada	Aircraft		0.31	
Hall & Taylor (1977), JSV	Canada	Road		0.92	
Hede & Bullen (1982), JSV	Australia	Rifle range	201	0.29	0.95
Hiramatsu et al. (1987), Internoise	Japan	Aircraft	6080		0.94
Job et al. (1991), Internoise	Australia	Aircraft (military)	624	0.58	
Job & Hede (1989), Internoise	Australia	Power station	301	0.49	
Kamperman (1980), Internoise	U.S.A.	Sonic boom	2000		0.96
Ko et al (1976), JSV	Hong Kong	Aircraft	552		0.80
Ko et al (1976), JSV	Hong Kong	Road	552		0.72
Kono & Sone (1988), JSV	Japan	Road	147	0.70	
Kurra (1983), Internoise	Turkey	Road	525		0.86
Langdon (1976), JSV	U.K.	Road	1359	0.21	0.85
Langdon et al (1983), JSV	U.K.	Neighbour	709	0.24	0.36
Langdon et al (1981), JSV	U.K.	Neighbour	917	0.40	0.84
Large & Ludlow (1975), Internoise	U.K.	Construction	535	0.52	
Large & Ludlow (1975), Internoise	U.K.	Road	535	0.38	
Lercher & Widmann (1993), NPHP	Austria	Road	1966	0.27	0.92
Lopez-Barrio & Carles (1993), NPHP	Spain	Road	800	0.30	
May (1972), JSV	Germany	Sonic boom		0.39	
May (1971), JSV	U.K.	Sonic boom	14	0.62	
McKennell(1978), NPHP	U.K	Aircraft		0.26	
McKennell(1963/73), NPHP	U.K.	Aircraft	1731	0.46	0.99
MIL Research (1971), Her Majesty's Statnry Off.	U.K.	Aircraft	4699	0.40	
Moehler & Knall (1983), Internosie	Germany	Railway	525		0.94
Moehler & Knall (1983), Internosie	Germany	Road	525		0.66
Murray & Avery (1984), Wilkinson-Murray Rpt.	Australia	Quarry blast	170	0.29	0.89
Nemecek et al (1981), JSV	Switzerland	Road		0.49	0.93
Nivison & Endresen (1993), J. Behav. Med.	Norway	Road	82	n.s.	
Oehrstrom (1993), NPHP	Australia	Rifle range	309	0.06	
Oehrstrom (1993), NPHP	Sweden	Road	434		0.90
Persson & Rylander (1993), NPHP	Sweden	Home	93		0.91
Putra & Lawrence (1991), Internoise	Australia	Road	426	0.55	
Rohrmann et al (1973), NPHP	Germany	Aircraft	660	0.58	
Rylander et al (1993), NPHP	Sweden	Artillery	1483		0.52
Rylander et al (1980), JSV	Sweden	Aircraft	3746		0.96
Rylander et al (1976), JSV	Sweden	Road	811		0.78
Rylander et al (1972), JASA	Sweden	Aircraft	2900		0.78
Rylander et al (1972), JASA	Sweden	Sonic boom	33		0.85
Sato (1993), NPHP	Japan	Road	584	0.29	
Schield & Zhukov (1993), NPHP	U.K.	Light rail	149		0.59
Schomer (1983), JASA	U.S.A.	Aircraft	231		0.89
Schuemer & Schuemer-Kors (1983), Internoise	Germany	Railway	1516	0.46	
Schuemer & Schuemer-Kors (1983), Internoise	Germany	Road	1516	0.52	
Seshagiri (1981), JSV	Canada	Drop forging	609	0.31	0.63
Seshagiri (1981), JSV	Canada	Road	609	0.19	
Shibuya et al (1975), Internoise	Japan	Road	939	0.36	
Sorensen & Magnussen (1979), JSV	Sweden	Rifle range	323		0.99
Spickett et al (1983), Dpt Cons. & Env., W.A., Bull.	Australia	Aircraft	140	0.46	
Taylor et al (1980) [book: McMaster University]	Canada	Aircraft	21	0.40	
TRACOR Inc. (1971), NASA Rpt.	U.S.A.	Aircraft	3590	0.37	
Vallet et al (1978), JSV	France	Road	900		0.80
van Dongen (1980), Int. Congress Acoustics	Netherlands	Road	220	0.30	
Wolsink & Sprengers (1993), NPHP Germany/ Netherlands	Denmark/ Wind turbine	574	0.09		
Yano et al (1993), NPHP	Japan	Road	201	0.30	
Yano et al (1991), Internoise	Japan	Road	147	0.27	
Mean			916.74	0.42	0.81
s.d			1094.16	0.17	0.15
Number of cases			89	65	53

KEY:
NPHP: Proceedings of the International Congress on Noise as a Public Health Problem
JASA: Journal of the Acoustical Society of America
JSV: Journal of Sound and Vibration
Internoise: Proceedings of Internoise

being related to stressful reactions to noise [33]; and, finally, knowledge and beliefs regarding the health effects of noise may influence reaction [34].

The circumstance in which the noise is heard also influences reaction, with more reaction occurring if the noise is experienced: from a noise source which is visible from the residence, during a quiet activity which requires concentration [2,18], or at night [35].

4. CORRELATIONS

As outline above, reaction to noise is influenced by a number of features of the individual hearing the noise. Thus, reaction to a given level of noise exposure could be expected to vary from person to person, and correlations between noise exposure and reaction are low when they are based on individual data. However, noise and reaction may be averaged across individuals within groups (say, across individuals living in a particular area) in order to remove the effects of individual differences before the correlations are assessed (using the grouped data). A considerably higher association between noise exposure and noise reaction could then be expected [21]. We conducted an extensive review of the relevant literature, selected studies which reported a noise-reaction correlation, identified whether each correlation was based on individual or grouped data, then calculated the average correlation for individual and for grouped data [see Table 1]. The average noise-reaction correlation is greater when based on grouped rather than individual data. However, it should be noted that on average noise exposure still accounts for only 65.6% of the variance in community reaction to noise. Nonetheless, this percentage would be a slight underestimation due to errors of measurement (in both noise exposure and reaction) and the assumption of a linear relationship between the variables in a correlation despite the reported dose-response curves being curvilinear [26].

5. THE FUTURE

Many important theoretical issues relating to noise reaction remain to be resolved and practical solutions to the noise problem which recognise the importance of noise reaction and other psychological variables need to be developed.

For example, has the population become more sensitive to noise with the "greening" of many other environmental arenas, and if so how? Of those variables thought to modify noise reaction, which have a genuine causal role, which are themselves influenced by reaction, and which are components of reaction? How does personality affect reaction, and what implications does this have for self-selection of residents in higher noise areas? How is reaction related to other possible health effects of noise? Such issues should not be ignored in our ever increasing focus on the immediate benefits of any research expenditure. The history of science shows that better understanding of the exact causal sequences involved in negative reactions to noise will help the process of combating its detrimental effects on people.

The belief that a silent world would be the ideal solution to the noise problem is misguided. Much sound is not unwanted, and therefore, by definition, not noise. Both the practical aim of zero sound and the naive epidemiological assessment of the effects of sound in terms of the dose-response relationships between total sound exposure and effects (such as reaction or health), ignore psychological reality. Much sound is desired, and is thus unlikely to be stressful, arouse negative reaction, or harm health.

Focus on reduction or elimination of noise emissions as a solution to the noise problem should not preclude the development of other viable measures to alleviate the problem. Alternative solutions which may be fruitfully researched or implemented include: changing features of the noise other than its energy level in order to reduce reaction; understanding and resolving negative reactions to home noise insulation; promoting positive attitudes towards relevant noise sources; and use of positive sound environments.

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CONSEQUENCES OF NOISE-INDUCED HEARING LOSS: EFFECTS OBSERVED IN FAMILIES

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ABSTRACT: The physical effects of noise on hearing are well understood; consequences at a personal and social level are not so evidently appreciated. Noise-induced hearing loss may be especially associated with the phenomena of, 1) reluctance on the part of the person with the injury to acknowledge hearing disabilities, and 2) misinterpretation in the family of the effects of hearing loss. These may be due in turn to, 1) fear of discrimination at work, and 2) lack of anticipated hearing problems at home. The impact of hearing injury within the family system takes the form of battles over the level of the TV, restricted social lives, and loss of intimacy within the relationship. Partners' adjustments to the effects of hearing loss suffered by a working-age spouse vary from action to achieve distance from or to minimise apparent problems, or to protect the spouse in contexts of communication difficulty.

1. INTRODUCTION

The consequences for the sense of hearing that arise from different amounts of exposure to excessive noise are well established and well known. Among several surveys, that by Burns and Robinson (1970) remains a standard work of reference on relations between noise doses encountered in different occupational settings and resulting damage to the auditory end-organ, as reflected in the increased threshold for detection of tones at different audio-frequencies.

Also well established, and reasonably well known, are the consequences of even low levels of such injury for related auditory functions, such as speech hearing in noise (Lutman & Robinson, 1992; Suter, 1978) and the detection/localization of meaningful environmental signals (Hétu, Getty & Quoc, 1995). Finally, it is evident that noise-induced hearing loss gives rise to personally experienced disabilities and handicaps, as revealed through the application of self-assessment scales (Noble, 1978).

The consequences of noise-induced hearing loss that seem to be less well appreciated are to do with the family lives of people whose hearing is affected by this aspect of the working environment. There is a body of research on that subject, aspects of which I will review in this article, but it remains relatively less well recognised than work which shows the links between physical noise 'dose', and (the average) sensory/physiological response to that dose. One can speculate that it is relatively straightforward to understand physical/physiological sorts of linkages, complex though they can be in relation to differences in temporal and spectral patterns of exposure. It may call for the exercise of more imagination for us to appreciate the ways in which a disorder of hearing, ongoingly sustained at work, manifests at home.

Interestingly and, so far as I can judge, the earliest systematic study of effects flowing on to family life, as a consequence of a member suffering noise-caused hearing injury, was one conducted in Australia at the behest of the Deafness Foundation (Victoria) (Blaikie & Guthrie, 1984). It is consistent with my suggestion above, about the 'psychosocial' dimension being more obscure, that this study has remained outside of the usual domain of published research. It came to light during a seminar tour on Occupational Noise-Induced Hearing Loss, undertaken in November 1990 by a group comprising Louise Getty and Raymond Hétu of the University of Montreal, Dick Waugh of Worksafe Australia, and the present author. Copies of Blaikie and Guthrie's report were given to each of the four seminar presenters by representatives of the Deafness Foundation when the tour reached Melbourne.

2. BLAIKIE AND GUTHRIE'S (1984) STUDY

The starting point for this study was an extensive questionnaire-based survey of people who had gained financial compensation for occupational noise-induced hearing loss during a 28-month period. The final sample responding to the mail-out questionnaire was 313. Of these, 24 people (plus members of their families — making 60 in all) were interviewed, on the basis of several relevant criteria, not the least being a report of family difficulties associated with the claimant's hearing loss.

The interviews covered several themes, including the experience of working in noise, and the use of personal hearing protection; experiences in the family, and the extent of reliance on behavioural or technical aids to hearing. One detail highlighted by the authors was the unwillingness of participants to lodge claims for compensation before they retired, or in other ways to draw attention to any problem with their hearing, for fear of jeopardising their ongoing employment. This feature is related to one that has been noted in later research in Quebec. It constitutes a consequence of hearing loss that may be particular to this sector of the population, intensifying the more generally observed phenomenon (e.g., Jones, Kyle & Wood, 1987) that loss of hearing gradually acquired is not a condition sufferers rush to acknowledge. Such reluctance has its own consequences for family life, as I explain later.

The principal issue for families is the stress and irritation caused by the hearing impaired person's continual requests for repetition of things said by other family members. The ongoing expression of this behaviour leads to accusations of inattention, of not caring about what is going on. A consequence is exclusion of the hearing impaired person from conversation, including avoidance of conversation with her or him by telephone (incidentally, most participants with hearing impairment in this study were males). A critical source of conflict is the volume setting of the family TV set: others in the household are continually in conflict with the person who cannot hear it properly at a level comfortable for them. Paradoxically, and partly because other noise sources are so disruptive to hearing, children's audio gear (stereo systems and the like), are complained about as being too loud for the impaired hearer to bear. As clarified in subsequent work in Quebec, the stress on the hearing impaired worker caused by the noise of other appliances in the household is also due to fatigue and irritation from being exposed to noise in the workplace all day. Peace and quiet are actively sought — the TV being, exceptionally, a source of information and entertainment.

2.1 Interpreting these findings

A force that drives much of the domestic conflict reported by the above authors is the absence of recognition that hearing loss is the most parsimonious explanation for it. Here is where the obscure nature of the problematic consequences of noise-induced hearing loss might need some imagination to recognise. Even if members of a household can 'rationally' appreciate that hearing impairment would account for the non-responses or inappropriate responses of the partner or parent in question, the emotional impact of communicative failure is not diminished. The here-and-now expectation for communicative competence overrides a 'sympathetic' reading which might be made of any specific incident. Add to this the point that reluctance to disclose impaired hearing in the context of work may well generalise to the home setting, and this can make acknowledgment of hearing loss as the cause of communication failure harder to achieve (subsequent work in Sweden bears on this issue).

An issue that lies amongst the foregoing ones is the unpreparedness of relatively youthful families (people in their 40s, for example) for the 'brutal' fact that one member is suffering a malady normally to be expected only of older-aged people. This element possibly finds support in comparative outcomes from studies in which effects of having a hearing loss are rated by both the sufferer and by their partner. In a recent analysis (Noble, in press), it was noted that certain studies comparing 'self' and 'other' ratings of difficulties due to hearing loss, have yielded somewhat contrary outcomes. Thus, a report by Chmiel and Jerger (1993) showed similar ratings by others compared with self-rating, whereas one by Noble (1967) showed greater self-rating of difficulty compared with other's rating. One factor distinguishing the samples was the greater age of the people in Chmiel and Jerger's case. Furthermore, the people being rated had comparatively mild hearing losses, and their partners could well have had mild hearing losses also. In contrast, the sample in Noble's case was younger, and those rated had varying degrees of noise-induced hearing loss. In such cases there would be little likelihood of hearing loss in the partners. There was a low correlation between self and other's ratings of hearing difficulties in Noble's sample, a rather closer one than in Chmiel and Jerger's The suggestion in this contrast between the samples is that rating by the other, in Chmiel and Jerger's study, might contain an element of 'empathic' self-rating, whereas the partners in Noble's study would have no personal awareness of the experience of hearing loss.

If the foregoing interpretation is plausible it suggests that hearing loss is not anticipated, during someone's working lifetime, as a feature of life in families in which one member has noise-induced hearing loss. Combined with the reluctance on the sufferer's part to acknowledge hearing loss as a fact of their own life, a consequence within the family is less likelihood that communication problems will be attributed to the state of the person's hearing, more chance that they will be perceived to arise from personal and interpersonal failings. A further factor here is that other family members do not experience the agent which is causing the injury, and there are no signs of injury to the worker in the ordinary sense of that term: no visible cuts or abrasions.

3. THE UNIVERSITY OF MONTREAL ACOUSTICS GROUP

Several aspects of the above discussion are informed by detailed studies undertaken by a research group in Quebec, headed by Hétu and Getty (Hétu & Getty, 1990; Hétu, Lalonde & Getty, 1987; Hétu, Riverin, Getty, Lalande & St.Cyr, 1990; Hétu, Riverin, Lalande, Getty & St-Cyr, 1988). The program of work there has been to reveal the patterns of difficulty experienced by the partners of men whose hearing is affected by noise. Besides the sorts of consequences within the household identified in the Blaikie and Guthrie study, are those experienced in larger social settings. Many of the wives of the men reported the efforts they endure in social settings, having to act as interpreters for their partners, being required to be by their side at all times so that they will not be isolated or at a loss in terms of participating in conversation.

Beyond this were expressions of sadness and distress about the loss of a meaningful social life for themselves and their partners — both feel cut off from ordinary interaction just because of the continual dependence on the wife to act as interpreter, to be 'the ears' for the two of them. The sense of sorrow pervades the couple's relationship itself, and this is brought home very poignantly in the severe limits on intimate conversation at home. Such effects are not confined, of course, to people whose hearing is injured by noise (see, e.g., Hétu, Jones & Getty, 1993; Jones et al., 1987). But the 'epidemic' character of these consequences (occurring across substantial numbers of people who work daily alongside each other), has its own paradoxical quality. The fear of discrimination at work, of being passed over for promotion, of being side-lined within the system, helps to maintain a general concealment of the fact of hearing loss. A cogent finding by Hétu et al. (1990) was the hostility shown by other workers toward those who made public disclosure of hearing problems. Thus, a substantial occupational and public health problem is allowed to perpetuate in no small part because victims take no action to address the problem at source.

4. SUBSEQUENT WORK IN SWEDEN

A variety of studies of the nature of experienced handicaps has been conducted by researchers at the University of Gothenburg. One that bears especially on certain of the themes in the present paper is by Hallberg and Barrenäs (1993), detailing the types of responses engaged in by the wives of men with noise-induced hearing loss, in the face of their reluctance to acknowledge hearing difficulties. Some wives, in some contexts at anyrate, go along with the position that there is no real problem, hence the couple act in concert to maintain a view that normal conditions prevail. Others seek to minimise the impact of any communication difficulty, even where the husband will allow that a problem exists. In some contexts, the partners act as 'shields and swords' for the husband who is reluctant to acknowledge difficulty; in yet others, the wife copes, as it were, by distancing herself from the problem, leaving the husband to work out his own solutions.

These strategies for handling a problem that strikes at the basis of any human relationship may be interpreted with varying degrees of insightfulness by different researchers, and there may be a risk that victims, in some sense, are treated condescendingly in being categorised one way or another. The general point to take away from all of the studies mentioned here is that the consequences for those affected directly, and their families, are substantial and various, as well as potentially very destructive of any close personal life.

Findings like these re-emphasise the urgency of needing to address the problem of noise in the workplace. The consequences go beyond physical injury to an end-organ, pointing to corrosive effects on mental and social well-being.

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ALLOCATION OF MEASURED HEARING LOSS BETWEEN AGE AND NOISE

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ABSTRACT: A convenient way of allocating a person's measured hearing loss between the competing causes of age and noise is explained. It uses spreadsheets and each of the person's measured hearing thresholds. The spreadsheet compares individual data to population data in International Standards ISO 1999 and ISO 7029. The method leads to a calculated "worst case effect of age" assuming a typical pattern of age related hearing loss. This gives a measure of the individuals hearing "toughness" or susceptibility to loss due to age. Assuming the same susceptibility to noise induced loss of hearing, it is possible to calculate hearing losses at each frequency assuming we know the person's noise exposure history. The results are plotted as graphs. The technique has been found useful in court cases for industrial deafness. Apart from the calculation advantages, it graphically illustrates when there is a component of hearing loss explainable more probably than not by noise exposure.

1. SPREADSHEET CALCULATION OF "WORST CASE EFFECT OF AGE"

ISO 1999 Acoustics - Determination of occupational noise exposure and estimation of noise induced noise impairment [1] sets out two databases for the component of age related loss of hearing. The "highly screened" database A is used to calculate hearing threshold solely as a function of age. The method described in this paper initially allocates as much as possible of a person's measured hearing loss to age related hearing loss (ARHL). That component in decibels is given the symbol A when we quantify ARHL.

The reason for doing this is to test whether adoption of such an allocation still results in a person having a noise induced hearing loss (NIHL) or N when we quantify NIHL.

ISO 1999 and ISO 7029 1994 Acoustics - Threshold of hearing by air conduction as a function of age and sex for otologically normal persons [2] set out population statistics. They give median hearing thresholds and the standard deviation measure of the population variability of that median. Analysis leads to the probability of a person's measured hearing loss in the population distribution.

In his book Medical-Legal Evaluation of Hearing Loss [3], Dobie sets out the process of differential diagnosis (identifying the cause or causes of hearing loss) and of allocation (estimating the relative contribution of different causes to the total hearing loss and also to the total hearing handicap).

2. CALCULATION OF THE AGE COMPONENT

The technique described here fits the individual directly into the population statistics. By assuming a person's hearing threshold (or loss) is not worse than the measured loss, we establish the "worst case" susceptibility due to age. It is assumed that the general shape of ARHL getting worse with increasing frequency and with increasing age is exactly described by the population statistics summarised in ISO 1999 and ISO 7029.

If the audiologist has been unable to exclude all of an exaggerated loss, the person's sensorineural loss could be less. If a conductive hearing loss is present too, the person's loss could be better than indicated too. This leads to some certainty, required in court cases, that the noise induced component is no more than calculated.

International Standards ISO 1999 and ISO 7029 describe the median permanent threshold shifts (PTS) of hearing as a function of noise exposure and of age along with their standard deviations. Their data are precise and easy to use in computer spreadsheets.

To calculate how much of a person's hearing loss is noise induced, or even whether any of the losses are due to noise, assume all the losses are due to age. Compared to other allocation methods, this technique reduces uncertainty and the range of each allocation. Solving for "A" first makes the allocation of hearing loss between alternative causes easier to understand. The calculations are immediately simplified.

3. INDIVIDUALISING THE DATA

To work out a person's "worst case" susceptibility to age, the person's measured hearing threshold at each test frequency is examined to calculate the likelihood at each frequency that the threshold is entirely due to their age at the time of the hearing test. The minimum number of standard deviations better than the median explains their measured hearing threshold as a function of age. The number of standard deviations positions that person's audiometric data in the normal population statistics.

All the usual audiometric test frequencies are examined in the above analysis. It is necessary to have audiometry at 8,000

Hz to identify the often better hearing at 8 kHz in a person who has noise induced hearing loss at 3, 4 and 6 kHz. A person with a significant noise induced hearing loss might appear to have just very bad age related hearing loss unless their hearing is also measured at 8 kHz. The calculated result is illustrated in Figure 1.

A person's measured hearing threshold in decibels is tabulated as a function of frequency for each ear, shown at the top of Tables 1 and 2. The dashed line shows the person's hearing loss measured for his left ear at each frequency marked with a cross. The person's hearing loss in his right hear is shown as a solid line with circles at each frequency. The man was aged 49 at the date of his audiometry.

Table 1 Measured Hearing Threshold

MEASURED HEARING THRESHOLD [in decibels] as a function of FREQUENCY [hertz] for each EAR [Left or Right]								
250	500	1,000	1,500	2,000	3,000	4,000	6,000	8,000
L R	L R	L R	L R	L R	L R	L R	L R	L R
10 15	10 10	10 5	10 5	5 10	30 35	35 40	55 55	40 50

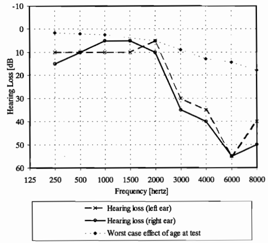

Figure 1. Measured hearing loss and worst case effect of age

The 5 dB hearing threshold in the man's left ear at 2,000 Hz corresponding to 0.21 standard deviations better hearing than the median for 49 year old men in an otologically screened population enables the "worst case effect" due to age to be calculated at the other test frequencies and plotted in the graph. It ranges from 2 dB at 250 Hz to 18 dB at 8,000 Hz. The spreadsheet calculation showing this is in Table 2.

Table 2 shows the population median hearing threshold of a man (in this case) aged 49 without ear disease other than age and noise. The spreadsheet calculation looks for the ear with the best hearing threshold at each frequency. The number of standard deviations from the median to reach the best hearing at that frequency is then calculated. At 250 Hz, the 10 dB hearing threshold in his left ear is 0.89 standard deviations worse than the median. This is shown in Table 2 in the second row labelled "Standard deviations from median". The man's best hearing compared to the normal population distribution is his 5 dB hearing threshold in his left ear at 2,000 Hz. It is 0.21 standard deviations better than the median. At all other frequencies, his best hearing in each ear is either 0.04 standard deviations better than the median (at 1,500 Hz) or worse than the median age related loss of hearing for a 49 year old man.

Because his measured hearing threshold was 5 dB at 2,000 Hz, at least in his left ear, we can assume that his hearing "toughness" is at the 58th percentile. The word "toughness" is used, instead of "susceptibility" because toughness in the population increases with increasing percentile. Note that the population susceptibility in ISO 1999, ISO 7029 and Australian Standard/New Zealand Standard 1269:1998 [4] use a population descriptor that has the 95th percentile as the least susceptible and the 5th percentile as the most susceptible.

In the absence of any better assumption, once a person's susceptibility to age is known (as a worst case assuming reliable audiometry), their susceptibility to hearing loss from noise exposure is assumed to be the same. This seems reasonable because there are unexplained differences in hearing threshold between ears at frequencies thought not to be susceptible to noise induced hearing loss (at 250 Hz in our example). Because the rate at which hearing is lost with frequency must also vary between individuals, the overall population statistics indicate where an individual fits in a population but not how unusual their particular shape of age related hearing loss is.

4. CALCULATION OF THE NOISE COMPONENT

The next part of the analysis explains some of the difference between the worst case effect of age and the person's measured hearing loss.

Hearing toughness at the 58th percentile can be used from ISO 1999 to calculate the effect of 13 years of exposure at 100 dB(A), shown in the second last row of the table. The last row of the table shows the calculated hearing losses due to age and noise added together with the slight compression (total loss = A + N - AxN/120) described in ISO 1999. The thin solid line of the graph with square boxes at the frequencies from 500 Hz to 6,000 Hz show the calculated combined age plus noise effects.

Table 2. Effect of age and effect of noise

	HEARING LOSS [in decibels] as a function of FREQUENCY [hertz] for each EAR [Left or Right]								
	250 L R	500 L R	1,000 L R	1,500 L R	2,000 L R	3,000 L R	4,000 L R	6,000 L R	8,000 L R
Loss [dB]	10 15	10 10	10 5	10 5	5 10	30 35	35 40	55 55	40 50
Std. deviations from median	0.89	0.87	0.15	-0.04	-0.21	1.49	1.29	2.20	0.94
Hearing toughness					58%				
Worst case effect of Age	2	2	3	4	5	9	13	14	18
Effect of noise 13 years 100 dB(A)		4	6	7	9	25	31	22	
Age + Noise		6	8	11	14	32	41	34	

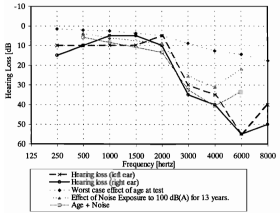

Figure 2. Effect of age and effect of noise

After the person's maximum susceptibility to age is calculated, "N" is calculated at each frequency using the same susceptibility. Figure 2 shows the person's hearing at the frequencies most susceptible to noise induced hearing loss is measurably worse than his calculated hearing loss due to age alone.

Each calculated maximum effect of age assumes a hearing loss with the same number of standard deviations from the median at each frequency. This always results in a similar curve shape.

Robert A Dobie [5] summarises other work of the relationship between ARHL and NIHL with "The inner ear degeneration that accompanies aging causes a sensorineural hearing loss that initially affects the highest frequencies in most cases. Men usually have greater losses than women of the same age." He reports that "aging affects several elements in the cochlea – at least hair cells, neurons, and stria vascularis – and these elements may deteriorate more or less independently. In this sense, ARHL is clearly different from noise induced hearing loss where … hair cells are virtually the only affected cochlea elements."

ARHL lacks the dip between 3 kHz and 6 kHz seen in NIHL; ARHL accelerates over time, while NIHL decelerates. "Allocation" is the process of determining the relative contributions age and noise have made to a person's sensorineural hearing loss (SNHL). Assuming head injury, ototoxic drugs and other otologic disorders have been eliminated by an ENT doctor (p.262).

Losses unexplained by age and noise could be due to other causes or measurement tolerances.

5. CONCLUSION

The assumptions made to arrive at the allocation between age and noise are set out. Although individuals will have patterns of loss different to population data, the probability that a person's loss includes a noise component is displayed graphically.

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SOME ISSUES IN NOISE-INDUCED SLEEP DISTURBANCE

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ABSTRACT. Research using the sleep polygraph to monitor sleep has indicated the main noise parameters related to sleep disturbance and the preferred noise metrics to be used. Evaluation and prediction of population statistics of noise-induced sleep disturbance due to noise has begun, using methods of detecting sleep disturbance more suited to large population testing. This work must continue if adequate guidelines for environmental noise control for the prevention of sleep disturbance are to be developed. Equally, the need for concurrent basic research on the effects of noise on sleep and health must not be lost sight of.

1. INTRODUCTION

The problem of sleep disturbance by noise has long been recognised in Australia. The 1971 report of the (Australian Parliament) House of Representatives Select Committee on Aircraft Noise (HORSCAN) stressed the need for research into the effects of aircraft noise on sleep and rest, particularly that of shift workers and older people [1].

In spite of this early recognition of the importance of sleep research in the assessment of the effects of aircraft noise on people, such research has not been well supported here. Exceptions have been some studies on possible health effects of noise during sleep [2,3,4], and a laboratory study on traffic noise and sleep [5].

Justification for noise effects research in Australia has mainly been that it should lead to the development of standards and regulations for noise control. The question of regulations and standards on noise and sleep has not yet been properly discussed in Australia, and so there is no agreement yet on the preferred aims of this research. The main alternative aims appear to be the following:

- to provide methods for predicting sleep disturbance per se (however that is defined);
- to find out whether or not there are harmful consequences of noise- induced sleep disturbance for health and/or daily functioning;
- to enable planners to avoid complaints about noise from, for example, airports and roadways;
- all of the above.

The aims agreed on will influence the choice of methods used in the research. In this paper the main methods for measuring sleep are outlined. Fortunately, perhaps, for the Australian community, many studies have been carried out elsewhere in the world which have yielded valuable information for the assessment of the effects of noise on sleep. Some results from that research are presented. Some possible health issues are also considered.

2. METHODS OF MEASURING SLEEP DISTURBANCE

2.1. The Sleep Polygraph

The sleep polygraph records continuous electro-encephalograph (EEG) activity, eye movement and muscle tone overnight. These data are used to classify sleep into various 'stages'.

With the possible exception of effects of noise on sleep latency (time to fall asleep after lights out) and on total time spent overnight in Slow Wave Sleep (SWS) in young people, results of research on noise effects on total time in the various stages of sleep have been inconsistent [6]. Reasons for this are not hard to find. There is normal variation between people in the duration of sleep and its various stages, and variation between nights in the same people. Individuals differ in their susceptibility to disturbance of sleep by noise. Substantial numbers of subject/nights are needed to obtain reliable results, but the costs of using the sleep polygraph in large population studies are prohibitive.

Reliability aside, it has never been clear what the implications of noise induced changes in overnight sleep architecture were for people, largely because the biological and psychological functions of the various sleep stages were unknown [7].

Polygraphic indicators of responses to individual noise events in the form of changes in sleep stage, body movement, arousal and awakening are much more repeatable measures than measures of e.g. total slow wave sleep (SWS) overnight [5]. The latter are, however, essential for studies of possible health effects and their mechanisms.

2.2. Actimetry

Actimetry records arousals and awakenings (activity) by means of accelerometers (actimeters) worn on the sleeper's wrist. Validated as measures of arousal/awakening against the sleep polygraph, actimetry has recently been used to monitor sleep disturbance in large numbers of people exposed to aircraft noise while sleeping in their homes [8, 9].

Actimeters are 'objective' (independent of subject bias), cheap and convenient, and have minimal effects on sleep, factors which make them the technique of choice in the study of noise-induced arousals in large populations. Disadvantages are that they are limited to detecting arousals (do not reveal sleep stage changes) and may not indicate how long the subject remains awake if they are lying quietly. This precludes their use if the aim is to assess sleep disturbance in terms of sleep stage changes, or if research is aimed at finding what aspects of sleep other than number of arousals may be related to health or daytime functioning.

Fidell et al. [9] found that while overall the correlation between actimetric measures of disturbance ("motility") and indoor A-weighted sound exposure level (ASEL) of individual noise events was relatively high, correlation with measures of behavioural awakening (button-pressing) was less than might have been expected. This may be a defect of the behavioural awakening method rather than actimetry.

2.3. Behavioural Awakening

Reliable results have been found by asking the subject to indicate all awakenings by pressing a button connected to a bedside computer [10].

This method has a great deal of face validity in that it can hardly be questioned that the subject is awake for each button-press. It may have a higher (noise) threshold than other methods of sleep monitoring. Unlike brief EEG arousals, it is easily recalled the next day and should correlate highly with public complaints about aircraft and traffic noise.

One disadvantage of the method as a basis for standardisation is that it may underestimate brief awakenings, especially from the 'deeper' stages of sleep (SWS), because of the degree of sleep inertia present at these times.

Another disadvantage is that subjects may give biassed responses or unconsciously provide results which they believe are 'desired' or expected by the experimenter. An important question, not yet investigated, is the relation of noise-induced sleep disturbance to subjects' general noise sensitivity and their attitudes to the sources and controllers of noise (airlines, road transport authorities etc.). Attitude and noise sensitivity have been shown to be powerful modifiers of annoyance due to noise [11] and, because auditory scanning of the environment and perception of the meaning of sounds continues during sleep [12, 13] could affect sleep disturbance as well. Research on this issue requires that the method of sleep monitoring be (and be seen to be) as objective as possible.

As with actimetry, button-pressing cannot record how long subjects remained awake after arousal.

3. RESEARCH RESULTS

3.1. Noise Characteristics and Metrics Related to Sleep Disturbance.

Laboratory and field research has established the following (see [6] for review):

- intermittent noise is more disturbing than continuous noise of similar average energy;
- the probability of sleep disturbance is related to the maximum levels of single noise events (such as that due to truck passbys and aircraft flyovers);
- single event noise levels are best measured in LAmax or ASEL;
- the likelihood of sleep disturbance due to noise events is related to the 'emergence' of noise events (roughly, the difference between LAmax and ASEL of noise events and background noise level);
- total sleep disturbance is related to the number of single noise events during the night. The form of this relationship is not clear and may depend on which measure of sleep quality is used as the outcome variable.

3.2. Sleep Disturbance - Dose/Response Curves

Several authors have collated the results of a number of studies and developed dose/response curves of probability of arousals and awakenings, and sleep stage change (from 'deeper' to 'lighter' stages of sleep) as a function of LAmax or ASEL of noise events.

A review and analysis by Pearsons et al [14] showed that dose/response curves derived from laboratory and field studies are dramatically different, probably because people sleeping at home in familiar surroundings were much less sensitive to disturbance by noise than when they slept in the laboratory. This suggested that much of the variation between various published synthesised curves was due to pooling data obtained in the laboratory and in the field in varying proportions.

It was also clear that sleep stage change was much more sensitive to noise than arousals/awakenings in both laboratory and field studies. The curve for sleep stage change from field studies was very similar to that of laboratory studies of arousal/awakenings. Three field studies of aircraft noise and sleep disturbance, using actimetry and/or behavioural awakening as the response measure, have been reported since this review was written, broadly confirming the dose/response curve for arousal/awakening developed by Pearsons et al. from previous field studies [8, 9, 10].

3.3. Prediction Of Chronic Noise-Induced Sleep Disturbance

Passchier-Vermeer [15] developed a calculation method which permits the number of aircraft overflights to be increased if the level of individual overflights is reduced. In her method the probability of sleep stage change and arousals/awakenings (based on work by Pearsons et al., [14] and Horne et al. [8]) were a linear function of the number of noise events overnight and the ASEL of these events, but she combined these measures of individual noise events overnight in an LAeq, and the limit of permissible exposure was set in LAeq. For example, if a maximum permissible LAeq overnight of 27 dB is set, then (in terms of percentage awakenings) the worst case (most arousals or sleep stage changes) consistent with this value is 5 aircraft noise events per night, all with indoor ASEL values of 64 dBA. This is calculated to induce an average of 13 aircraft noise-induced awakenings per person per year in an average population. Fewer aircraft with higher levels than 64

ASEL (up to a maximum permitted level), or a greater number of aircraft flyovers with lower noise levels, will lead to fewer awakenings. Similar calculations for sleep stage change showed a much greater number of sleep stage changes overnight and over one year than arousals/awakenings.

3.4. Outdoor/Indoor Noise Attenuation

Estimates of noise-induced sleep disturbance require indoor noise levels, but environmental noise assessment necessarily entails outdoor noise measurements. The available data on outdoor/indoor noise attenuation are quite inadequate to estimate indoor noise levels.

Finegold et al. [16] refer to the US Environmental Protection Authority's (USEPA) "average house noise reduction" as 17 dB for windows open and 27 dB for windows closed. The influence of noise spectrum and other variables [17] on outdoor/indoor attenuation make it unlikely that these values will be accurate for all environmental noise sources.

Passchier-Vermeer [19] assumed outdoor/indoor attenuation of 15 dB with single glazing (presumably windows closed) and 25 dB for double glazing. For regulatory purposes she stated that 15 dB was appropriate. However she later indicated that Netherlands' night time aircraft noise regulations specified that sound insulation be determined for windows in the "ventilation position" (partly open). For this window position the attenuation was given as 22 dBA for landings and 20.5 dBA for take-offs. For windows fully open the attenuation is lessened by 5 dBA [15].

Carter, Ingham and Tran [17], in a study of traffic noise in a Sydney suburb, found that the average attenuation depended on which noise metric was used, and whether the window was closed or partially open (up 20 cm), the latter probably corresponding to Passchier-Vermeer's "ventilation position". The mean attenuation values in dB (windows partially open) were:

Metric:	LAeq	LAmax	LApk	LA90	LA10	LA1
Attenuation:	17.05	17.35	17.2	13.39	17.77	17.63

For windows closed the attenuation values (in dB) were:

Metric:	LAeq	LAmax	LApk	LA90	LA10	LA1
Attenuation:	21.52	23.08	21.11	12.05	23.72	23.72

USEPA attenuation values for open windows and Carter et al.'s [17] data for partially open windows are somewhat similar but since the latter were determined for traffic noise they may not be appropriate for aircraft noise [cf. 16]. On the other hand the Netherlands' [15] regulatory figures (20.5 and 22 dB) may well be appropriate for aircraft noise and apartment buildings, but not for single storey dwellings.

The magnitude of variations in estimates of outdoor/indoor attenuation are significant in the context of noise reduction achievable by quieting aircraft and motor vehicles, buffer zones for airports, and sound barriers near roadways. Further field work on noise and sleep should take every opportunity to increase information on bedroom outdoor/indoor noise attenuation values and their determinants.

3.5. The Context: Non Noise-Induced Awakenings

Fidell et al. have consistently argued that in studying noise-induced sleep disturbance, cognizance should also be taken of the likelihood of an arousal/awakening in the absence of a noise event [18]. In a field study using behavioural awakening they found that the number of awakenings in the absence of any noise event was only slightly less than the number of non-noise induced awakenings [9]. Horne et al., [8] found that idiosyncratic, non-noise factors accounted for more arousals than aircraft noise events, though in their study the levels of aircraft noise were lower than in many areas near airports, and the prevalence of double-glazing was greater. In a laboratory study of traffic noise Carter and Ingham [5] found that the total number of body movements was similar in subjects exposed to noise and quiet overnight, even though there were clear (polygraphic) arousal responses to particular noise events. They suggested that this may be because body movements are necessary during sleep to relieve pressure points, and that noise events sometimes triggered body movements which may soon have occurred anyway.

'Net' increase in arousals/ awakenings or sleep stage changes should be considered in assessing noise-induced sleep disturbance in the community. Nevertheless public policy must be accountable for sleep disturbance for which avoidable sound sources such as aircraft and traffic noise are responsible.

4. NOISE-INDUCED SLEEP DISTURBANCE, HEALTH, TASK PERFORMANCE

4.1. Task Performance

LeVere et al. [20] exposed subjects to bursts of narrow band noise during sleep. They found that even though the EEG response to each noise event decreased as the number of noise events increased, impairment of performance of a reaction time task the next day was proportional to the number of noise events. This could mean that counting arousal responses overnight may underestimate the effects of chronic exposure to noise during sleep. However, data by Carter and Ingham [5] did not support this earlier finding.

4.2. Blood Pressure Response

Guilleminault and Stoohs [21] exposed sleeping subjects to 5-sec. 1000 Hz tones. They found that an increase in diastolic and systolic blood pressures followed the tone, even when there was no EEG response. Chronic repetition of such blood pressure changes could in theory lead to morphological changes in arterial blood vessels and permanent increases in blood pressure [22]. A study measuring blood pressure response in subjects exposed to traffic and aircraft noise during sleep is presently being completed in Sydney.

4.3. Immune Response

Twelve reports have suggested that slow wave sleep (SWS) is reduced by noise [cf. 6]. It has been speculated that reduction in SWS may impact on immune response [23], and an exploratory laboratory study has been carried out [4]. Until this question is clarified it constitutes a further reason for adopting a conservative approach to setting criteria for permissible noise exposure for the protection of sleep.

5. CONCLUSIONS AND RECOMMENDATIONS

Past research has provided valuable insights into noise and sleep. Nevertheless the aims of research on noise and sleep should be re-examined. There is a critical difference between research which is limited to determining the extent of sleep disturbance (as a form of activity disturbance and a forerunner of complaints) and that aimed at determining whether or not there are effects on daily functioning and physical and/or psychological health. While it may appear that measures of sleep disturbance are related to the likelihood of health effects this is not necessarily so, and until this is established health variables should be studied in their own right.

Most sleep/noise research to date has concentrated on relating measures of noise to measures of sleep disturbance. However, the role of psychological factors (for example attitude to the noise source and noise sensitivity) lifestyle variables (such as shiftwork) and demographic modifiers (age) may prove to be as influential as noise level in determining effects of noise on sleep and health.

Noise-induced sleep disturbance has mainly been related to indoor noise levels, but regulations and standards must be stated in terms of outdoor noise levels. Variation in outdoor/indoor attenuation is of the same order of magnitude as potential noise reduction due to quieting noise sources, buffer zones and noise barriers. The available information on outdoor/indoor attenuation is inadequate for estimating the effects of most noise environments on sleep.

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THE NATURE AND ORIGIN OF OTO-ACOUSTIC EMISSIONS

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ABSTRACT: Transient-evoked otoacoustic emissions have been used for some years now as a screening and diagnostic tool in detecting hearing loss of cochlear origin but still little is known about how these emissions are generated and what information is really carried in them. In short, the basic physiology simply has not been done. Recently, Robert Withnell and I have been investigating emissions from the scientific rather than clinical viewpoint and have shown that, in the guinea pig at least, they are not what has previously been assumed. They are in fact a form of nonlinear distortion and this has some significance for the interpretation of transient otoacoustic emissions.

1. INTRODUCTION

You can probably image the scepticism which greeted the announcement by David Kemp, in 1978, that he had recorded echoes apparently coming from within the inner ear. He had inserted tightly-fitting probes, containing a hearing aid receiver and microphone, into the external ear canals of human volunteers, generated a short click with the receiver and then recorded the sound in the ear canal in the time following. To the great surprise of almost everyone except himself he recorded, in the period after the initial transient had decayed, 'echoes' or re-emissions of sound extending out to as much as fifty milliseconds. A succession of scientific papers in the following two years eventually convinced almost everyone that these echoes were genuinely from the cochlea and that they were evidence for a mechanical amplifier. It is now widely accepted that there is such an amplifier and that it acts within the ear to enhance the vibrations of the basilar membrane, the structure within the cochlea that carries and stimulates the sensory cells of the ear.

In the years since then these and related sounds from within the ear, collectively known as oto-acoustic emissions, have been applied clinically with varying degrees of success. The idea is that if the emissions genuinely reflect the status of the cochlear amplifier then they should also reflect any hearing loss caused by damage to the cochlear amplifier, the most common cause of acquired hearing loss. Today they form an essential part of the audiologist's toolbox, providing a useful adjunct to standard audiology both for screening and diagnostic purposes. Unfortunately, the headlong rush to embrace oto-acoustic emissions, by ambitious political and commercial forces together with well-meaning health-workers, has driven as the 'new technology' of audiology ahead of the basic science. Today it is in widespread use and yet its basic mechanisms are still poorly understood.

Several years back I realised that the need for some basic research here was critical: how could we have full confidence in using oto-acoustic emissions to screen all new-borns (as is now mandatory in some states of the USA), to assess workers for compensation damages, to distinguish between simple hearing loss and acoustic nerve tumours and to support expensive epidemiological studies when we still do not understand even the basics of how they are generated. True, several clinical studies have shown their empirical usefulness, usually in simple pass-fail screening programs such as in pre-term neonatal clinics or population studies, but we can have little confidence in the more subtle interpretations of the various forms of emissions applied clinically. How do we interpret spectral changes in the click-evoked emission, for example? Can we simply look at such an emission and confidently infer the precise location of hearing loss in a patient? And can we accept some of the claims for a 'predictive' ability for oto-acoustic emissions or is there an alternative explanation? Funding from the Australian National Health and Medical Research Council has made it possible for me to make a start on this basic research.

Robert Withnell, a Ph.D. student in this laboratory, and I started with the click-evoked emission first. Almost all research labs world-wide use the commercially-available system widely available and endorsed by the USA National Institutes of Health for use in screening programmes, but I felt that it was too inflexible for basic research. So we put together our own system after searching widely for the best sound generators and microphones we could find for our purpose, and we wrote our own software so that we could vary our experiments as we saw the need. The rest of this paper discusses some of our recent findings and their possible implications.

2. THE CLICK-EVOKED EMISSION

Current wisdom has it that a click stimulus sets the entire length of the basilar membrane vibrating and that the mechanical amplifier is therefore stimulated along the entire length of the cochlea. The emission then results, it is held, from reflection of a small part of the stimulus energy from irregularities along the cochlea; that the vibrations are not perfectly balanced along the basilar membrane and some of the original sound energy, or of the new energy from the amplifier, is sent back towards the middle ear to be recorded in the ear canal as a delayed echo of the original. As such, the spectrum of the emission should contain energy corresponding only to regions of the ear which are working competently and any spectral deficits should reveal problems with hearing. The problem is that there have been some serious holes in this argument for some time: for example, the work of Paul Avan in France showed that high-frequency hearing loss had an effect on the low-frequency region of the emission spectrum, an entirely unexpected result.

We started work with experimental animals, using guinea pigs to study how the click-evoked emission really was generated. The first work was to use masking tones to inhibit locally small regions of the cochlea. We reasoned that the conventional explanations implied that the tones should function as a local hearing loss (this is certainly what happens in recordings from individual nerve fibres in the same animal) and that emissions should be inhibited in the small range of frequencies either side. In fact we found no such inhibition but instead found a complex pattern of interactions across the emission spectrum, sometimes increasing, sometimes decreasing the emissions (Withnell and Yates, 1998). We were forced to the conclusion that energy at any specific frequency in the click-evoked emission could come from almost any part, and probably from all parts, of the cochlea.

How could this come about? We know that the cochlea is a highly non-linear mechanical system and if we present two tones to the ear simultaneously, a third tone may be heard quite clearly, slightly out-of-key and at a frequency lower than the original two. This new tone may also be detected in the sound field of the external ear canal. It has a simple frequency relationship with the original two and is produced by nonlinear distortion generating the new tone as an intermodulation product of the original two tones. Its frequency is equal to the frequency of the lower tone minus the difference between the lower and the higher tone, or $2f_1 - f_2$. It is another form of oto-acoustic emission and is known as the cubic distortion tone (CDT). It is not the only intermodulation product, however, and a range of other new frequencies are detectable, at frequencies of $mf_1 - nf_2$, where m and n are integers.

Now, since a click is a wide-band stimulus, consisting of all frequencies across the bandwidth of the loudspeaker, it presents many opportunities for intermodulation distortion. Every spectral component of the click could, potentially, interact with every other component, each interaction producing its own range of intermodulation products. If this were in fact what was producing the click-evoked emissions then it would easily explain our perplexing 'suppression' results: simply suppressing one region of the cochlea would not change emissions particularly at that frequency but would only reduce the contribution of the suppressed region to a wide range of emission frequencies. But how to confirm this? In general, if you want to detect intermodulation distortion in a system, you introduce a signal consisting of two or more frequencies and look for new frequencies not present in the stimulus and generated by the system. Since the click has a continuous spectrum there are no 'holes' between frequencies in which we could look for intermodulation distortion, so we had to make a hole in order that any distortion could be seen separately from the stimulus.

In fact, we chose high-pass filtered clicks, not entirely arbitrarily but based on an understanding of cochlear mechanics. We generated a high-pass filtered click by direct software synthesis rather than passing a wide-band click through a filter, so that we could be sure it contained no low-frequency components. When we played this filtered click to the ears of guinea pigs and recorded the total sound, stimulus and potential distortion components, in the ear canal, we found a wide range of additional frequencies present below the 4 kHz cut-off frequency of the click, and at a surprisingly high relative amplitude, well above the 60 dB or greater stop-band of the stimulus waveform. The distortion components of the spectrum were only 30-40 dB below the stimulus components, indicating a very high degree of distortion within the cochlea. Several tests convinced us the distortion was genuinely coming from within the cochlea: first we could find almost no distortion when we tested the transducers in a plastic cavity, second, the phase characteristics told us that the distortion was generated later than the stimulus, by between 300 ms and 2 ms, and third, when we interrupted the middle ear chain, by breaking the ossicles, the distortion all but vanished. Clearly the click-evoked emission consisted of intermodulation distortion at a level much higher than that generated by our equipment.

When we reported these new results at the Midwinter Meeting of the Association for Research in Otolaryngology, in Florida in February 1998, we expected some serious challenges on our claim, but received none, even from David Kemp himself who was in the audience.

So how does this new interpretation influence the raft of existing results on click-evoked oto-acoustic emissions? In fact it doesn't change a lot of the basic confidence in the technique, especially in its role as a simple screening tool. No understanding of basic physiology can ignore the fact that many large studies have confirmed that click-evoked emissions can indeed detect hearing loss. If the cochlear amplifier is not working well in a given subject, then the basilar membrane vibrations will not be great enough to generate distortion components and so little or no emission will be recorded. It is in the more subtle aspects of their use, however, where the results must be more cautiously interpreted. For example, Paul Avan's studies are now easily understood. Remember, Avan found that high-frequency loss in humans resulted in a decrease, on average, in the amplitude of low-frequency emissions. We now see how this comes about. The standard testing equipment generates a click extending up to around 10 kHz, stimulating well into the basal region of the cochlea, and yet it records emissions only up to 6 kHz in frequency. In the case of a normally hearing person, we expect intermodulation products from all regions of the cochlea, including and regions processing the higher frequencies. If the higher frequency regions, say 6-10 kHz, are damaged, however, they will generate little intermodulation and so we expect the emissions to fall, even at lower frequencies around 1-2 kHz. In other words, the changes in the click-evoked emission do not necessarily imply threshold changes in the corresponding regions of the cochlea: they simply imply losses in some region.

3. ORIGIN OF THE $2f_1 - f_2$ DISTORTION PRODUCT

The other cochlear emission which has become of clinical importance is the simple intermodulation distortion component, variously known as the cubic distortion product (CDT, after the polynomial simplification for it's mathematical analysis), the intermodulation distortion product (IDP), $2f_1 - f_2$ (the formula for calculating its frequency from those of the primaries) and, simply, the distortion product (DP). It arises as one of several spectral lines which are generated by the inner ear when presented with two, pure sine waves. The largest, most easily seen and certainly the most easily heard of the lines is the one at frequency $2f_1 - f_2$. It has been found useful in clinical practice but has the perceived disadvantage that it monitors hearing at only a single site along the cochlea. The basic mode of generation, however, is still very poorly understood.

Perhaps one of the biggest mysteries is why this particular spectral line should be most prominent. Theoretically, its symmetrical counterpart, at $2f_2 - f_1$, should be just as prominent but it is only seen at somewhat higher intensities. Des Kirk and I have been studying electrically-evoked emissions and we believe we know the answer. Electrically-evoked oto-acoustic emissions (EEOAEs) are similar to other emissions but are generated by direct electrical stimulation of the cochlea. Of course, we can do this only on experimental animals at the moment, but it tells us a great deal about the mechanisms by which emissions propagate within the cochlea. We have found that energy generated at any particular place along the cochlea will only propagate back to the middle ear, where it emerges into the external ear canal as emissions, will only propagate if its frequency is below that at which the particular site responds best, its characteristic frequency (CF). This is not a clear-cut rule, the separation is not absolute, but there is a very great asymmetry on the magnitude of propagation above and below CF. The explanation lies, however, in the fluid mechanics of the basilar membrane, which analyses the incoming sound signal into its Fourier components. Although its tuning properties are bandpass, its propagation properties are lowpass, i.e., any given place along the cochlea will propagate a wave so long as its frequency is lower than the local CF, but the magnitude will vary. For frequencies above CF, however, the wave motion is evanescent and decays away exponentially and, since the physics is reversible, no energy will propagate as an emission if its frequency is greater than the CF of the site at which it is generated. When we consider the distortion products, it is clear that the frequency $2f_1 - f_2$ is always below the CF of the primary generation site, i.e., somewhere between the f_1 and f_2 sites, whereas $2f_2 - f_1$ is always above the primary site CF.

4. CONCLUSION

Ours is basic research. Our day-to-day efforts are not immediately directed to solving practical problems of audiology. Rather, we are taking the longer-term view, that if we can understand the basic physics and biology behind the hearing process we will then be better equipped to tackle the other, clinically-relevant problems of hearing.

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Correction

Sound Proofing of a Forge

by Stephen Cooper

Acoustics Australia, vol 26, no 1, page 22

Figures 1 and 2 in original should be replaced by figures below.

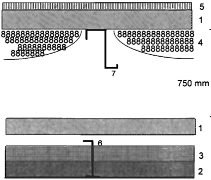

Figure 1. Forge Roof Construction

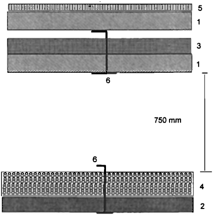

Figure 2. Forge Wall Construction

OCCUPATIONAL NOISE-INDUCED HEARING LOSS: ORIGIN, CHARACTERISATION AND PREVENTION

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ABSTRACT: Permanent hearing loss due to noise exposure constitutes premature aging of the ear caused by depletion of the outer hair cell population. Describing it is complex because many other factors also contribute to this depletion. Managing it is still more difficult because reduction of sound levels reaching the ear is not an adequate strategy by itself. Adequate prevention of any disability is only afforded by predetermination of individual risk coupled with comprehension of its severity. Otoacoustic emission data show that neither have traditional hearing tests given early warning, nor has the terminology 'mild hearing loss' indicated that extensive cochlear damage has accumulated.

1. ORIGIN

The cause of noise-induced hearing loss is, by definition, over-exposure to loud sound. The condition was first described over a hundred years ago when Dr. Thomas Barr of Glasgow realised that boilermakers suffered premature loss of hearing. In modern times the condition is regarded as a very complex problem. Last year it cost over one hundred million dollars in direct compensation costs (Macrae, 1998) and indirect legal costs as well as all the social consequences of poor communication at a personal level.

The primary factor responsible for Noise-Induced Hearing Loss (NIHL) is premature depletion of the three rows of cells in the cochlea called the Outer Hair Cells (OHC). The motor activity of these cells (dubbed the "cochlear amplifier") is essential to normal hearing. When the OHC are subjected to very loud sounds (120 to 130 dB SPL), the basilar membrane on which they sit can be forced into vibrational amplitudes approaching the size of the cells themselves, causing shear forces rupturing cell membranes or, for still louder sounds, producing complete disruption of the surrounding structure. In the mammalian ear new cells do not re-grow – the damage is permanent. Typically the spatial pattern of permanent loss of cells is related to the frequency and level of the sounds. An exposure to one-third-octave white noise for years will typically result in heavy loss of OHC of up to one tenth the length of the basilar membrane; repetitive impact noise can take out one third the starting population OHC (about 12000 in each ear). This adds to the scattered loss of OHC that occurs with aging beginning from birth, with the cells at the high frequency end being more vulnerable.

Recent research has focussed on the many mutually potentiating influences (McFadden, 1986a; Morata, 1998) which act upon the ear reducing the population of active OHC. These include hereditary factors (several lines of defective genes are being studied) and the protective presence of melanin in the cochlea (originally assessed using eye colour). Then there are the acquired defects such as due to maternal infection during pregnancy, birth trauma leading to hypoxia, infections, particularly during the first decade of life, plus a whole gamut of toxic influences ranging from heavy-metal poisoning, naturally occurring toxins and commercially-produced chemicals including solvents such as benzine and toluene (Johnson, 1994) to antibiotics and loop diuretics. To these we have to add physical injury, due to head impacts and raised barometric pressure. In the past these many effects have been regarded as outside the area of interest. The reason for considering all these "unrelated" effects here is that we now suspect that all these other synergistic factors (let us lump them together as determining "individual susceptibility") are swamping the main noise effect we are trying to measure, confounding attempts to control the rate of accumulation of cochlear damage by setting limits on sound exposure. A second reason the problem is difficult to manage is that we have no way of isolating occupational noise exposure from any other kind of excess sound exposure, eg. music exposure – it all appears to add up to deplete the OHC population.

2. CHARACTERISATION – OLD AND NEW

Typically the first clinical signs of noise-induced hearing loss are indistinct speech perception, particularly in conditions of raised background noise, while pure tone audiometry first reveals a "noise-notch" at 4 to 6 kHz. It is generally accepted that this dip in sensitivity occurs because the ear canal and drum has a resonance at 3 to 4 kHz emphasising this component of any sound to peak levels at the ear drum of up to +20 dB higher than entering the ear canal and producing a loss of sensitivity at a higher frequency (McFadden, 1986b).

By the time a person seeks help for a noise-induced hearing loss the noise-notch may be no more than 25 dB in depth, and the person is accorded typically a 5 percent hearing loss (Macrae, 1998). In traditional compensation parlance the disability is termed "mild" by comparison with possible moderate and severe noise-induced hearing loss. Despite this, it is not the loss of hearing sensitivity that drives sufferers to seek help. Ironically, the most common symptom first presented is the loss of voluntary ability to distinguish between sounds of different source location or frequency, particularly under conditions of multiple sources, reverberation or moderately raised background noise. There exist audiometric tests for cochlear selectivity, which is essential for voluntary selection (both pure tone masking and speech in noise tests). However, until now this initial and significant form of hearing disability has not only been too time-consuming to test, it has been still harder to describe in lay or even legal terms.

The inherent difficulty in raising awareness of, and preventing the most common form of hearing loss is describing what the average person wishes they had avoided only after the symptoms of loss of selectivity developed. Yet there is a simple experiment that any person can conduct on himself or herself which we suspect better describes hearing loss than simply reducing the volume to mimic loss of sensitivity. Turn on the radio to a talk program and have the volume at normal speaking level. Now try to hold a conversation with someone. Next, turn down the radio and experience the relief. Finally, turn it up again and imagine the frustration of never being able to turn the radio down in situations of such conflict. Hearing loss is so subtle and so poorly appreciated because the nature of the complaint is qualitatively no different from the experience of a normal-hearing listener. We learn from birth to wait for a gap in the conservation before beginning to speak. It is not so much that competing sounds are "masking" what our listener is trying to "hear", it is more the case that once the signal-to-noise ratio drops below about 10 dB (where here "noise" is defined as any signal we are not interested in) even the normal hearing listener doesn't cope too well. However, once the active OHC processing power is degraded the central task of voluntarily selection is disabled. The onset of hearing loss is so subtle because qualitatively things are the same as for the normal listener. Quantitatively, however, the presence of competing sound affects the damaged ear much more. For the person with a problem with selection, if they cannot remove the competing sound, such as trying to "hear" in a crowded room, they cannot cope.

The important question investigated at NAL since 1989 is whether the otoacoustic emission technique can provide not just a fast objective measure of hearing ability (LePage et al, 1993), but yield a parameter which better indicates loss of frequency selection ability than behavioural tests. Otoacoustic emissions being objective, there is a good likelihood that they will indicate loss of OHC function as a general slowing of cochlear activity. Further impetus to test this idea came from an animal study by Altschuler et al (1992), in which it was shown that while the inner hair cells and just one row of OHC remain intact, hearing sensitivity can remain normal, which suggests that the mammalian ear uses redundancy, or excess numbers of OHC to cope with progressive aging of, and damage to the hearing organ. Since audiometry is an untimed test it gives absolutely no indication that the loss of OHC amounts to a significant reduction in the rate of adjustment to sound level. If such redundancy is demonstrable in humans then a possible correlate may be the net level or reduction in the rate of activity of the outer hair cells before symptoms present.

A transient otoacoustic emission is the sound re-emitted into the ear canal due to an incident click. Important to this endeavour is the understanding that this stimulus is just large enough to drive all OHC into saturation. The 40 μs pulse delivered to the earphone generates a click, which is preset to 80±1.5 dB SPL peak. Kemp has shown that this level obtains a saturating response suggesting that the net emission power should reflect the remaining number of active OHC. The resulting emission is typically 0 to 10 dB SPL and so signal averaging (sample period of 40 μs, duration 20.48 ms) is used to improve the signal to noise ratio by 24 or 30 dB, taking about one minute. Also because the click response will be determined by the characteristics of the external ear and middle ear as well, in the standard protocol, a method of differencing is employed such that clicks of two different levels are used and any linear component of the response is subtracted away leaving only the nonlinear response due to the level-dependent change in outer hair cell activity. Also alternate responses are summed into two arrays and the reproducibility between the final averaged waveforms is calculated. If the ear has a fast recovery from the previous click it will respond with high waveform reproducibility (a correlation coefficient of 1.0); if the ear is still recovering it will respond differently and the reproducibility will be lower, towards zero. It turns out that this parameter can be thought of as speed of recovery or more loosely, "reaction time". However, being a bounded parameter [-1, 1] and non-normally distributed, the waveform reproducibility is typically used to weight the sound level of the emission so that the net response is a sound level. In our experiments we have used a parameter Coherent Emission Strength (CES dB SPL, which is the average sound pressure multiplied by the square of the reproducibility) to quantify the average reproducible (or coherent) component of the emission sound level. Test-retest variability for CES is ±4 dB SPL (Murray et al, 1997).

By comparing strength of the emission with hearing thresholds for the same frequency range (1 to 4 kHz) there should be a range of emission strengths over which hearing sensitivity does not change. Figure 1 shows the results of a study of 505 ears (LePage and Murray, 1993) if the strength of the emission is compared to hearing level for the same frequency range (1-4 kHz). It is seen that most cases of hearing loss are on the left side of the figure for which the emission strength is below some critical value (LePage et al, 1994) less than 0 dB SPL. The notable exceptions to the pattern, points on the right side of the figure, were cases subsequently confirmed as belonging to two categories: those with a hearing loss which is more central in origin, or those from individuals who at first did not correctly indicate their true thresholds. Naturally the figure does not include points from newborns for which CES values have been recorded up to 38 dB SPL. The complete picture including neonates suggests that there is a range of CES (about 80% of the total) for which the hearing level does not change, supporting the notion of redundancy in OHC motor capacity. This suggests that there is a period of accumulation of latent or subcritical damage during which a person who has had occupational exposure for some years may not be distinguished audiometrically from one whom has led a noise-free life.

In turn Fig. 1 may explain why in the new standard (AS/NZS1269:1998) emphasis upon monitoring hearing thresholds in occupational workers has been reduced in favour of higher attention to noise-level management. Regular hearing tests not only provide no early warning, they essentially do not measure the parameter which most

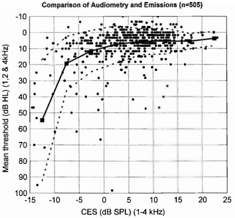

Figure 1. Comparison of behavioural and objective measures of hearing for 505 ears. The ordinate is a 3 frequency average hearing level (at 1, 2 and 4 kHz) as usually plotted in audiograms versus frequency. The abscissa is Coherent Emission Strength (CES dB SPL) - a measurement of the reproducible component of power of the click evoked emission. The heavy line and square symbols represent the mean value of the hearing thresholds for the appropriate 5 dB band of CES values. The dashed lines represent ±1 standard deviation about those mean values.

represents the disability – loss of selection. Our estimates suggest that a 5 percent hearing loss (Macrae, 1988) may constitute in excess of 80% loss of outer hair cells while a 20 percent hearing loss, the most ever typically presented in cases of compensation for noise-induced hearing loss, represents almost total loss of OHC processing power, certainly the case for frequencies above 1 kHz. The advent of the rapid, objective, non-traumatic otoacoustic emission test clearly has highlighted the inadequacies of traditional approaches to occupational noise-induced hearing loss and of compensation issues.

While many hundreds of studies conducted using Transient Evoked Emissions (TEE) have concerned themselves with neonatal screening, Narelle Murray and I have been questioning why the problem of noise-induced hearing loss is inherently difficult to manage and have proceeded to separate the normal aging effect from any accelerated aging effect. We believe the otoacoustic emission results have again shed new light.

Using the more sensitive technique has revealed that population variance in emission strength is huge. Figure 2 shows a scatter plot of CES for teenage and adult subjects between the ages of 10 and 60. These data represent the largest transient emission database (2038 people, pathological cases removed) so far presented in the literature. At any particular age, the range of emission strengths is about 80 percent of the total span of 40 dB. The high level of scatter implies that there are significant additional sources of variability never previously seen in otoacoustic emission data, or alternatively discounted. Of immediate concern is that the scatter represents a problem in the measurement technique (such as variability of transmission through the middle ear) so that the variation is not due to variation in OHC motility (for whatever cause). After nearly a decade of study at NAL we suspect that the scatter in these results irrespective of age is real and not attributable to some form of measurement error or misinterpretation of the origin of the emissions. The variability is more likely to reflect some individual component of the OHC response such as efferent involvement in the determination of susceptibility or maybe systematic variations in conditions of cochlear regulation (LePage, 1993).

Comparing Figs 1 and 2, if subjects with emission strengths below some critical value are more susceptible to acquiring a hearing loss than those with very high values then the scatter indicates that many young people are at imminent risk of hearing loss. Also since the relationship in Fig. 1 is monotonic, we suspect that any lowering of emission strength represents increased risk. Indeed we have studied the apparent dip (Fig. 2) in the values in teenagers and young adults with normal hearing (LePage and Murray, 1998) and conclude that despite the scatter, there are highly significant effects of certain kinds of noise exposure such as personal stereos. The sloping lines show the results of a linear regression for left and right ears separately (left below right) and indicate a significant decline with age. Our current studies also include a cohort in whom we are tracking both TEEs and pure tone audiometry for confirmation.

The interpretation of the scatter (Fig. 2) we are investigating is that it represents high variability in individual susceptibility to hearing loss due to the very many synergistic factors mentioned in Section 1. These must be taken into account in any trend analysis in which the independent variable is aging effect, or noise exposure, or effect of toxic substances or head injury and so on. Although our longitudinal epidemiological study has made several assumptions, our data support the notion of redundancy of OHC function. Since mammalian OHC do not regenerate when permanently damaged it would almost appear that, like many other systems in the human body such as that involved in insulin production, the evolutionary process has arrived at a cochlear structure with considerable excess capacity. We appear to have many more OHC at birth than we need to hear normally (or in terms of the cochlear amplifier hypothesis, than we need to maintain adequate gain) so we can afford to lose the greater portion of them before any disability is evident.

3. PREVENTION

Previous Australian Standards (eg. AS1269-1970) have specified three basic aims: 1) reduce the level of the noise being produced by machinery or enclose it to keep the sound inside the enclosure, 2) if silencing is not possible to an acceptable level then reduce the level of noise reaching the ear drum with obligatory hearing protection devices (ear muffs or ear plugs) and 3) monitor the hearing levels to identify those at risk for noise damage. Until recently most efforts to limit sound exposures have not been supported by convincing evidence of a reduction on numbers affected (Royster, 1993). Why? Is it simply a problem of more effectively enforcing or

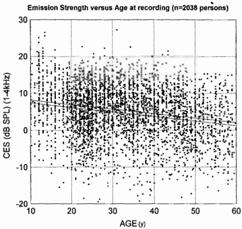

Figure 2. A scatterplot of Coherent Emission Strength as a function of age at the time of recording in a population of 2038 people reporting no current hearing problems, left and right ears. The regression lines indicate a slight but significant decline versus age (left below right). The important features are the normally large scatter in values of emission strength and the fact that having low values can occur at any age, reflecting high risk for hearing loss.

motivating employers and workers to conform to guidelines, or is there a more basic reason?

The key to the success of any prevention program is early warning. In the past behavioural hearing tests such as pure tone audiometry were the only way of monitoring hearing and suffered the inherent problem of trying to use the same parameter both as a measure of disability and also as a predictor for that disability. We now appreciate that behavioural tests have provided no early warning. Accordingly, the title of the latest Australia/New Zealand Standard AS/NZ1269-1998 has been renamed "Occupational Noise Management" to reflect that more emphasis is being given to reducing sound levels at source and less emphasis given to the monitoring of the onset of hearing loss by conventional means, but foreshadows the use of otoacoustic emissions in the future.

The rationale of the new standard continues to be based on the logic that limiting the peak sound levels in the workplace say from $L_{Aeq,8h}$ values of 90 dB to 85 dB SPL must limit worker exposure and therefore should produce a reduction in the incidence of NIHL. It is too soon, however, to tell if these latest measures are effective. The basic principle which has guided the trade-off between acceptable sound levels and time of exposure dates from the so-called Equal Energy Hypothesis – a 3 dB increase in sound level equates to halving the maximum duration of exposure, the point of reference now being an $L_{Acq,8h}$ of 85 dB. 88 dB equates to a 4 hour limit and so on, to say, 115 dB at which level the rule limits exposure to less than a minute. Set in the context of the discussion in Section 2, we can see this traditional rule is important for protecting the bulk of the population, but it may do very little for the most susceptible people. Without them being identified and targeted for special attention they will likely still be the first in any program to suffer a hearing loss and so their management program will appear to be ineffective, whereas it is only breaking down by failing to detect those most at risk.

Much effort has also been expended on obtaining an adequate method of rating hearing protectors so that the type of device can be matched to the application, not just how its rating must depend upon how they are worn in practice, but taking into account how steeply the rating must be degraded for intermittent use. Because of tremendous variability in real ear attenuation, debate continues as to the best method of rating them so that at least most of the population of users has their hearing protected. The predominant rating method in Australia continues as the so-called "SLC_{80}" – a nominal "real-world" value of attenuation that derived from the pioneering work of Dick Waugh at NAL. This method of rating is designed to stem hearing loss by protecting the bulk of the noise-exposed worker population, but our concern here is for workers who may already be most at risk – in Figure 2, those with critically low emission strengths. The traditional approach may not do much for preserving their hearing because workers whose OHC processing power is reduced may be the very people who feel their immediate need to hear is being compromised further by the wearing of protectors. In addition the notion of redundancy means that any measure designed to reduce the incidence of occupational hearing loss may not be manifest for decades. We are therefore optimistic that the otoacoustic emission approach may be an important adjunct to hearing conservation strategies. Clearly we need to continue to reduce overall rates of accelerated depletion of the OHC population by reducing sound levels, fully realising that irrespective of that measure the most susceptible people will still likely be outside that level of control. Hence we are working towards a new strategy for adoption sometime in the new Millennium. We advocate a two-pronged approach: 1) to reduce sound levels, thus protecting the bulk of the population and 2) to introduce the more sensitive method of assessing the level of redundancy in OHC activity providing the capability of using limited resources to target workers most at risk in plenty of time for all concerned to consider all the career choices still available to them.

4. SUMMARY

We have shown that individual susceptibility may be hampering our efforts to show that industrial hearing conservation programs are worthwhile and we should continue to push for reduction of noise levels. However, it is unrealistic to expect to see an effect except in the long term using behavioural measures such as audiometry. Refinement of the new objective techniques such as otoacoustic emissions may provide a better handle on early warning in terms of the notion of assessing cochlear redundancy. If this new approach can eventually be used with more confidence to quantify the population of OHC in any ear, it is possible to conceive it may be used as a general screening tool for early detection such as has been applied to early warning of glaucoma. Finally

research into noise-induced hearing loss is leading to some exciting developments both in basic hearing science and in practical field strategies which may eventually substantially change the incidence of premature hearing loss.

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AN OVERVIEW OF RESEARCH ON THE EFFECTS OF NOISE ON ANIMALS

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ABSTRACT: While there is recognition worldwide for the need to assess the influence of noise on animals, both in terms of ecological disturbance in the wild, and effects on stress or productivity of domesticated animals, limited research has been undertaken in these fields. The paper presents an overview of this research activity and the contexts in which it has been carried out. Much of the literature deals with the impact of military activities, seismic and other exploration activities, and transport. The paper identifies relevant Australian work in the field and identifies some limitation in current work and avenues for further research.

1. INTRODUCTION

The effects of noise on humans have long been recognised. In contrast, the effect of noise as a stressor for wildlife and for captive/domesticated animals has received far less attention [1]. Animals depend on acoustic stimuli for communication, navigation, mating and foraging functions. Research into the effects of noise on these functions, and the effects of noise on overall disturbance to the individual animal, the habitat and the ecosystem in which they reside, is important for wildlife management, for management of anthropofaunal conflict in areas such as tourism and aviation, and for sustaining or maximising animal productivity. Research into the effects of noise on animals has also been undertaken for the purpose of extrapolating the results to humans, particularly within a health context.

This brief article provides a sketch of the body of research activity in this field, illustrates the different categories of research undertaken, introduces the reader to the published Australian work in this field, and some work in progress.

Most of the work on noise and animals can be placed within the four broad research methodologies shown in Table1. These methodologies include studies based on field observations, and both field-based and laboratory-based experiments. Much of the literature reports research based on field observations, and while this has provided valuable insights, the absence of any control over the acoustic stimulus and little other than gross measures of response (for example, observing gross fly off, or observing "no visible response") means that these studies have little chance of replication. Field experiments, controlling the stimulus, and/ or making detailed measures of response, are extremely difficult to conduct, and this presumably explains their paucity in the literature. Laboratory experiments are far simpler, but of course raise questions of applicability of their results in the field, particularly given the complexity of the ecology of disturbance discussed below. The fourth category, in Table 1, while not measuring effect, provides critical baseline studies of natural acoustic environments in which organisms live and against which measures of intrusive human generated noise can be assessed. For example, Cato [2,3] has made significant contributions to the understanding of the acoustic characteristics of the marine habitat near Australian waters. His studies provide a setting within which biological effects of marine acoustical disturbance can be addressed.

Table 1. Research methodologies

RESEARCH METHODOLOGY	POTENTIAL EXPERIMENTAL TREATMENTS	MEASURES OF RESPONSES
Field observations	Usually nil, or presence/ absence of acoustic stimulus with no control of stimulus	field observations (e.g. gross fly off), anecdotal evidence
Field experiments	Controlled stimulus or uncontrolled stimulus	Observed behavioural response, but more recently physiological measures
Laboratory experiments	Generally controlled stimulus (sometimes uncontrolled stimulus)	Physiological measures (heart rate, blood pressure, catecholamine levels), behavioural response
Baseline acoustic studies	Not applicable	Not applicable

2. CONTEXT AND MANAGEMENT IMPLICATIONS

Research into the effects of noise on animals has been in two major contexts: animals in the wild, and captive/domestic animals. Table 2 indicates the scope and areas of management implication within each of these contexts, and cites representative research studies. The examples in Table 2 are by no means a comprehensive survey of the literature, but provide at least a starting point for readers interested in particular situations. Australian studies are indicated in Table 2.

Research on the effects of noise on wildlife (and to some extent on captive/ domestic animals) needs to be undertaken within a theoretical framework of the ecology of disturbance of animals as illustrated in Figure 1 [40]. This framework incorporates various existing ecological models for concepts

Table 2. Context and Management Implications

CONTEXT	SCOPE	AREAS OF MANAGEMENT IMPLICATIONS	EXAMPLES (REFERENCES)
Wild	Wildlife management & conservation	Tourism & ecotourism	Great Barrier Reef (Readhead [4]*; Hicks et al. [5]*) Off-road vehicles (Brattstrom & Bondello [6]) Aircraft noise (Kushlan [7], Brown [8]*, Stockwell & Bateman [9]; Gipson [10], Gabrielsen & Smith [11])
		Military activities	Military aircraft (Ellis et al.[12]; Russell [13]; Weisenberger et al [14]; Temple et al [15])
		Research activities	Antarctic and sub-Antarctic Islands (Rounsevell & Binns [16]*; Woods et al.[17]*)
		Mining and exploration	Seismic exploration (Gunn & Livingstone [18]; McCauley [19]*; Pearce [20]; Lane [21]*)
		Transport • Surface • Marine • Air • Pipelines, etc. Impact Assessment	Road traffic noise (Reijnen [22]; Reijnen & Foppen [23]; Reijnen et al.[24]; Reijnen et al.[25]) Marine exploration (Richardson et al.[26]) Aircraft noise (Dunnett [27])
	Urban wildlife management	Airports Roadways	Road traffic noise (Reijnen [22]; Reijnen & Foppen [23]; Reijnen et al.[24]; Reijnen et al.[25])
	Animal Scares	Protection of human safety Protection of primary produce Protection of buildings	Bird scares (Slater [28]; Bomford & O'Brien [29]*; Jaremovic [30]*; Nicholls [31]*; Bomford [32]*; Andelt et al.[33])
Captive/ Domestic	Production	Cattle	Milk production or pregnancy (Head [34]) Pregnancy (Henley & Rybak [35]; Gipson [10])
		Poultry	Egg production (Belanovskii & Omel' yanenko [36])
	Human/ Public Health	Physiological research	Auditory physiology (Kiernan & Cranney [37]; Robertson & Anderson [38])
		Urban stock	Effects of animal noise on human health in suburbia (Tickell [39]*)

*indicates research activity in Australia

such as tolerance range, niche, habitat and life-history strategies and provides a sound basis for the study of noise as ecological disturbance. Figure 1 summarises the complex means by which disturbance characteristics alter the existing environment of an organism and as a result the organisms' requirements are no longer met by the habitat. Not only must the dose of the acoustic stimulus be fully understood e.g. nature (type of noise – aircraft noise, etc.), intensity, spectral frequency, duration, frequency of occurrence (how often the target organism is exposed in a given amount of time), predictability, coexistence with another stimulus (eg visual stimuli), scale (range of exposure e.g. footprint of a sonic boom), timing (time of day), but so too must the organisms' characteristics e.g. tolerance level, physiological state, timing (in terms of life-history stage exposed), powers of dispersal and behaviour. Further, the critical measures of response to the noise disturbance include the individual's, colony's, and the species', chances of survival and reproduction as a result of the exposure to the hazard. It is vital to note that characteristics of the disturbance do not act independently of one another in producing an impact [40].

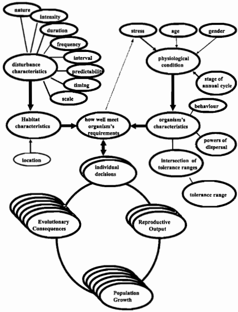

Fig 1. Theoretical framework of the ecology of disturbance [40]

3. AUSTRALIAN RESEARCH

The authors conducted a comprehensive search of published literature in preparing this paper – but the conclusion is that there is sparse Australian work in this field. Two published examples of field research, one marine (McCauley, 1994) and the other terrestrial (Brown, 1990), provide good examples of work contributing to an understanding of the significance of noise as ecological disturbance and these are summarised below. In addition to these examples of field research, brief reference is made to some Australian laboratory work on noise and its influence on animal physiology, and to some unpublished work and to work in progress.

The study by McCauley [19] was carried out as a review of the impact of oil and gas exploration, particularly seismic surveys and its implications for marine habitats. This study is interesting and such comprehensive investigations are rare in the literature. Various features of this study make it a significant contribution to this field of research. McCauley [19] provides a thorough documentation of the ambient noise in marine habitats of Australia comprising both biological (e.g. invertebrates, fish and marine mammals) and non-biological sources (e.g. marine transport noise, wind, rain and earthquakes). In the context of the ecology of disturbance [40] these data provide a description of the acoustic habitat characteristics. He then reviews the potential disturbance characteristics, seismic survey sounds, and goes on to comprehensively document the characteristics of marine organisms and their various life-history strategies which make them more susceptible to impacts resulting from noise exposure, and reviews the pathological and behavioural effects of seismic exploration noise among the various taxa. McCauley [19] defines various zones of influence of marine acoustic disturbance that include audibility, masking, behavioural response, avoidance, pathological effects and lethal effects. A zone refers to the radius from a point source within which organisms exposed are susceptible to a certain effect. Under each of these zones he addresses the effects on various marine fauna and identifies existing gaps in the knowledge. He also ranks the significance providing a framework for the effects of noise as ecological disturbance, and presents the long term implications of seismic exploratory activity and a template to assess noise effects in marine habitats.

The study by Brown [8] was carried out to assess potential impact of aircraft noise on seabirds. Almost all studies prior to Brown [8] were undertaken on birds that had prior exposure, thereby introducing the potential issue of habituation to noise stimuli. Furthermore a majority of these studies used stimuli that were either partially controlled [5, 27, 41] or used only gross measure of response to assess the impacts of such stimuli [5, 7, 18].

Table 3. Experimental design and results. Brown [8]

STUDY COMPONENT	NOTES
Study site	Eagle Cay (Cairns-Cormorant Pass section of the Great Barrier Reef Marine Park)
Target species	Crested tern (Sterna bergii); one large and one small colony
Acoustic stimulus (Disturbance characteristics)	Nature: recordings of aircraft noise at cruising speed (100 knots) at altitudes ranging from 1000 to 250 feet Intensity: Amplitudes of the flight signatures conditioned to devise seven treatments with peak fly-over levels of 65 dB(A) to 95 dB(A), at 5dB intervals Duration: 30-35 seconds Scale: the scale of exposure controlled by controlling the position of speakers to ensure that the radiation patterns establish a uniform sound field over the target group of birds. The birds were exposed to all seven treatments with 10 min intervals between them, for four days.
Ambient noise (Habitat characteristics)	Wave action (55 to 65 dB(A)) Bird Calls (60 to 75 dB (A)) (bird call activity unrelated to the experiment observed to exceed those due to wave action)
Potential behavioural response (Organisms' characteristics)	Scanning, alert, startle/ avoidance and escape, in ascending order of behavioural responses, recorded on film 20 seconds prior to peak exposure and 25 seconds after peak levels. All observations were recorded on film. The response of each bird in the target group was scored separately. (Note: The birds exhibit this range of behaviours even without exposure to the stimulus and there a control segment of 45 seconds without any stimulus was also recorded. Only those behavioural responses directly attributable to the stimulus were recorded.)
Results	Proportion of individuals responding with a higher order behavioural response to exposure increased with the level of noise exposure.

Research by Brown [9] provides a baseline study on influence of aircraft noise on a seabird colony that had no prior exposure. Care was taken to present a controlled, but variable, stimulus to test for habituation effects, and to measure a range of behavioural responses. Details of the study are summarised in Table 3.

This study brought to light key factors that further research in this field must observe:

a) The acoustical stimulus to which the organism is exposed has to be controlled/ measured.
b) Observations of response have to be recorded on film to capture a hierarchy of responses (direct measures of physiological response, for which equipment is now available, would be preferred)
c) Baseline information on previously undisturbed individuals or colonies is required to ascertain the significance of habituation to noise exposure.
d) Research needs to be directed at ascertaining the ecological consequences of animal exposure.

Other Australian work [29, 30, 31, 32] has been directed at the use of sound to scare wild animals away from primary production activities. This is part of a considerable body of worldwide literature [28, 33] on this commercially relevant topic. The work is directed primarily at birds feeding on agriculture and aquaculture produce.

The Human Impact Research Program, within the Australian Antarctic Division, currently has work in progress to quantify the effect of helicopter noise on Antarctic wildlife (M. Giese pers.com). The experimental work has been conducted over two field seasons with wildlife responses measured by videotaping changes in animal behaviour and by utilising a range of physiological monitors.

The reviewed literature also included reports of a wildlife incident on an Australian sub-Antarctic islands which could relate to an aircraft noise stimulus. Rounsevell and Binns [16] and Woods et al [17] reported the discovery of approximately 7000 dead penguins at Lusitania Bay, Macquarie Island in 1990. The mass deaths in this breeding colony of king penguins (Aptenodytes patagonicus) was a result of asphyxiation probably resulting from a stampede. These authors listed potential causes of the stampede to be harassment by natural enemies, seismic activities, unusual weather events or anthropogenic disturbance. However, the overflight of an aircraft flying to the Australian National Antarctic Research Expeditions station, which was known to have occurred before the discovery of the stampede deaths, was speculated to be the most likely cause of this event. As these reports were based entirely on field observations after the discovery of the dead birds, and after post mortem examination, it must be emphasised that the cause of disturbance must remain speculative. However, the authors still advise caution in allowing aircraft to approach breeding colonies that have had no prior exposure.

There has been some Australian laboratory work. Kiernan and Cranney [37] examined the influence of an immediate-startle stimulus on the freezing response in Wistar rats under laboratory conditions. They found that a controlled startle-stimulus of 117dB (SPL, 20mPa) amidst a background of white noise (70dB SPL, 20mPa) for 60s failed to elicit freezing responses. Robertson and Anderson [38] examined the cochlear modulation of the deafening effects of loud sound in guinea pigs. The objective of this study was to provide an understanding of cross cochlear pathways in hearing physiology and a subsequent extrapolation of the results to physiological effects of noise on human hearing. Within the theoretical framework of disturbance, these studies address the effect of a hazard out of the context of the target organisms' habitat. However, they potentially provide insight into tolerance levels and behavioural responses to acoustic stimuli and into potential response in the wild, though this was not the immediate objective of the studies.

4. CONCLUSIONS

The review of the literature indicates that Australian work in this area is sparse and sporadic (though close examination of the references cited by McCauley [19] suggests that there is considerable information available in unpublished documents and government reports). Much of the literature deals with the impact of military activities, seismic and other exploration activities and the influence of transport noise. Influence of noise on the effect of terrestrial animals is relatively unexplored. A study is required for terrestrial habitats, dealing with ambient noise levels and acoustic characteristics of terrestrial fauna and potential responses to acoustic disturbance. However, the smaller areas of terrestrial habitats, and the limited distribution of previously undisturbed regions, makes such baseline studies difficult.

Difficulties in replication of research into effects of noise on animals is accentuated by the use of uncontrolled stimuli and the measurement of gross responses. Though such studies are useful as pilots, critical examination of a particular response to a pre-defined stimulus is vital for future noise management. Internationally, very few studies in this field have designed experiments with a level of precision that can identify a threshold stimulus above which the target animal is likely to experience detrimental effects. Habituation to noise could enable animals to increase tolerance but, as with humans, anecdotal evidence of habituation is inadequate, and will need to be proven by appropriate studies. The influence of habituation, and overall tolerance to acoustic disturbance, are areas that require further investigation.

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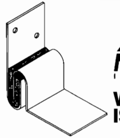

BINAURAL HEARING IN MUSIC PERFORMANCE

The perception of music is binaural, two ears working together, and most of the research thereto uses binaural hearing, unlike the monaural assessment process for the health of hearing. Also music perception research generally stops at music perception and does not venture into the production of music sounds.

But the primary element of music performance function is the production of sounds by voice or musical instrument, solo or in relation to other instruments and voices. This within certain variable limits if the music is to obey the need for such as form, pitch, intonation, harmony, ensemble, rhythm and timing.

The possibility of noise-induced hearing from music exposures remains the principal object in looking at musician's hearing levels. Research has shown musicians often exhibit less than so-called normal hearing resulting from many different etiologies, beside the effects of aging, called presbyacusis. For practising professional musicians, particularly older persons, monaural pure tone audiometry often exhibits little sensitivity for frequencies above 3 or 4 kHz. Also the audible frequencies are sometimes depressed in one or even both ears. Although the harmonic structure of most orchestral instruments can extend as high as 15 kHz, fundamental pitch ranges lie below about 1.6 kHz, perhaps a redeeming feature.

The range of hearing levels for musicians can vary from the most unusual case of Evelyn Glennie, world famous percussionist, completely deaf from early teens, to young persons whose hearing extends as high as 20 kHz at audiometric zero. What then are hearing criteria to establish performance abilities ?

Details of measured hearing levels of many musicians suggests it is difficult if not impossible to make predictions about a person's ability to perform music on the basis of the information derived from pure-tone audiometry or otoacoustic emission testing to determine residual hearing. Indeed the assessment by a musician's peers, listeners, sound recordist and music critic appear to remain the final arbiters of the integrity of music performance. Additionally, attempts to quantify music performance by measurement presents difficulties in application thereto, since variability and inconsistencies exist even though the musical and cognitive aspects may satisfy all concerned.

Preliminary research at Boston University Hearing Research Center during June 1997 was directed to estimate the degree of hearing changes musicians may sustain, from any etiology, before performance appears affected, or the degree of hearing impairment where performance becomes stressful to the player. Experiments may determine such an estimate essentially individual, or an estimate that is true only for a class of instruments or voice, or an estimate of general application.

Practising musicians of wide age range in and around Boston, some from Berklee College of Music, were enlisted to take part in music performance experiments. Conductive hearing losses were induced using ear muffs over one and both ears. Noise masking of higher frequencies above 4 kHz were also used to simulate sensorineural losses. All sessions were recorded and assessments and comments made by players.

Audiograms of each player indicated a variety of hearing levels, but this information gave no indication of performing expertise for non-experimental conditions. In fact added hearing impediments, although stressful to players, did not appear to materially impair performance. It was significant that players of wind instruments found increased stress by the presence of the earmuffs, which inhibited skull vibrations. Also there was a handedness among players, some of whom relied on one ear more than the other. Thus unobservable changes to performance quality with practically no increase in player stress occurred when the ear less important to performance was covered. But covering the most useful ear caused increased stress for players even though playing changes appeared imperceptible. This is not surprising, since some players during performance often use one or two ear plugs, or the musician's Earplug ER 15, by Etymotic Research in Chicago. Good evidence to support the robustness of musical hearing and player adaptability.

A very interesting fact about musicians' hearing is that even though a person may have a compensable noise induced binaural hearing loss derived from monaural measurements, and have difficulties in discriminating speech and the sounds of everyday life, that same person may be unstressed in performance with no observed impediments. Why? One explanation is the over-learned elements of music performance and cognitive skills can somehow make up for depressed hearing levels, that is providing a degree of residual hearing is present.

Boston University Biomedical Engineering Hearing Research Center is one of international recognition with emphasis on binaural hearing. Headed by Professor Steve Colburn, a close liaison is maintained with laboratories at MIT and Northeastern University. Symposia are presented regularly by in house, out of state and overseas researchers on a wide range of topics in psychological acoustics and the neural system. This laboratory is thus an ideal venue for continuance of the work.

Donald Woolford
Visiting Scholar, Hearing Research Center, Boston University.

Books...

Attenuation and Use of Hearing Protectors - 8th Edition

National Acoustic Laboratory

National Acoustic Laboratories, Chatswood 1998 ISBN 0 64 09114 2, 80 pp, soft-cover. Available from: NAL, 126 Greville St, Chatswood, NSW 2067, tel. (02) 9412 6800, fax (02) 9411 8273. Price A$25.00

This is the latest edition of the reference document listing the performance of the hearing protectors that have been tested at the National Acoustics Laboratory in Australia. The stated aim of this publication, in the Introduction by Warwick Williams, is to present information on the 'selection, fitting, use and maintenance of hearing protectors' in addition to the performance data. From the slender document of around 30 pages for the former editions, this 8th edition comprises 80 pages of which less than 20 are devoted to the data on hearing protectors.

The first parts of the considerably expanded information sections include descriptions of the rating and measurement procedures. Theses are followed by the practical guide to the selection, fitting and use of protectors. There are descriptions of the various types of muffs, plugs and comments on the use of combinations. A table clearly lists the advantages and disadvantages of muffs and plugs. The appendices include glossary of terms, typical noise levels, use of a sound level meter as well as contact details for the various OH&S agencies around Australia and New Zealand.

The tables, with the hearing protector data for approx 180 protectors, include the name, model, mass, clamping force, octave band attenuation data, SLC80 and the class for each item. This is the first time the values for the 'class' have been included. The recent version of AS/NZ 1269:1998 introduces this class system as a means to reduce the amount of work for the selection of protectors. The standard lists the range of noise levels appropriate for each of five classes of protectors.

The data is presented in alphabetical order for the brand name of the protector. It would be of some advantage if the data was also presented in class order so that it was possible to see at a glance all the protectors of a particular type that satisfied a particular class or SLC80. It would be of even more assistance if the data was available in 'soft' copy so that the user could rearrange it in an order to suit particular tasks.

This document is an essential reference to any who are involved in occupational noise assessments and subsequent recommendations for hearing protectors. The National Acoustics Laboratory should be commended for producing this expanded and updated edition.

Marion Burgess

Marion Burgess is a research officer at the Acoustics and Vibration Unit, Australian Defence Force Academy in Canberra. She has been involved in a number of projects which required occupational noise assessments and recommendations of appropriate hearing protectors.

New Members...

NSW

Member - Mr A Candalepas
Associate - Mr S Williams
Subscriber - Mr A. Tordoroski
Student - Mr G. Mace

WA

Subscriber - Mr C. Ong
Member - Mr J McLoughlin, Dr P. Keswick

SA

Subscriber - Mr J. Turner, Mr B. Kidd

News...

Noise Effects 98

Noise Effects 98, an international congress, will take place in Sydney, Australia from 22 to 26 November 1998. This follows the Internoise Conference Symposium in nearby New Zealand.

Noise Effects 98 is the 7th Congress in the series on Noise as a Public Health Problem, organised under the International Commission on Biological Effects of Noise (ICBEN). These conferences are only held every five years and this is the first to be held in the Southern Hemisphere. It offers a unique opportunity to participate in a conference that will deal with the full range of the effects of noise on people and animals. The key speakers are internationally acknowledged experts in their fields. This conference will be of interest to all those involved with any aspect of the effects of noise.

The scientific program will include invited and submitted oral presentations, posters and workshops in the nine subject areas: Noise-induced hearing loss; Noise and communication, Non-auditory physiological & health effects induced by noise, Influence of noise on performance and behaviour, Effects of noise on sleep, Community response to noise, Noise and animals; Combined effects of noise and other agents; and Implications for regulations and standards

The keynote speakers will include Prof Guido Smoorenburg, Utrecht University, Netherlands, Prof Andy Hede, Sunshine Coast University, Australia, Dr Judy Edworthy, University of Plymouth, UK and Prof Gary Evans, Cornell University, USA. Also Prof Birgitta Berglund (Sweden) will outline the work of ICBEN, Dr Dieter Schwela will talk on World Health Organisation Guidelines and Dr. John Franks (NIOSH - USA) will review potential new methods for the prevention of noise-induced hearing loss. Professor Jerry Tobias (USA) will present the Congress summary and overall conclusions.

Over 45 invited papers will be presented in the nine plenary sessions, one for each of the subject areas. Around 200 abstracts have been submitted to be presented in the parallel sessions of contributed papers to be held throughout the time for the Congress. In addition there will be poster papers and workshops on specific topics.

The congress venue is at Darling Harbour, which is a delightful tourist area and close to the city centre. The Welcome and the Farewell Receptions will also be held at this venue. The Congress dinner will include a ferry trip across Sydney Harbour to Taronga Zoo. Here delegates will have the opportunity to meet some of Australia's unique animals as well as enjoy the food and hospitality. A comprehensive optional social program has been organised, including a Chinese Banquet, Harbour Twilight Cruise and Opera House Performance. Optional tours around Sydney as well as pre and post congress tours have also been organised.

For details and registration:

Noise Effects '98,
GPO Box 128, Sydney NSW 2001,
tel +61 2 9262 2277, fax +61 2 9262 3135,
noise98@tourhosts.com.au,
http://www.acay.com.au/~dstuckey/noise-effects98.

Internoise 98

Internoise 98, the 1998 International Congress on Noise Control Engineering, will be held in Christchurch, New Zealand November 16 - 18, 1998 . The theme of INTER-NOISE 98 is "SOUND AND SILENCE: SETTING THE BALANCE". The conference is sponsored by I/INCE, the International Institute of Noise Control Engineering, and is being organised by the New Zealand Acoustical Society. The technical programme will provide for the presentation of posters and both invited and contributed papers with as many sessions in parallel as needed to accommodate the topics offered. Distinguished Lectures will be given by Dr Leo L Beranek, and Professors Jeremy Astley, Christopher Rice and Colin Hansen as plenary sessions. Topics will be grouped with a Keynote Paper invited for each session. Technical Papers will be presented in a wide range of topics on noise and vibration. An interesting social program will also be part of the conference. Registration booklets available now.

Further Information:
http://wwwauckland.ac.nz/internoise98 or from INTER-NOISE 98, NZ Acoustical Society, PO Box 1181, Auckland 1001, New Zealand.
Tel: +64 9 623 3147, Fax: +64 9 623 3248,
internoise98@auckland.ac.nz

Recreational Noise Symposium

This Symposium on Recreational Noise, November 20 in Queenstown, New Zealand, follows Internoise 98 in Christchurch. Of interest to all those involved in public health, this symposium is targeting the hidden factor in many of our public health problems today. Little has been done to quantify the effects of, and no compilation of data is available for, noise received during recreation and leisure periods – periods in which our occupational safety and health legislation, almost without exception, assumes are free from noise. We know that shooting can cause hearing loss and that other activities such as regular attendance at discotheques may have similar consequences, but we have little published knowledge of the effects of noise in other recreational activities. The Symposium will bring together the world experts on noise to present papers on their work and to discuss the overall problem and what can be done about it. The results of the discussions (proceedings) will be compiled into a book that will be sent to all delegates shortly after the Symposium.

The venue is the Lakeland Hotel on the shores of beautiful Lake Wakatipu where a block of rooms, all with views of the lake and mountains has been reserved. From Christchurch to Queenstown is a short 45 minute flight or a coach trip through the beautiful Mackenzie Valley, Following Queenstown it may be possible to travel direct to Sydney on the Sunday via Air New Zealand to arrive in time for Noise Effects 98. Alternatively there are scheduled flights via Christchurch to Sydney

Further information: P O Box 76-068, Manukau City, New Zealand, fax +64 9 279 8833, grantm@bitz.co.nz

AAS Memorandum etc

All members of the Australian Acoustical Society should have received a copy of the current Memorandum of Association, Articles of Association and By Laws. The revised version was passed at the Annual General Meeting in 1997 and then approved by the Australian Securities Commission (ASC) on 30 March 1998. If any member has not received a copy of this document then please contact the General Secretary.

FASTS

The peak body for scientists and technologists in Australia said that it was disappointed in the recent Budget. Professor Peter Cullen, President of the Federation of Australian Scientific and Technological Societies (FASTS), said that once again Australia seemed to be missing opportunities. "By dithering we are likely to continue to miss the boat in the biotechnology revolution in the same way as we missed the boat in information technology in the 80s and 90s. The Government seems bereft of ideas. Competitive success in the next century will be won by countries which follow the knowledge-based path, to generate real and enduring employment. This requires a strong science base and smart programs to link industry with science. This needs strong leadership from Government."

Australia has just recorded its first fall in business expenditure on R&D since the Australian Bureau of Statistics began measuring R&D in the mid 1970s. This is another gloomy sign for Australia's economic outlook, and a bad sign as we enter a millennium which is going to place an increasing emphasis on industries that are sophisticated, intelligent and sustainable. It is clear that industry in Australia does not have the confidence or conviction to invest in R&D under the present financial settings and economic climate.

FASTS believes that research and development should be encouraged as an activity vital to Australia's future. There is a strong argument for scientific research activity (as well as the provision of educational services) to be zero rated in any GST. This is a simple and explicit means of encouraging R&D.

ASA and EAA Joint Meeting

The 137th Meeting of the Acoustical Society of America and the 2nd Convention of the European Acoustics Association: FORUM ACUSTICUM 1999 - integrating the 25th German Acoustics DAGA Conference will be held in Berlin, March 14-19 1999. The meeting is being organised by the Acoustical Society of America, the European Acoustics Association, the Deutsche Gesellschaft für Akustik (German Acoustical Society) and the Technical University Berlin, in cooperation with the German Physics Society, DPG, the Association of German Engineers, VDI and the German Institute of Communication Technology, ITG.

The meeting will be held at the Technical University Berlin, which is located in the centre of Germany's capital, Berlin. The technical program will consist of invited and contributed papers presented as lectures and posters. The topics covered include acoustical oceanography, animal bioacoustics, architectural acoustics, biomedical ultrasound, bioresponse to vibration, engineering acoustics, musical acoustics, noise, physical acoustics, psychological and physiological acoustics, signal processing in acoustics, speech communication, structural acoustics and vibration, underwater acoustics and education in acoustics. In addition there will be an exhibition, technical committee meetings and an attractive social program.

For the first time, acousticians from America and from Europe will be holding their regular meetings under one roof. This meeting will bring together experts from all fields of acoustics and provide an international forum for the open exchange of scientific and engineering information worldwide.

Information from Institut für Technische Akustik Einsteinufer 25 10587 Berlin, Germany Fax: +49 30 314 251 35 e-mail: forum99@mach.ut.tu-berlin.de http://forum99-asa.tu-berlin.de/

Congress on Sound & Vibration

Following the successful 5th Congress in Adelaide, 1997, the 6th International Congress on Sound and Vibration will be held 5-8 July 1999 in Copenhagen. Denmark has a long tradition and a unique position in acoustics and vibration and it is a quarter of a century since last time a major acoustic congress took place in Denmark.

This Congress sponsored by International Institute of Acoustics and Vibration, the Technical University of Denmark, the Danish Acoustical Society, Brüel & Kjær, and Ødegaard & Danneskiold-Samsøe. The programme includes invited and contributed papers in specialised sessions organised by the 48 members of the Scientific Committee, and tutorials and workshops. There will be several keynote presentations: Episodes from a Century of Acoustics by Per V. Brüel, New Developments in Fluid-Structure Interaction Theory by David Crighton, Recent Developments in Aeroacoustics by Stewart Glegg, State of the Art of Energy Methods Used for Vibro-Acoustic Prediction by Jean-Louis Guyader, Recent Advances in Active Control of Interior Noise by Colin H. Hansen, Some Inverse Problems in Acoustics by Philip A. Nelson, and Developments in the Prediction of Sound Radiation from Real Structures by Andrew Seybert.

Information; Congress Secretariat, Department of Acoustic Technology, Technical University of Denmark, Building 352, DK-2800 Lyngby, Denmark; tel: +45 4588 1622; fax: +45 4588 0577; icsv6@dat.dtu.dk., http://icsv6.dat.dtu.dk.

Metrology Conference

This conference, 22 - 24 September 1999, in Sydney is the third national forum within Australia that will enable all members of the measurement community; professionals, students, researchers and teachers, to meet and share experiences. Measurement can be one of the most objective and acceptable tools provided there is broad agreement between the interested parties about the suitability and accuracy of the methods employed. The relevance of measurement extends from international political issues, through to the viability of particular industries down to processes operating within a company or organisation. The conference will welcome contributions from all areas of metrology including acoustics (eg sound level, vibration, ultrasonics, underwater etc).

Information: Dr Suszanne Thwaites, NML, PO Box 218, Lindfield NSW. Tel; (02) 9413 7416, Fax; (02) 9413 7161, Email; suszanne.thwaites@tip.csiro.au.

Buried Objects

The second Vic Division technical meeting for 1998 was held on May 6 at Monash University with the topic "Using Acoustic Impulses to detect buried objects". In the initial talk, Charles Don and David Lawrence reported on their more recent work done in detecting land mines, work done since the earlier research described by Rogers and Don in Locations of Buried Objects by an Acoustic Impulse Technique (see Acoustic Aust. 1994, vol 22/1, pp5-9).

This recent research has been concentrated on locating land mines. There are currently 100 million of over 600 types throughout the world, which kill 25,000 people each year, are of low cost to make, and could take up to 1,000 years to be cleared.

Of the other existing detection methods,

(i) metal detection has limited applicability since many mines are almost wholly plastic.

(ii) ground penetrating radar (requiring vhf of GHz order) is costly, (iii) infra-red imaging, though among the more useful detection methods (through differential heat sensing), is not wholly reliable, being too dependent on weather conditions, and (iv) dogs, though they can smell very small amounts of explosive, are costly to train, bite quickly, and have poor sense of localisation (only to within 1m radius).

This left considerable scope for their detection from the differences in the acoustic impedances between ground and land mine. These are detected after the various reflections from a burst of sound (in a band centred on 1kHz) from a loudspeaker directed at the ground are picked up by 2 microphones from whose outputs is selected the difference signal. In this method, the microphones picked up the direct loudspeaker sound, the ground reflection, and any further reflection from a buried object.

In the later development of this method, only one microphone was used, which picked up the direct sound, the ground reflection, together with any other reflection from a buried objects. The various reflections are identified by the amounts of time they are received after the original burst. Single or averaged responses from the direct burst and the ground reflection are then subtracted from the total signal to detect any residual due to a buried object. In this subtraction process, some care was found to be necessary if any averaged ground response was used.

The latest improvements include reducing the centre frequency of the sound burst from 1kHz to 700 Hz (with the ban half-power points at 400 and 2000 Hz), and in using 4 microphones to scan more ground at a time.

With this method, mines to a depth of 10cm can be detected, though unlikely in hard or wet ground, or under a rock.

Louis Fouvy

Audio Visual Theatre

The third Vic Division technical meeting for 1998 was held on June 24 at the B&H Home Theatre in East Malvern, a visual communications company in the ever growing area of high quality audio-visual presentation.

Currently, the use of Digital-Video-Disk (DVD) video theatre in domestic applications is popular in the USA, and is expected to significantly impact of the Australian domestic market over the next 5 years or so.

Discussion included the optimizing of the presentation space, often a living room, and sometimes a dedicated theatre room in a home. Sound absorptive panels of 25mm thickness with decorative fabric finish have been used in the showroom theatres to reduce flutter echoes and rear wall reflections, and to optimize the general reverberation characteristics of the room.

Sound insulation is likely to be an important consideration for the future expansion of the domestic market as the Residential Noise Regulations under the Victorian Environment Protection Act require that noise from electrical amplifying sound reproducing equipment during some periods be inaudible in a neighbouring residence.

Louis Fouvy

Noise Guideline

In February 1998 the Liquor Administration Board of NSW has released the following noise guideline for licensed premises. The LA_{10} noise level emitted from the licensed premises shall not exceed the background noise level in any Octave Band Centre Frequency (31.5Hz - 8kHz inclusive) by more than 5dB between 07.00am and 12.00 midnight at the boundary of any affected residence.

Notwithstanding compliance with the above the noise from the licensed premises shall not be audible within any habitable room in any residential premises between the hours of 12.00 midnight and 07.00am.

Interior noise levels which, although restricted in accordance with the above condition, still exceed safe hearing levels are in no way supported or condoned by the Liquor Administration Board.

This is a minimum standard. In some instances the Board may specify a time earlier than midnight in respect of the above condition.

For the purposes of this condition, the LA_{10} can be taken as the average maximum deflection of the noise emission from the licensed premises.

NSW EPA Drafts

Comments on the following draft EPA (NSW) noise policies are invited. Details can be found on either from http://www.epa.nsw.gov.au or hard copies obtained from the EPA tel 131555 or 02 9325-5555.

Draft Stationary Noise Policy

Submissions due before 28 September 1998. This Policy sets out the ways in which the impacts of noise from stationary (industrial) noise sources on residences and other sensitive land uses can be assessed and dealt with.

Draft Environmental Criteria for Road Traffic Noise

Submissions due before 7 September 1998.

User's Guide

A User's Guide to the Queensland Environmental Protection (Noise) Policy has been produced by the Qld Dept of Environment It explains the key provisions of the Act and the framework to which the Policy belongs. Notes provide a short explanation of every provision in the Policy. The 44 page booklet has been written to explain how the policy is designed to work.

Copies are available from Goprint Bookshop, PO Box 364 Wooloongabba Queensland 4102, fax (07) 3246 3534, for $10 plus $2 postage and handling.

Sir James Lighthill

Sir James Lighthill, the founding President of the International Institute of Acoustics and Vibration died, aged 74, on July 17 while attempting to swim around the island of Sark. Sir James was an expert swimmer but after nine hours into his attempt, when he had nearly completed his swim, he was found dead in the water. Twenty-five years ago, James Lighthill became the first person to swim around the Channel Island of Sark, calling it "a most pleasant way to see the scenery".

Sir James was one of the great mathematicians of the Twentieth Century. He was a pioneer in several fields including supersonic aerodynamics, biofluiddynamics and aeroacoustics. He virtually created the field of biofluiddynamics, the study of how animals move through air or water, as well as the study of the fluid mechanics of the cardiovascular system. His famous law that the acoustic power of a jet is proportional to the eighth power of the jet velocity is known to many of us. He held the senior mathematical chair at Cambridge, and became a leading adviser on government scientific policy.

Those who attended the 5th ICSV in Adelaide in 1997 will well remember his stimulating lectures and talk at the dinner. He will certainly be missed.

ASA Award

Neville Fletcher has been awarded the Silver Medal of the Acoustical Society of America for his research in musical acoustics. This was announced by ASA Vice-President elect, William Hartman, at the satellite meeting on musical acoustics, held at Leavenworth following the ICA-ASA Congress in Seattle in June. The medal will be presented at the next ASA meeting, which will be held in Norfolk, Virginia, in October.

IEAust Hon Fellow

Louis A Challis has recently been elected as Honorary Fellow of IEAust. His citation stated: buildings and structures - including the new Parliament House in Canberra, Parliament Houses in NSW and Qld, the NSW State Library, Sydney Harbour Tunnel and the Monorail - have benefited from the work of acoustics engineer Louis Challis. He pioneered the development and use of statistical methods for the assessment of community noise in Australia. He has worked in the field of forensic acoustics. For the special problems of blind, deaf pedestrians at signal crossings, he developed the successful audio-tactile device used in all Australian and many overseas cities. Although offered the right to patent his invention, he declined believing that it should not be encumbered by added costs.

Eng Aust 1998

STANDARDS AUSTRALIA

AS/NZS 2399:1998

Acoustics - Specification for personal sound exposure meters.

Specifies acoustical and electrical performance requirements for personal sound exposure meters. Specifications are applicable to instruments intended to be worn on a person for measurement of A-weighted sound exposure resulting from steady, intermittent, fluctuating, irregular or impulsive sounds. This Standard is technically equivalent to, and has been reproduced from IEC 1252:1993.

AS/NZS 3817:1998

Acoustics - Methods for the description and physical measurements of single impulses or series of impulses.

Describes preferred methods for the description and the physical measurement of single impulsive sounds or short series of impulsive sounds and for the presentation of the data. It does not provide methods for interpreting the potential effects of series of impulses of noise on hearing, community response or structures. This Standard is identical with and has been reproduced from ISO 10843:1997.

New Products...

Nicolet
Laser Doppler Vibrometer

The Nicolet Orion Laser Doppler Vibrometer uses a unique optical implementation to accurately measure vibration over a wide frequency range from 5Hz to 80kHz at distances of up to 7m. The Orion works on almost any surface without the need for painstaking setup or messy surface preparation.

The Orion mounts on any standard camera tripod or laser stand. Switchable front panel low and high pass filters enable measurements to be limited to only the frequency range of interest. Standard +/-10V analog output enables the Orion to be used with any standard FFT analyser or data acquisition system. The Nicolet Orion uses a Class IIIb laser and unlike other non-contact devices is capable of off-axis measurements. A breakthrough in optical technology minimises internal optics, enabling a smaller sized unit available at a much lower cost than conventional vibrometers.

Further information: Mark Breznik, Emona Instruments Tel: (02) 9519 3933, Fax: 02 9550 1378, testinst@emona.com.au

ARL
Entertainment Noise Monitor

Hearing damage is becoming more and more of an issue both in the workplace and now in the entertainment industry. Combine this with tighter controls on noise as measured at neighbouring premises as local residents make their voices heard and the need for a simple way of controlling noise output becomes more and more necessary.

A recently released entertainment noise monitor, the BB-01 model, is now available. This monitor is designed to cut the power to the amplifiers should the noise level exceed a pre-set (user adjustable) level. A series of LED's on the front of the unit act as a warning display enabling the operator of the sound system to keep the volume below the trip threshold.

Further Information: Acoustic Research Laboratories, Tel: 02 9484 0800 Fax: 02 9484 0884 or your local branch of ARL.

CEL 400 Series
Noise & Logging Dosimeters.

Stantron Australia have released a new series of acoustic personal exposure meters made by CEL-400 series which work as a personal exposure meter, a sound level meter and are lightweight, compact (about the size of a cigarette pack), and ruggedly built. They have high capacity memories for up to 16 measurements and the storage of detailed time-history profiling (up to 14 hours recording or 53,000 points). Measurement ranges from 30 - 140dB(A). They are also equipped with A, C Fast, Slow and impulse.

The instruments can be connected directly to printers with report ready formats held in memory, as well as PC's for further data processing. Download software is available for use in Windows. An intrinsically safe version is also available.

This instrument would be ideal for monitoring surrounding noise that an individual is being exposed to or for general noise measurement.

Further details: Stantron Aust, PO Box 4760 North Rocks, NSW 2151, tel 02 9894 2377, fax 02 9894 2386, stantron@internet-australia.com

FANTECH
Silencer Membrane

On some applications it is critical that there is absolutely no possibility of mineral fibres used in the splitters of attenuators entering the conditioned space. The use of a protective membrane on a standard silencer will seriously degrade the acoustic performance. This error has lead to some disastrous results caused by unpredictable silencer performance.

To overcome this problem a unique combination of materials has been developed and tested by Q-Tech. Q-Seal is more than just an impervious facing which enveloped the fibreglass or mineral fibres. It also involves a tuned selection of perforated metal lining and special acoustic insulation fill to ensure optimum silencer performance. It also prevents moisture entering the acoustic fill making these attenuators suitable for exposed to weather situations such as cooling tower attenuators or attenuators exposed to the rain.

Further details: Fantech Pty Ltd, PO Box 346, Mulgrave North, Victoria, 3170 Tel: 03 9560 2599 Fax: 03 9561 4428, info@fantech.com.au

SONY
Data Recorder

The PC200Ax Series data recorders have been specially developed for use both in the field and as laboratory instruments. Compact and lightweight, they deliver the very highest level of performance available today.

There are three recorder models – 2/4Ch 2/4/8Ch and 2/4/8/16Ch – all A4 size and range from 3.5 to 4.5kg. These instrumentation recorders utilise the highly reliable, four motor, direct drive, Sony DDS tape streamer transport. Providing 1x and 2x standard DAT linear speed and performance. A comprehensive selection of accessories are available to meet the needs of an ever-expanding variety of scientific and industrial applications.

In order to perform lab analyses with large volumes of location data Sony provides a PC interface package - PCscan. PCscan enables high-speed digital data transfer to PC such that a Real-Time display is used to find event data which can be converted to any common data format required by professional analysis software such as DADiSP, MATLAB, SnapMaster, STAR and nVision. PC200Ax series recorders can be easily controlled from a PC using the PCscan Graphical User Interface which displays a Tape Remote Panel, Tape Search, Teal-Time Plot, Level Bar Meter and a Work Bench Window.

Further details: Mr Peter Norman B&P Pro Audio & Data Sony Australia Limited 33 Talavera Rd, North Ryde, NSW 2113 Tel: (61) 2 9887 6674 Mob: (61) 0418 265 012 Fax: (61) 2 9805 1151

SoundPLAN Wins

SoundPLAN is a software package for environmental noise and air pollution evaluation, simulating noise from roads, railways, industry as well as aircraft. Developed by German consulting engineers Braunstein & Berndt, SoundPLAN is known as a reliable, fast and easy to use tool, with excellent graphic capabilities. A major new version of this highly regarded noise and air pollution evaluation software - SoundPLAN for Window NT/95 (SoundPLAN Wins) has now been released.

Whilst maintaining the strengths of the previous versions, the Windows environment and user interface help speed up the learning curve for the new version SoundPLAN Wins. All SoundPLAN modules have extensive full colour graphic capabilities on screen and in printed form, suiting all requirements for project, community and court room presentations. Graphics include single point calculations for spreadsheets and tables, grid noise maps, noise contour maps, difference maps as well as cartography.

Further details: Vipac Engineers & Scientists Ltd, 275 Normanby Road, Port Melbourne VIC 3207, Tel: 03 9647 9700 Fax: 03 9646 4370.

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Diary...

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1998

September 14-18, CZECH
35th Int. Conf. Ultrasonics & Acoustic Emission.
Detail: H. Kotschova, Geophysical Inst AS CR Bocni II/401, 14131 Prague 4 Czech Republic, Fax: +42 2 761549, hko@ig.cas.cz, http://www.ig.cas.cz

September 16-18, BELGIUM
Int. Conf. on Noise and Vibration Engineering
Details: Ms L Notré, KU Leuven, Division PMA, Celestijnenlaan 300B, 3001 Leuven, Belgium, Fax: +32 16322987, lieve.notre@mech.kuleuven.ac.be,
http://www.mech.kuleuven.ac.be/pma/events/isma/isma.html

September 21-25, ITALY
4th European Conf. On Underwater Acoustics
Detail: Secretariat ECUA 98, Istituto di Acustica - CNR, ia del Fosso del Cavaliere, 00133 Roma, Italy, ecua98@idac.rm.cnr.it

September 23-26, USA
24th Int. Symp On Acoustical Imaging
Details: H. Lee, ECE Dept, Uni of California, Santa Barbara, CA 93106, USA

October 4-7, GERMANY
EURO-Noise 98
Details: CSM, Industriestrabe 35, D-82194 Grobrnzell, Tel: +49 8142 570183, Fax:49 8142 54735, csm_congress@compuserve.com

October 7-8, SLOVENIA
1st Cong. Slovenian Acoutical Soc.
Details: Erika Zelezic, Mech Eng'g, Uni Ljubljana, Askerceva 6, 1000 Ljubljana, Slovenia, Fax: +386 61 218567, erika.zelezic@fs.uni-lj.si

October 12-16, NORFOLK
Meeting of ASA,
Details: ASA, 500 Sunnyside Blvd., Woodbury, NY 11797 USA. Fax: +1 516 576 2377, asa@aip.org

October 12-16, BEIJING
4th Int. Conf. On Signal Processing (ICSP'98)
Details: Fax: +86 10 6828 3458, yuanbz@sun.ihep.ac.cn

Oct 31 - Nov 3, DENMARK
AES Int. Conf "Audio, Acoustics and Small Spaces
Details: Acoustical Soc. Denmark, Bldg 352 DTU 2800 Lyngby, Denmark. Fax: +45 4588 0577, atc.das@dat.dtu.dk

November 12-15,UK
Inst. Acoustics Autumn Conf.: Speech and Hearing
Details: Inst. Acoustics, Agriculture House, 5 Hollywell Hill, St Albans, Herts AL 1 1EU, UK, Fax: +44 1727850533, acoustics@clus1.ulcc.ac.uk

November 11-13, SINGAPORE
APAV 98
Details: APAV 98, 1 Selegie Rd #09-01, Paradiz Centre, Singapore 188306, Tel: +65 3399129, Fax: +65 334 7891, apavcon@singnet.co.sg

November 16-20, CHRISTCHURCH
INTER-NOISE 98
Details: NZAS. P.O. Box 1181, Auckland, NZ, Fax +64 9 309 3540
http://www.auckland.ac.nz/internoise98/

November 20, QUEENSTOWN
I-INCE Symp. on Recreational Noise
Details from: Conference Secretary Grant Morgan ECS, P O Box 76-068 MANUKAU CITY New Zealand Fax: (+64) 9 279 8833 email: grantm@bitz.co.nz
Or from the General Chairman: Dr Philip Dickinson Fax: (+64) 4 234 1185 email: philip_d@iconz.co.nz

***November 22-27, SYDNEY**
Noise Effects 98
ICBEN Congress
Details: Noise Effects '98, GPO Box 128, Sydney NSW 2001 Australia Tel: 02 92622277 Fax: 02 92622323, tourhosts@tourhosts.com.au, http://www.acay.com.au/~dstuckey/noise-effects98/

***Nov 30 - 4 Dec, SYDNEY**
5th Int. Conf. on Spoken Language Processing
Details: Tour Hosts, GPO Box 128, Sydney NSW 2001 Australia, Fax: 02 92623135, tourhosts@tourhosts.com.au, http://cslab.anu.edu.au/icslp98

December 6 - 11, SYDNEY
Transport '98
Details: Margaret Husselbee, ARRB Transport Research 500 Burwood Highway, Vermont South, VIC 3133 Tel: 03 9881 1578 Fax: 03 9887 8104, marghu@arrb.org.au

***December 8-11, TASMANIA**
COMADEM 98
Details: Centre of Machine Condition Monitoring, Monash Uni. Dept. of Mechanical Engineering, Wellington Rd, Clayton VIC 3168, Tel: 03 99055699, Fax: 03 99055726, maltezos@eng2.eng.monash.edu.au, http://www.monash.edu.au/cmcm/

December 15-17, INDIA
"Designing for Quietness" an Int. Symp.
Details: Prof. ML Munjal, Senter of Excellence for Technical Acoustics, Dept. of Mechanical Engineering, Indian Institute of Science, Bangalore 560 012, India, munjal@mecheng.iisc.ernet.in

1999

March 15-19, BERLIN
Forum Acusticum & ASA Meeting
Details: ASA, 500 Sunnyside Blvd., Woodbury, NY 11797 USA. Fax +1 516 576 2377, asa@aip.org, http://forum99-asa.tu-berlin.de

April 27-29, VENICE
Int. Conf. Vib. Noise & Struct Dynamics
Details: D. Hill, Staffordshire Uni, PO Box 333, BeaconsideST18 ODF, UK Fax: +44 1785 353552

May 10-14, TRIESTE
4th Int. Conf. Theory & Comput Acoustics
Details: Fax: +39 40 327040, ictca99@ogs.trieste.it

May 24-26, ATHENS
2nd Int. Conf. On Emerging Technolgies in NDT.
Details: Ms. M. Bourlau, Free University Brussels, TW-KB, Pleinlann 2, 1050 Brussels, Belgium, Fax: +32 2 6292928, mbourlau@vub.ac.be

June 28-30, RUSSIA
EEAA Congress - 1st Int. Cong. East European Acoustical Society
Details: EEAA, Moskovskoe Shosse 44, St Petersburg 196158, Russia, Fax: +7 812 1279323, krylspb@sovam.com

June 28-July 1, LYNGBY
Joint Conf. Ultrasonics Int '99 & World Congress Ultrasonics '99
Details: Dept Industrial Acoustis, Denmark's Technical University, Bldg 425, 2800 Lyngby, Denmark, Fax: +45 45 930190, lb@ipt.dtu.dk, www.msc.cornell.edu/~ui99/

July 5-8 DENMARK
6th Int. Congress on Sound & Vibration
Details: Dept Acoustic Tech, Tech Uni of Denmark, Bldg 352, DK-2800 Lyngby, Denmark. Tel: +45 45 881622 Fax: +45 45 880577 icsv6@dat.dtu.dk, http://www.icsv6.dat.dtu.dk

September 1-4 GERMANY
15th Int. Symp. Nonlinear Acoustics (ISNA-15)
Details: W. Lauterborn, Drittes Physikalisches Inst., Universitat Gottingen, Burgerstr 42-44, 37073 Gottingen, Germany, Fax: +49 551 39 7720, lb@physik3.gwdg.de

22 - 24 September, SYDNEY
Metrology Conference
Information: Dr Suszanne Thwaites, National Measurement Laboratory, PO Box 218, Lindfield NSW. Tel; (02) 9413 7416, Fax; (02) 9413 7161, Email; suszanne.thwaites@tip.csiro.au.

November 1-5, COLUMBUS
138th Meeting of ASA
Details: ASA, 500 Sunnyside Blvd., Woodbury, NY 11797 USA. Fax +1 516 576 2377, asa@aip.org

December 2-4, FORT LAUDERDALE
ACTIVE 99
Details: Fax: +1 914 4624006, inceusa@aol.com

December 5-9, USA
Inter-noise 99
Details: INCE, PO Box 3206 Arlington Branch, Poughkeepsie, NY 12603, USA, Fax: +1 914 4624006, inceusa@aol.com

2000

October 3-5 KUMAMOTO
WESTPRAC VII
Details: Dept Computer Science, Kumamoto Uni. 2-39-1 Kurokami, Kumamoto, 860-0862. Tel: +81 96 3423622 Fax: +81 96 3423630 westprac7@cogni.eecs.kumamoto-u.ac.jp http://cogni.eecs.kumamoto-u.ac.jp/others/westprac7

December 4-8, NEWPORT BEACH
Meeting of the ASA
Details: ASA, 500 Sunnyside Blvd., Woodbury, NY 11797 USA. Fax +1 516 576 2377, asa@aip.org

COURSE

September 21-22, 1998
The State Of The Art In Vibration-Based Structural Damage Identification
Presented by Los Alamos Dynamics at RMIT Melbourne
Details: http://www.la-dynamics.com/

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Student	$20

DIVISIONAL MATTERS

Enquiries regarding membership and sustaining membership should be directed to the appropriate State Division Secretary

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Professional Centre of Australia
Private Bag 1,
DARLINGHURST 2010
Sec: Mr D Eager
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Fax (02) 9514 2665
david.eager@uts.edu.au

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