Noise Effects '98

SYDNEY, AUSTRALIA

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VOLUME 2

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FOREWORD

These two volumes are the Proceedings of Noise Effects '98, the Seventh International Congress on Noise as a Public Health Problem, which took place in Sydney, Australia, from 22-26 November 1998. The Congress was organised under the auspices of the International Commission on Biological Effects of Noise (ICBEN). The papers contained herein are those which were presented at the Congress and submitted for publication. They are grouped according to the subject matters of the ICBEN International Noise Teams, as follow: Team 1: Noise Induced hearing Loss; Team 2: Noise and Communication; Team 3: Non-auditory Physiological Effects Induced by Noise; Team 4: Influence of Noise on Performance and Behaviour; Team 5: Effects of Noise on Sleep; Team 6: Community Responses to Noise; Team 7: Noise and Animals Team; 8: Effects of Noise Combined With Other Agents; Team 9: Regulations and Standards.

Volume 1 contains papers from Teams 1-4; Volume 2 Teams 5-9. Within each Team, the papers are further grouped according to Keynote Addresses, Invited Papers, and Workshop and Contributed Papers.

Publication of these Proceedings was sponsored by the United States Department of Defence, the U.S. Army, Navy and Air Force, and the National Aeronautics and Space Administration. The Editors wish to thank these sponsors, as well as all contributors, the ICBEN team leaders, and the staff of Tour Hosts Pty Limited, Sydney, especially Ms Denyse Robertson.

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INTRODUCTION

These volumes represent the research papers submitted to Noise Effects '98, the 7th International Congress on Noise as a Public Health Problem, organised under the auspices of the International Commission on Biological Effects of Noise (ICBEN). Since its creation in 1973, at the Dubrovnik conference (the 2nd International Congress on Noise as a Public Health Problem, the first being held in Washington in 1968) ICBEN has become a premier international body in the field of research into the biological effects of noise and their prevention. To cite two examples, ICBEN is acknowledged for its help with the recent review of noise effects by the World Health Organisation (see Berglund & Lindvall, 1995) and is also involved in advising the European Commission on noise effects.

International Representation on ICBEN

A primary attribute of ICBEN which has contributed significantly to its success is its truly international representation. The three office bearers (who, in keeping with equal opportunity across gender, are all female at present) come from three different countries, the President from Sweden, the Secretary from Germany, and the Vice-President from the United States. This international representation is also evident in the Chairs and Co-chairs of the nine International Noise Teams.

Structure of ICBEN

The success of ICBEN may also be attributed to its structure, which allows for no continuing funding of ICBEN itself. As a result ICBEN does not become bogged down in financial concerns, such as annual auditing of accounts. ICBEN does not operate a bank account. The original constitution of ICBEN contains only one article on finances, which simply states: "The officers and the Executive Committee are authorized to solicit funds in support of the activities of the ICBEN." Thus, the office bearers must meet costs from their institutions and from their own resources, selecting for committed persons. This also means, however, that the conferences must be run without any financial support from ICBEN. While this creates a more daunting task at the outset, strong sponsorship has been forthcoming for the conferences, and the present conference is no exception. In part at least, this level of sponsorship arises from the knowledge that the conferences are run as non-profit ventures, and that sponsorship of the conferences does not amount to sponsorship of an ongoing account held by ICBEN.

International Noise Teams

The powerhouses of ICBEN are its International Noise Teams. ICBEN is organized around nine teams: Team 1 is responsible for efforts in relation to noise-induced hearing loss; Team 2 for noise and communication; Team 3 for non-auditory physiological effects induced by noise; Team 5 for effects of noise on sleep; Team 6 for community response to noise; Team 7 for noise and animals; Team 8 for combined agents; Team 9 for regulations and standards. Each team consists of up to 10 experts in the relevant field, with an elected Chair and Co-chair. The chairs are limited to two periods of office to allow for new ideas and fresh approaches to the problem at hand. Team membership is limited to no more than two members from any one country to ensure the maintenance of the international representation of ICBEN. This team structure allows for many of the valuable outcomes of ICBEN and its twice per decade conferences, in the following ways:

1. Research endeavours can be focused, and can avoid unwanted duplication within the team.
2. The team members can be kept abreast of recent developments in their field. This is done in part through correspondence between team members, and partly by means of the summaries of the developments in each field over the preceding five years, which are presented by each team at each conference.
3. While each team maintains a focus on the specific issues of the team, the isolation of teams is avoided by ensuring that each team presents its five-yearly review of research and invited addresses in plenary. In this way members of all teams may witness the advances being made in each of the other eight primary areas of endeavour.
4. The teams themselves are not fixed. The original constitution of ICBEN only states that such teams will exist but does not specify the number or subject-areas of the teams. Indeed, the teams have been changed to meet the growing and changing face of noise research. The most recent change was the addition of Team 9: Regulations and Standards, at the Stockholm conference in 1988.
5. The team structure can allow for international collaboration, and agreements regarding findings, approaches, applications, methods, measurement, and/or reporting. A prime example of this has been the collaborations in Team 6 (Community Reaction) regarding standards of reporting which have been agreed on within the team after considerable discussion, and since published by the team (see Fields et al., 1997).

Collaborative research is also fostered, such as the international research on the wording of questions on reaction to noise, resulting in several papers presented in the present volumes.

Conferences and Proceedings

The five-yearly international congresses on Noise as a Public Health Problem are a centrepiece of ICBEN's productivity. High standards of scientific quality and sensitive application of research to practical solutions are the norm. Shared information and experience raise the knowledge base for all. The polite yet sometimes spirited discussions also serve ICBEN well. The production of quality Proceedings from these conferences has allowed them to maintain an impact rarely seen of conference publications. Indeed, as a measure of awareness of the features of quality conferences shown by the founders of ICBEN, the constitution requires that Proceedings be produced for each conference. This maximises the impact of the conference, advertises the conferences, and increases the motivation to present quality work at such conferences, knowing that a Proceedings will be produced. We can all identify classic papers in our respective fields within previous volumes from this conferences series.

An objective measure of the impact of these conferences lies in the level of scientific citation of the Proceedings. The most recent Proceedings, edited by Michel Vallet, are recorded as having been cited 14 times in the Science Citation Index and the Social

Science Citation Index in the years 1994-1997. It is an unusual achievement for a Proceedings to be cited so frequently in refereed journals.

The conference on which the present Proceedings are based continues to reflect these advantages of the ICBEN structure in many expected ways. The plenary session from each team is programmed. The conference maintains the international representation of researchers and workers on noise effects. The conference boasts papers offered from all continents, as well as from 'Oceania'. International keynote addresses are included. Each team has organised its own sessions from invited and contributed papers, with the results of these decisions being passed on to the local Organising Committee for implementation.

Noise Effects '98 is also innovative. There are sessions based on the joint work of more than one team. Thus we have combined sessions from Teams 3 and 4 (physiological effects and performance), and from Teams 3, 6 and 8 (physiological effects, community response and combined agents), demonstrating fruitful cross-team collaborations. A contributed workshop addressing the economic costs of noise countermeasures is of relevance to deliberations regarding solutions to noise from the perspective of many of the teams (Section 10).

Two other features of the Congress are noteworthy. First, it is appropriate that one quarter of a century after the founding of ICBEN, one of the two people most responsible for its creation, Dixon Ward (who together with Gerd Jansen founded ICBEN) is honoured by the Dixon Ward Memorial Address, one of the two keynote addresses delivered at the Opening Ceremony. This address is presented by Guido Smoorenburg. Second, the global role of ICBEN is emphasised in this conference, the first to take place outside Europe. Previous ICBEN conferences (after the 1973 Dubrovnik conference from which ICBEN arose) have been held in Germany in 1978, Italy in 1983, Sweden in 1988, and France in 1993.

These are exciting times in the field of noise research. The effects of noise on humans and animals is better recognised and better understood than ever before; solutions as expensive as shifting airports to unpopulated areas, or even offshore are being considered and implemented. New approaches, such as positive sound environments are being evaluated; communities are more informed and more reactive to this information (or misinformation) about noise than before (see Carter et al., 1996). Artificial hearing and hearing protection are advancing. Yet, these are also worrying times in terms of the effects of noise. The combined effects of greater industrialisation, greater mechanisation (especially of transport), and greater concentration of populations in noisy cities rather than quiet rural settings has caused greater noise exposure of the population globally than ever before. It is our earnest hope that Noise Effects '98, the 7th International Congress on Noise as a Public Health Problem, and these Proceedings, will contribute significantly to furthering our understanding of the biological effects of noise, and their mitigation.

Norman L. Carter
R. F. Soames Job

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SLEEP DISTURBANCE BY NOISE: RECENT ORIENTATIONS

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1. INTRODUCTION

Surveys carried out during the 1990s highlight the significance of the impact of night time noise and high demand from populations exposed to noise to conserve the quality of their sleep.

Since the last congress in Nice, France, research into sleep disturbance by noise basically falls into three categories:

- experimental research aiming to describe the physiological effects of noise on sleep. In addition to conventional parameters used to describe sleep (electroencephalograms, electrocardiograms, occulograms, breathing and actigraphics), biochemical scales are now used to explore noise- related modifications. All psycho-sociological field and laboratory surveys are also included in this category as are epidemiological studies demonstrating sleep disturbance after effects.

- research which aimed to determine the noise levels sleepers can tolerate by re-working data collected in previous studies or by obtaining new data specifically for this purpose.

- reviews of existing research, usually to prepare regulations such as the often stringent recommendations of the World Health Organisation and national standards.

2. INCLUSION OF NOISE

Applying research findings for regulatory purposes immediately invites questions about the way in which noise should be included; it is not a new problem to note that "operational" regulations consider external noise levels - usually on the facades on buildings - whereas experimental studies into sleep disturbance by noise measure acoustic levels perceived by sleepers with microphones located inside bedrooms and laboratories. The quality of the acoustic insulation of facades and the possibility of opening windows make the relationships between internal and external noise levels in these investigations somewhat uncertain.

The scientific community was surprised by the results of a vast survey carried out by the British Civil Aviation Authority: "for outdoor event levels in the 90-100 dBA SEL (80-95 dBA Lmax) range the chance of an average person being wakened is about 1 in 75" even if the most sensitive subjects were disturbed twice as much as less sensitive subjects. Despite attempts to understand what variation factors could create such a difference from the findings of other studies, it was simply observed (Latham 1994) that average insulation provided by the windows of homes situated around British airports was, on average, 36 dB(A) which attenuated Lmax levels in bedrooms by 44 to 59 dB(A).
But no one knows if people who live around airports in Great Britain sleep with their windows open! A second aspect of the inclusion of noise in sleep disturbance studies is understanding the extent of multiple exposure.

In 1978, in a brilliant experiment using twins sleeping in laboratories with an identical low background noise, Blois and Mouret showed that the amount of noise to which people were subjected during the daytime determined the extent to which their sleep was disturbed. This daytime noise memory effect on night time sleep, confirmed by Frusthorfer in 1983, reveals the necessity for scientists - and law-makers - to include noise from all sources and even noises which people do not complain about. People living near roads are a good example.

In 1979, M. Vernet examined the impact of intermittent noise events from trains and trucks. This study was mostly dedicated to comparing the respective effects of two types of traffic rather than to assess the synergy due to multiple exposure. Griefahn et al (1997) is currently conducting similar research on a larger scale (400 subjects), with a structured procedure in 8 sites to assess the impact of each separate source. The results will be published in the near future.

3. EXPERIMENTAL WORKS

These body of research describes the primary and secondary effects of noise on sleep.
Primary effects are assessed by a arousals which are observed as a response to intermittent noise (EEG analysis):

- by the effects of noise on cardiac rhythm, including arrhythmia during sleep,
- the analysis of urinary catecholamin secretions which gives further insight into the activity of the sympathetic nervous system.

Secondary effects of noise on sleep are examined in the light of:

- modifications to the immune system,

  changes in the secretion of some hormones, particularly growth hormone.

  The Japanese school opened this path by studying the influence of noise on the size and weight of new-borns,
- the level of blood cholesterol and risks of chronic cardiovascular disorders.

Despite the broad panorama of investigative methods, the overall number of experiments fell between 1993 and 1998 and the research published concerned relatively small populations. Carter (1994) studied the effects of road traffic noise on the cardiac rhythm of seven old men and showed the effect of noise on four subjects afflicted by cardiac arrhythmia during some sleep phases. Two of the four subjects with arrhythmia presented a significant response during phase four sleep to a single loud indoor noise event.

Carter (1995) attempted to demonstrate relationships between road traffic noise, modifications in slow sleep and immune response in two groups of shift workers. Some of the results are significant and others are not.

This type of research requires large populations to minimise the impact of multicolinearity and relatively large research teams which implies significant long term funding. To some degree it is an adaptation to a new situation in noise-sleep research which was initiated by Ollerhead (1993), use a simpler method than EEGs. Actimetrics are somewhat more basic than conventional polygraphics and enable investigation of larger sleeper populations. However, as Griefahn showed (1997), this method still needs to be validated on a general, statistical and individual level. During their first visit, the German team records EEG and motor activity for each subject.

4. REVIEWS OF PUBLISHED WORK

These cover the overall field of sleep disturbance by noise and include attempts to develop a predictive model to forecast impact severity as a function of noise exposure.

Carter (1995) prepared a broad-spectrum review describing the different effects of noise on sleep classified by experimental conditions (laboratory or field), noise type (continuous or intermittent) and emergence to background ratio. The effects of noise on sleep are included in a comprehensive manner, including arousals, phase changes, awakenings, phase durations and phases appearance latencies together with physiological measurements (cardiac rhythm, actimetrics) and after effects. Carter's objective was to determine physiological modifications which have a strong probability of inducing effects on health such as cardiovascular system and immune system response at some time in the future.

The review prepared by Pearsons et al (1994) uses data from 21 studies to propose a dosage-response function for the effects of noise on sleep. The authors observed a significant difference between the results obtained in laboratories - where the noise effect is high - and the results obtained in the field in which subjects seem to become accustomed to the impact of noise.
The influence of noise on the sleep function depends on noise and sleep modification types as well as the noise source, the background noise level, the length of the study and the sex of the subject. It was not possible to validate a model for sleep disturbance by noise using data sampled from the main studies. It should be noted that this review basically addresses the effects of separate noise events (aircraft and trains) and does not include the effects of continuous noise on sleep structure.

Confronted with this lack of results, ICBEN team 5, led by K. Pearsons, acting for the American Standards Institution, was invited to define some of the elements of the problem. An initial, somewhat modest, version of a standard was written and submitted for scientific appraisal. This initial work must now be continued and an attempt should be made to include the wealth of results from noise/sleep research.

5. SUMMARIES USED TO PREPARE REGULATIONS

The scientific community is extremely interested in research designed to assist decision-makers in preparing guidelines for night time sleep protection, particularly as modifications to neuro-hormonal sleep seem to influence the probability of the appearance of physiological disorders and their consequent impact on health.

At the end of the 1980s and in the early 1990s, several programmes addressed this topic.
Firstly, Griefahn (1990) proposed the inclusion of both the Lmax and the number of events during the night so as to prevent awakenings totally or at least 90% of them. This gave decision-makers a nonogram to determine permissible levels for aircraft and train traffic as a function of emitted Lmax levels, facade insulation properties and the number of noise events.
Vallet (1991) used this idea and applied it to night time aircraft noise based on experimental results acquired in the field.
Lercher (1993) observed that the factor which explains the greatest difference in the levels of blood cholesterol in a population exposed to road noise is whether windows are open or closed at night.

More recently Bullen et al (1996) proposed a specific index to assess sleep disturbance from environmental noise. Based on the observation that the global concept of disturbance is not sufficiently protective at night and that this disturbance is usually included by the Leq index, the authors suggested the adoption of a specific method for considering sleep disturbance in addition to Leq - the Sleep Disturbance Index of the average number of night time awakenings due to external noise.
In our opinion this proposal is interesting for several reasons:

- 24h Leq and the disturbance concept are a little too general to reflect impact on sleep correctly. The American LDN and the night time aircraft noise weighting have included this dimension for many years already and they were embodied in the preparatory reflections for rules in Holland (1994) and Europe (Lambert-Vallet 1994, Green Paper 1996),
- the model presented can be enlarged to all research on sleep,
- it enables accurate definition of the specific peak values to be included in addition to their influence already included in the Leq.

The question of night time noise around the airports has led to a review of research results in this field in order to determine acceptable noise levels. After a documentary review, Passchier-Vermeer (1994) proposed a noise level threshold inside bedrooms of 27 dB for Leq 23h-6h. This figure can be attained by the incidence of 5 aircraft noises with a SEL of 64 dB(A) indoors or by a high number of events with lower SELs. This proposal confirms the suggestion by Vallet (1996) not to exceed 15 to 20 noises per night with an indoor Lmax of 48 dB(A). Night time duration was not determined.

Fidell (1996) discusses the noise penalties at night-time at the light of sleep disturbance.

These recommendations can be used for noise prevention. For example, Porter (1997) examined the possibility of plotting "noise" footprints specifically for night time aircraft noise.

6. CONCLUSION

The period 1993-1998 was not rich in experimental research into the effects of noise on sleep although the general public complains about disturbance to their elective representatives. Let us hope that, as the European Union is working on a directive for noise containment to be adopted by all member nations as well as the specific problems of airport operations at night, scientists working in this field will be allocated sufficient research funding.

Reviews carried out to develop a model demonstrating a relationship between noise dosage and impact on sleep and others carried to prepare new regulations have flourished but most frequently using different methods particularly in the way the global effects of noise are considered; what should happen now is that authors should apply their hypotheses and their calculations to the same research results base.

In the future we can hope that:

- team 5 develops a common and minimal method like "Community Noise" team 6,
- simple epidemiological research centred on night time noise enables assessment of the risk of cardiovascular disorders, excessive consumption of medicine and modifications to the immune system ("observational research"),
- the ICBEN seeks to interest basic research teams in analysing the neuro-hormonal mechanisms which can modify physiological responses and induce the appearance of pathologies in the long term ("explanatory" research).

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AWAKENING AND MOTILITY EFFECTS OF AIRCRAFT NOISE

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1. BACKGROUND

Although sleep disturbance due to noise can be quantified in many ways, one easily interpreted measure of this disturbance is awakening. Participants in sleep disturbance studies are asked to "push a button" or otherwise confirm awakening when awakened for any reason. Contemporaneous noise measurements are made in sleeping quarters, and noise events that occur within an established time window of an awakening are assumed to have caused the awakening. Noise events associated with these awakenings are typically grouped into bins or ranges of noise levels for analysis purposes. Within each noise level range, the percentage of awakenings is determined by dividing the number of button pushes by the total number of button bushes that could potentially have occurred within the noise bin. Samples of such results are shown in Figure 1. The figure shows that in studies of sleep disturbance conducted in laboratory environments, lower noise levels are associated with awakenings than in studies conducted in a field environment, such as in a home.

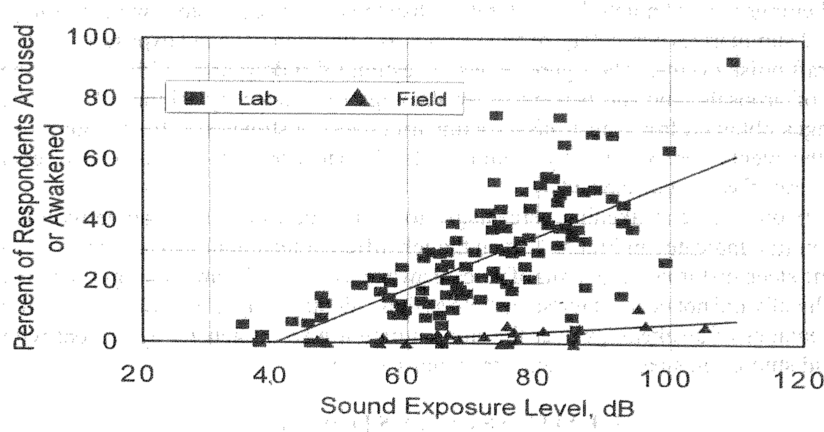

Figure 1. Awakenings associated with noise events from laboratory and field research.

The large difference between the numbers of awakenings observed in laboratory and those observed in field settings, together with the relative paucity of data collected in field environments, suggested that additional research should be conducted to determine (a) whether the laboratory data were representative, and (b) whether the difference between the results found in the two environments was related to habituation to noise, or to response to a familiar *vs.* an unfamiliar environment.

2. UNITED KINGDOM STUDY

The best known recent study in this area was a large-scale field study of sleep disturbance conducted in eight neighborhoods in the vicinities of commercial airports in the United Kingdom. The study [1] monitored test participants for 15 days, producing a total of 6,000 subject nights of data. The study used a wrist-worn motility recording device (an "actimeter") as the primary method of obtaining sleep disturbance data, rather than requiring that the participant press a button upon awakening. This device measured and recorded the amount of gross arm movement during the nighttime hours. Movement was characterized by the amount of time during 30-second time periods that the motion of the actimeter exceeded a preset acceleration threshold (nominally 0.1 g). Actimeter data were designed to indicate when a participant was awake or asleep. A subset of the participants produced both actimetric and electroencephalograph (EEG) data. Data from the 200 subject-night subset suggested that the disturbance indicated by actimeter data was greater than the "awakening" found by processing EEG records.

Also, the times of occurrence of sleep disturbances indicated by the two data sets did not match well. However, reduction of the results of the actimeter data by 40% produced a comparable number of awakenings from the two methods (about 18 per night). Although this number is much higher than the 2-4 times per night normally associated with sleep, the awakenings were of much shorter duration than those reported the following morning.

Figure 2 summarizes percentage of awakenings as a function of sound exposure level of the aircraft noise events. The figure shows the estimated indoor level of the events, the percent of arousals, and the percent of awakenings (estimated by taking 40% of the percentages obtained from the arousal [actimetric] data). Estimates of the indoor noise level of the events were obtained by assuming a 15 dB reduction in A-weighted noise level of the aircraft flyover noise events.

Comparisons of the awakening percentages for field studies appear to agree with the regression line indicated in Figure 1, even though different techniques were employed to determine sleep disturbance in terms of percent awakened. Still, the awakenings predicted actigraphically did not occur at the same time as those identified by EEG techniques. Only the percentages of awakenings over the study duration were in general agreement with prior field studies on sleep disturbance from noise events.

3. UNITED STATES STUDIES

The next large-scale field study of aircraft noise-induced sleep disturbance was sponsored by the U.S. Air Force. This 1993 study gathered about 1,800 subject-nights of sleep data. Behavioral awakening was the primary means of assessing sleep disturbance. Neither actimeters nor motility techniques were used. Subjects were chosen from locations near a military training base and a commercial airport, and areas remote from aircraft noise.

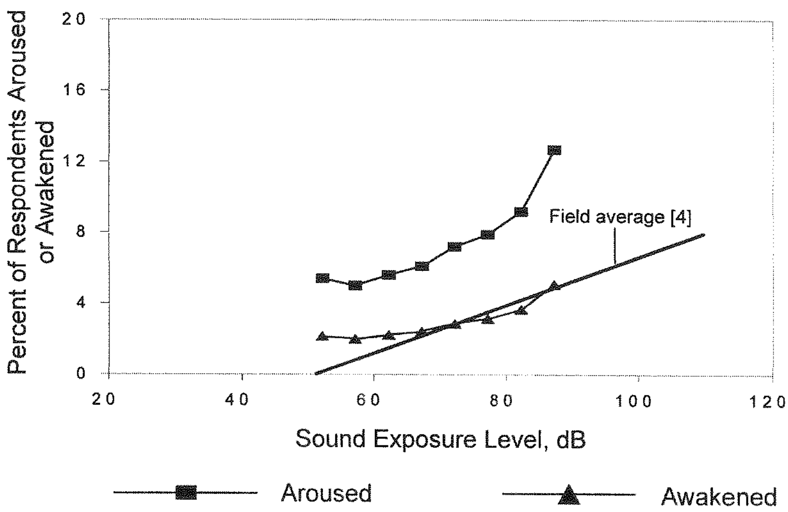

Figure 2. Sleep disturbance from aircraft flyover noise at United Kingdom airports [1].

The results of this study [2] were also in general agreement with the limited data for field studies shown in Figure 1.

Following the Air Force study, NASA sponsored a field study near an established civil airport in Denver, Colorado that was soon to be closed, and near a new airport nearby [3]. The study observed the effect of changes in noise exposure on sleep disturbance, from a decrease in noise exposure in neighborhoods in the vicinity of the original airport, and from an increase in noise exposure in neighborhoods in the vicinity of the new airport. The study measured both behavioral awakening and actimetric activity. Delays in the opening of the new airport complicated the study, but behavioral awakening results gathered during the course of 2,700 subject-nights of observations agreed with the prior field studies, as reported previously [4].

The motility data gathered in the NASA study showed no effect of sudden increases or decreases of aircraft activity. However, a relationship was observed between estimates of sleep disturbance from some of the motility data and the SEL of noise events. The motility data gathered in this study used two different types of wrist-worn devices: Swiss-made actimeters, which were also used in the Ollerhead *et al.* [1] study, and U.S.-made actigraphs. The smaller actigraphs recorded the number of times that a threshold (0.03 g) of wrist motion was exceeded during a 30-second time period, while the actimeters recorded the amount of time a threshold was exceeded. The results using the actimeters employed in the UK study and the methodology of predicting sleep disturbance did not show a significant association with indoor measured SEL of intruding noise events. However, use of the actigraph did provide significant results when using Cole *et al.* [5] prediction schemes, as shown in Figure 3 [3]. The relationship suggests a greater effect than indicated by behavioral awakening measurements in prior field studies.

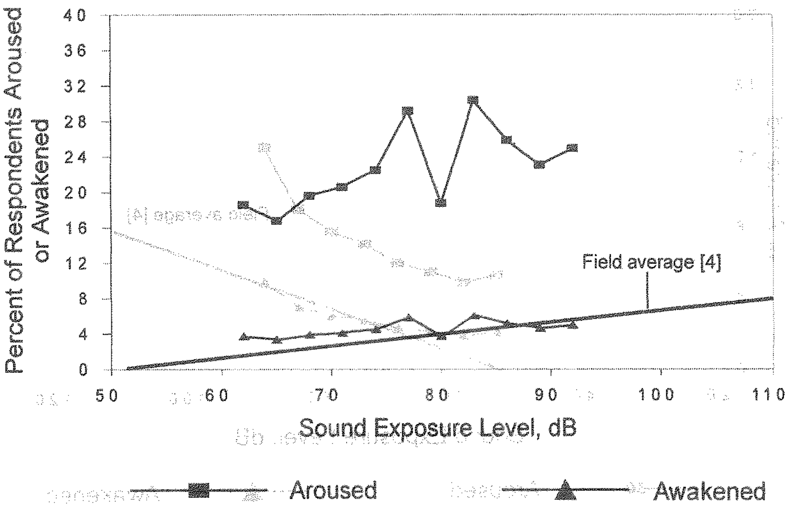

Figure 3. Sleep disturbance "arousals" [5] and predicted awakenings in the vicinity of Denver, CO airports.

Since the actimetric predictions from the Ollerhead *et al.* [1] study also overpredicted awakenings when compared to awakening results using EEG, a similar procedure was tried in the current overprediction using actigraphic data from the NASA study. However, using the 40% employed in the UK data for the NASA data yielded results still higher than the average of behavioral awakening for prior studies. The 40% factor may not have been suitable for the NASA data due to differences in hardware and procedures used in the two studies. To obtain closer agreement with prior studies, a factor of 20% was used, yielding the results indicated by the solid triangles in Figure 3. These "estimated awakenings" are in much closer agreement with the results for previous behavioral awakenings also shown on Figure 3. This is not to say that other factors would not yield still closer agreement with previous studies, but the 20% does appear to be a reasonable first choice.

The most recent study involving changes in aircraft activity and associated effects on sleep disturbance was performed under an Air Force contract to improve understanding of the role that habituation might play in sleep disturbance caused by aircraft noise events [6]. The site and time frame selected for the study was a regional airport near Atlanta, Georgia in the summer of 1996. The site was selected because of anticipated changes in nighttime aircraft noise exposure due to increases in air traffic during conduct of the Olympic Games in Atlanta. Data were collected in residences over a six-week period: during the eighteen days prior to the games, for the seventeen days during their conduct, and for seven days after their conclusion. Both behavioral awakening and actigraphic techniques were used in determining sleep disturbance. The smaller actigraphs were used in this study, rather than the actimeters employed in the UK study.

As in the NASA study, despite changes in aircraft noise exposure, no changes in sleep disturbance were noted for the nearly 700 subject-nights of sleep data collected before, during and after the Olympic Games. Again, however, the data supported relationships for behavioral awakening and arousal and SEL of aircraft noise events. Figure 4 shows similar results to Figure 3 for the arousals predicted from actigraphic data. Applying the 20% correction used for the previous data also provides closer agreement with the behavioral awakening results.

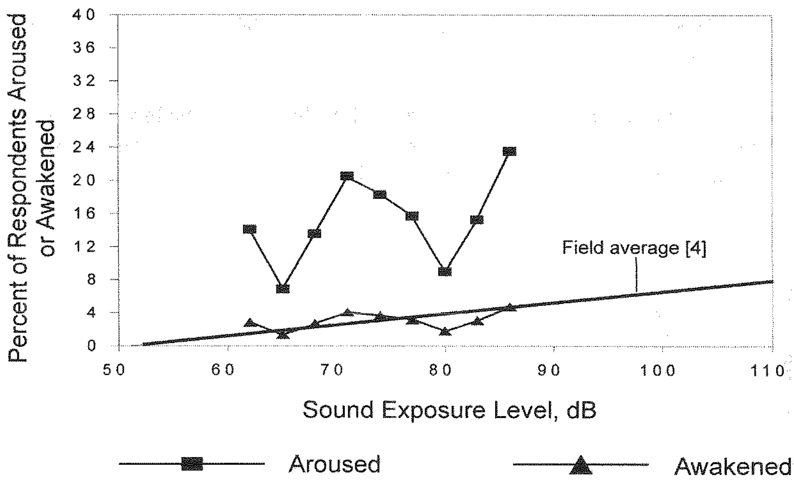

Figure 4. Sleep disturbance "arousals" [5] and predicted awakenings in the vicinity of DeKalb-Peachtree Airport, Atlanta, GA.

4. SUMMARY

Plotting the data from all of the field studies using the behavioral awakening and estimates of behavioral awakening taken from actigraphic data from the UK and the two U.S. studies puts the actigraph-generated data in perspective. The results shown in Figure 5 indicate that the predictions using actigraphic data with 40% (UK) and 20% (U.S.) corrections are well within the spread of data for the behavioral awakening data. Further sleep research already underway and under consideration in Europe may provide more data to support these initial efforts.

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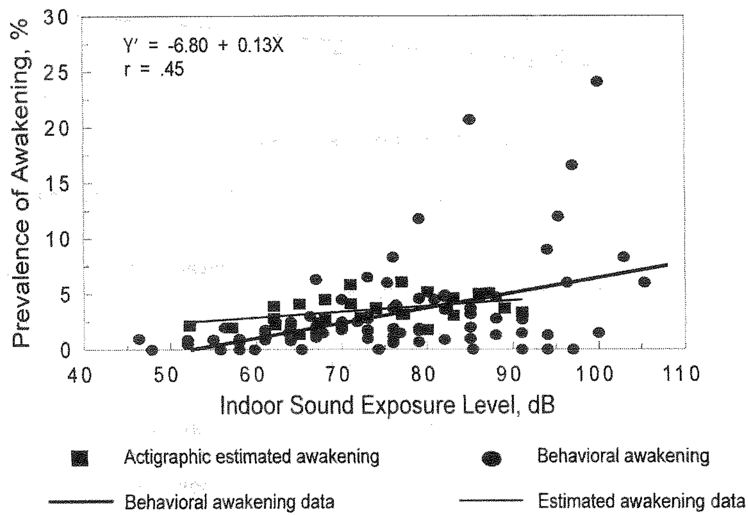

Figure 5. Summary of behavioral awakening as measured directly and as predicted by actigraphic techniques.

NOCTURNAL AIRCRAFT NOISE AND ADAPTATION

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1. INTRODUCTION

As with every stressor, noise triggers a non-specific response profile consisting primarily of neural and humoral processes. The nerve impulses induced by the noise find their way via the auditory nerves to the auditory cortex and the hypothalamus-hypophysial system. For the last mentioned path, noise can cause stress reactions in the body, during which e.g. adrenaline, noradrenaline and cortisol are secreted. The intensity of the stress reaction is moderated for example by predisposition, experience and self-control patterns. The stress hormones stimulate the effected organs and influence among other things the cardiovascular system, metabolism and the blood lipids. The biological purpose of the stress reaction is to make energy available, so that the body is prepared for fight, flight or defeat.

The hormones adrenaline and noradrenaline maintain the fight /flight reaction for a short time (minutes); cortisol however, has a longer half-life (1 hour) and is related to the defeat situation. The stress hormones are excreted in the urine. The intensity of stress reaction can be determined by the quantity of such secreted hormones.

2. NOCTURNAL AIRCRAFT NOISE AND STRESS

That nocturnal aircraft noise must be classified as a stressor is e.g. shown by a field study carried out in 1993 in the area of Berlin Tegel airport. The test persons were exposed to noise in their apartments from 16 or 64 flyovers at maximum sound levels of 55 or 65 dB(A). Recorded among other things, was the cortisol excretion collected through the night. The test persons were "healthy", with normal hearing, between 35 and 65 years old and participated voluntarily in the investigation [1]. The first figure shows the cortisol excretion, averaged over one week.

- For a noise group without exposure to nocturnal aircraft noise (**"without"**)
- For the same group with additional nocturnal aircraft noise (**"with"**)
- For a control group in a quiet neighbourhood (**"quiet"**)

For the medical assessment of the increased cortisol excretion, the measured values are represented as excretion quantities over a 24 hr period. The limits for the normal medical range are shown.

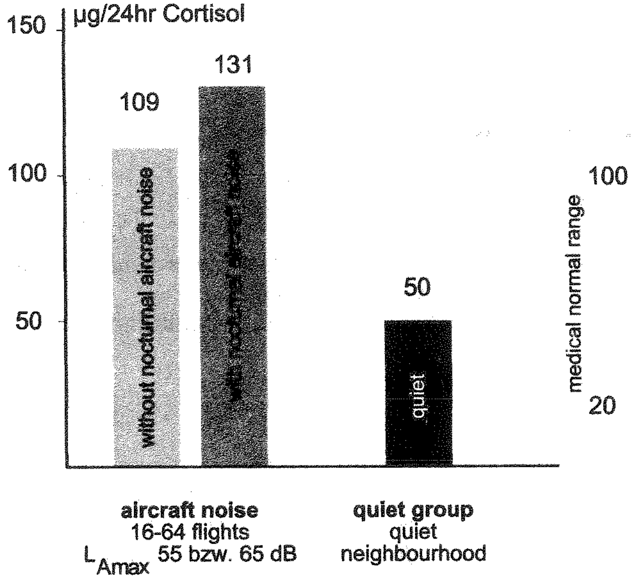

Figure 1: Night time Cortisol excretion extrapolated for 24 h [2] [3]

The cortisol values in the urine of the airport residents were already slightly above normal, and exhibited a pronounced and highly significant increase for the nights with aircraft noise exposure.

The results of the Berlin field study attributed an acute stress reaction to the nocturnal aircraft noise but did not however contain detailed information on adaptive processes during exposure to nocturnal aircraft noise. This question was followed up by an experimental longitudinal study at Hamburg-Fühlsbüttel airport.

3. NOCTURNAL AIRCRAFT NOISE AND ADAPTATION

A total of 16 airport residents were studied over a period of 40 nights. The test persons slept in their own apartments and were exposed to nocturnal aircraft noise. During this period, 32 takeoffs and landings with sound levels of $L_{max} = 65$ dB(A) were simulated electro-acoustically. The night urine discharge was collected and analysed. Furthermore, subjective data were collected daily by questionaire. At the beginning and end of the study, a stress regulation test according to Balzer and Hecht [4] was conducted.

The time curve of cortisol excretion shows that no uniform reaction to persistent nocturnal aircraft noise exists. On the contrary - according to the results of extensive animal studies [5] - three reaction patterns can be distinguished, as represented by the following figures.

Plotted is the 24 hr cortisol excretion over the 40 days of study. Included in the figures are both the measured course of the average cortisol excretion and their trend (2nd order). The cortisol excretions exhibit rhythmic fluctuations as expected. For preventive medical assessment, the normal medical range is shown - as in the previous figure. During the first three days of the study no extra nocturnal flight noise was played. These days are labelled with a vertical line. One person was not taken into account because of their pathologic high cortisol excretion.

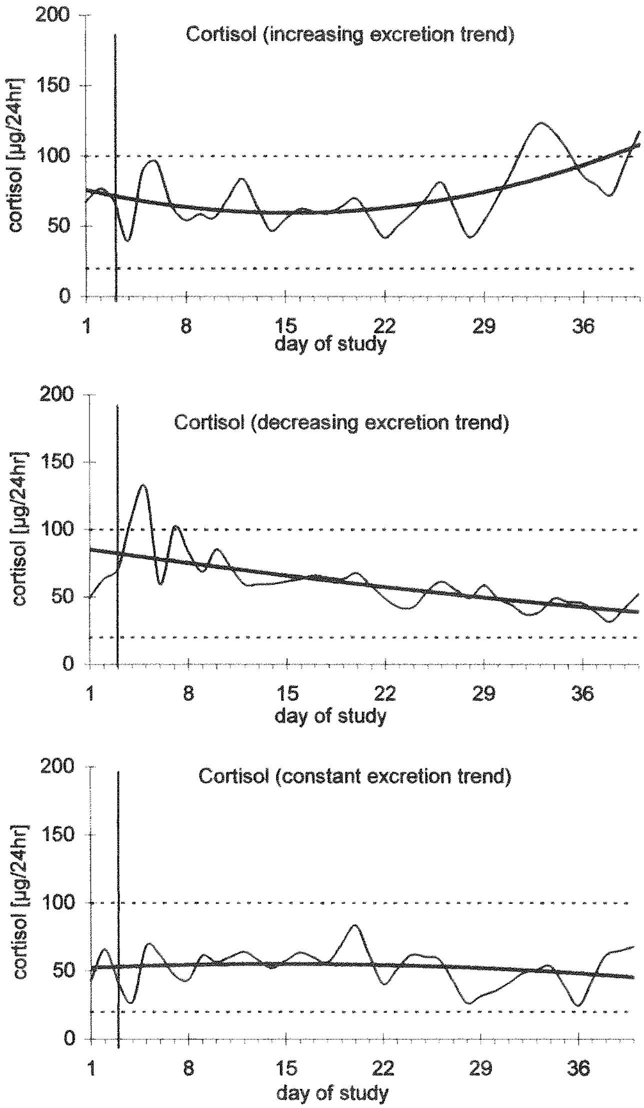

Figure 2,3,4: Different types of cortisol excretion [6]

The first figure (6 test persons) shows a reaction pattern, in which a sensitizing phase with an increasing cortisol excretion trend follows a phase of contra-regulation (decreasing cortisol excretion). At the end of the study the cortisol excretion exceeds the normal medical range. The initial reaction to the added nocturnal aircraft noise is marked; however the cortisol values remain within the normal medical range.

The second figure (4 test persons) shows a pronounced initial reaction followed by a decreasing cortisol excretion trend. The initial reaction clearly exceeds the normal medical range. The cortisol values of the first week correspond approximately to the results of the Berlin field study.

The third figure (5 test persons) shows the cortisol excretion barely changes. The initial reaction is slight. The weekly rhythm of cortisol excretion predominates.

4. ADAPTATION AND HEALTH

Referring to the results of an advanced regulatory-diagnostic test, a close link exists between the reaction types of the cortisol excretion and the health condition of the subjects. The test was developed by the Institute for Stress Research (ISF) in Berlin and the usage was allowed before the professional version comes onto the market in 1999.

In the regulatory-diagnostic test, the persons involved are subjected to a short acoustic stressor (1 min) during a relaxation phase. The dermal skin-resistance is analysed - before, during and after the irritation. The test supplies information on the regulatory condition of the test person. A limited ability of the regulation can be interpreted as a precursory stage to illness (premorbid phase).

The abundant results of the test could be summed up in two simple points.

- All test persons with a sensitizing phase (reaction type 1), as well as those with decreasing cortisol excretion (reaction type 2), already exhibited a disturbed regulation.
- The test persons with unchanged cortisol excretion trend (reaction type 3) possessed normal regulation (with 1 exception).

An increasing cortisol excretion as well as a decreasing cortisol excretion was only observed in persons who had to be classified as "no longer healthy", even before the noise exposure. But on the contrary to reaction type 1, for all subjects with a decreasing cortisol excretion (reaction type 2) there is observed after exposure a further noise induced constriction of the regulation (2^{nd} regulation test). This reaction type with a decreasing cortisol level can be identified as "protective inhibition" (over-stressing inhibition). It represents probably the transition from the resistance phase into the exhaustion phase and must be classified as a health hazard.

The increasing cortisol excretion (reaction type 1) exceed the normal medical range in the process of adaptation and also represent a health hazard. The effects of high Cortisol levels on health are discussed in the literature (e.g. [2]).

5. SUBJECTIVE DATA AND HEALTH

Figures 5, 6, & 7 display the course of the well-being factor acquired by factor analysis from the questionaire data, separated for the three cortisol types. Lower values indicate a reduced "well-being".

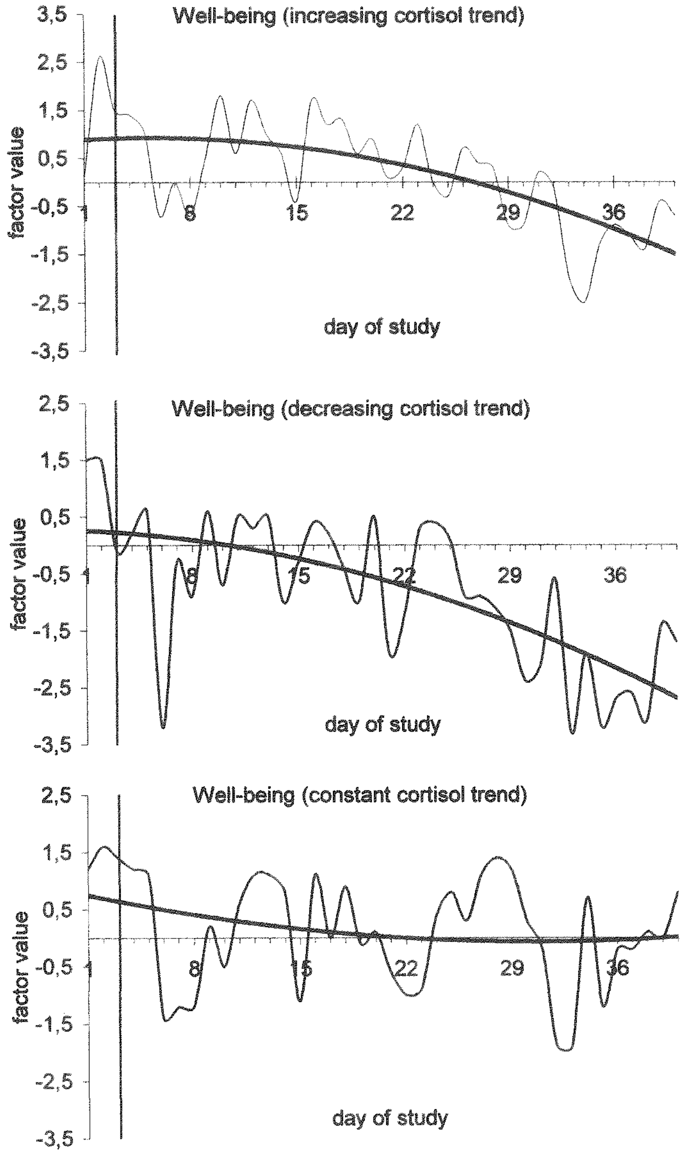

Figure 5,6,7: "Well-being" separated for the cortisol types [5]

The daily answers show that „well-being" declines during the course of the study for all cortisol types. The course of well-being however, exhibits clear differences between the reaction types.

- For reaction type 1 (cortisol trend increasing), the feeling of comfort declines continuously approximately 1 week after the start of the nocturnal aircraft noise.
- For reaction type 2 (cortisol trend falling), a continuous decline of well-being is to be

observed immediately after the set in of the nocturnal noise exposure. "Well-being" is already reduced at the start of the study.

- For reaction type 3 (cortisol trend remaining constant), a slight fall in well-being is to be observed during the first half of the study. In the second half of the study, "well-being" remains all but constant.

The result suggests a close link between the cortisol excretion and the self-rated "well-being". The "well-being" (investigated in the evening) may be a possible subjective indicator for the health condition, so far as the time series were analysed.

6. SUMMARY

Under persistent nocturnal aircraft noise, adaptation procedures are noted which are interpreted as the resistance phase in terms of the general adaptation syndrome (Selye). The adaptation types, decreasing cortisol excretion as well as increasing cortisol excretion are joined with a health hazard. The increasing cortisol concentrations exceed the normal medical range in the process of adaptation. the decreasing cortisol level can be identified as "protective inhibition" (over-stressing inhibition).

The subjective well-being (investigated in the evening) may be a possible indicator for the health condition, so far time series are used. In addition, the results shows that simple cross-sectional studies are unfit to identify noise induced health effects, because of the different reaction types and the considerable biological rhythms.

The level of the health risk must be quantified by adjusted epidemiologic studies.

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CARDIOVASCULAR RESPONSE TO ENVIRONMENTAL NOISE DURING SLEEP

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1. INTRODUCTION

Parliamentary committees of enquiry [1], as well as medical experts [2], have considered that noise-induced sleep disturbance has deleterious effects on health. These include healing processes in the sick, and long term effects on the cardiovascular system. It is curious therefore that in the face of these views from expert and influential sources so little research has been carried out which could define and evaluate these actual or potential health effects.

From a theoretical point of view, deleterious health effects might be expected to follow from chronic noise-induced interference with sleep of healthy persons because it could impair the functions (biological usefulness) of sleep.These functions are largely unknown [3], but can plausibly be related to brain restitution [3], some aspects of the immune system [4], and the cardiovascular system.

Concerning the cardiovascular system, it is known that high blood pressure, over-secretion of catecholamines and increased outflow of sympathetic neurotransmitters to the heart can be harmful. Conversely, sleep is known to be a state of reduced activity, as well as reduced sympathetic autonomic tone, heart rate and blood pressure [5]. Sleep could be cardio-protective by re-setting and thereby preserving the sensitivity of baroreceptors to blood pressure elevation. Because of this we have hypothesised that one of the 'functions' of sleep is to provide a period of respite for the cardiovascular system, and that chronic reduction of this respite due to noise could have implications for long-term cardiovascular health [6].

This paper reviews some research on responses of the cardiovascular and autonomic nervous systems to noise during sleep, and presents some preliminary data from a recent laboratory study. Desirable general characteristics of future studies of noise, sleep and the cardiovascular system are also suggested.

2. CARDIOVASCULAR RESPONSE TO NOISE DURING SLEEP

Effects On Heart Rate in Healthy Individuals

Minute-by-minute average heart rate, as well as heart rate response (acceleration followed by deceleration) and finger pulse amplitude response to single noise events during sleep have been shown in laboratory as well as field studies. The response evidently does not habituate completely since many of the subjects had slept in the same noise environment for many years [7], [8]. Of itself this response is not sufficient evidence of long-term effects on the cardiovascular system.

Studies of Noise and Cardiac Arrhythmia During Sleep

A field study of people with mild forms of cardiac arrhythmia (single ventricular premature contractions (VPCs)) found that the likelihood of a VPC may be increased shortly after noise peaks in some subjects sleeping in their homes near a busy highway [9]. However this result was not replicated in a subsequent laboratory experiment using recorded truck and aircraft noises (65-72 dB L_{Amax}) [10].

The traffic and aircraft noises in the foregoing studies [9], [10] were familiar and were of gradual onset. Wellens et al. [11] reported a case of a cardiac patient in whom noise of an alarm clock regularly induced ventricular fibrillation (VF). This suggests that patients with more severe arrhythmias should be studied, especially if they are exposed to noise of sudden onset.

Blood Pressure Responses to Noise During Sleep

Elevated blood pressure (BP) regularly accompanies sleep apnoea. In an attempt to find out whether this increase in blood pressure was due to repeated arousals or to blood oxygen desaturation, both of which characterise the sleep of these patients, Guilleminault and Stoohs [12] exposed sleeping (normal and apanoeic) subjects to 5-second 1000 Hz tones at levels ranging from 50 to 130 dB. They found that an increase in diastolic and systolic blood pressures always followed administration of the tone, even when there was no change in the electroencephalograph (EEG) nor any increase in heart rate, and concluded that the blood pressure rise in apnoeics was due to these repeated arousals. Chronic repetition of such blood pressure changes could lead to morphological changes in arterial blood vessels and permanent increases in blood pressure [13]. Such changes need only to exceed 5 mm Hg to have implications for individuals' long-term cardiovascular health [14].

Michalak et al. [15] found very marked increases (up to 30 mm Hg) in systolic and diastolic blood pressure in awake residents of an old persons home when they were presented with high level sudden onset noise (recorded noise from a military aircraft flyover at low altitude). No studies have been done on BP responses of elderly people to noise during sleep. Data on heart rate response (HRR) indicate that habituation to repeated noise events occurs in awake persons but not when they are asleep [8]. If this is also true of blood pressure response then elderly people may be at particular risk of blood pressure increase due to environmental noise events during sleep. This possibility should be investigated.

3. AUTONOMIC RESPONSES TO NOISE DURING SLEEP

Catecholamines

Assays of overnight urinary catecholamines are one way of assessing sympathetic nervous activity, but studies measuring this following exposure to environmental noise during sleep have produced conflicting results [10], [16]. Overnight urinary catecholamines represent the total catecholamines released and not taken up by sympathetic nerve endings. While they may be reliable indicators of total catecholamine secretion overnight they cannot reflect short term increases (surges) in the peak levels of circulating catecholamines such as may occur in response to bursts of noise during sleep. Measurement of peak noradrenaline, adrenaline or dopamine levels would require plasma measures taken within 30 seconds of noise onset.

A second limitation of assays of overnight urinary catecholamines for estimating potential effects on the heart is that the sympathetic nervous system is not an "all or nothing system" [17]. Large regional and organ-specific differences in noradrenaline release have been demonstrated in response to mental challenge [17]. Noradrenaline release from the heart could occur in response to noise-induced arousal from sleep, but not be detected by measures of urinary noradrenaline, adrenaline or dopamine.

Neurographic Studies of Sympathetic Response to Noise During Sleep

Okada et al. [18] studied cardiovascular response and muscle sympathetic nervous activity in the leg in response to sound, in people in light sleep. They found that 125 ms, 880 Hz tone bursts (level not specified) induced EEG 'K' complexes (EEG complexes with a single sharp negative component followed immediately by a positive component), increases in muscle sympathetic nervous activity, and peaks in blood pressure and heart rate. The neurographically measured muscle sympathetic nervous activity did not occur in response to sound while subjects were awake. This again suggests that sleep may be a particularly sensitive state in which low levels of sympathetic nervous activity serve some functional purpose. However, as already stated, other data indicate that autonomic nervous system activity has regional differences, so that these measures may not be representative of such activity in the heart itself.

4. LABORATORY STUDY OF BLOOD PRESSURE AND AUTONOMIC RESPONSES TO NOISE DURING SLEEP

Introduction

The results of studies using artificial sounds with instantaneous rise times by Guilleminault and Stoohs [12] and Okada et al. [18] may not apply to familiar environmental sounds with relatively gradual onset, such as civilian aircraft flyovers and road traffic. Again, the use of invasive methods to evaluate autonomic nervous system tone in healthy subjects (where there is no medical imperative for the use of such methods) is undesirable for obvious reasons. The present study sought to remedy this situation by studying the effects of recorded noise from passenger aircraft and trucks, which have relatively slow 'rise times' (time from noise onset to peak sound pressure level), as well as tones and low-flying military aircraft, which have instantaneous or very fast rise times, on beat-by-beat heart rate and blood pressure. Sympathetic and parasympathetic nervous tone was also studied, by non-invasive means which could be used in more extensive laboratory and field studies in the future.

The study was carried out by the author in collaboration with Saroj Lal, Robyn Henderson, Sharon Booth and Professor Stephen Hunyor of Sydney's Royal North Shore Hospital Cardiovascular Research Unit. Technical assistance by Walter Phelps of the National Acoustic Laboratories is also acknowledged.

Study Aims

The aims of the study were:

- to examine beat-by-beat heart rate and blood pressure responses to noise events during sleep as a function of noise type and level, and sleep stage at noise onset;
- to compare autonomic nervous system tone in intervals occupied by noise with that in intervals of quiet;
- to examine the data for changes in baroreceptor sensitivity on repeated exposure to similar sounds.

Study Plan

Ten healthy female nurses on permanent night-shift slept in a laboratory during the day for four successive days. The four types of recorded noise were replayed during each day according to a predetermined schedule. Sleep was monitored throughout each day by a four-channel sleep polygraph. The noise events replayed into the sleep room were sensed by means of a microphone placed above the subject's bedhead and fed into the same computer as the sleep polygraph. Simultaneously, but for the first 90 minutes of the sleep period only, beat-by-beat diastolic and systolic blood pressures (SBP and DBP) and pulse rate (in bpm) were recorded using a volume clamp finger plethysmograph. Respiration and each cardiac interbeat interval (IBI) in msec for the entire sleep period were also recorded. The computers were synchronised to enable noise events, arousals and measures of blood pressure and heart rate to be precisely time-related in subsequent analyses.

Noises were of truck passbys, Boeing 747 aircraft landings, 5-sec 1000 Hz tones, and low-flying Tornado military aircraft overflights replayed into the sleep room. Each noise was replayed at 55, 65, and 75 dB L_{Amax} at the subjects' head position.

Data Obtained

- Sleep stage in 20-sec. epochs for the full experimental session;
- spectral analyses of the EEG data in four frequency bands for each 20-sec. epoch

for the entire experimental session;
- beat-by-beat measures of systolic (SBP) and diastolic (DBP) blood pressure during the first 90-min. of each session;
- respiration, and beat-by-beat heart rate (HR) in b.p.m. and (R-R) interbeat intervals (IBI) in msec. throughout each sleep session.

Initial Results

Beat-by-beat cardiovascular responses to noise events. The mean and standard deviation of heart rate (HR), interbeat interval (IBI), SBP and DBP were obtained for 10 beats immediately before noise onset (Pre), following the peak SPL of the noise (Peak), and immediately after each noise event (Post). The differences between HR, IBI, SBP and DBP immediately prior to each noise event and at the peak of the noise (Pre v. Peak), and prior to each noise event and immediately after each noise (Pre v. Post) were calculated for each subject/noise event. Cluster regression and cluster logistic regression analyses tested the association of these Pre v. Peak and Pre v. Post differences with noise type and level. Similar statistical analyses were carried out on the association of sleep response variables Wakening (W), Alpha Response (AR) and Movement Arousal (MVT) with noise type and level. The dependence of changes in HR, IBI, SBP and DBP on the subjects' sleep stage at noise onset was also investigated. The main results were:

- IBI was reduced (HR increased) by noise exposure. Both Pre v. Peak and Pre v. Post noise differences were related to noise level but not to type of noise. Pre v. Peak and Pre v. Post HR were also not significantly related to noise type or level.
- SBP and DBP increased immediately after noise onset. The magnitudes of Pre v. Peak and Pre v. Post SBP and DBP differences were related to noise type ($p<.05$), and were greatest following military aircraft and tones (in that order). Mean changes due to civilian aircraft and trucks were in the same direction but were very much smaller.
- Tests of association between type and level of noise and Wakening (W), Alpha Response (AR), and Movement Arousal (MVT) indicated that while W was only related to noise level both AR and MVT were related only to type of noise ($p<.05$).
- There appeared to be no relation between sleep responses (W, AR, MVT) and IBI and HR. There was however a consistent and statistically significant association between AR and SBP and DBP responses ($p<.05$).

Discussion of Initial Results on Beat-by-Beat Cardiovascular Responses

The most salient findings of these results are:

- The greatest BP responses occurred to recorded noise from military aircraft and to 5-sec. 1000 Hz tones. Both are of short duration and rapid onset.They were also relatively unfamiliar to the subjects of this experiment.
- Alpha EEG responses to noise were sensitive to noise type but not its level, and were strongly associated with blood pressure increase.

The association of alpha response with blood pressure increase suggests that both may be part of a scanning process carried out during sleep, in which the sleeper assesses the significance of the noise. That wakening does not follow may be due to the relatively short duration of military aircraft overflights and tones.

As is well known, alpha responses are common to noise events during sleep. Unlike awakenings persisting for more than one minute, alpha responses are seldom recalled the next day, even when recall is solicited by the experimenter [10]. This could mean that a very large number of noise events, alpha responses, and brief episodes of increased blood pressure, could occur nightly without people recollecting them the next day. If these responses have a cumulative effect (not shown as yet) then cardiovascular health effects could occur without complaints (based on recall of noise effects on sleep) or awakenings, whether the latter are measured by objective means or subjects' reports.

Spectral Analyses of Heart Rate Variabilities

It has been known for some time that spectral analyses of heart rate and arterial pressure variabilties can be used to assess sympathetic and vagal input to the sino-atrial node, and vasomotor sympathetic tone [19]. Recent studies have analysed these variables in relation to sleep stage, time of night, and arousals [20]. In the present study variability analyses are being carried out for 10-minute periods containing noise and quiet. Limitations of space and the preliminary nature of the analyses of these data at the time of writing preclude their inclusion here.

5. CONCLUSION. A STRATEGY FOR FUTURE STUDIES OF CARDIOVASCULAR EFFECTS OF NOISE DURING SLEEP

In the author's opinion the results of past studies and currently available non-invasive technology mean that definitive studies of the effects of environmental noise during sleep on the cardiovascular system are now possible. It is recommended that further research into the effects of noise during sleep on the cardiovascular system should have the following characteristics.

Field Studies. Sleep disturbance due to given levels of environmental noise is much less when people sleep in their own homes than when exposed to similar noise sleeping in a laboratory [21], suggesting that field studies are essential for health effects as well. Field studies may not necessarily show less effect of noise on health variables than laboratory studies because of the operation of potential modifying and potentiating factors in 'real life' situations (see below).

Longitudinal Studies. Longitudinal studies using repeated measures on the same individuals permit measurement of modify and confounding variables and causal inferences, and allow for the appearance of cumulative, or conversely, for habituation effects.

Representative Sampling of Study Populations. Studies of sufficiently large and representative samples of populations to which the results are to be generalised are necessary to adequately assess impact of environmental noise on sleep and the cardiovascular system in the community.

Measurement of Modifying and Confounding Variables. In field studies of population samples, individuals' psychological characteristics (optimism-pessimism, trait anxiety, depression), attitude to the noise source, predictablilty and perceived control of the noise, and noise sensitivity are a few of the possible modifying factors in physiological reaction to noise during sleep. Sensitivity to sleep disturbance in general (independent of the particular type of noise) may be unrelated to other measures of noise sensitivity. Hereditary predispositions to stress-related physical diseases and hypertension may be potentiating factors in cardiovascular effects, and can only be studied effectively in the field.

Inclusion of Real-Time Measures Of Autonomic Tone Over The Period Studied. The laboratory study described earlier in this paper included measures of heart rate and arterial pressure variabilities to assess the effects of environmental noise on the autonomic nervous system and vascular tone (full results to be reported). These techniques could be applied in field studies, and if used in longitudinal studies could establish whether or not there is a relation between chronic noise exposure during sleep and cardiovascular health in the long term.

Responses to a range of sounds. Familiarity, as well as acoustical characteristics of the noise events, such as rate of onset and duration, may be important factors in their effects.

Pathological and other vulnerable groups. Hypotheses as to existence of vulnerable groups can come from clinical observation, laboratory experimentation, and prior longitudinal field studies in which modifying and confounding variables have been accurately chosen and measured. The 'laboratory' study of the large blood pressure responses of elderly people to sudden loud noise [15] is an example of laboratory experimentation which may help identify a vulnerable group. Some groups may also be described as 'vulnerable' if their life-style results in greater noise exposure during sleep (for example, shift workers).

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WHAT NIGHTTIMES ARE ADEQUATE TO PREVENT NOISE-EFFECTS ON SLEEP ?

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1. INTRODUCTION

Sleep disorders are major and still increasing problems that cause many persons to take sleeping pills or tranquilizers. These measures, however, should be restricted to exceptional situations and to limited times. With respect to preventive measures sleep disorders are classified into

- those caused by underlying diseases that need to be treated individually and causally
- and those caused by environmental stimuli that can be prevented by an appropriate design of the environment where an additional individual treatment may be useful in case of exceptional personal vulnerability.

Sleep disturbances related to the environment are frequently evoked by noise, where traffic noise plays a dominant role. Though noise emission of the single mean of transport, particularly of road vehicles and aircrafts was successfully reduced within the last ten years the overall noise increased nevertheless due to an increasing number of movements. A further increase of traffic density of about 80 % until the year 2 010 is expected for Europe and the increase will be greater during the night than during the day. Simultaneously, the flexibility of working hours will be extended considerably and more and more persons sleep at least partly outside the legally defined night where noise pollution is limited. Accordingly, noise-induced sleep disturbances are expected to become more frequent but, the low relation between sleep disturbances and noise stress in the field contradict these expectations [Pearsons et al. 1994].

The possible reasons are manifold. First, partial habituation takes place in most cases where sensitization is possible but rather seldom. Second, the overall stress level is much higher in the field due to a great variety of (competitive) influences which may mask or pronounce the effects. A highly significant relation between the physical parameters of noise and the extent of noise-induced disturbances of sleep was found only in the controlled situation in the lab. The influences in the field are classified into

- individual factors which may increase a persons resistance respectively his or her vulnerability against external stimuli (e.g. age, gender, sensitivity to noise, lability, morningness-eveningness, increased expectancy, psychosocial stress)
- situational factors, i.e. simultaneously or successively acting influences that mask or enhance a person's response (type of noise, working hours, sleep hours).

2. OBJECTIVES

The main goal of the present study was to scrutinize the legally prescribed advantage of railway noise which admits a 5 dBA higher rating level for noise from railway than from road traffic. The study is still under evaluation and some results are still tentative.

The analysis of the data presented here was executed to elucidate the role of individual and situative factors which possibly interfere with noise processing. So, in addition to the physical parameters of noise such as sound pressure levels and number of passages the following individual and situational variables were regarded: gender, age, self-estimated sensitivity to noise, morningness-eveningness type of noise (railway vs road) and times for sleep onset and sleep offset.

Particular interest was given to the awakening time as almost half of the participants were found to wake up later than 6 o'clock which is the legally determined end of the night. It was assumed that the later a person goes to bed the flatter is his or her overall sleep and the more likely are noise-induced awakenings, particularly for those people who rise after 6 o'clock as noise levels then increase considerably. On the other hand in this time span traffic density becomes greater and noise becomes more continuous which is less disturbing than intermittent noise.

3. METHODS AND MATERIAL

Participants. Altogether 377 persons equally distributed with respect to noise exposure (railway, road) and to gender were observed in their usual environment 2 times 5 nights each from Sunday evening to Friday morning. The weekends were disregarded as sound pressure levels and sleep behavior then alter considerably. The participants were 18 to 66 years of age and lived in the respective area since 1 to 64 years.

Sites. The study was executed in 2 times 4 areas with either prevailing road or railway traffic but similar with respect to rating levels, buildings, social and demografic characteristics of the residents.

Social survey. Shortly before the sleep observation period randomly selected persons were extensively interviewed where personal data, actual health state, occupation, housing conditions, environmental noise and sleeping habits were ascertained. Persons interested in participating in the sleep observation period completed a questionnaire on their actual state of health. Habitual consumers of sleeping pills and those with diseases which possibly are accompanied with sleep disorders, with allergies etc. were excluded.

Sleep Observation Period

During 2 times 5 nights body movements were continuously registered, short questionnaires were completed just before going to bed and just after getting up. Performance tests (4-choice) were executed during one week, every evening and morning. The instruments were distributed every evening and collected the next morning. All the data were daily checked and saved.

Acoustic data. Sound pressure levels were continuously recorded during each night at the dominant noise source (railway track, road), during one night additionally in the bedroom and outdoors in front of the bedroom.

Movements, actigrams. Body movements were registered using actimeters which were previously applied in a field study on the effects of aircraft noise on sleep in the UK [Horne et al. 1994]. They were validated and calibrated for this purpose. To determine their validity for the present study, the electrophysiologic parameters of sleep (EEG, EOG, EMG) were recorded from 238 subjects during one night simultaneously with the actigram. During these nights the sound pressure levels were registered indoors.

Questionnaires. Short questionnaires were completed every evening and morning. The morning questionnaire comprized tension, tiredness, bedtime, subjective sleep quality, intermittent awakenings, and position of the windows, the evening questionnaire included actual tension and tiredness, physical, mental and emotional stress, tension and tiredness during the day, intake of alcohol or remedies.

Performance test. A conventional 4-choice reaction time test was executed, where one out of 4 LEDs arranged in a square lights up randomly. After one out of four keys below the LEDs is pressed the next signal occurs after a defined delay. After 3 minutes the admissible response time is shortened if the preceding 3 answers are correct and prolonged if at least 1 answer is false. The total test endured 5 minutes.

4. RESULTS AND DISCUSSION

Noise stress. Typical courses of equivalent sound pressure levels emitted from railway and from road traffic were calculated using 8 nights of each participant (excluding Sunday night to Monday morning) and shown in figure (1). Where road traffic noise is characterized by a decrease during the early night and an increase towards the end of the

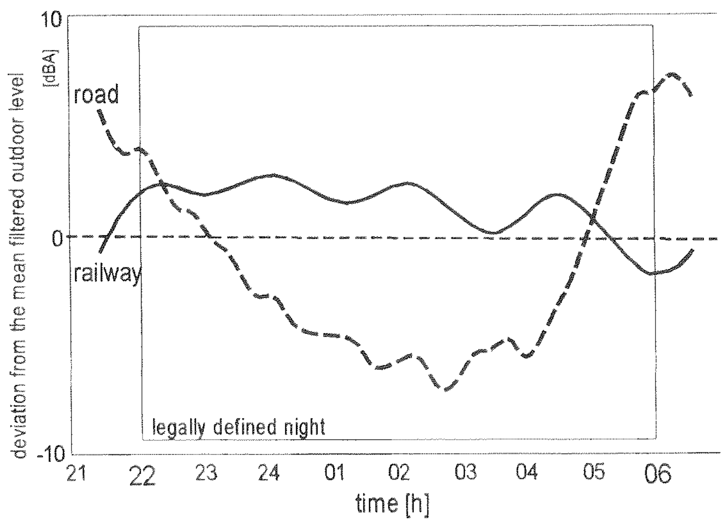

Figure (1): Daily average courses of the measured and calculated outdoor level in the four railway and four road traffic areas night, noise from railway traffic remains constant. Outdoor levels, 1 m before the windows of the bedrooms, varied - according to the distance of the noise source - between 36 and 78 dBA. None of the dependent variables recorded with the actimeters, the questionnaire or the 4-choice test revealed any statistically significant relation to any of the acoustical data (number of noise events, maximum levels, Leq, L1, L1-L95 etc.) neither for the whole night nor for the single events. Support for dependencies between the sleep indicators and the outdoor noise level could only be found in additional post hoc analyses for the subgroup of those individuals living next to roads who classified themselves as sensitive to noise.

Overall, the expected influence of the quality (railway, road) and quantity (number, sound pressure level etc.) of noise was scarcely verified in the present study. As this concerned the physiological data (i.e. body movements as indicated by the actigram) as well as subjective evaluation of sleep and the quantity (speed) and quality (errors) of test performance (4-choice), the results are per se probably valid and they confirm the results of other field studies (Fidell et al. 1995). However, though there are certainly several residents who are fully habituated to their environment, the conclusion that there is no noise effect is rather premature. These effects may be masked by various simultaneous influences, as well as by the structure of noise itself.

The number of noise events was rather high at both sites characterized by noise from roads and from railways. Previous analyses have shown that there is no linear relation between the number of noises and the probability of awakenings. Instead, the risk to be awakened by a single event decreases with the number of acoustical stimuli [Griefahn 1992]. Though the number of awakenings (indicated by gross body movements) may even decrease, it is not unlikely that the overall sleep becomes flatter and that the sympathetic tone increases correspondingly.

In the present study, noise was measured at the dominant source, either at the road or at the railway track. Individual noise immission was then calculated while disregarding any other acoustical influences. This is justified with respect to the primary goal of the study to scrutinize the advantage of railway noise, but this does not meet the real situation as demonstrated in figure (2), where the calculated source-related Leq were compa-

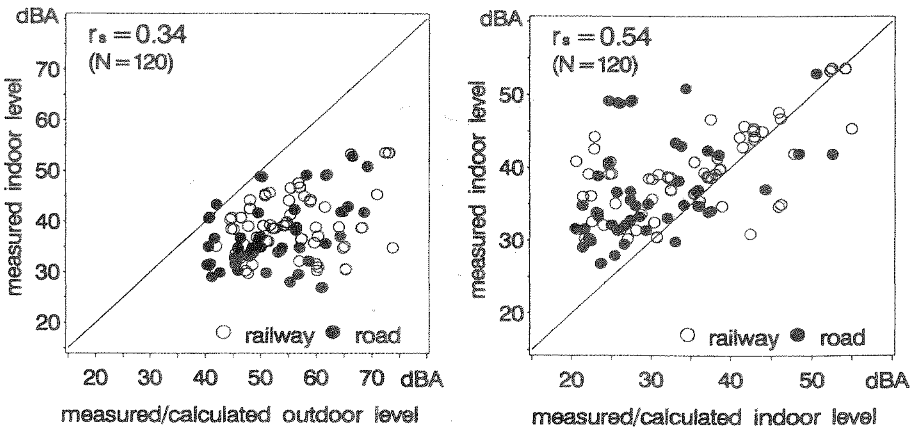

Figure (2): Measured indoor leves vs calculated autdoor and indoor source related levels red with the indoor levels as measured during a single night. Indoor noise differs considerably from the source-related noise due to various additional indoor noises such as snoring, noises from air conditioning and other electric devices including radio and television which operate frequently during the entire night, noises produced by the family (children), by the neighborhood etc.. These noises might be less loud but their content of information might be much higher and may disturb more than external noises.

Thereafter, further analyses were executed by applying the General Linear Model while taking various moderators into account. All the moderators included into the model had influences on the dependent variables. The moderators can be classified into individual factors and situational influences.

Sleep times were determined by the daily sleep logs and verified by the actimeter records (r_s>.9). The distribution of the times for going to bed, getting up, falling asleep and final awakening are shown in figure (3). Where the majority of the participants go to bed and fall asleep within the legally defined night, half of the participants get up after

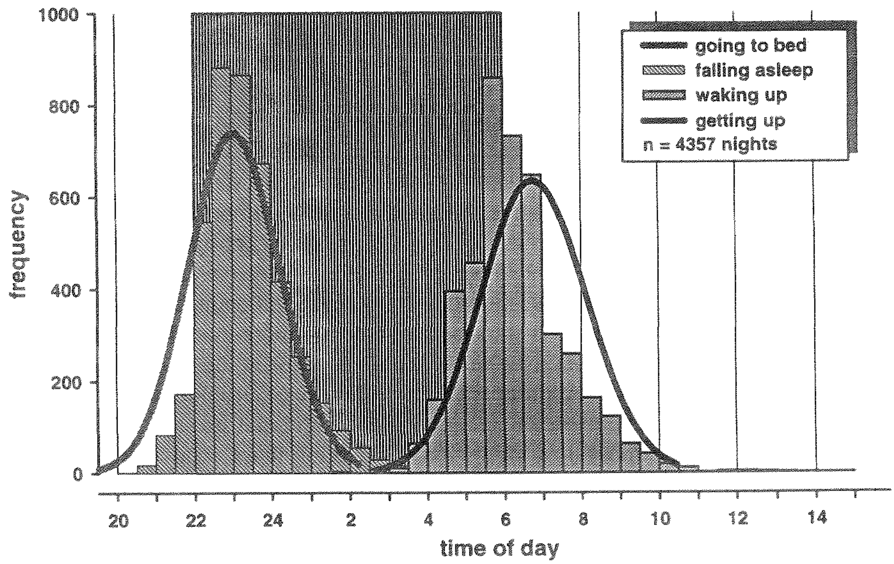

Figure (3): Distribution of bedtimes and of sleeptimes

the end of that period. Noise-induced sleep disturbances were particularly expected in the latter group as the most vulnerable phase of sleep then coincides with relatively high noise levels as shown in figure (1). Traffic density and thereby the sound pressure levels varied considerably for road traffic which is - in contrast to railroad traffic - determined by a characteristic dip between 12 p.m. to 4 a.m. However, contrary to expectations sleep disturbances did not reveal any relation between sleep as indicated by movements, by questionnaires and performance on the one hand and the qualitative and quantitative parameters of noise on the other hand. Most of the other relations, however, expected due to the reports in the literature were confirmed in the present study. Using the time of sleep offset as a moderator variable there is a significant difference in body movements depending on the sleep offset with the expected increase of movements with later times. The later sleep offset, the greater the number of body movements and the time spans between movements decrease with later final awakenings. The movements are also influenced by gender and the degree of feeling tired in the evening. Men exhibited a higher movement rate than women and had shorter intervals between movements. The more tired a person feels in the evening the less movements occur and the longer are the times inbetween. Accordingly, reported difficulties to rise depend on timing of sleep, on reported daily psychological and physiological loads and the degree of eveningness. Subjective assessments such as sleep quality were found to be influenced by lability in the sense of Eysenck. Persons with lower lability ratings reported better sleep.

The expected and frequently described relations between age and body movements, self-estimated sleep quality and performance test were found.

During the social interview which preceded the sleep observation period the participants estimated their sensitivity to noise using a 5-point scale and were accordingly divided into 2 groups. As already mentioned, the sensitive residents living near roads with vivid traffic were the only subgroup where a significant influence of noise exposure was determined for body movements. The higher the noise level the higher the movement index.

5. CONCLUSION

The primary goal of the present evaluation of an extended field study, the determination of nighttimes with respect to preventive measures against the impact of noise could not be answered yet, as no relations were found between noise exposure on the one hand and sleep disturbances as indicated by body movements, subjective assessment of sleep and performance. However, this question has to be answered soon, as even today the legally defined night does not cover the sleeping times of more than 50 % of the participants in the present study. This may be especially harmful in the morning hours and for residents living near roads. Additionally, the variability of sleeping time will increase with increasing work flexibilization and, may be an additional stress for already sleep disturbed persons with unusual working hours, and for those who are particularly sensitive to noise. The discrepancy between the clear effect of noise on sleep determined in the laboratory and in the field may be due to full habituation (at least for the majority of people) or to strong masking effects due to individual and situational influences. Directed studies have to be done to answer this particular question. Therefore, respective field studies should partialize the above mentioned moderators, preferably by selecting appropriate subjects and/or situations.

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SLEEP DISTURBANCES BEFORE AND AFTER REDUCTION IN ROAD TRAFFIC NOISE

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1. INTRODUCTION

There is extensive evidence in the literature that environmental noise causes various adverse effects and the evidence are strongest for annoyance, sleep disturbance and performance by school children [1]. Concerning long term non-auditory health effects, e.g. effects of noise-induced sleep disturbances and psychosocial wellbeing, the evidence is weaker and more research is required. Longitudinal studies and intervention studies in connection with extensive noise abatement activities, 'natural experiments' are far more informative than cross-sectional studies.

2. BACKGROUND AND AIM

This paper deals with an investigation of sleep disturbances, annoyance and psychosocial symptoms among residents living at different distances from a highly trafficked road in Göteborg city, Sweden. Two studies were performed among people living in the same residential area in 1986 and 1987 before and after traffic regulations during night [2,3]. The results from these studies indicated that road traffic noise not only causes adverse effects on sleep quality and various daily activities, but may also cause more long term effects on psychosocial health and wellbeing. These previous studies also showed that prohibition of heavy vehicles during night was not sufficient to reduce adverse effects on sleep and general wellbeing. A tunnel for the road traffic is now being built to facilitate transport and to solve the noise problems in the residential area. This provided a good opportunity to perform a new study before and after the opening of the tunnel.

The aim of this investigation was to assess:

(1) the adverse effects on people of long term exposure to road traffic in terms of sleep quality, annoyance, activity disturbances and psycho-social wellbeing

(2) and how people living in the area are affected by the changed traffic situation.

3. METHOD AND MATERIALS

Method

A first study was performed in October – December 1997 before the opening of the new tunnel for road traffic. The tunnel was opened In January 27th 1998 and a first, minor, follow up study on sleep was performed 3 months later. During August – December 1998, the existing roads and green areas in the residential area will be renewed and the final follow up study is planned in 1999.

The area of investigation was divided into an exposure and a control area in which the houses were situated 25 – 67 m and 125 – 405 m respectively from the trafficked main road.

Evaluation of effects. The effects on the population were evaluated by a main questionnaire that was delivered by a project assistant at the door/mailbox together with an introductory letter to one, or two, persons in each household between 18 and 75 years of age. The questionnaire was similar to those previously used [2] contained questions about the dwelling, annoyance to different sources in the neighbourhood, sleep and sleep disturbances and health and psycho-social symptoms and wellbeing. A second questionnaire on sleep was given to those who had answered the main questionnaire to be answered during 3 consecutive days. A smaller sample also took part in a sleep study including questionnaires and registration of body movements by actigram during 3 nights. The actimeters (type AMI – Mini-Motionlogger Actigraf) have been used in studies of effects of aircraft noise [4].

Assessment of noise exposure. A noise level meter, Larson & Davis type LD 820, which was operated as a remote station via a wireless transmission system was used. Measurements were done 3-4 days continuously in 5 different positions in the garden. A mean for each position was calculated for: LAeq, L01, L90, LAmax, Noise events >70 dBA for 3 periods; 24 hours, daytime (06-22) and night time (22-06). Traffic statistics was obtained from the local Traffic Office.

Materials

The total number of respondents was 142 persons and the response rate was 62 % for the main questionnaire. Of these 116 persons (82%) answered the 3-day sleep questionnaire. 26 persons took part in the sleep-actimeter study in 1997 and 24 persons in the first follow up study (2 persons had moved from the area). These 26 persons were chosen to achieve a similar distribution according to age and sex in each area.

4. RESULTS

Noise exposure

The total number of vehicles in the 1997 study was 24 600 per 24 hours including 4600 heavy vehicles and 1 375 during night including 125 heavy vehicles (h.v.). After the opening of the tunnel in 1998 the number of vehicles decreased to 4 600 per day (740 h.v.) and to 550 per night (80 h.v.). The measured outdoor noise levels in LAeq 24h were reduced from 64 to 49 dB in the noise area. LAeq levels in the control area were not affected, LAeq 47 dB.

Effects on the population

The population sample. Preliminary results of the main 1997-study [involving 50 persons in the noise area and 92 persons in the control area] revealed no significant differences between the noise and the control area in socio-demographic aspects, time of residence etc. However 55% of the respondents in the noise area had renovated the facade of their house versus 34 % in the control area. Perceived noise sensitivity was somewhat (sign.) higher in the noise area.

Annoyance and activity disturbances. Noise from road traffic caused annoyance reactions (rather + very annoyed) among 96 % of the respondents in the noise area as opposed to 13 % in the control area. Noise annoyance as measured by a 0-10 point scale was 8.9 versus 2.3. Traffic noise was reported to cause difficulties to fall asleep and awakenings by about 25 % in the noise area versus 2-3 % in the control area. The percentage of people who only "sometimes or seldom/never" kept their bedroom windows open when sleeping was 90 % in the noise area versus 59 % in the control area.

Psychosocial wellbeing *[based on the sum of 7 symptoms scored 1-4, according to their occurrence; daily, weekly, monthly o yearly]* was significantly lower in the noise area (p=0.007 X^2-test). The three symptoms "low social orientation", "nervous stomach", and "depressed" were the main reasons for this, whereas "headaches", "very tired" and "irritated or anxious/nervous" did not differ between the areas.

Sleep quality parameters (time to fall asleep, sleep quality [scale 1-10 and 1-5], alertness in the morning [scale 1-10 and 1-5] were significantly lower in the noise area. Number of reported awakenings did not differ between the areas.

The results based on the study on 116 persons [40 in noise and 76 in control area], who answered a more detailed sleep questionnaire during 3 consecutive nights, showed significantly lower alertness during day (p=0.02) and morning [p=0.008] in the noise area. The respondents in the noise area also needed a longer time to fall asleep (22 versus 15 minutes, p=0.003), they perceived they had moved more in the bed (p=0.003) and slept more badly (p=0.02). The number of reported awakenings per night was *not* more frequent in the noise area; 1.7 versus 1.6 per night. Of those who woke up, however, 19 % in the noise area versus 1 % in the control area reported awakenings due to noise.

Body motility. The preliminary analyses of the results from the study on body motility (actimeters) and perceived sleep quality among 24 persons before and after road traffic noise reduction are summarised below. The values represent average values for three nights per person before and after noise reduction.

The table shows few significant results. In spite of a reduction in number of vehicles from 1375 to 550 per night and in LAeq levels with 13 dB during night, no significant effects on the various sleep parameters were found in the noise area. (A tendency (p=0.06) was seen, however, for a better perceived sleep quality). There was a significant difference between noise and control areas before traffic reduction for mean activity per minute and wake minutes. The results are, however, unclear since these parameters showed higher values in the control area in the after-study.

Table 1. Mean values for sleep parameters based on actimetry and questionnaires.

	Noise site (n=11x3x2)		Control site (n=13x3x2)		Noise/ control*	Noise/ control**
Actimeter parameters:	*Before*	*After*	*Before*	*After*	*Before*	*After*
Sleep latency	8.9	3.9	4.7	5.2	0.09	>0.10
Mean activity per minute	3.3	3.0	2.7	3.4	0.04	>0.10
Wake minutes	55.3	45.8	38.3	57.2	0.03	>0.10
Sleep minutes	407	397	382	342	0.06	>0.10
% sleep	88.3	89.9	91	86	0.08	>0.10
Perceived sleep quality:						
Minutes for falling asleep	24	19	19	12	>0.10	>0.10
Awakenings	2.1	1.2	2.1	1.6	>0.10	>0.10
Sleep quality (1-10)	6.2	7.3	6.2	6.8	>0.10	>0.10
Moved in bed (1-10)	5.2	5.1	5.1	5.1	>0.10	>0.10
Alertness morning (1-10)	5.3	5.8	6.6	6.5	0.01	>0.10

** t-test, one-tailed, ** t-test, two-tailed*

5. COMMENTS AND CONCLUSIONS

No final conclusions can be drawn from the investigation before the final study is carried out in 1999, about 1 year after the reduction in traffic. The noise exposure situation will be analysed in detail and the relation between noise levels and effects will be analysed. E.g. indoor noise immission in the bedrooms are of specific importance since the windows most often was facing the garden and not the main road in the noise area.

The results obtained in this study on sleep quality and psychosocial symptoms are in accordance with the findings in the previous study 1986 and 1987 [2,3] in the same area. Among the studied sleep parameters, sleep quality and time for falling asleep and alertness during morning and day seems to be more indicative of noise-induced sleep disturbances from road traffic than reported awakenings.

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TRAFFIC NOISE AND SLEEP DISTURBANCES WITH REGARD TO AGE

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1. INTRODUCTION

Sleep disturbances induced by community noise have been comprehensively studied in numerous investigations [1,2]. However, it is still unclear how important age is for these noise effects. In laboratory conditions younger adults might be less sensitive to noise stimulation during sleep than middle-aged and elderly [3]. There is a lack of results from field studies to test these experimental findings.

The aim of this field study was to investigate the effects of urban traffic noise on sleep of adult residents in relation to age.

2. MATERIAL AND METHODS

An interview method was applied to a sample of 409 adult residents in the center of Belgrade. In the noisy area [Leq^{24} > 65 dB(A)] there were 252 interviewed inhabitants, and 157 interviews were performed in the control zone [Leq^{24} < 55 dB(A)].

Besides personal data, the questionnaire consisted of 14 questions regarding sleep : average duration of night sleep (hours), difficulties in falling asleep (1 - 4 graded scale - "not at all", "mainly not", "mainly yes" and "very much"), time to fall asleep (1 - 4 graded scale - "less than 15 min.", "15-30 min."," 30-60 min." and "more than 60 min."), awakenings, subjective sleep quality (1 - 5 graded scale - "very bad", "bad", "changeable", "good", "excellent"), tiredness after awakening (1 - 5 graded scale - "very tired", "tired", "changeable","alert",very alert"), and the consumption of sleeping pills (1 - 4 graded scale - "every day", "several times a week", several times a month", "seldom or never").

Noise measurements were performed with the "Brüel & Kjær" 4426 Noise Level Analyzer. An equivalent noise level (Leq) was measured in three daily periods (9.00h-10.00h.14.00h-15.30h.,18.00h-19.30h.), and in two night periods (0.00h-1.30h,3.30h-5.00h.). The time interval of each measurement was 15 minutes, with the speed of sampling of 10 per second.

3. RESULTS

The noise measurements have showed a significantly higher average noise level in the noisy area, compared to the control zone, during both day (Leq = 77 dBA and 52 dBA, respectively) and night (Leq=69dBA and 40dBA, respectively).

The investigated samples of residents of the noisy area and the control zone were similar concerning gender (63% and 61% females respectively). The results of sleep questionnaire showed that there were no significant differences considering time to fall asleep, difficulties in going back to sleep, duration of night sleep, and consumption of sleeping pills. However, the residents of the noisy urban area had significantly more difficulties in falling asleep, with worse subjective sleep quality, and more pronounced tiredness after sleep. When the samples were stratified in three age groups it was showed that these significant differences in sleep quality appeared only in the group of younger adults (Table 1).

Table 1. Sleep variables in relation to age and exposure to urban noise

Variable	Age group	Noisy area		Control zone		P*
		N	Mean ± SD	N	Mean ± SD	
Difficulty in falling asleep (grade)	21-40	98	2.02±0.78	76	1.77±0.62	<0,05
	41-60	118	2.00±0.76	55	1.92±0.81	>0,05
	Over 60	36	2.16±0.94	19	1.89±0.65	>0,05
	Total	252	2.03±0.80	150	1.85±0.70	<0.05
Subjective sleep quality (grade)	21-40	96	3.50±0.89	75	3.73±0.77	<0,05
	41-60	118	3.38±0.85	54	3.57±0.83	>0,05
	Over 60	35	3.14±0.80	20	3.30±0.80	>0,05
	Total	249	3.40±0.87	149	3.62±0.81	<0.01
Tiredness after sleep (grade)	21-40	98	2.81±0.80	77	2.45±0.78	<0,01
	41-60	118	2.84±0.83	59	2.74±0.84	>0,05
	Over 60	34	2.94±0.81	21	2.66±0.91	>0,05
	Total	250	2.85±0.82	157	2.59±0.83	<0.01

* Mann-Whitney U-test

4. DISCUSSION

Our findings about the specific sleep disturbances related to community noise are in accordance with the results of a similar field study that was performed among the residents of Gothenburg exposed to traffic noise of Leq about 72 dB(A) [4]. They also had more difficulties in falling asleep, with worse subjective sleep quality, and frequent tiredness after sleep compared to control population exposed to Leq of about 56 dB(A). This field study has not supported the experimental findings of a positive correlation between sensitivity to noise during sleep and age [3]. This contradiction between experimental and field findings might be influenced by the difference in research method (objective vs. subjective assessment). The most important confounding factors were controlled in this study (sex, socioeconomic status), although there might exist some influence of some personality factors, such as subjective noise sensitivity and the level of neuroticism [5]. However, the finding of enhanced sensitivity to noise during sleep in younger adults was systematic in this study. This is of importance for predicting the sleep effects of urban noise in relation to the age structure of a population.

5. CONCLUSION

The field study of sleep disturbances induced by urban noise has showed that the age group 21-40 years may be considered as a part of adult urban population particularly sensitive to noise during sleep.

6. SUMMARY

An interview method with specific questions concerning sleep was applied to a sample of 409 adult residents in the center of Belgrade. In the noisy area [Leq^{24} > 65 dB(A)] there were 252 interviewed inhabitants, and 157 interviews were performed in the control zone [Leq^{24} < 55 dB(A)]. Sleep quality was found to be worse among the inhabitants of noisy streets, compared to the control zone, and the specific sleep disturbances were: difficulties in falling asleep, subjectively estimated sleep quality and tiredness after sleep. When the samples were stratified in three age groups it was showed that significant differences appeared only in the age group 21-40 yr.

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A PRACTICAL INDEX FOR ASSESSMENT OF SLEEP DISTURBANCE

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1. INTRODUCTION

There have been several recent attempts to synthesise data from studies of sleep disturbance into a general predictive scheme [1 - 3, 6 - 8]. It would appear that as agreement is reached as to the most appropriate methodologies, the general form of this relationship is becoming clearer, although there remains some residual variation between different studies. However, there is still some distance between a methodology for prediction of the probability of awakening by single noise events, and a practical tool which can be used for general noise assessment.

This paper considers the possibility of formulating a Sleep Disturbance Index, or SDI, which would describe the potential of general intermittent noise to cause sleep disturbance. In formulating such a tool, the issues to be addressed include:

- range of noise types to which the index can be applied;
- predictability, using available information;
- measurability and monitoring; and
- criterion values for different noise types and land uses.

2. FORMULATION OF A SLEEP DISTURBANCE INDEX

The objective in formulating a Sleep Disturbance Index is to allow comparison of the sleep disturbance potential of various intermittent noises, leading to realistic assessment of their relative impact and the setting of acceptability criteria. Only intermittent noises are included in the scope, although there is evidence that continuous noise at a sufficiently high level can also result in various types of sleep disturbance [4].

It has been well documented that traditional measures of noise exposure, such as the long-term L_{eq}, do not provide an adequate prediction of the extent of responses such as awakening or changes in sleep state resulting from individual events (e.g. [5]). To describe these impacts, an alternative measure is required which is directly related to properties of individual events.

The proposed formulation is based on the following assumptions.

1. *The impact of intermittent noise on sleep quality can be adequately assessed by*

the expected number of behavioural awakenings due to the noise per night. This is, of course, not to assume that behavioural awakenings represent the only, or even the most important, effect on sleep. However, most studies indicate a strong correlation between the probability of awakening and other indicators of sleep quality.

2. *Awakenings due to noise events which are separated by more than 15 seconds can be assumed to be statistically independent.* This, of course, is not strictly true, in that if one event has caused a change to a lower sleep state, another event soon after will have a greater probability of causing an awakening. Also, there is some indication in [5] that after a large number of noise-related awakenings the probability of further awakenings may decrease. However, in any practical system these effects will need to be neglected, since it would generally be impossible to predict the time-distribution of events during a night.
3. *The most important acoustical parameters determining the probability of awakening are the maximum noise level (or the SEL) and the "emergence", which can be gauged from the difference between the maximum noise level and the ambient L_{eq} level.* These two parameters have been consistently shown to be strongly related to the probability of awakening. Other factors are also probably important, but have not been studied in sufficient detail to allow inclusion in a quantitative assessment methodology. Of the two descriptors of noise level, SEL appears to provide a better measure of potential behavioural awakening [1], but is less well understood and more difficult to measure, particularly for sources such as road traffic noise. In the following discussion, use of the maximum noise level is assumed.

Given the above three assumptions, a Sleep Disturbance Index can be defined as follows:

$$SDI_{10} = \sum_i W(L_{max}(i), L_{eq}) / 10$$

where W represents the **percentage** probability of awakening due to an event with maximum noise level L_{max} if the ambient noise level is L_{eq}, and i is summed over all events during an assumed 8-hour sleep period. This differs from a previous published formulation [6] in that it represents the number of awakenings per **ten** nights, rather than per night (hence the subscript 10).

The above formula leads to an index which typically takes values ranging from less than 1 (representing one awakening every 10 nights) to greater than 40 (representing four awakenings per night).

3. DEFINITION OF THE FUNCTION W

Much analysis has recently been devoted to estimating the form of the function W, at least for the case $L_{max} >> L_{eq}$. Figure 1 shows results from several syntheses, each of which consists of a re-analysis of raw data from a number of individual studies. It seems clear that if field studies only are considered, a reasonable consensus can be derived as to the probability of awakening, and either the FICAN curve [3] or the curve

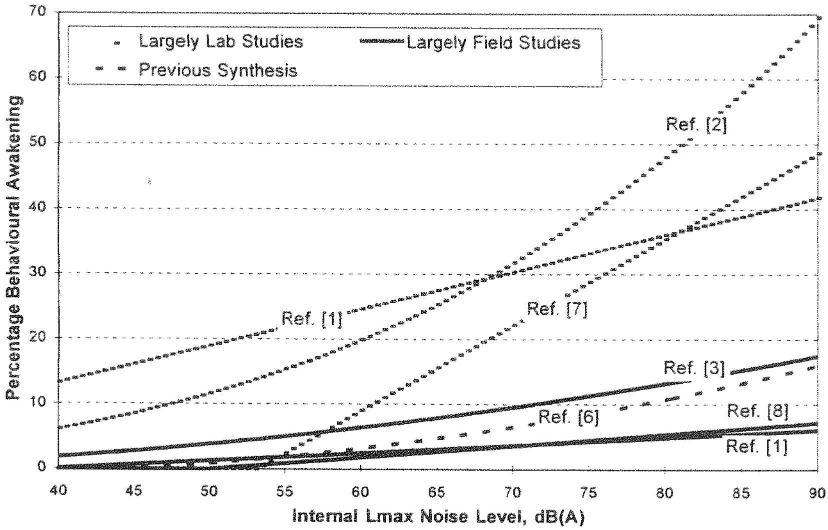

Figure 1. Predicted Percentage of Behavioural Awakenings - Various Sources

developed previously for SDI calculations [6] can be taken as representing this consensus. As L_{max} approaches L_{eq}, available studies provide only sketchy information as to the likely changes in W. The proposed assumption is a linear scaling-down between $L_{eq} + 20$ and $L_{eq} + 5$:

$W = W_{base}$	$L_{max} >= L_{eq} + 20$
$W = W_{base} * (L_{max} - L_{eq} - 15)/15$	$L_{max} > L_{eq} + 5 < L_{max} < L_{eq} + 5$
$W = 0$	$L_{max} <= L_{eq} + 5$

where W_{base} is the value derived from the FICAN curve.

3. CALCULATION AND MEASUREMENT OF SDI_{10}

To calculate SDI_{10}, one needs in general to predict the maximum noise level from all intermittent events during an assumed sleep period. (This period could be chosen as required, but 10pm - 6am has been used in trials.) An advantage of the methodology is that a "partial" SDI_{10} can be calculated for individual sources (e.g. different vehicle types) which depends on the level and number of events in each type. These "partial" values are then simply added to give the final SDI_{10} value.

Calculation is relatively easy for cases where $L_{max} > L_{eq} + 20$, which is generally the case for aircraft or rail traffic noise, and many other neighbourhood noises. Output from models such as INM can be used directly to calculate values of W for each aircraft type at any point, and other software can then be used to produce contours, if required. For road traffic, the L_{eq} noise level requires calculation, in addition to L_{max} levels from individual vehicles. The FHWA prediction methodology can be adapted for this purpose, although this does not predict maximum levels due to multiple passbys at the same time.

Direct measurement of SDI_{10}, based only on a recorded time-history of A-weighted noise levels during the night, requires closer definition of an "event". A working definition is that an event occurs if: a) the noise level reaches a maximum; b) the level drops at least 5 dB between this and any other maximum; and c) the maximum is separated from any other event by at least 15 seconds.

With this definition, there is no reason why automated noise loggers could not directly measure the SDI_{10} over a night. (Note that with a definition involving SEL, this would be much more difficult.)

4. INTERPRETATION AND CRITERIA

In the form described above, it would be best to consider SDI_{10} as an index related to physically-measurable properties of the noise climate, rather than as a direct prediction of number of awakenings per ten nights. However, the latter interpretation is certainly relevant in determining criteria.

As with other noise indices, criteria will depend on the type of source, the number of people affected and the possible control measures. In the case of some neighbourhood noises it is probably relevant to set a criterion close to zero (implying internal noise levels do not exceed L_{eq} + 5 dB(A), or else are below about 45 dB(A)). In the case of industrial noise and some transportation noise sources, experience appears to indicate a criterion of about 2. For road traffic noise, a criterion of about 15 appears to be consistent with current practice and goals. This represents an impact approximately equal to the "ambient" level of disturbance which is associated with noise [3], i.e. approximately 1.3 - 1.8 awakenings per night.

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SLEEP DISTURBANCE REPORTED AROUND KADENA U.S. AIRFIELD IN THE RYUKYUS

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1. INTRODUCTION

This study deals with the sleep disturbance of the people living around the U.S. Airbase, Kadena, in the Ryukyus. The results of the questionnaire survey are analysed in relation to the level of noise exposure.

2. METHODS

Details on the method of study are described in the paper presented by K. Hiramatsu *et al.* [1]. The respondents were 3,560 male and female inhabitants around the base randomly sampled from the areas of different levels of aircraft noise exposure expressed in WECPNL, from 75 to 95 or more, and 685 from the area without noise exposure. They answered five questions on sleep disturbance, which are listed in

Table 1. These questions did not specify the sleep disturbance as caused by the aircraft noise.

The answers were required by five alternatives; "1. More than two days a week", "2. One or two days a week", "3. One or two days a month", "4. Scarcely", "5. Not at all".

Two types of scores indicating the degree of the sleep disturbance are calculated based on the answers to five questions on sleep disturbance as follows: The score "Once or more a week" is the number of questions answered for the alternative 1 or 2; and the score "Once or more a month" for 1, 2 or 3. Either score has the range from zero to five. It is safe to say that higher score indicates high degree of the sleep disturbance.

3. RESULTS AND DISCUSSION

In Figures 1 and 2 are shown the percentages of the scores on the sleep disturbance for the different level of noise exposure expressed in WECPNL and the control. Note the percentage is adjusted for the distribution of age and sex of the control. It is shown in the figures that the rate of the respondents with high score increases as WECPNL gets higher, thus the clear dose-response relationships between the scores of sleep disturbance and the level of noise exposure are found. It is also shown that about 20% among the control respondents complain the sleep disturbance with a frequency of once or more a week, which indicates that people may have the experience of sleep disturbance generally to such a degree. This fact requires examining how the rate of sleep disturbance among exposure groups increases in comparison with that of the control.

For this purpose, logistic regression model is applied with the independent variables of age, sex and the interaction of age and sex. In Figures from 3 to 6 are shown the results of the analyses. The abscissa and ordinate of each figure indicate the noise exposure expressed in WECPNL and the odds ratio of the respondents, respectively. Vertical bars in the figures show the 95% confidence limits of odds ratios. The three asterisks indicate the cases where significant differences are found in odds ratios between the exposure group and the control with the significance level of 0.001. In the figures p_t indicates the significance probability of trend test.

Clear dose-response relationships are found in all the figures, which are supported

Table 1. Questions on sleep disturbance

- How often do you have difficulty getting to sleep?
- How often do you have so much difficulty that you can't get to sleep after waking up in the middle of the night?
- How often are you in trouble with waking up early in the morning?
- How often do you feel that you did not have a good night's sleep?
- How often are you worried before going to bed about whether you can sleep well?

also by the result that p_t is less than 0.0001. The odds ratios of the group of highest noise exposure are from 3.0 to 4.8 where that of the control group is one, so as to suggest that the residents exposed to high level of aircraft noise suffer from serious sleep disturbance.

There is found little difference between the odds ratios of "Once or more a week" and "Once or more a month" in such highly exposed groups as more than 95 of WECPNL. In lower exposed groups, however, the odds ratios of "Once or more a month" are higher than those of "Once or more a week", which shows the sensitive increase for the increase of noise exposure. Moreover, in the case of "Once or more a month", significant differences from the odds ratio of the control are found even in lower exposed groups. These results imply that the sleep disturbance of comparatively low degree occurs among residents even in areas of lower noise exposure.

ACKNOWLEDGEMENTS

The authors wish to express their gratitude to Okinawa Prefectural Government for its support to carry out the study.

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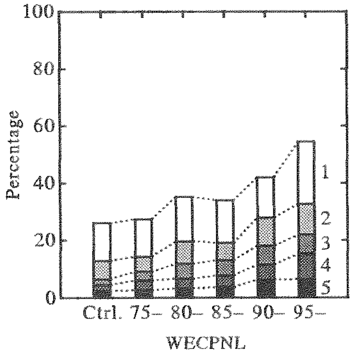

Figure 1. Percentage of score "Once or more a week"

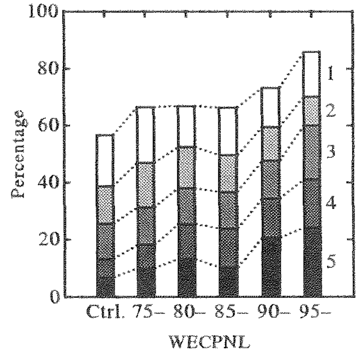

Figure 2. Percentage of score "Once or more a week"

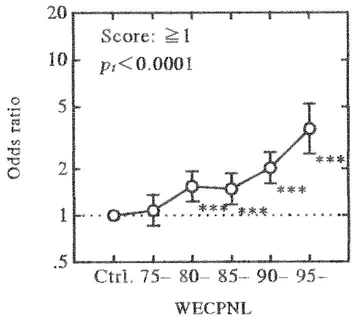

Figure 3. Odds ratio of score "Once or more a week"

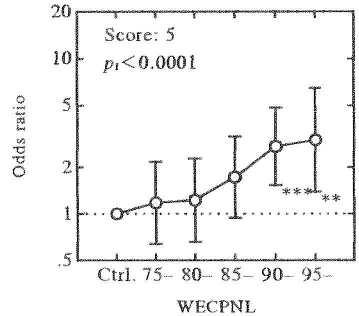

Figure 4. Odds ratio of score "Once or more a week"

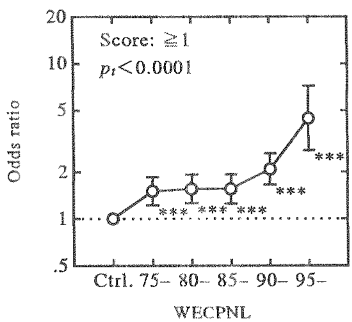

Figure 5. Odds ratio of score "Once or more a month"

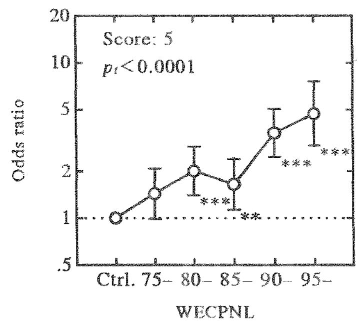

Figure 6. Odds ratio of score "Once or more a month"

ACOUSTIC ENVIRONMENT MEASUREMENT AND SLEEP DISTURBANCE

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1. INTRODUCTION

Although the assessment of noise induced sleep arousal is often attempted, there is still no criterion in Australia to predict it reliably [1]. Noise level measurements in Sydney, Australia show typical suburban background sound levels are statistically so variable that current criteria assess existing road traffic as leading to unacceptable sleep disturbance.

At present the Environment Protection Authority (EPA) Environmental Noise Control Manual [2] defines sleep arousal as an event when a person may not actually be woken by a noise, but a person's rest may be significantly disturbed by noise. Griefahn [3] says that sleep disturbance is measurable and is characterised as subjectively experienced deviations from the usual or desired sleep behaviour.

The sleep arousal criterion [2] the NSW EPA currently uses is the level exceeded for 1% of the sample time (L_{A1}) of any specific noise source should not be greater than the background noise level exceeded for 90% of the sample time (L_{A90}) by more than 15 dB(A) when measured outside a bedroom window. To make such a general criterion responsive to short duration events, the measurement durations need to be specified. Acoustic consultants in Sydney commonly use a measurement procedure to test whether the level exceeded for 1% of a one minute time sample of the event(s) being investigated $L_{A1,1\ min}$ is greater by 15 dB(A) than the level exceeded for 90% of a 15 minute time sample of the background $L_{A90,15\ min}$. It is thought that if there is one such exceedance then sleep arousal is expected and if there are more than three or four such events in a night, the events are assessed as unacceptable.

Carter et al [1992] raised the point that the current acoustic criterion for sleep disturbance needs review as it does not adequately predict sleep arousal. In 1998, there is still no criterion that properly predicts sleep arousal. Such a reliable criterion is necessary to discriminate between noisy events that are so intrusive people are likely to have their sleep disturbed and existing background noise that is either widely tolerated in the community or which does not disturb sleep. This paper reports Acoustic Dynamics' measurements and analysis showing existing background noise at houses facing a busy suburban road and outside in a quiet carpark, exceeds the criterion by a wide margin.

2. MEASUREMENT PROCEDURE

In March 1998 Acoustic Dynamics tested the current sleep disturbance criterion, during a project we were working on. The project involved predicting whether people using a large club carpark at night and in the early morning would be acceptable or not. The club is located on a busy access road, which has fairly constant traffic during the day and less traffic at night. Away from the busy road, the club borders residential properties in quiet residential streets. The assessment task was to predict the acceptability of extending the club's trading hours based on the noise from patrons leaving in the early morning.

At two locations, two environmental noise loggers (type 2 accuracy) measured ambient A-weighted statistical noise levels in the area with the club closing normally at midnight or 1am. One measurement location was on the verandah of a house facing the noisy main road and the other was in the club's carpark adjacent to the quieter residential area.

Placed next to each other, one measured the level exceeded for 1% of the sample time L_{A1} in 1 minute intervals, the other measured the level exceeded for 90% of the sample time L_{A90} in 15 minute intervals. If the $L_{A1,15\ min}$ were to be compared to the $L_{A90,15\ min}$, then short duration loud noises such as the slamming of a car door would not be picked up by the logger, as 1% of 15 minutes covers 9 seconds. The criterion of marginal acceptability is whether the noise exceeded for 0.6 seconds over a 60 second period exceeds the $L_{A90,15\ min}$ by 15 dB(A) more than three or four times a night. We wrote our own program to allow manual comparison of the two different data streams.

3. MEASUREMENT RESULTS

Noise was measured over three consecutive nights. Figure 1 shows the typical $L_{A90,15\ min}$ and $L_{A1,1\ min}$ noise levels. The difference is typically greater than 15 dB(A). Extreme values are of course greater. On a Friday night, the measurements showed the $L_{A1,1\ min}$ exceeded the $L_{A90,15\ min}$ by more than 15 dB(A) 439 times. For a Saturday night, the number of exceedances was 123 and on the Sunday it was 81, a smaller number largely due to a unexplained higher background level. The highest measured exceedance was 41 dB(A) over the background noise level at houses facing the main road. The equivalent continuous noise level $L_{Aeq,15\ min}$ was typically 60 dB(A) and up to 69 dB(A) after 10pm.

In the club's carpark, Figure 2 shows that the difference between the $L_{A1,1\ min}$ and the typical $L_{A90,15\ min}$ at the carpark boundary in a quiet residential area is less frequently over 15 dB(A) than for houses facing the main road. The $L_{A1,1\ min}$ exceeded the $L_{A90,15\ min}$ by more than 15 dB(A) 51 times on the Thursday night, 80 times on Friday night and 111 times on Saturday night. The $L_{Aeq,15\ min}$ was typically under 55 dB(A) and at times 57 or 58 dB(A) between 10pm and 6am each night, reaching 71 dB(A) on one occasion.

An alternative criterion, that the equivalent continuous noise level, measured outside a bedroom window, should not be greater than 55 dB(A), was also frequently exceeded. Such an absolute equivalent continuous noise level is not considered further for two reasons. The criterion is unrelated to background noise and more importantly, the L_{Aeq} is largely unresponsive to short duration events likely to startle a sleeping person, probably more directly correlated with sleep disturbance

Using the current criterion, the road noise measured on both the nearest house verandah and in the carpark would be assessed as causing sleep disturbance. Such an assessment implies that the people living in the houses along the busy main road are woken frequently by normal road traffic during the night. However this does not seem to be the case. It would not be called "sleep" if it was disturbed that often.

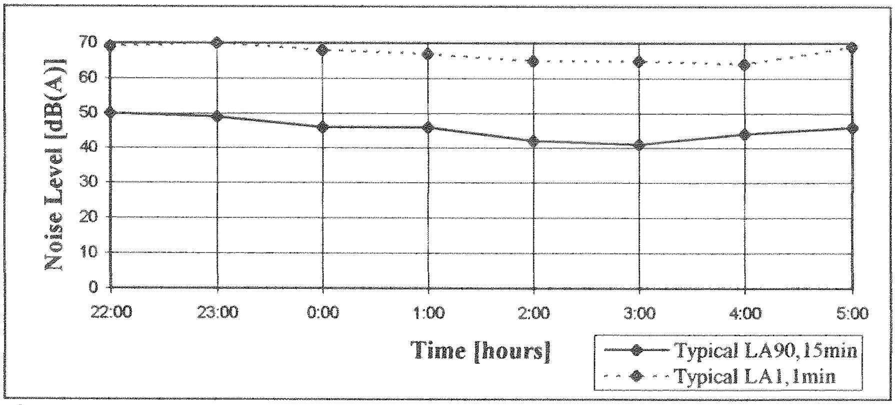

Figure 1. Typical Noise Levels for a main road outside house facade.

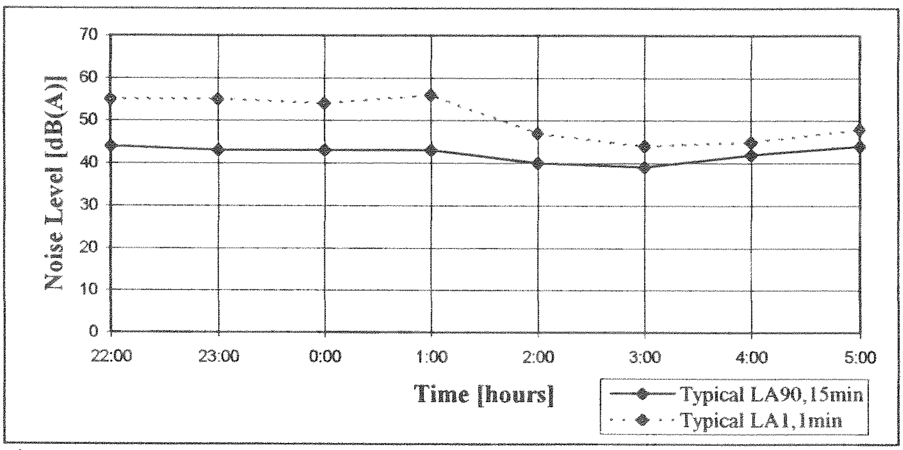

Figure 2. Typical Noise Levels for a club's carpark in a residential area, outdoors.

4. CONCLUSION

The suburban environmental noise measurements reported here show the current sleep disturbance criterion $L_{A1,1\,min}$ not to exceed $L_{A90,15\,min}$ by any more than 15 dB(A), cannot predict sleep disturbance. Even in this form, refined enough for it to be used, is insufficiently correlated with sleep disturbance, resulting in false negative assessment of background noise from road traffic.

A new, more responsive prediction method should be developed. An assessment method which directly measures noise character plausibly related to sleep disturbance is more likely to discriminate between tolerable background noise and unusual noise that is out of character with noise in the area. Modern digital signal processing can measure the "startle" character of transient noise such as the rapid rise time or "attack" of short duration events, unusual frequency characteristics and impulsiveness. A measurement of transient events incorporating a duration measurement and a threshold level change of a selected decibel jump in less than a selected millisecond duration would help eliminate road traffic and other background noise contributing to the level exceeded for 1% of the time that sleepers seem to tolerate without disturbance. It is hoped such a "startle" measure will discriminate and weight the measurement further towards sudden noises that contrast with the immediately preceding background noise.

Trying to correlate existing statistical measures with observed sleep disturbance can not be reliable in an environment where the background noise level exceeded for 1% of the time is 15 dB(A) greater than the background level exceeded for 90% of the time. Under these circumstances when the L_{A1} is 15 dB greater than the L_{A90}, more usual than not in areas where road traffic is sporadic, the guide to sleep disturbance should include measures that indicate rapid or startling changes from an existing background.

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CARDIOVASCULAR RESPONSES TO AIRCRAFT NOISE IN SLEEPING SUBJECTS

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1. INTRODUCTION

Environmental pollution, due to transportation noise, is on the increase. In many previous studies, the effects of noise on sleep have been evaluated using various techniques eg. EEG recording and subjective reports.

However, there is little literature on evoked autonomic arousal, particularly outside the laboratory. Enhanced effects of noise on the cardiovascular system have been found during sleep, probably due to the removal of cortical inhibition, evident during waking (Di Nisi *et al.*, 1990). Hence, aircraft noise could be especially problematic during sleep of residents living close to busy airports. These individuals could be subject to numerous transient cardiovascular arousals throughout the sleeping period.

The objective of this study was to investigate cardiovascular arousals, during sleep, due to aircraft noise, using data collected in a previous field study (Ollerhead *et al.*, 1992).

2. METHOD

The effects of aircraft noise events (ANE), greater than 60dBA outdoors, on heart rate in residents living close to one of four major UK airports, were assessed.

Three microphones linked to a central processing system, were positioned around the perimeter of each site and were set to record the time and level of all noises. Road traffic noise and other localised noise failed to trigger all three monitors at any one time. The time at which the aircraft noise exceeded 60dBA was noted and used as a reference time for the analysis. Portable Oxford Medilog recorders (9200), with internal clocks, were used to record electrophysiological data (EEG, EMG, EOG and

ECG) onto cassette tape over the sleeping period. Subsequent playback of the tapes, through the Medilog system, allowed for computer based and manual analysis of the data.

Simultaneous actimetric and electrophysiological data was recorded for 178 subject nights. For the present study, a sample of 150 subject nights was chosen for ECG analysis. The subjects were 20 males and 24 females in age bands 20-34 years (n=16), 35-49 years (n=14) and 50-70 years (n=14). 150 subject nights of electrophysiological recordings were analysed for a cardiovascular response to aircraft noise events which occurred in the time window 22.00-06.00.

3. DATA ANALYSIS

To analyse cardiac response to ANE, 56 second (8 seconds prior to ANE>60dBA and 48 seconds after) fragments of ECG data associated with the aircraft noise were stored to floppy disc. These were then sent via E-mail to CNRS laboratories in Strasbourg for HRR (heart rate response) analysis. Additionally, no-noise control fragments of data were analysed in a similar way, randomly chosen 2-5 minutes prior to each ANE. A heart rate response was defined when the amplitude of the biphasic cardiovascular response was greater than 8 beats/minute (Bach *et al.*, 1991).

Data contaminated by artefacts eg. excessive EMG, were excluded from the analysis.

For all heart rate responses, maximum and minimum instantaneous heart rate values and response latencies were recorded. These measures allowed for both the magnitude of the response and the latency at which it occurred after noise onset (>60dBA) to be calculated.

4. RESULTS

Cardiovascular Reactivity

Heart rate changes were seen for 26.8% of fragments when aircraft noises were present. While only 17.9% of fragments were found to contain a HRR when there was no aircraft noise. Therefore, the propensity for autonomic arousal increased by 8.9% when aircraft noise was present.

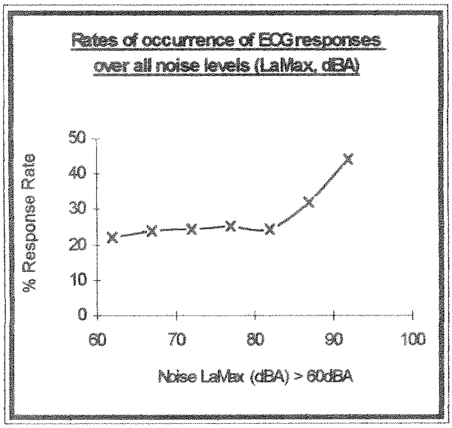
The magnitude of the response was found to be significantly greater when an ANE was present. The mean response magnitude was 18.54 beats/minute (s.d.=9.40) for ANE data compared to 16.39 beats/minute (s.d.=8.36) for control data.

There was no significant difference between the response latency for ANE and control data.

Noise Metrics

To evaluate any association between heart rate changes and aircraft noise level (LaMax) and duration, data was banded (5 dBA and 5 second bands respectively).

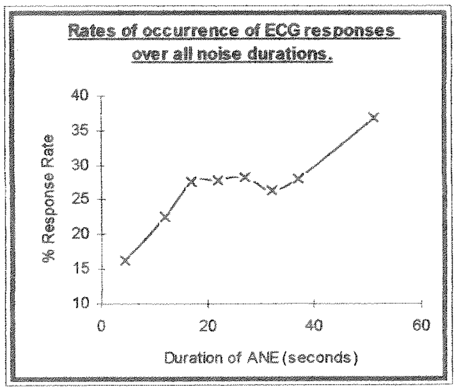
Figure (1)



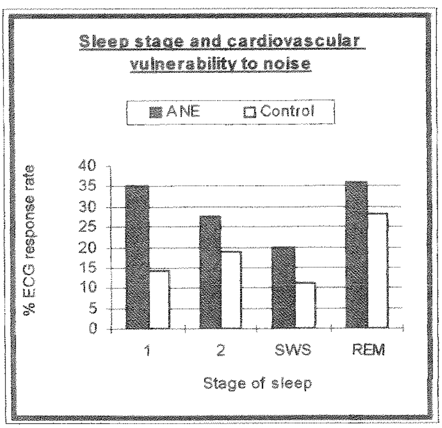
There was a clear relationship between the response rate and noise level (figure 1). The graph has two separate sections. Up to 84 dBA there was a slow rise in response rate followed by a much more rapid rise above 85 dBA. Results showed that noises louder than 84dBA were more likely to induce a heart rate response than noises below this level ($p<0.001$). There was no indication of any relationship between the noise level and either response magnitude or latency.

Figure (2)

Results showed (figure 2) no clear relationship between the duration of the noise event and the occurrence of a cardiovascular response. However, shorter noise events appeared to induce fewer ECG responses than longer noises. Response magnitude andlatency appeared to be unaffected by noise duration.



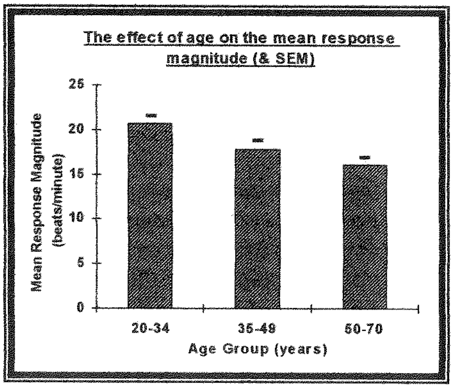
Sleep Stage
Figure (3)



The effect of sleep stage (one epoch prior to the ANE) was investigated and showed (figure 3) that heart rate reactivity to ANE was high during stage 1 and REM and progressively lower for stage 2 and SWS. However, REM showed the greatest number of noise and control responses. SWS was shown to have the lowest rate of cardiovascular response for both noisy and quiet periods. Mean response magnitude and latency did not differ significantly between sleep stages.

Age & Gender

Figure (4)



Males responded more often to an ANE than females and tended to react faster. For males 30.3% of ANE fragments showed an ECG response, compared to 24.6% for females.

The effect of age on the mean response magnitude was significant. Figure 4 shows that as age progressed, the size of the response declined ($p<0.01$). There was no effect of gender on the mean response magnitude nor were there any significant age / gender interactions.

Time of Night (2 hour blocks 22.00-06.00)

The time of night did not appear to influence response rate, magnitude or latency.

5. CONCLUSIONS

- Cardiac reactivity increased when noise was present.
- Positive association was evident between cardiovascular reactivity and noise levels (outdoor) > 80 - 84dBA.
- Sleep stage prior to the ANE appeared to affect cardiovascular reactivity, with the lowest response rates in SWS.
- Males appeared to be more responsive to ANE than females and responded faster.
- Significant decline in HRR amplitude as age increased.
- No tendency for response rate, magnitude or latency change throughout the recorded period (22.00 - 06.00).
- These results agree with earlier anlayses (Ollerhead *et al.*, 1992) which showed very little disturbance as measured by actimetry yet slightly more when assessed by cortical arousal. Autonomic arousals were more frequent, but were still at low levels.

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WHO GUIDELINES ON COMMUNITY NOISE

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1. INTRODUCTION

Community noise (also called environmental noise, residential noise or domestic noise) is defined as the noise emitted from all noise sources except noise at the industrial workplace. Main sources of community noise include road, rail and air traffic, industries, construction and public work, and the neighbourhood. The main indoor sources are ventilation systems, office machines, home appliances and neighbours. Typical neighbourhood noise come from premises and installations related to the catering trade (restaurant, cafeterias, discotheques, etc.) live or recorded music, sport events including motor sports, playgrounds, car parks, and domestic animals such as barking dogs. Many countries have regulations on community noise from road, rail and rail traffic, construction machines, and industrial plants through applying emission standards, and on the acoustic properties of buildings. In contrast, few countries have regulations on community noise from neighbourhood, probably due to lack of methods to define and measure it, and the difficulty of controlling it.

The extent of the noise problem is large. In the European Union countries about 40 % of the population are exposed to road traffic noise with an equivalent sound pressure level exceeding 55 dB(A) daytime and 20 % are exposed to levels exceeding 65 dB(A) (Lambert & Vallet, 1994). Taking all exposure to transportation noise together about half of the European Union citizens are estimated to live in zones which do not ensure acoustic comfort to residents. More than 30 % are exposed at night to equivalent sound pressure levels exceeding 55 dB(A) which are disturbing to sleep. The noise pollution problem is also severe in cities of developing countries and caused mainly by traffic. Data collected alongside densely travelled roads were found to have equivalent sound pressure levels for 24 hours of 75 to 80 dB(A) (e.g. National Environment Board Thailand, 1990).

The scope of WHO's effort to derive guidelines for community noise is to consolidate actual scientific knowledge on the health impacts of community noise and to provide guidance to environmental health authorities and professionals trying to protect people from the harmful effects of noise in non-industrial environments. Guidance on the health effects of noise exposure of the population has already been given in an early publication of the series of Environmental Health Criteria (WHO, 1980). The health risk to humans from exposure to environmental noise was evaluated and guidelines values derived. The issue of noise control and health protection was briefly addressed. At a WHO/EURO Task Force Meeting in Düsseldorf, Germany, in 1992, the health criteria and guideline values were revised and it was agreed upon updated guidelines in consensus. (WHO, 1993; Berglund & Lindvall, 1995).

The essentials of the deliberations of the Task Force were published by Stockholm University and Karolinska Institute in 1995 and are summarised here. In a forthcoming task force meeting the guidelines for community noise will be made globally applicable, and the issues of noise assessment and control will be addressed in more detail. It is expected that the WHO Guidelines for Community Noise will be available by end 1999.

2. PHYSICAL ASPECTS OF NOISE

The exposure to noise from various sources is most commonly expressed as the A-weighted average sound pressure level over a specific time period T, such as 24 hours. This gives a value in the equivalent continuous sound pressure level L_{eq}^{T} in units dB(A). It is derived from the following mathematical expression.

$$L_{eq}^{T} = 10 \log_{10}\{(1/T) \int_0^T 10^{Lp(t)/10} dt \} \text{ [dB(A)]} \qquad (1)$$

The integral is a measure of the total sound energy during the period T. Thus, L_{eq}^{T} is the level of that steady sound which, over the same interval of time T as the fluctuating sound of interest, has the same effective sound pressure. The A-weighted sound pressure level $L_p(t)$ in dB(A) is defined through

$$L_p(t) = 20 \log_{10}\{p(t)/p_{ref}\} \text{ [dB(A)]} \qquad (2)$$

where p(t) denotes the sound pressure level at time t and the reference pressure p_{ref} has an internationally agreed value of $2 \cdot 10^{-5}$ N/m^2 (often given in micropascal, 20 mPa). For practical calculations of the equivalent sound pressure level the integral in (1) is replaced by a sum.

This is a physical concept that implies that the same average level of chosen time can either consist of a larger number of events with relatively low levels or fewer events with high levels. It does not necessarily agree with common experience on how environmental noise is experienced, nor with the neurophysiological characteristics of the human receptor system.

3. EVALUATION OF HEALTH RISKS AND GUIDELINES

Community noise needs to be assessed with respect to risks for both human health and well-being. Adverse physiological, biochemical, psychological, sociological and economic consequences of exposure to noise must be critically evaluated for relevant aspects of human behaviour, such as work, communication and social interaction, residential activities, recreation and sleep. Intensity, frequency, reversibility and avoidability are pertinent criteria for the severeness of noise effects. Additionally, indices of population response, for example, the percentages or absolute numbers of disturbed people in exposed areas, are relevant figures.

The equivalent continuous sound pressure level basically is not fully adequate as a single measure for community noise, since most community noise-induced adverse effects are correlated with a combination of several exposure parameters, simultaneously, such as, equivalent level, maximum level of a noise event, number of noise events over time, and time of the day. The equivalent measures of sound pressure level, L_{eq}^{T}, should be qualified with an appropriate time base T before guideline values are being applied.

Human perception of the environment through hearing is characterised by a good discrimination of stimulus intensity differences and a decaying sensitivity to a continuous stimulus. Single events can only be discriminated up to a certain threshold, above which the exposure is interpreted as continuous. Thus, it is relevant to consider the importance of the background level, the number of events, and the noise exposure level independently when assessing the effects of environmental noise on man.

There may be some populations at greater risk for the harmful effects of noise. Young children (especially during language acquisition), the blind, and perhaps foetuses are examples of such populations. The guidelines described here are for the population at large and have not addressed the topic of potentially more vulnerable groups. To protect sensitive persons still lower guideline values could be preferred.

Specific effects that are considered in the fixing the guidelines include interference with communication, noise-induced hearing loss, sleep disturbance effects, cardiovascular and psycho-physiological effects, performance effects, annoyance responses, and effects on social behaviour.

Communication interference starts about sound levels of 50 dB(A); a speech spoken in background levels of about 45 dB(A) is 100% intelligible, and can be understood fairly well in background levels of 55 dB(A). Speech communication is affected by the reverberation time. Even in quiet environments a reverberation time of below 0.6 s is desirable.

High level noise giving rise to noise-induced hearing deficits can occur in occupational situations, open air concerts, discotheques, motor sports events, shooting ranges, and from loudspeakers or headphones within dwellings. Due to the considerable variation in human sensitivity with respect to hearing impairment the hazardous nature of a noisy environment is described in terms of "damage risk". This is defined as the probability in a noise exposed population to suffer from noise-induced hearing losses. This risk is considered to be negligible at equivalent noise exposure levels below 75 dB(A) over an exposure period of 8 hours.

Measurable sleep disturbance effects start from about 30 dB L_{eq}. They increase with increased maximum noise level. Even if the total equivalent noise level is fairly low, a small number of noise events with a high maximum sound pressure level will affect sleep. Therefore, guidelines for community noise to avoid sleep disturbance are expressed in terms of equivalent sound pressure level of the noise as well as maximum levels, and number of noise events. It is especially important to limit the noise events exceeding 45 dB(A) where the background level is low. In consequence, in noise exposure control, one should consider at the same time the equivalent sound pressure level, the levels of the noise peaks and the number of noise events.

With respect to cardiovascular diseases the overall evidence suggests that a weak association exists between long-term noise exposure and blood pressure elevation or hypertension. Evidence on psycho-physiological effects, such as gastrointestinal motility, is less clear. More research is required in order to estimate the long-term cardiovascular and psycho-physiological risks due to noise. In view of the equivocal findings, no guideline values may be given with respect to this critical effect. Noise can act as a distracting stimulus and may also affect the psycho-physiological state of the individual. A novel event, such as the start of an unfamiliar noise will cause distraction and interfere with many kinds of tasks. Noise annoyance may be defined as a feeling of displeasure evoked by a noise. Annoyance is affected by the equivalent sound pressure level, the highest sound pressure level of a noise event, the number of such events, and the time of the day. Methods for combining these predictors for annoyance have been extensively studied. Community annoyance varies with activity. The threshold of annoyance for steady-state, continuous noise is around an the equivalent sound pressure level of 50 dB(A). Few people are seriously annoyed during the day time at noise levels below around 55 dB(A). Noise levels during the evening and night should be 5 to 10 dB lower than during the day. For intermittent noise it is necessary to take into account the maximum sound pressure level and the number of noise events. Guidelines or noise abatement measures also should take into account residential outdoor activities.

Table (1) summarises the noise guidelines derived by the WHO task force. These guidelines should be amended by recommendations on which site locations compliance with these noise levels should be determined. E.g. for ambient noise levels it could be agreed that monitoring should take place 0.5 m before a window; in closed spaces noise levels could be determined in a distance of 1.2 m from any walls. For environments in which hearing deficits or hearing impairment are to be expected monitoring is to be performed at the level of the ears.

Table (1): Guidelines for Community Noise

Environment	Critical effects	L_{eq} [dB(A)]	Time base T [hours]	L_{max} [dB(A)]	Setting of instrument for L_{max}
Bedroom (night-time)	Sleep disturbance, annoyance	30	8	45	fast
Dwelling room (daytime)	Annoyance, speech interference	50	16	-	-
Outdoor living areas (daytime)	Serious annoyance, Moderate annoyance	55 50	16	-	-
Outdoor living areas (night-time)	Sleep disturbance with open windows	45	8	-	-
School classroom	Speech interference, disturbance of information extraction, message communication, annoyance	35	8	-	
School outdoor playground	Annoyance	55		-	
Hospitals: patient rooms	Sleep disturbance, communication interference	35	8	45	fast
Hospitals: Ward rooms	Sleep disturbance, communication interference	30	8	40	fast
Concert halls Outdoor concerts Discotheques Play-back headphones	Hearing impairment	100	4	-	-
Impulsive sounds from toys and fireworks	Hearing deficits	-	-	140	impulse

8. SUMMARY

In big cities throughout the world, the general population is increasingly exposed to community or environmental noise due to vehicle traffic in busy streets, aircraft starting and landing, outdoor concerts, noise in indoor environments, and industry. The health effects of these exposures are considered to be a more and more important public health problem. Specific effects to be considered in the fixing of the community noise guidelines include interference with communication, noise-induced hearing loss, sleep disturbance effects, cardiovascular and psycho-physiological effects, performance effects, annoyance responses, and effects on social behaviour. Since 1980, the World Health Organization has addressed this problem. Health-based guidelines on community noise can serve as the basis for the derivation of noise standards within a framework of noise management. Key issues of noise management include abatement options, models for forecasting and assessment of source control action, standard setting process for existing and planned sources, noise exposure assessment, and testing compliance of noise exposure with noise standards. In 1992, the WHO Regional Office for Europe convened a task force meeting which set up guidelines for community noise. A preliminary publication of the Karolinska Institute, Stockholm, on behalf of WHO appeared in 1995. This publication serves as the basis for a document on the globally applicable Guidelines for Community Noise that are being developed by WHO.

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RECOMMENDATION FOR SHARED ANNOYANCE QUESTIONS IN NOISE ANNOYANCE SURVEYS

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1. INTRODUCTION

In 1997 Team #6 (Community Response to Noise) of the International Commission on the Biological Effects of Noise published guidelines for the reporting of results from combined social/acoustical surveys of noise annoyance[1]. The present paper offers the team's current recommendations on a related subject, the choice of noise-annoyance questions to be placed in community noise-annoyance surveys for the purpose of enhancing comparisons between surveys. This recommendation is based on over five years of correspondence, workshops at four international congresses, and initial analyses of a 10-nation study of 738 subjects' ratings of annoyance modifiers.

Although understanding reactions to noise will benefit from creative new study methods, the development of cumulative information for public policy also requires that new studies be designed to maintain linkages with previous studies and develop linkages with other new, innovative methods. Many of the cultural, acoustical, and situational impediments to combining study results and thus forming a cumulative body of knowledge about reactions to noise are inherent in the subject matter. One impediment that could be directly resolved at the survey design stage is the absence of common, shared noise-reaction questions. After more than 35 years and 350 surveys, different studies continue to use their own diverse, non-comparable reaction questions. While it is not clear that any particular annoyance question is best, it is clear that the lack of a shared annoyance question hinders the accumulation of comparable information.

The long-term objective for the work described in this paper is to have community surveys of noise reactions produce directly comparable noise reaction measures with minimal effort[2]. This paper argues that those comparable reaction measures will be possible if: (1) two identically formatted questions are shared across surveys; (2) researchers in different regions, countries and languages conduct uniform, small-scale studies of subjects' ratings and preferences for annoyance modifiers and then follow uniform analysis techniques to select words for annoyance scales in each language; (3) some widely-shared question-placement and other practices are accepted; and (4) questionnaire design practices are accepted that permit the inclusion of both unique and shared reaction measures. The two latter points have been discussed in a previous publication where it was noted that though placement of an annoyance question early in questionnaires is standard practice, some research indicates that comparable results are obtained with an annoyance question at the end of a questionnaire. If the recommended questions were placed at the end of surveys they need not displace other questions[3].

2. RECOMMENDED REACTION QUESTIONS FOR COMPARISONS

The team proposes that two scales, one verbal and one numeric, be used to strengthen comparisons between surveys. The wording and structure of the questions have been agreed upon although the choice of the exact words for the answers is still tentative. This is the proposed wording for English language usage:

Verbal Question:

"Thinking about the last (..12 months or so..), when you are here at home, how much does the noise from (..noise source...) bother, disturb, or annoy you; Extremely, Very, Moderately, Slightly or Not at all?"

Numeric Question:

"Next is a zero to ten opinion scale for how much (..source..) noise bothers, disturbs or annoys you when you are here at home. If you are not at all annoyed choose zero, if you are extremely annoyed choose ten, if you are somewhere in between choose a number between zero and ten. Thinking about the last (..12 months or so..), what number from zero to ten best shows how much you are bothered or annoyed by (..source..) noise?"

Both questions should be accompanied by visual answer cards in face-to-face interviews that display the words or numbers at equally-spaced intervals without a thermometer bulb or similar asymmetrical marking. Both questions have been worded so that they can also be used in telephone interviews. The exact wording of each question has been carefully considered.

Both questions are direct, noise-annoyance rating questions rather than comparison or indirect questions. As has been explained elsewhere [3] comparison questions are not suitable for between survey comparisons because there is no stable, uniform point of comparison. Direct questions are recommended over indirect questions for comparative purposes because the indirect questions are either less highly related to noise level or do not summarize respondents' overall reactions to an environmental noise.

Essential Elements of the Two Recommended Questions

The two recommended questions incorporate eight design elements that are intended to enhance comparability between studies. Table 1 lists the eight elements together with short justifications. Three of these elements are discussed next.

Table 1 Eight essential elements to ensure comparability for the recommended questions

	Element	Rationale	Support
1	Ask all respondents (no initial filter for "hearing" noise).	●"Hearing" is interpreted as a low grade annoyance question. ●Surveys without filters do not have rapport problems.	● Road traffic is heard everywhere, but 11 % of the English answer "not hear." [5]
2	One-part annoyance questions are used.	● Two part questions (annoyance filter + direct question) yield ambiguous counts of scale points[1].	● Both number of points and wording influence answers. ● Filter questions affect responses. [6][2]
3	The location ("at home") & time of day are not narrowly defined.	●Policy makers need a combined reaction. ●Only residents can integrate feelings for a total reaction.	●High noise/annoyance correlations (r=0.57) are possible. [7]
4	The time reference is long & somewhat indefinite ("last 12 months or so").	● Reduces seasonal effects ● A shorter period implies a recent change is being studied. ● Long-term is primary interest.	●Respondents may attempt to give overall impressions. ● People are not accurate about time periods.
5	Unipolar, negative scale and reference to "noise."	● Respondents would be confused by a positive pole for a negative concept. ● Regulations need assessments of problems.	●Surveys with positive poles report few positive responses. ●"Noise" is used in normal speech.
6	Ask "disturb" "annoy" and "bother."	● Three terms evoke a general negative reaction that is less sensitive to translation problems	●Other terms would probably have little effect on responses.
7	11-pt numeric scale, 5-pt verbal.	● 0-10 numbering is familiar ● Reduces end-point effects	● Five points give more accuracy than four points[8]
8	Bottom point is "not at all."	●The term has a definite meaning (zero annoyance).	●This is the lowest from adjective studies. [6, 9]

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[1]An example is a 2-point annoyance filter question ("annoyed" or "not annoyed") with only the "annoyed" asked the following 4-point question ("a little", "moderately", "very", "extremely"). The entire upper 50% of the second scale ("very", "extremely") is conventionally counted for high annoyance.

[2]In a laboratory rating experiment with repeated ratings on a printed 5-point scale an annoyance filter question reduced annoyance reports by the equivalent of 5 decibels at the lowest noise levels. [5] Larger effects might be expected in a field survey, especially for telephone interviews, as the respondent is unaware that the annoyance question is a filter question and does not see the full 5-point scale.

Elements 3 and 4 recommend that these general questions *not* solicit reactions for a particular location (e.g. outdoors in the back garden near the house) or time (between 09:00 and 17:00 on weekdays). Instead, the vague place and time references require respondents to integrate their experiences to provide a total, long-term assessment, the assessment that is most relevant for policy and comparisons of the total impact of noise on living conditions.

The recommendation for the 11(0-10) numeric categories (element 7 in Table 1), is based on the assumption that experiences with decimal-based currency and other base-10 systems make respondents more cognitively familiar with 0 to 10 scaling than with shorter 7 or 9-point numeric scales. The recommendation for a five-point, rather than a four-point, verbal scale is based on the slightly greater resolution provided by a five-point scale, an ambiguity in defining the end points of scales, some information from the annoyance modifier study (described in the next section) and the finding in that study that the most widely-used four-point scale in English is not evenly spread across an intensity dimension.[3]

The ambiguity concerning endpoints is whether the highest word on a verbal scale represents the most extreme end of a scale (100%) where almost no one might agree or whether it represents a midpoint of the highest category (i.e. at 90%, the midpoint of the top fifth of a scale). Respondents who interpret the end point AS 100% annoyance and do not have such extreme views can only use two points on a four-point scale to express degrees of annoyance. On a five-point scale three points are available.

3. A STUDY TO SELECT WORDS FOR SCALE POINTS

Given agreement on the above principles, including the acceptance of the phrase "Not at all annoyed" for the bottom of the scales, the remaining task is to choose the words for the high end of the numeric scale and for the four remaining points on the five-point verbal scale. The team decided that the best approach was not to negotiate an English version and then translate it into other languages, but instead to conduct identical annoyance-modifier studies in each country and then to adopt a uniform set of criteria that could be applied in each country to select the verbal scale modifiers.

These non-survey tests have been completed by 738 subjects at 22 sites in 10 countries in 8 languages (English, French, German, Hungarian, Japanese, Norwegian, Spanish, Turkish). This work is described in more detail in another paper at this conference[4]. The researchers in each language first choose 21 words from their language. The subjects performed four tasks to evaluate these 21 words: (1) placing each word in one of nine categories of intensity; (2) placing each word on a line by marking its position between "No/lowest degree of annoyance" and "Highest degree of annoyance;" and (3) after choosing a word for the "greatest amount of bother or annoyance you might feel", then expressing a preference for the remaining two points

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[3]When 230 subjects at five sites in three English-speaking countries placed 21 annoyance modifiers on a scale, the average locations (measured as a percent of the line scale) for the four words on the most popular four-point English scale were skewed toward the bottom on a 0 to 100% scale at: 1% for Not at all, 13% for "A little", 44% for "Moderately" and 76% for "Very".

on a four-point scale and (4) three points on a five-point scale.

The team adopted three principles to guide this selection: (1) equidistant intensity: the words should be roughly equidistant from one another on the intensity scales in the line-marking and category-placement questions; (2) preference: words should be preferred by being frequently chosen for the five-point scale; (3) agreement: there should be high agreement (low variance) on both intensity and preference among respondents as well as among different study sites for the same language.

When the study data for all languages were evaluated using the three principles neither the four-point nor the five-point verbal scale was clearly superior. Although the five-point verbal scale (Element 8, Table 1) was slightly, but not significantly, better on most criteria it was chosen for the other reasons that were enumerated earlier.

The three selection principles have not yet been turned into objective rules to uniformly select words for each language. Such rules must overcome the following difficulties: resolving ambiguities in the definition of the principle; choosing words when no single word is clearly superior on all criteria; evaluating words that may be different for different populations; and evaluating the effects of the test methodology.

Each of the three selection principles contains unresolved issues. For the preference principle a primary issue is whether a word should be scored on the total number of choices for a word or whether the score should be decreased if subjects do not agree upon the particular scale point a word should represent. For the equidistance principle, the most serious issue is whether the ideal equidistant criteria should be at 0%, 25%, 50%, 75%, 100% of the underlying intensity scale and thus have words at the two ends of the scale that include a narrower range of intensity than do the three middle points, or the criteria should be at 10%, 30%, 50%, 70%, 90% of the underlying intensity scale with the result that each word represents equal segments of 20% of the intensity scale. For the high agreement principle, a satisfactory method for evaluating site differences has not been accepted and the exact method for dealing with the high correlation between scale values and the variance of those values has not been tested. The pearson correlation for scores below 50% is $r=0.69$ and over is $r=-0.71$.

Choices of words are difficult when subjects do not all agree on the same words. For example the percent of the subjects who agree on all five words for the five-point scale is never greater than 13 percent for any single language. In addition some words may be used differently by some subgroups. Some of the most popular words in three of the languages (German, Japanese, and Turkish) might be used differently by the younger age groups who participated in many of these tests. A test is evaluating this possibility in Japan.

The procedures that were used for our study should also be considered. Because respondents were presented with a low item "not at all annoyed" and were then asked to choose a word for the "greatest amount of bother or annoyance you could feel" the word that is preferred for the top point may, as previously noted, not in fact encompass as much of the annoyance scale as do other words. Additionally two Norwegian tests selected different words when respondents followed one protocol that almost matched the standard protocol and another protocol that simply asked people to recommend five words for the scale. The second protocol generated words that are in greater popular usage but did not seem to be as evenly spread across the underlying intensity scale.

The choice of the specific words for the five-point English language scale illustrates the range of experiences in selecting words. "Extremely" was readily chosen because it rated highest on all criterion. "Slightly", "moderately", and "very" were each the highest, by at least a tiny margin, on either the preference ranking or line-marking equidistance criterion but not on both. The three remaining words were chosen after eliminating words that failed two minimum acceptability criteria: preferred by at least 20 percent and within 10 percentage points of the 0-25-50-75-100 percent equi-distance criterion. These three selected words were considerably more highly scored than any alternative word on either the preference or equidistance criterion, but relatively similarly scored on the other criterion. These words' standard deviations are equal or no more than three percentage points higher than alternative words (agreement principle), and give an overall scale that deviates the least from the equidistance criterion.

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ANNOYANCE DUE TO RAILWAY AND ROAD TRAFFIC NOISE: FIRST RESULTS OF AN INTERDISCIPLINARY STUDY

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1. INTRODUCTION

Several field studies have shown that for equal noise levels (Lm), railway noise is less annoying and disturbing than road noise (the so-called 'railway bonus'; see e.g. the summarizing articles [1, 2]). A study conducted in Germany about 20 years ago [3] showed that the amount of this difference in annoyance depends on: a) the annoyance / disturbance response considered; b) time of day (daytime / night); c) the noise level (among other factors). Although the amount of the difference depends on the factors mentioned, a *general* 'bonus' of 5 dB(A) has been set by the German noise regulations, i.e., it is assumed that railway traffic noise must be 5 dB(A) louder than road traffic noise to reach the same amount of annoyance. There has been some debate on the justification for this bonus regulation. Thus, it was decided to conduct a new study on the annoyance difference between road and railway traffic noise. This study has not yet been completed. Thus, only preliminary results may be described here.

2. METHOD

Acoustical measurements have been taken in 8 areas with either predominant railway or road traffic noise. Both sources were present in each of the areas. Residents in these areas were interviewed with regard to their annoyance and disturbance by each of the two sources. 1600 interviews were done altogether in the 8 areas.

The data allow one to test whether there is a difference in annoyance between the two sources. The analyses are based on the 'general linear model' (GLM). A one-factorial design is used: with 'source' (railway / road) as the independent variabale and the noise level (A-weighted sound level Lm, expressed in decibels) as a covariate. (The noise levels are estimated for each source and for each individual subject by taking into account the distance between the home of the subject and the source and the number of trains or cars passing.) Separate analyses were done for each time of day: a) daytime, b) at night, and c) for 24h (day *and* night). The dependent variables considered in the analyses are: (a) for *daytime:* 'DD1: disturbance of conversation - indoor', 'DD2:

disturbance of listening to radio/music and TV', 'DD4: disturbance of relaxation - indoor', 'DD6: disturbance of conversation - outdoor', 'DD7: disturbance of relaxation - outdoor', and 'DDT: total disturbance - daytime'; (b) for the *night:* 'DN8: preventing from falling asleep', 'DN9: wakening up at night', 'DN10: wakening up in the morning', and 'DNT: 'total disturbance - at night'; and (c) for the *whole day (24h)*: 'GA: general annoyance' and 'TD: total annoyanace / disturbance at home'. - All variables but one are measured on a 5-point verbal scale (1: not / 5: very annoyed / disturbed). Only the 'total disturbance - at home' (TD) is measured on 11-point graphical scale (from '0: not at all annoyed' to '10: extremely annoyed'). Results for further annoyance variables are not presented here because of lack of space. - The design allows univariate as well as multivariate tests for the main effect.

3. RESULTS

The results are described separately for the annoyance / disturbances a) during the day (6am – 10pm), b) at night (10pm - 6am), and c) for annoyance responses not specifying the time of day.

a) Annoyance / disturbances during the day: The multivariate test shows that the factor 'Source' is significant (source: F=49.4; p<=.0001; the F- and p-value for the multivariate test refer to the 'partial sums of squares' and the F-approximation for Wilk's lambda).

The univariate analyses with regard to the factor 'Source' show that the annoyance differences between the sources (road / railway noise) vary depending on the annoyance / disturbance aspect considered: there is a significant greater disturbance for railway than for road traffic noise for 2 variables referring to communication indoor (see Table 1): DD1: conversation - indoor (F=50.6; p<=.0001); DD2: listening to music / radio / TV (F=78.0; p<=.0001). In contrast to that, a significantly greater disturbance due to road than to railway traffic is found for another 2 variables: DDT: total disturbance - during the day (F=25.1; p=.0001) and DD7: relaxation - outdoor (F=11.4; p=.0008). For the remaining 2 variables (DD4, DD6) the 'source effect' is not significant (F<1.0).

A higher intensity of disturbance due to road traffic noise is found for some further variables not described here in detail; for example, there is a stronger tendency to close the windows during the day for road than for railway noise.

Table 1. Response means and standard deviations (std) for each source (road / railway noise): daytime

Source	N	DD1: conversation - indoor		DD2: listening to music, radio, TV		DD4: relaxation - indoor		DD6: conversation - outdoor		DD7: relaxation - outdoor		DDT: total disturbance - daytime	
		Mean	std	Mean	std	Mean	std	Mean	std	Mean	std	Mean	std
RAIL	703	2.27	1.46	2.33	1.48	2.01	1.29	2.67	1.54	2.42	1.46	2.17	1.19
ROAD	880	2.12	1.30	2.05	1.30	2.29	1.37	2.99	1.50	3.01	1.55	2.76	1.26
Means adjusted for the covariate (Lm, day)													
RAIL		2.45		2.50		2.16		2.88		2.61		2.33	
ROAD		1.98		1.91		2.17		2.82		2.86		2.63	

b) Annoyance / disturbances at night: The multivariate test shows again that the factor 'Source' is significant (F=50.0, p<=.0001). The univariate analyses with regard to the factor 'Source' show that the annoyance due to road traffic noise is significantly higher than the annoyance attributed to railway noise. This is true for all variables considered (see Table 2): DN8: preventing from falling asleep (F=84.4; p<.0001); DN9: wakening up at night (F=61.6; p<.0001); DN10: wakening up in the morning (F=185.2; P<.0001); and: DNT: total disturbance at night (F=43.0; p<.0001). Considering these results, one has to take into account that the variables DN8 - DN10 refer to *subjective* sleep disturbances, which are attributed by the *Ss* (when questioned) to the noise from each source. The analyses by which the (non-) correspondence between such subjective responses and objective indicators of sleep quality are investigated have not yet been completed. - As during the day, there is also a stronger tendency at night to close the windows for road than for railway noise.

Table 2. Response means and standard deviations (std) for each source (road / railway noise): at night

Source	N	DN8: preventing from falling asleep		DN9: wakening up at night		DN10: wakening up in the morning		DNT: total disturbance at night	
		Mean	Std.	Mean	Std.	Mean	Std.	Mean	Std.
RAIL	708	1.89	1.26	1.60	1.08	1.50	1.01	2.13	1.29
ROAD	886	2.18	1.39	1.81	1.20	2.10	1.40	2.24	1.19
Means adjusted for the covariate (Lm, night)									
RAIL		1.68		1.44		1.32		1.95	
ROAD		2.35		1.94		2.24		2.39	

c) Annoyance / disturbance responses for day and night (without specification of time of day): As in the analyses described above, the multivariate tests show that the factor 'Source' is significant (F=22.5; p<=.0001). The multivariate test and the corresponding univariate tests for the factor 'Source' indicate that the total general annoyance / disturbance is significantly higher for road than for railway noise; this is true for 'GA: general annoyance' (5-point scale; F=33.4; p<.0001) as well as for 'TD: total annoyance/disturbance' (11-point scale; F=44.3; p<.0001). - Similar results are found for some further variables not described here in detail; for example, *Ss* report that they are startled, made nervous or suffer from headaches to a higher degree because of road than because of railway noise.

Table 3. Response means and standard deviations (std) for each source (road / railway noise): annoyance reactions without specification of time of day.

Source	N	GA: general annoyance		TD: total annoyance / disturbance at home	
		Mean	std.	Mean	std.
RAIL	708	2.78	1.28	3.52	2.85
ROAD	886	3.20	1.28	4.61	2.98
Means adjusted for the covariate (Lm, 24h)					
Rail		2.82		3.63	
Road		3.17		4.52	

4. DISCUSSION

The preliminary results of this not yet completed study confirm on the whole the results from previous field studies (e.g. [3, 4, 5, 6]; for some conflicting results see [7]) and laboratory studies (e.g.: [8]). For example, Moehler et al [3] also reported greater annoyance due to railway noise (railway disadvantage) for variables referring to communication and greater annoyance due to road traffic noise (railway 'bonus') for variables like 'general annoyance' and 'sleep disturbances'.

The analyses referring to the subjective 'sleep disturbances' should be complemented by analyses of the relationship between such subjective responses and objective indicators of sleep quality (as 'motility during the night'); but these analyses have not yet been completed.

Finally, in assessing the results one has to take into account that only those residents were interviewed who live along a railway line where the number of trains passing is less than 260 in 24h, where the speed of passing trains ist restricted to an upper limit of 200 km/h, and where the proportion of freight traffic does not exceed 67% (of the total number of trains passing in 24h). Thus, two further studies (conducted at present) deal with the annoyance caused by high speed trains (the German ICE) or by freight traffic (Zeichart et al, in prep.).

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REVISED DNL-ANNOYANCE CURVES FOR TRANSPORTATION NOISE

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1. INTRODUCTION

A very influential attempt to integrate results from individual exposure-annoyance studies was Schultz's synthesis (Schultz, 1978). His paper was followed by an intense discussion between Schultz and Kryter (Schultz, 1982; Kryter, 1982, 1983). In his 1978 article Schultz discussed 24 noise annoyance surveys carried out in several countries. These investigations concerned aircraft, road traffic, and railway noise. In an attempt to make the investigations comparable Schultz used the available data to estimate a common noise measure and a common annoyance measure, namely, DNL and the percentage of respondents who could be considered to be highly annoyed.
For each of the investigations he drew a curve showing the percentage highly annoyed persons as a function of DNL (Schultz, 1978: figures 1 and 2). On the basis of 11 individual "clustering" surveys he synthesized a single curve as the 'best currently available estimate of public annoyance due to transportation noise of all kinds'. Eight "nonclustering" surveys were not included in the synthesis. Five surveys were obtained after the analyses and discussed in an addendum. They were not included in the synthesis.
Fidell, Barber, and Schultz (1991) extended the original compilation of Schultz and arrived at substantially the same curve. Their curve was based on 26 datasets: the 11 datasets Schultz (1978) used as a basis for his synthesis curve, 4 of the 5 datasets which he discussed in his addendum, and 11 additional datasets.
Fields (1994) reviewed the above mentioned original and updated synthesis. Although his review was not conducted with the objective of identifying errors in the data, "a few major errors and a large number of minor inaccuracies have been identified" (cf his section 2.5). This paper presents a synthesis based on all studies examined by Schultz (1978) and Fidell, Barber, and Schultz (1991) for which DNL and percentage highly annoyed meeting certain minimal requirements could be derived, augmented with a number of additional studies. Consequently, the present synthesis is more comprehensive. Moreover, the kind of errors and inaccuracies Fields (1994) found in the previous syntheses are avoided.

Results from previous analyses on a part of the data have been reported at the ICBEN conference in Nice by Miedema (1993), and a more extensive report on the results presented here can be found in Miedema and Vos (1998).

2. DATA

Existing datasets are reanalysed to establish functions which summarize the relationship between annoyance experienced in and around the house and the incident noise at the most exposed facade in steady state situations.We use the term dataset for the data with respect to a single noise source (aircraft, road traffic, or railway) from a single survey. In datasets derived from the same survey the exposure and effect variables related to the noise source have different values in each dataset while other variables, e.g. characterizing the respondent

or his dwelling, have identical values in each dataset. Note that more datasets are only derived from a single survey when more than one noise source is evaluated.
The 55 datasets in the present synthesis encompass information for a total of 63,969 respondents (counting respondents twice if they appear in two datasets). They are derived from 45 surveys with a total of 58,065 respondents. Only respondents for whom DNL and an annoyance response are available are counted.

3. DNL AND PERCENTAGE HIGHLY ANNOYED (% HA)

Following Schultz (1978) and Fidell, Barber, and Schultz (1991), we use DNL as a noise exposure measure and percentage highly annoyed (%HA) as a noise annoyance measure. DNL is a measure with a night-time penalty of 10 dB calculated from L_{Aeq} for the daytime and L_{Aeq} for the night-time:

$$DNL = 10 \lg \left(15.10^{L_{Aeq}(7\text{-}22h)/10} + 9.10^{[L_{Aeq}(22\text{-}7h)+10]/10} \right) / 24.$$

The L_{Aeq}'s are measured, or calculated with noise transportation models. As much as possible we derived the L_{Aeq}'s for the incident sound at the most exposed facade of a dwelling for the one year period preceding a social survey. However, it is not a common practice to report information on these aspects of the determination of L_{Aeq}, so that often they were unknown.
%HA is the percentage of annoyance responses which exceed a certain cut-off point. To assess the percentage above a cut-off point, the response alternatives have to be quantified. This quantification is simplest when the following two assumptions can be made:

- Equal intervals: each category from a set of response alternatives occupies an equal portion of the annoyance continuum;
- Equal extremes: the extreme (lower and upper) category boundaries from different sets of annoyance response alternatives coincide.

Quantification of boundaries of annoyance categories based on the above assumptions depend only on the number of effective categories:

$$score_{boundary\ i} = 100\, i / m,$$

where m is the number of effective categories and i = 0,1,..,m is the rank of the boundary, starting with the lower boundary of the lowest annoyance category.
To arrive at a percentage responses above a cut-off point x, a score is assigned to each respondent in the following way. Let L and U be the quantifications of the lower and the upper boundary of the category selected by a respondent. Then the score assigned to the respondent for the calculation of the percentage is 0 if the respondent chose a category that is below the cut-off point x (i.e., $U < x$) and is 1 if the respondent chose a category that is above the cut off point x (i.e., $x \leq L$). If the category chosen by the respondent encompasses the cut-off point (i.e., $L < x \leq U$), then it is not known whether this is a response below or above the cut-off point. The score assigned to these respondents is the probability that the annoyance score for the respondent actually is above the cut-off point, assuming that the annoyance score is uniformly distributed within a category.
Schultz (1978) used a cut-off at 72 in his influential synthesis, and he called the percentage obtained with this cut-off point the percentage 'highly annoyed'. The interpretation of a percentage does not depend on this label, but on the value chosen as the cut-off point, i.e.

72. We also use the label 'highly annoyed', if the cut-off is (sufficiently close) to 72. An advantage of using a cut-off at 72 over lower cut-off values is that percentages obtained with the cut-off at 72 are less affected by differences between studies in the usage of a filter question (see section 5).

4. EXPOSURE-RESPONSE RELATIONSHIPS

To determine synthesis curves DNL is divided per mode of transportation into intervals of 5 dB. Then for each mode of transportation a quadratic ordinary least squares regression was carried out, weighting each point according to the number of observation on which it is based. Extreme exposure levels (< 45 and > 75 dB) were excluded from this analysis. It turned out that the three curves reached %HA = 0 at circa DNL = 42 dB. Therefore a new analysis was conducted in which the curves were forced through zero at 42 dB. Above 50 dB the (absolute) %HA difference between the curves forced through zero at 42 dB and the curves with a free intercept is smaller than 0.8 for aircraft, 1.5 for road traffic, and 0.3 for railway noise. The equations of the curves with zero annoyance at 42dB(A) are:.

Aircraft: $\%HA = 0.53\,(DNL - 42) + 0.0285\,(DNL - 42)^2$
Road traffic: $\%HA = 0.03\,(DNL - 42) + 0.0353\,(DNL - 42)^2$
Rail: $\%HA = 0.01\,(DNL - 42) + 0.0193\,(DNL - 42)^2$

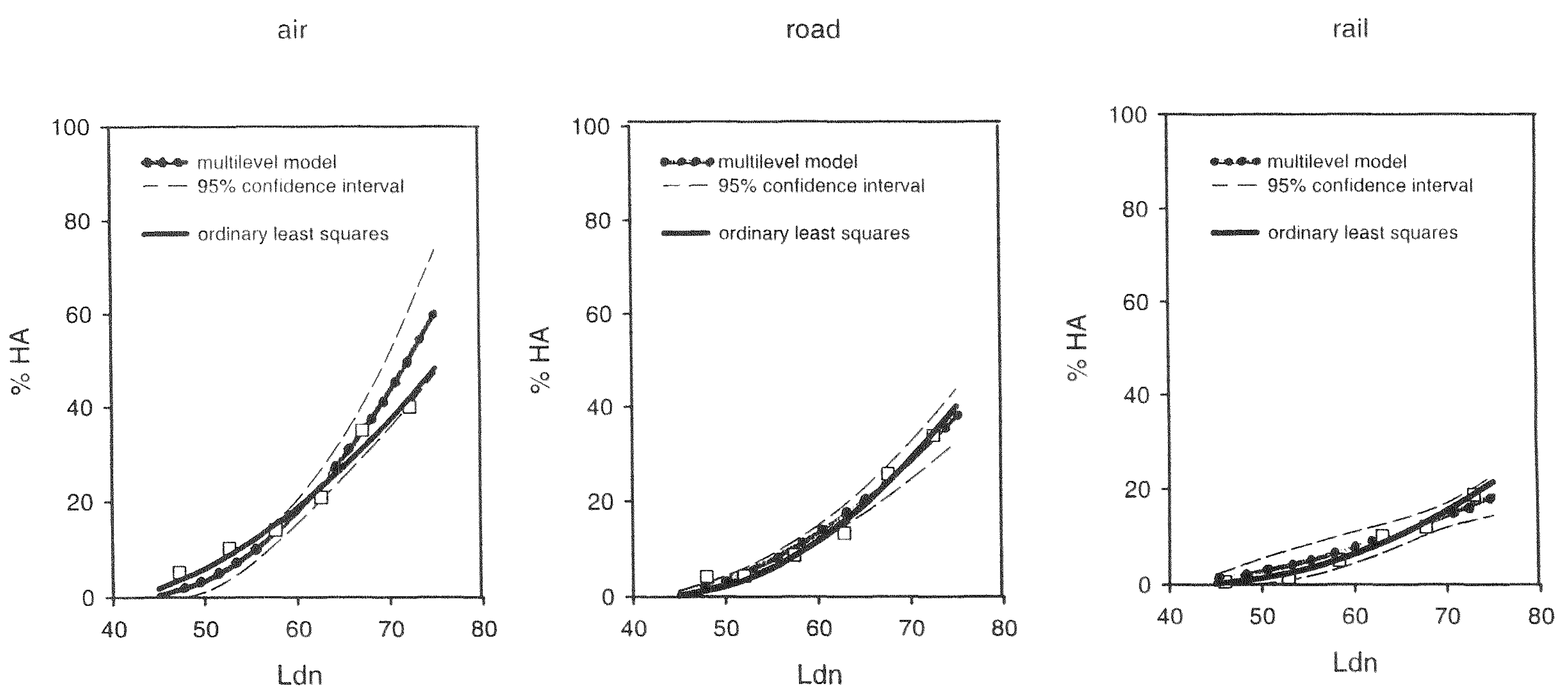
Figure 1 shows the curves for the three modes of transportation fitted with the ordinary least squares regression procedure together with the data points. At a given exposure level aircraft noise causes the highest %HA, followed by road traffic and rail traffic, respectively. Standard procedures for estimating confidence intervals around regression curves are based on the assumption that the cases have been drawn at random from a population. Actually, however, the cases in these analyses are not drawn at random, but can be thought of as having been drawn in clusters defined by the studies. If this study level in the sample is ignored and simple random sampling is assumed, then the width of the true confidence intervals is underestimated.

Therefore, curves were also fitted by a multilevel procedure which takes into account that the cases are selected in two stages: first the studies and then the cases within each study. In the multilevel model (Goldstein, 1995) studies are assumed to have a normally distributed effect on the parameters of the (quadratic) curves fitted. The parameters of the curves, and the mean and standard deviation of the distributions of these parameters were estimated using the software package MLn (Rasbash and Woodhouse, 1995). The curves and the confidence intervals found by this procedure are also shown in figure 1. The equations of the curves are:

Aircraft: $\%HA = -0.02\,(DNL - 42) + 0.0561\,(DNL - 42)^2$
Road traffic: $\%HA = 0.24\,(DNL - 42) + 0.0277\,(DNL - 42)^2$
Rail: $\%HA = 0.28\,(DNL - 42) + 0.0085\,(DNL - 42)^2$

The curves fitted with the two different procedures are similar except for aircraft noise at high exposure levels. The curve for aircraft obtained with the multilevel procedure predicts

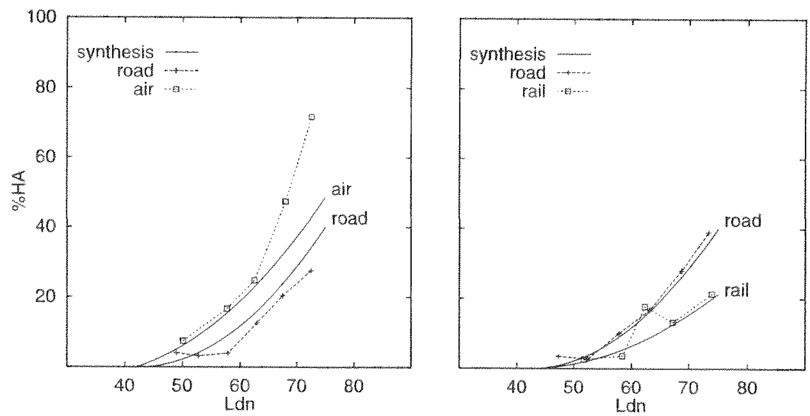
Figure 1. Percentage highly annoyed persons (%HA) as a function of DNL. Two synthesis curves per mode of transportation, and the datapoints are shown. For the curves obtained with multilevel analysis the 95% confidence intervals are shown



at high exposure levels more annoyance than the other curve. The curve obtained with the multilevel approach may be preferred because this approach takes the structure of the data better into account. An important observation is that the confidence intervals are mutually exclusive at higher levels. This is a strong indication that the curves for the three modes of transportation are different.

In order to determine whether the variation between modes of transportation can be attributed to methodological or other differences, studies in which the same respondents evaluated more than one noise source were examined (5 aircraft and road traffic studies, and 3 railway and road traffic studies). Differences between modes of transportation found with these respondents cannot be attributed to study characteristics. Figure 2 shows the results.Overall the road traffic curve in figure 2 lies below the aircraft curve and above the railway curve, indicating a systematic and substantial difference between these sources. Each data point contains at least 100 responses. Aircraft noise and railway noise could not be compared directly, because no studies treating both sources were available. Figure 2 supports the interpretation that the differences between modes of transportation found when analysing all datasets are indeed related to the mode of transportation and not caused by differences between studies.

Figure 2 Comparison of curves giving percentage highly annoyed persons (%HA) as a function of DNL. They are based on the responses of persons who evaluated both aircraft and road traffic noise (left), or both road traffic and railway noise (right).



5. CONCLUSION

The percentage highly annoyed persons (%HA) is zero below 40 - 45 dB, and increases at higher levels monotonically as a function of DNL. Different functions were found for aircraft, road traffic, and railway noise. The rate of increase is higher for aircraft noise than for road traffic noise, which in turn has a higher rate of increase than railway noise. The 95 % confidence intervals around the different functions are mutually exclusive at higher exposure levels. Moreover, differences between sources were found using data for all studies combined and for only those studies in which respondents evaluated two sources. These outcomes justify the conclusion that the differences between sources cannot be explained by random factors or differences in study methodology. Thus, above 40 - 45 dB the %HA at a given DNL depends on the mode of transportation that causes the noise.

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STRATEGIES FOR MITIGATING AIRCRAFT NOISE IMPACTS ON OUTDOOR RECREATIONISTS

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1. BACKGROUND

In the past several years, there has been growing public concern regarding aircraft flights over national parks and designated wilderness areas. Responding to these growing concerns, the United States Congress enacted Public Law 100-91 in 1987 [1]. This law mandated an assessment of the impacts of aircraft overflights of national parks and designated wilderness lands and an evaluation of recommendations for remediation in areas where overflights are determined to be a problem. In response to this mandate, both the Park Service and the Forest Service sponsored research to measure aircraft noise levels in national parks and designated wilderness areas and assess attitudinal responses of outdoor recreationists to aircraft overflights [1, 2]. Based on this research, dose-response relationships between aircraft noise levels and attitudinal responses were developed. However, these results were derived from data collected in areas where the overflights were almost exclusively from fixed-wing and helicopter air tour operations. Consequently, the United States Air Force recently sponsored a collaborative research project with the National Park Service to assess attitudinal responses to military aircraft overflights and also to evaluate the effectiveness of three mitigation strategies proposed to minimize negative reactions to aircraft overflights among outdoor recreationists [3]. The findings of these research projects will be used to establish guidelines and procedures for minimizing aircraft noise impacts in national parks and designated wilderness areas.

2. RESEARCH FINDINGS

Noise measurements and attitudinal surveys of recreational visitors collected for the United States Forest Service examined responses to overflights experienced at several wilderness areas [4]. Both on-site and telephone interviews were used to gauge attitudes towards aircraft overflights in wilderness areas. Findings indicated that annoyance due to aircraft noise was generally quite low (see Table 1). The majority of respondents were not at all annoyed by aircraft noise. The percent of respondents moderately to extremely annoyed by aircraft ranged between 3 and 20.5 across sites with and average of 9.4 percent (see Figure 1). The percent of respondents highly annoyed, defined as the percent of respondents that indicated they were very or extremely annoyed, was greater than what is typically observed in residential areas under similar noise conditions. The theoretical tolerance level for aircraft noise, referred to as D*, was estimated to be between 62.1 dB and 65.6 dB among respondents participating in the wilderness surveys [2,4]. In comparison, the mean value of D* derived from several aircraft noise surveys in residential settings was 73 dB. This finding suggests that individuals may have a lower tolerance (approximately 7-10 dB) for aircraft noise in outdoor wilderness settings [2,4]. However, aircraft noise was not significantly correlated with visitors' overall enjoyment or satisfaction with their wilderness experience. Nonetheless, respondents who were annoyed by aircraft noise reported less satisfaction with the absence of sounds of civilization that they expected from their wilderness experience. Low-altitude, high-speed aircraft were identified as causing the highest degree of annoyance. While low-altitude, high-speed overflights were quite rare, individuals exposed to these events were frequently annoyed. While some respondents were annoyed by overflights, this generally did not affect any intentions to return to the wilderness site.

Table 1. Distribution of annoyance responses (based on data from Refs 2 & 4).

	Degree of Annoyance				
Percent of Respondents:	Not at All	Slightly	Moderately	Very	Extremely
	84.2	6.4	5.5	1.8	2.1

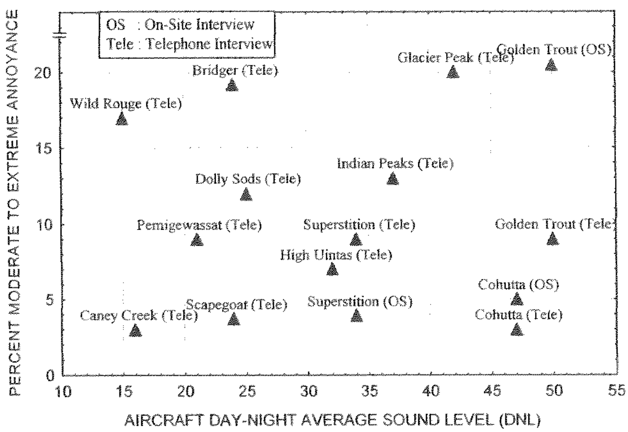

Figure 1. Percent of visitors moderately to extremely annoyed as a function of day-night average sound level (DNL) at twelve wilderness areas (Based on data presented in Refs. 2 & 4)

In research sponsored by the National Park Service, noise measurements and visitor surveys were collected at sites within three parks considered to have large numbers of daily air tour flight operations: Grand Canyon, Haleakala and Hawaii

Volcanoes National Parks [1,5]. Detailed visitor surveys were administered on-site and noise measurements were taken during respondents' visits in order to estimate each respondent's exposure to aircraft noise. Data collected at these sites were used to derive dose-response relationships between aircraft noise levels on the one hand and annoyance and perceived interference with natural quiet on the other. (see Figures 2 and 3). These results indicated that respondents were more likely to perceive that aircraft noise interfered with their enjoyment of natural quiet than perceive those aircraft noise intrusions to be annoying. Furthermore, first time visitors and individuals who considered natural quiet to be of great importance were significantly more sensitive to aircraft noise. These findings indicate that respondents' prior experience and expectations are important mediators in determining their reactions to overflights. The characteristics of the site also had a significant impact on visitor's reactions to aircraft. In particular, visitors to short-hike sites were generally more annoyed by aircraft than visitors to overlook sites. This suggests that the types of activities engaged in at a particular site as well as visitors expectations about a site can significantly affect visitors' tolerance for aircraft noise at a given location.

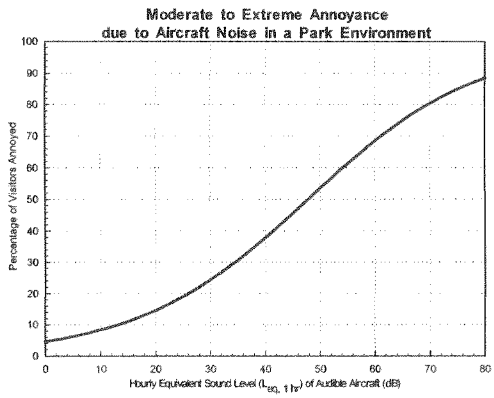

Figure 2. Visitor annoyance as a function of aircraft sound level (from Ref 1).

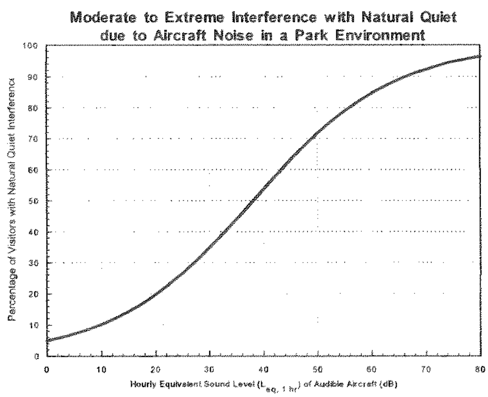

Figure 3. Dose-response relationship of interference with natural quiet as a function of aircraft sound level (from Ref. 1).

The data collections sponsored by the National Park Service were obtained at sites primarily impacted by propeller driven fixed wing and helicopter tour aircraft. Consequently, generalization of these results to other flight activities and aircraft such as jet propelled scheduled air carriers and military flight operations may not be appropriate. In order to obtain more generalizable conclusions and investigate the reactions of outdoor recreationists to military overflights, the United States Air Force recently sponsored a collaborative research project between the Department of Defense and the National Park Service. Noise exposure levels were collected and a questionnaire was administered to hikers at White Sands National Monument in New Mexico. Due to its proximity to Holloman Air Force Base, the survey site is frequently overflown by military fighter jets. Results indicated that the degree of annoyance and interference with natural quiet reported by hikers was less than levels previously observed in the National Park Service studies (see Figures 4 and 5). Results also indicated that annoyance decreased as the slant distance between hikers and overflying aircraft increased. However, this effect was sufficiently accounted for by decreases in noise level with increasing slant distance. Furthermore, annoyance was lower when overflights occurred in close succession as compared to occasions when overflights were dispersed throughout a respondent's hike. That is, hikers were less annoyed when overflights were grouped together and consequently a smaller proportion of their visit was interrupted by aircraft noise intrusions. Finally, respondents who remembered receiving information regarding overflights were significantly less annoyed than respondents that did not remember receiving such information (see Figure 6). Such information can be provided in the form of informational signs or pamphlets or may be contained in a display or multimedia presentation at the park's visitor center. In this study, information was provided on a wooden sign erected at the trail entrance that read: "Military aircraft can regularly be seen or heard on this trail". This sign was visible during approximately one half of the respondents' visits. These findings support the three mitigation strategies proposed to alleviate aircraft noise problems in parks and wilderness areas. These mitgation measures include: 1) the use of airspace planning to increase the distance between aircraft and noise sensitive areas, 2) the use of flight scheduling to group overflights and minimize the amount of time that aircraft are audible, and 3) the use of informational tools to inform visitors about potential aircraft overflights.

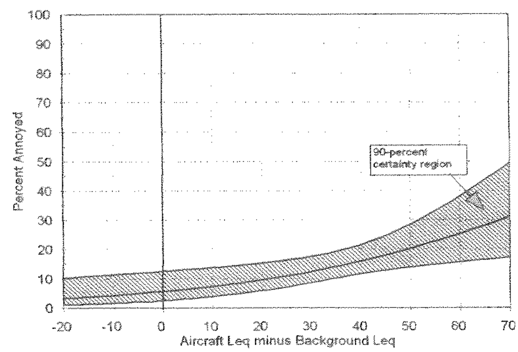

Figure 4. Annoyance as a function of aircraft sound level (From Ref. 3).

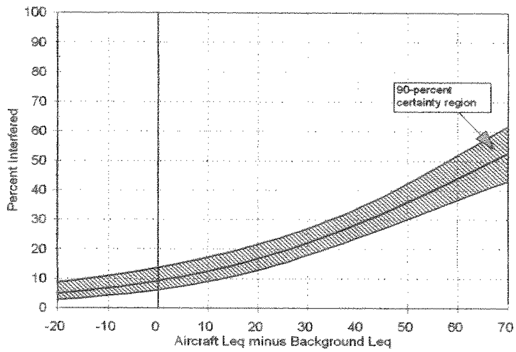

Figure 5. Dose-response relationship of interference with natural quiet as a function of aircraft sound level (from Ref. 3).

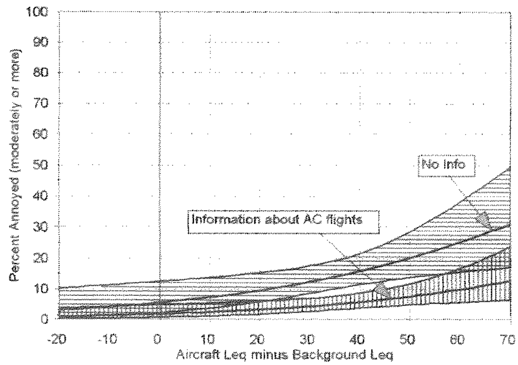

Figure 6. The effect of information on annoyance (from Ref. 3).

3. STRATEGIES FOR NOISE MITIGATION

Three core strategies have been evaluated and appear to be effective solutions based on the data collected at White Sands National Monument. First, potential impacts of aircraft noise on outdoor recreationists may be reduced by rerouting flight paths and restructuring airspace over parks and wilderness areas to avoid overflights of locations frequented by outdoor recreationists or other specific noise-sensitive locations. When deemed practical, airspace can be restructured to reduce or eliminate aircraft noise at noise sensitive locations within a park or wilderness area. This mitigation strategy is being recommended as an alternative to altitude restrictions, flight-free zones and flight bans over vast expanses of park and wilderness lands. This alternative appears viable based on results indicating that distant aircraft are less annoying than aircraft flying at close slant distances due to decreases in noise levels with increasing distances. Second, flight operations that occur over noise sensitive park areas can be scheduled to avoid overflights during times when visitors are most likely to be present or other noise sensitive times at a specific site. Furthermore, overflights can be grouped to minimize the amount of time that aircraft are audible. When feasible, flight schedules can be tailored to eliminate or reduce aircraft noise during specific noise sensitive times at a given park or wilderness area. This measure appears viable based on the finding that aircraft overflights that occur in close succession are perceived as less annoying than overflights that are dispersed throughout one's visit. Finally, by providing outdoor recreationists with a forewarning of potential overflights it is anticipated that some negative reactions to these overflights will be reduced. Outdoor recreationists seeking to experience natural quiet should be provided with information regarding specific locations and times within the park or wilderness area that overflights do not typically occur. Such information can complement other mitigation measures by making visitors aware of the steps that have been taken to reduce the impact of aircraft overflights and also by providing recreationists with the knowledge needed to enjoy the quiet locations and quiet times created by these mitigation measures. A comprehensive approach to noise mitigation is needed to ensure that aircraft noise impacts on outdoor recreationists are minimal. The success of these mitigation efforts is dependent on continued cooperation between park and wilderness managers and the agencies and groups that utilize the airspace over parks and wilderness areas.

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A ROLE OF AUDITORY INFORMATION ON ROUTE COGNITIVE PROCESS OF THE VISUALLY HANDICAPPED

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1. INTRODUCTION

The sound environment is composed of various sounds intermingling with each other in our daily life. The sound environment can't be identified only by analyzing sound volumes and qualities, because it is managed in different ways according to the mental and physical condition of each person. The visually handicapped walk around in town, considerably depending on auditory information instead of visual information. Therefore, they are supposed to manage the sound environment in greatly different ways from the non-handicapped. When the sound environment is designed for the visually handicapped, it is supposed to be necessary to take into consideration their characteristics of spatial cognition using auditory information. This study is to design a better sound environment for the visually handicapped, not only for the non-handicapped.

2. METHOD

The walking experiment, the visually handicapped walked to unknown places and reported self-observation, was conducted to investigate their route cognitive process and the role of auditory information. The experiment was on four routes of different types in town. Table 1 shows the outline of the routes. The subjects were two early (born) blind persons and two late blind persons. Table 2 shows the attributes of the subjects.

Subjects walked alone, 5 times per each route, after guidance. One of the experimenters walked beside the subject for the purpose of keeping away from danger. When the subject went off the course, the subject was took back to the correct routes, only in case that a return to the course was judged to be desperate.

While they were walking, the self-observation reports about their feelings were recorded. The direction of the starting point and the ending point were reported at the prescribed points on each course. The experimenters recorded surrounding environment and subjects on videotape, and recorded sound environment with a sound-level meter (RION NL-11) and a DAT recorder (SONY TCD-8). After each walk, remembrance about the route was tape-recorded, and at the same time, their mental maps were drawn on raise writers.

Table 1. The outline of the routes

two-level crossing course :	including two-level crossing. lots of corners. traffic sounds, human voice, railroad sounds, railroad-crossing signals and so on.
residential area course :	grid-arranged streets. sounds of super express, traffic sounds, voices of residents and so on.
green and hill course :	through the woods. lots of twittering of birds and insects, traffic sounds from a distance, occasional human voice.
shopping street course :	including a usual shopping street. traffic sounds, many kinds of sounds from shops, voices and footsteps of other pedestrians.

Table 2. The attributes of the subjects

	age	sex	handicap
A	40	f	late blind, partially sighted until 17 years old
B	25	m	early (born) blind
C	22	f	early (born) blind
D	50	f	late blind, lost her sight at 5 years and 8 months old

3. RESULTS AND DISCUSSION

Usage of the auditory information while walking

Considering from the self-observation reports and the observation of walking state, the auditory information was mainly used to avoid danger and as assistance of movements. This is in accord with the result of a past interview survey [1] by the authors.

As the use of the auditory information to avoid danger, all subjects used traffic sounds to avoid passing cars in all courses but green and hill course where cars were not there. Attentiveness to traffic sounds was raised especially when they crossed the streets.

Silent obstacles like parked cars or telegraph poles were generally recognized with canes. However, subject D sometimes recognized parked cars without using a cane at quiet places. She reported that she sometimes recognized large obstacles without using a cane. However, she recognized parked cars with her cane at the noisy places. It follows from these that she used echoes and sound shadows to find obstacles.

As the use of the auditory information as assistance of movements, traffic sounds from boulevard, railroad sounds, railroad-crossing signals, sounds from shops and so on were used to confirm their positions. All subjects used these sounds as landmarks, because these sounds were heard constantly or regularly, and noticeably. In residential area course and green and hill course, there were many reports that it was hard to confirm their positions for the lack of these sounds. Besides, traffic sounds were used to confirm the direction of progress walking along the stream of cars, and to grasp the street direction of progress, and to find crossings. In green and hill course, all subjects reported that it was hard to confirm the direction of progress due to the lack of traffic sounds. Subject D, using echoes and sound shadows positively, found crossings frequently without using a cane. Different from the other subjects, she did not follow the edges of the streets with a cane to find crossings, observing the presence of walls or buildings along streets.

Hierarchical level of the use of the auditory information

The same auditory information was used in different ways from case to case or from person to person. For example, traffic sounds are used in various ways, only to find out the existence of cars, to grasp the street direction of progress, to grasp the arrangement of streets and so on. From this viewpoint it seemed that the use of the auditory information had some hierarchical levels, and they were defined as shown below.

Level I : The use to grasp the points on the route with sound localization

Level II : The use to grasp the lines on the route with moving sound source

Level III : The use to grasp the parts or the whole of the route with two-dimensional images

Level IV : The use to conjecture the arrangement of streets in the wide area including the route

The use of the auditory information and the construction of mental map

The way of using the auditory information was greatly different from case to case or from subject to subject. The use of the auditory information in above-mentioned level I and II was found in all subjects. The use in level III and IV was also frequently found in subject A and D, however, rarely in subject B and C. The authors use the term "group 1" to refer to subject A and D and "group 2" to subject B and C. The difference of the use of the information observed between above two groups seems to have relation to the construction of mental image of the courses.

Group 1. Subject A and D are late blind and have visual representation. Both subjects reported that they remembered seeing maps, and they are familiar with two-dimensional maps. They also reported "First, I remember the form of whole route" or "I always walk around drawing the map in my mind". As seen in these reports, they tried to grasp routes or surroundings with two-dimensional images. Considering their sketch maps of the routes after walking, the whole forms of the routes were approximately drawn correctly, though there were a few mistake to some degree (Fig. 1). Occasionally, some streets where they didn't walk though were drawn on the sketch map with the use of the auditory information in level IV. And their answers to the question about the direction of the starting point and the ending point were approximately correct. Concerning the state of walking, they rarely swerved from the courses compared to subject B and C, and when they swerved the course, they could usually return to the course by themselves.

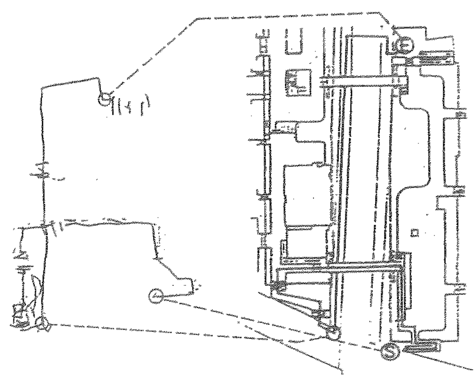

Fig. 1. Sketch map – A, two-level crossing course

Concerning the use of the auditory information, group 1 paid attention to the auditory information from a distance such as sounds from boulevard, railroad-crossing signals, sounds from shops and so on, and frequently confirmed the location of sources of these sounds. Moreover, they grasped and confirmed relative position of these sound sources.

As the result, they grasped geographic structure and surrounding areas of the routes, and even if the recollection of details was dim, they could reach the ending point, exploring and walking toward the direction of the ending point.

Group 2. Subject B and C tried to grasp the routes with linear images, in other words pseudo-one-dimensional mental maps, connecting the landmarks on the routes. They often reported "I try to remember the direction to turn one by one". The sketch maps after walking were drawn only based on the memories of the direction and the order to turn. As a result, when the recollection of turning point was uncertain, the sketch map after there was remarkably incorrect (Fig. 2). Concerning the state of walking, once they mistook the turning point or direction to turn, they noticeably swerved the course and hardly return to the course. And they could not answer to the question about the direction of the starting point and the ending point after they turned once or a few times.

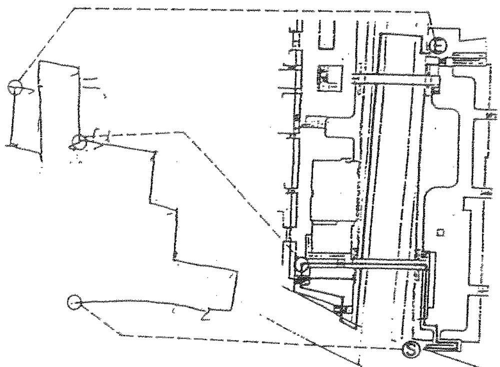
Fig. 2. Sketch map – B, two-level crossing course

Concerning the use of auditory information, group 2 frequently used traffic sounds to avoid cars, to walk parallel with stream of traffic and so on. From this, they positively use the auditory information in level I and II. However, as mentioned above, they didn't grasp routes or surroundings with two-dimensional images. Therefore, they paid little attention to the auditory information from the outside of the street they were on, and they sometimes reported "I don't remember what kind of sound were there" or "I've heard the traffic sound from a distance, but I didn't use it".

4. CONCLUSION

The ways of route cognition for the visually handicapped were divided into the following two types, the way to draw one-dimensional or pseudo-one-dimensional mental maps remembering the signs on the route in order, and the way to draw two-dimensional mental maps remembering the layout of the signs on the route. When walking with one-dimensional mental maps, the use of the auditory information were mainly for grasping the points and lines on the route, Level I and II. Two-dimensional mental maps rather help them walk correctly and applicably. The auditory information usable in Level III and IV is indispensable for formation of two-dimensional mental maps.

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PREDICTION OF COMMUNITY ANNOYANCE DUE TO A PROPOSED FREEWAY

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1. INTRODUCTION

Marshall Day Acoustics was commissioned to conduct the noise impact study for the Scoresby Transport Corridor Environmental Effects Statement. Four integrated transport options for the corridor were investigated.

In general, changes to heavy and light rail transport facilities were considered to have minimal noise impact. Changes to road transport facilities were considered to have greater potential for impact and were investigated in detail using a computer-based model to predict changes in community annoyance.

The Community Annoyance Model was based on recent research linking traffic volume changes on existing roads to changes in community annoyance, together with estimates of community annoyance near new roads based on previous experience. It was found that the total level of community annoyance increased as the extent of new roads increased, despite useful reductions in traffic volume on existing roads.

2. NOISE IMPACT AND COMMUNITY ANNOYANCE

Noise impact assessments based solely on an analysis of noise levels do not reflect the impact on the amenity and quality of life of the community affected. It is far more appropriate to assess impact in terms of community annoyance with noise. Annoyance with noise depends not just on the noise level, but on the character of the noise, whether there have been any recent changes to the noise environment and whether there are widespread negative associations with the source of the noise.

Community annoyance cannot be predicted accurately, even when general cases are considered (as opposed to specific communities). However, recent and established research does provide relationships between noise exposure and annoyance which allow the factoring-in of considerations such as the proportion of heavy vehicles and the noise environment prior to construction. For the noise impact assessment of the Melbourne City Link [1], these relationships were incorporated into a subjective evaluation framework. For the Scoresby Transport Corridor and the Shepparton Bypass, a quantitative method was developed.

3. AVAILABLE RELATIONSHIPS

Quasi-steady-state noise exposure

Annoyance with noise within a community that has had no recent sudden changes in noise exposure can be predicted using a relationship derived by Schultz in 1978 [2]. This relationship has been confirmed by a recent study [3]. The work by Rylander [4] give us a relationship between community annoyance and the number of noisy events due to heavy vehicles.

Changes in noise exposure near existing roads

Baughan and Huddart [5] have found that, for communities exposed to changes in traffic volumes on existing roads, there is a clear relationship between the change in community annoyance and the change in traffic volume. This suggests that community perception of noise intrusion is not just dependent on the noise level, but is also dependent on the number of noisy events. For example, a 25% increase in traffic volume would only increase noise levels by an imperceptible 1dB(A), but according to Baughan and Huddart, this would lead to an increase of 10% in the proportion of the community who are highly annoyed.

These responses to sudden changes in noise exposure can be very long-lived, with some studies [5, 6] indicating that it may take as much as 10-20 years for the level of community annoyance to fully return to steady state levels.

Community annoyance near new roads

Major roads have an associated zone within which traffic noise from the road predominates. Any residence within this zone could be said to be affected by noise from the road.

In 1989, Marshall Day Acoustics undertook a small-scale study of community annoyance with noise from the South Eastern Arterial. Of the 47 residences surveyed (all within 200-300m of the arterial road), we found that 51% of residents were still highly annoyed 2 years after opening. The L_{10}(18hr) at the residences where the survey was conducted varied from 55-68dB(A).

This result is broadly consistent with other studies. In a before and after study of attitudes to traffic noise near the F3 Freeway in New South Wales [7], the average noise level of the residences surveyed was 60dB(A) L_{10}(18hr) and the average level of community annoyance was about 25% highly annoyed.

4. THE COMMUNITY ANNOYANCE MODEL

The Community Annoyance Model currently exists in prototype form as a 4Mbyte spreadsheet. It can assess up to nine traffic scenarios for any one land use scenario. Traffic data (volume & composition) for all major road links are entered for the existing situation, the "no-build" scenario and up to 8 "build" scenarios. Land-use details (number of affected residences & schools) are entered for each road link.

Changes in community annoyance near existing transport routes

The community annoyance calculation begins with an assumption about the current level of community annoyance. For this project, we assumed that 20% of people living near existing roads would be highly annoyed with their existing noise exposure. A sensitivity analysis was undertaken which showed that the conclusions were virtually independent of this assumption.

Schultz's results were used to estimate community response to gradual changes prior to the opening of new sections of road. When the new sections of road are opened, there will be sudden changes in noise exposure near existing roads as the traffic settles into new patterns. The work by Baughan and Huddart was used to estimate the consequent change in community annoyance. It was assumed that the level of community annoyance would gradually, over a period of 20 years, return to a level consistent with Schultz's quasi-steady-state condition.

Rylander's work was not useful on this project, as almost no roads had a reduction in truck volumes below Rylander's break-point of 1,000 trucks per day.

Changes in community annoyance near new roads

For this project, a base figure of 50% highly annoyed was used for situations similar to those in the South Eastern Arterial study, where the traffic volume was about 90,000 vehicles per day, the residential area abutted the freeway reserve and was unaffected by noise from other roads. For other situations, the 50% figure was adjusted according to the traffic volume on the road, the distance between the road and the residential area, land-use between the road and the residential area and whether the residential area is affected by noise from other sources. For example, we estimated 35% highly annoyed for a residential area affected by noise from other roads and adjacent to a section of freeway with 50,000 vehicles per day.

A sensitivity analysis showed that our overall conclusion for Option 3 (see Table 1 below) was stable for a range of 33-52% highly annoyed for the base figure.

Overall change in community annoyance

For each scenario, an index (equivalent to the number of residences where the residents are highly annoyed) was estimated for each of the existing and proposed road sections. The overall effect was estimated by adding the change in the number of highly annoyed near existing roads to the change in number of highly annoyed near the new roads. For areas near the proposed new roads that were currently affected by noise from existing roads, the effects were considered to be additive.

Other considerations

Impact on schools near existing roads was assessed by reviewing the change in traffic volume. Changes above a certain cut-off point were considered significant. Changes in sleep quality near existing roads was assessed using the Sleep Disturbance Index developed by Bullen, Hede & Williams [8].

5. RESULTS

The decision to develop a quantitative basis for estimating changes in community annoyance was in order to allow a rigorous comparison of the many transport and land-use scenarios. It was acknowledged, however, that the method was in an early stage of development and that prediction of community annoyance, even at the best of times, was likely to be a very slippery fish. All results were reviewed to ensure that they made sense intuitively. The conclusions were reported in broad terms, not quantitatively. A very brief summary of our conclusions is shown in Table 1.

Overall changes in community annoyance near existing roads were mostly minimal. Some useful traffic volume reductions were predicted for some roads running parallel to the proposed new road, but these were generally balanced by increases on feeder roads.

Community annoyance near new roads (obviously) increased as the extent of new roads increased. Because changes near existing roads were minimal, the overall change in community annoyance was also determined by the extent of new roads.

Table 1
Summary of conclusions

Option	Description	Near existing roads	Near new roads	Overall
1	Currently programmed transport works	Minimal impact	-	Minimal impact
2	Additional arterial road works	Minimal impact	Minimal impact	Minimal impact
3, 3A	Northern half of the Scoresby Freeway constructed	Minimal impact	Medium negative impact	Low negative impact
4, 4A, 4M	Entire Scoresby Freeway constructed	Low positive impact	High negative impact	Medium negative impact

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COMMUNITY REACTION TO AIRCRAFT NOISE IN SYDNEY: A PILOT STUDY ON THE MONETARY VALUE OF ACTIVITY DISTURBANCES

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1. INTRODUCTION

Aircraft noise, like any other negative externality, is an unwanted 'nuisance' commodity. As early as 1971, the question was asked: 'Can aircraft noise nuisance be measured in money?' [1]. Since then, the predominant approach to imputing a monetary value to aircraft noise has been a method known as 'hedonic pricing' [2], [3], [4]. This method attempts to deduce a monetary value of transport noise from changes in real estate prices. However, this method assumes that a 'spanning condition' is fulfilled [5]. This condition is not fulfilled in cases like Sydney, where attempts are made since 1996 to spread aircraft noise almost over the entire metropolitan area. It is also not fulfilled, if a location *per se* has a positive value for an individual (eg closeness to relatives, history).

The need for an alternative method to estimate the monetary value (cost) of aircraft noise is demonstrated by the consequences of the decision to expand Sydney (Kingsford Smith) Airport by means of constructing a 'third runway'. This decision was made on the basis of a financial net present value analysis, as distinct from an economic analysis [6] and an application of the ANEF-system [7], [8], [9], [10] to assess aircraft noise impacts. The opening of the 'third runway' was followed by a public outcry about aircraft noise, a Senate Select Committee [11], the emergence of a new political party, the 'No Aircraft Noise Party' and the establishment of the Sydney Airport Task Force. The aim of this Task Force was to design flight paths, which would distribute aircraft noise 'more fairly' over the metropolitan area of Sydney [12].

2. THE COST OF ACTIVITY DISTURBANCES

An alternative method for imputing a monetary value (cost) to aircraft noise has been proposed, namely to value the time of activity disturbances, caused by aircraft noise, by the opportunity cost of each activity [6]. This method is derived from economic theory, which is concerned with non-dictatorial resource allocation systems with incomplete markets [13].

Activity disturbance was found to be a significant determinant of the response measure, 'general reaction', as used in the ANEF system [7] (see also [14]). There is evidence that 'excessive' and prolonged noise exposure reduces labour productivity [15]. Furthermore, this method complements a method used to impute a monetary value to positive externalities of road transport infrastructure, namely the value of travel time saved [16].

An application of this method requires observations on activity disturbances (measured in hours), caused by aircraft noise, classified by types of activities, and an hourly monetary value for each of the activities. If a 'market-oriented' approach is considered to be desirable, then the appropriate monetary values would be market prices (wage rates) for the various activities. If the provision of labour services is disturbed at a place of work, then the wage rates are relatively easy to obtain. Similarly, various activities, carried out by an individual at home (eg gardening), could be approximately valued by the corresponding market wage rate. In this framework, health effects of aircraft noise constitute an extreme case of activity disturbance and medical expenses are to be added to the costs of activity disturbances. There is no direct market value for sleep. However, the cost of loss of sleep could be approximated either indirectly via health effects, or by the hourly wage rate, assuming an individual has the choice between 'work' and 'leisure' [13]. Instead of using a 'market-oriented' approach, a socially sanctioned administered pricing system could be adopted. (An administered pricing system is used in the calculation of the monetary value of 'road user benefits' [16])

3. A PILOT STUDY

The present study takes a first step to providing quantitative information on the extent and type of activity disturbances, caused by aircraft noise in an area, located between 15 and 30 km north of Sydney (Kingsford Smith) Airport. This area had been totally ignored in the Environmental Impact Statement for the 'third runway' because it was outside the 'vicinity of the airport' as defined by the 20 ANEF zone and therefore individuals were assumed to be unaffected by aircraft noise [6]. As part of a social survey, based on the questionnaire used in [7], and described in [14], respondents were asked to estimate the number of hours of activities, which are disturbed by aircraft noise per week (Table 1). This survey was carried out in late 1995, about one year after the parallel north-south runway system had been introduced in Sydney. It involved a mail-out style questionnaire survey of 5000 people, selected from the electoral roll of one local government area with approximately 106,000 residents. This area extends over 84 square kilometres and consists primarily of low-density residential housing. The secure response rate was a little over 20%. In this survey, a coarse measure of aircraft noise exposure was used, namely relative 'flight density'. Four groups were formed (G1, ... G4 in Table 1), with G1 having the highest flight density and G4 the lowest. The area, identified as being most frequently over-flown (G1), was later officially identified as being also exposed to dB(A) $\geq$ 70 [12]. The sample size in each flight density group was selected proportionally to the population size. A slightly lower response rate was obtained for G4.

Activity \ Flight density group / Responses	All 1018	G1 439	G2 173	G3 287	G4 119
Conversation	1.222	1.601	1.267	1.007	0.227
Watching TV (flicker)	1.489	2.162	1.615	0.732	0.647
Listening to radio or music	1.509	1.954	2.167	0.805	0.605
Sleeping	1.917	2.477	1.989	1.227	1.412
Relaxing	1.746	2.139	2.057	1.283	0.958
Reading or studying	1.084	1.310	1.328	0.875	0.395
Entertaining	0.578	0.628	0.833	0.523	0.151
Working from home	0.809	0.497	1.787	0.830	0.480
Other	0.194	0.200	0.115	0.223	0.214
Total	10.548	12.968	13.158	7.505	5.089

Table 1, Activity Disturbances, Average Number of Hours Per Week

The correlation coefficient of the total number of hours of activity disturbance, caused by aircraft noise, with the 'general response' index is .47. This is consistent with the weight of the 'disturbance' variable in a regression equation, used in the construction of the general response index [7], [14].

Given the exploratory nature of this study, it may suffice to provide some possible monetary values (imputed prices). The minimum hourly price may be taken to be equal to the administratively determined price for travel time saved [16]. Private car travel time saved is valued at $6.92, and business travel time saved is valued at $22.17 (1996 values, linked to ABS Average Weekly Earnings data for August 1995). These two imputed prices may be used to estimate a range of monetary costs for the 1018 respondents. The range of annual costs is between $3,863,913 and $12,379,039. To provide a 'commercial' perspective, these cost estimates constitute between 5.6% and 18.1% of the after tax profit of the Federal Airport Corporation for the financial year ending June 1995 [17] on the basis of 1018 residents alone, who were assumed to be unaffected.

4. Concluding Comments

Given the survey questionnaire used, it is not possible to extrapolate from the data to all residents in the local government area. However, the data suggests that further analysis of the importance of activity disturbances, measured in hours and valued in monetary terms, is warranted.

The suggestion has been made that the reaction of individuals depend on psychological factors such as attitude towards the aviation industry, the government, etc. [18], [19]. While economists recognise the possibility of 'moral hazard' in survey data, ie the over- or under-representation of preferences, there is a fundamental methodological difference. Economic theory, which is concerned with non-dictatorial resource allocation systems, takes as given the preferences of individuals over physical things (eg types of yoghurt, types of acoustic environments, alternative airlines). This is how it should be, if one takes the notion of 'free will' or 'freedom of choice' seriously. However, empirical studies, which aim to elicit information about individuals' preferences, need to take into account the potential problem of moral hazard when designing a research method – the next step in our research program. On the issue of 'attitude' versus 'cost', some circumstantial evidence may be cited from the survey. Only G1 and G2 respondents wanted the airport to be moved and felt that the government was not doing enough. There was no difference in the responses of the four groups to questions concerning pilots, airport officials, and the aviation industry. Moreover, the data does not support the hypothesis that there is a negative attitude towards the aviation industry. In terms of the conceptual framework of this study, the responses are consistent with the data contained in Table 1. Aircraft noise is more costly for G1 and G2 residents in terms of hours of disturbance and they focus on the source of the cost and on the institution capable of removing this cost.

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SOME CONSEQUENCES OF AN INTERNATIONAL EMPIRICAL STUDY ON NOISE ANNOYANCE.

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1. INTRODUCTION

The concept of noise annoyance is central in the study of noise effects on residents.Many empirical studies show considerable covariation between acoustical parameters (however defined) and annoyance measures (however defined). But the interpretation, as well as the political effectiveness, of this covariation depend on the concept of annoyance and the way it is measured. More than 10 years ago, Koelega [1] noted his astonishment that a concept so widely used is so ill defined, and it seems that the situation has not improved in the mean time. Generally, noise annoyance is seen as a negative evaluation of environmental conditions, but its connotations are rather broad and diverse. The concept is associated with disturbance, aggravation, dissatisfaction, concern, bother, displeasure, harassment, irritation, nuisance, vexation, exasperation, discomfort, uneasiness, distress and hate. We could enlarge this list by adding the terms mentioned by Schönpflug [2]: somatic damage, connection with failure, loss of orientation, loss of control, negative evaluation of the source, and high sound levels. In addition, Höge [3] mentions "aesthetic displeasure" as a cause of annoyance, and Guski [4] stressed the conflict between attentional and action demands caused by environmental sound information at one hand, and actions intended by the affected person on the other hand.

Some years ago, Kuwano, Namba & Schick [5] found the semantic profiles (11 items) for the term "annoyance" to be similar for English and German students, but somewhat different between Japanese and English or German students. In an attempt to understand the meaning of noise annoyance by elaborated empirical tools, we asked noise experts from different nations to judge similarities between the concept of noise annoyance and related concepts.That is, we assume (1) that the concept of noise annoyance is more or less related to other concepts, (2) these concepts are similarly represented in different languages, and (3) the relations between concepts can be measured by means of similarity judgments. We assume further, that these judgments can be used to note common meanings of the annoyance concept, and differences between languages and/or nations can be used in order to guide the necessary discussions in the ongoing process of defining a set of common annoyance questions and common response scales in questionnaire studies on community noise effects. (See Fields [6] and Team VI discussions at this conference).

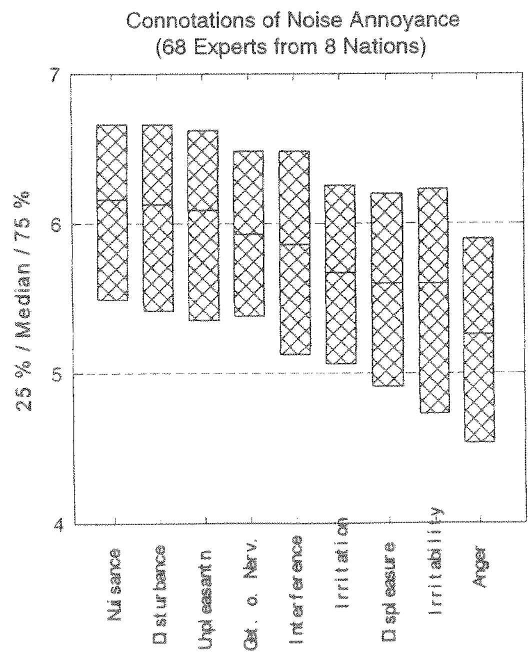
2. METHOD

We asked about 90 noise experts from 8 nations to participate in an empirical study about the meaning of noise annoyance. As a criterion for being an expert, we selected the responsibility for at least one empirical study on noise annoyance. 68 experts from Australia, France, Germany, Great Britain, Japan, Netherlands, Sweden, and the USA responded with a complete data set. The experts were asked (1) to name the main effect of noise, (2) to judge similarities between 38 noise effect concepts and their own main effect on a 7-point graphical scale, and (3) judge similarities between the noise effect concepts and "noise annoyance" on the same 7-point scale.

3. MAIN RESULTS

Since parts of the results have already been presented at Inter-Noise 98, these parts are presented here in abbreviated form, and additional results are given here.

Among the total of 68 answers, 23 were from German speaking countries, 12 from Japan, 9 from Australia, 8 from the USA, 7 from the Netherlands, 5 from France, 3 from Sweden, and 1 from the UK. The median age is 51.3 years; 82.5 % are male; the median duration of noise research is 22.5 years, about half of the experts describe their profession as "psychology" or "psychoacoustics". The main type of research was "field study" (42%), followed by "laboratory study" (32%), and the rest indicated both field and lab studies. The first (open) question showed "annoyance" to be the main effect of environmental noise (51%, followed by "disturbance" (32%). Those experts who indicated "disturbance" to be the main effect showed that their meaning of "disturbance" is very similar to their meaning of "annoyance".



The meaning of "annoyance", as measured by means of similarity ratings with related concepts on a 7-point scale, shows strong relations to "nuisance", "disturbance", "unpleasantness", "getting on one's nerves", "interfering with intended activities", "irritation", "displeasure", "irritability", and anger -- to name but those concepts which show the highest median similarities and the smallest variation between experts.

3.1 Comparisons between language groups

There are three major language groups:German (n=23), English (n=16), and Japanese (n=11). After testing for differences between Australian and US data, these were combined and form the English group.

Within the set of 9 concepts which were rated most similar to noise annoyance, there are 5 which are judged very similar in the 3 language groups: "displeasure", "getting on the nerves", "disturbance", "irritability", and "unpleasantness. The 4 others show significant differences ($p<0.05$), when subjected to the Kruskal-Wallis test. In order to avoid chance effects from multiple tests, we will only be concerned with the 2 greatest differences, these refer to "irritation" (Chi-Sq. = 10.95, p = 0.005) and "nuisance" (Chi-Sq. = 9.97, p = 0.007).

Table 1: Medians and Quartiles for 3 language groups

	English	German	Japanese
Irritation	5.5 / **6.2** / 6.8	4.5 / **5.4** / 6.3	3.8 / **5.0** / 5.8
Nuisance	5.0 / **5.8** / 6.5	5.4 / **6.2** / 6.8	6.2 / **6.7** / 7.0

For English experts, the concept "irritation" seems to be much more related to noise annoyance than for the other two language groups; on the other hand, the inter-quartile range seems to be smaller in the English group than in the other two groups. In German, the respective term, "Reizung", has an ambiguous meaning. For Japanese experts, the concept "nuisance" is much more related to noise annoyance, and it has a smaller inter-quartile range, too. In addition, there are other significant differences which will not be reported here, because they are related to variables which the experts rated less essential for noise annoyance.

3.2 Comparisons between laboratory and field researchers

Twenty experts marked themselves to do mainly laboratory research, 26 experts said they are mainly working in field studies, and 24 marked both positions. Regarding only those 9 concepts which are thought to be most essential, we found 2 of them to be significantly different between the two groups of experts: "disturbance" (Chi-Sq. = 3.9, p = 0.47), and "unpleasant" (Chi-Sq. = 9.0, p = 0.003). Laboratory experts stress "disturbance" somewhat more that field experts do, and they stress "unpleasant" clearly more than field researchers do. It is uncertain whether these are essential differences, because the lab experts in our sample generally tend to give more extreme answers.

4. DISCUSSION

Firstly, it should be noted that "nuisance" and "disturbance" are rated highest in similarity to noise annoyance in the total of 68 experts. In our view, this means that both behavior related data (like self-reported disturbance of intended activities, and interference) and evaluative data" (like "nuisance" or "unplesantness", which may be somewhat more affected by personal values and expectations than behavior related data) are significant for the term "noise annoyance". The majority of concepts which the total sample of experts rated high in similarity to noise annoyance is evaluative (unpleasant, getting on the nerves, etc.). Naturally, this depends on our selection of items to be judged, but we feel to have done a rather exhaustive selection of concepts related to noise annoyance. We argue that the concept of noise annoyance is mainly an evaluative concept with strong connotations to self-reported disturbances of intended activities.

On the other hand, the important term "nuisance" is weighted differently in the 3 language groups observed here. If we interpret small inter-quartile ranges in the international data set as indicating similar representations of the concepts applied in our study, then significant differences between the 3 language groups in similarity judgments about one ore more of the set of important concepts related to noise annoyance can be seen as indicating a somewhat different meaning of the term "noise annoyance". The reasons for this difference are not clear yet, but the pure fact of the difference points to the necessity of intensive discussions among experts from different language groups, if we intend to construct comparable annoyance questions in future studies on noise annoyance.

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A SURVEY ON JAPANESE AND ENGLISH DESCRIPTORS OF ANNOYANCE

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1. INTRODUCTION

A number of social surveys on community response to noise have been carried out throughout the world. Based on the accumulation of these data, the research method has shifted from large-scale surveys to comparison studies between these surveys. One of the main difficulties associated with directly comparing the data from different surveys is the difference in annoyance scales between the surveys, not only within one country but also among various countries with different languages.

As to noise annoyance scaling, Levine [1] and Fidell et al. [2] constructed 7- and 5-point verbal scales in English, respectively. Fields [3] proposed 4-point verbal scale in English as the most frequency used scale in the world. Furihata et al. [4] constructed 7-point scale suitable for Nagano area, Japan, and Yano et al [5] constructed 4- to 7-point verbal scales in Japanese. These scales are useful for surveys conducted in the individual countries. However, a standard scale must be necessary to compare the social survey data internationally. Therefore, the ICBEN Team 6 members have performed an international joint study to construct a standard annoyance scale in each country.

In contrast, we tried to construct compatible scales between Japanese and English, the international standard language. The aims of the present study were to investigate the correspondence between Japanese and English adjectives describing various degrees of annoyance and to establish equivalent Japanese and English annoyance scales.

2. OUTLINE OF THE SURVEY

A questionnaire survey on Japanese and English adjectives describing degrees of noise annoyance was administered to 45 bilingual persons who are fluent in both Japanese and English. They were selected by the following principles mainly in Kumamoto and partially in Osaka: 1) Japanese respondents have lived in an English-speaking area for several years and understand the nuances of English adjectives; 2) English respondents have stayed in Japan for at least several years and can read basic Chinese characters. However, a few participants did not meet these criteria.

The question items were divided into two parts: 1) questions on the translation and construction of scales; and 2) questions on the attributes of respondents. In part one, respondents translated 4- to 7-point Japanese scales, which we had constructed previously, into English, constructed their own equidistant 4- to 7-point scales both in Japanese and English, translated a 4-point English scale proposed by Fields [1] into Japanese, and selected words to usually express the adverse effect of noise. The attributes of the respondents were age, gender, native language and period of stay in Japan for foreigners or in English countries for Japanese. In constructing the scales respondents referred to a list of 65 English and 36 Japanese adjectives that were pre-selected.

3. RESULTS AND DISCUSSION

Attributes of respondents

About 90% of the respondents were their 20s, 30s and 40s. 24 of the respondents were males and 21 were females. The native languages of 25 respondents was Japanese, that of 16 was English, and the remaining four were German, Spanish, Norwegian and Finnish (Swedish). The numbers of participants having experienced extended stays outside their native countries were 23 for more than five years, 16 for less than five years and 6 for none. The responses of these six persons were included in the following analysis because they are all Japanese English teachers who understood English very well.

Corresponding adjectives between Japanese and English

The Japanese adjectives used in the 4- to 7-point scales we constructed are "···nai," "sukoshi," "yaya," "kanari," "hijooni," "taerarenaikurai" and no adjective. The extreme adjectives of "···nai" and "taerarenaikurai" in Japanese respond to "not" and "unbearably," respectively. However, "sukoshi" corresponds evenly to both "a little" and "slightly," "kanari" to "quite" and "very," and "hijooni" to "extremely" and "very." The respective two English adjectives corresponding to the latter two Japanese adjectives have different strengths of meaning.

In constructing 6- and 7-point scales, there were no adjectives at intermediate points which respondents commonly selected. Since it is difficult to construct standard 6- and 7-point scales in both Japanese and English, only results for 4- and 5-point scales are hereafter indicated.

Figures 1 to 4 show the frequency distribution of adjectives for 4- and 5-point scales in Japanese and English which the respondents constructed to be subjectively equidistant between points.

At the lowest point for the Japanese 4-point scale "zenzen...nai," "mattaku...nai" and "...nai" were fairly evenly selected and have almost the same meaning. However, at the other three points "sukoshi," "kanari" and "hijooni" were consistently selected and the separation of the meanings is clear. At the lowest point for the 5-point scale almost the same distribution pattern is shown as 4-point scale. "Sukoshi," no adjective, "totemo" and "hijooni" were selected frequently at the upper points. The separation of meanings for the 5-point scale is also clear.

Figure 3 shows that two or three adjectives were selected frequently for the

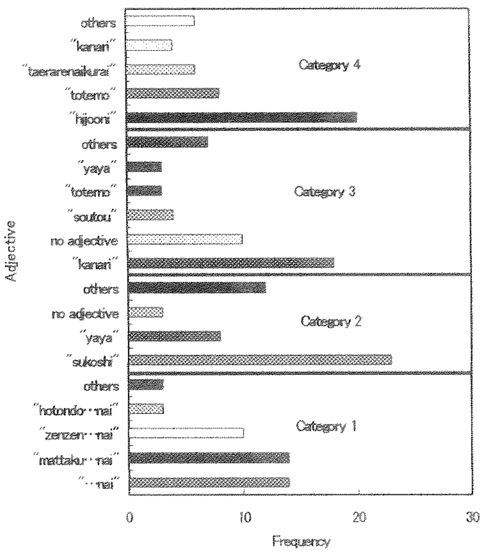

Figure 1 Japanese Adjectives for 4-Point Scale

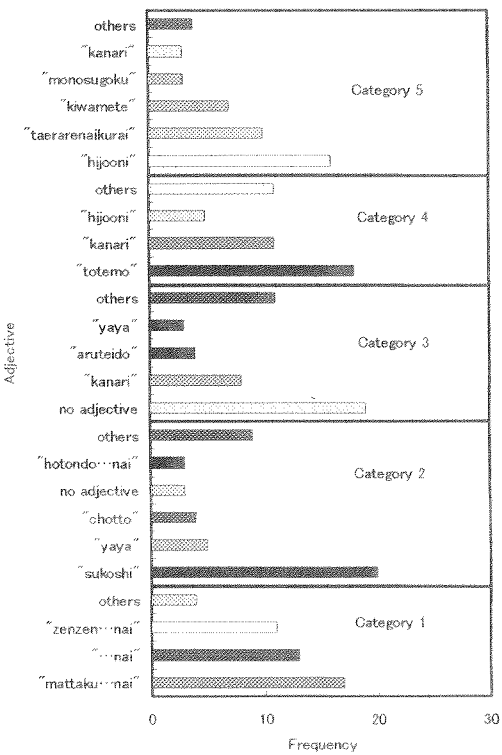

Figure 2 Japanese Adjectives for 5-Point Scale

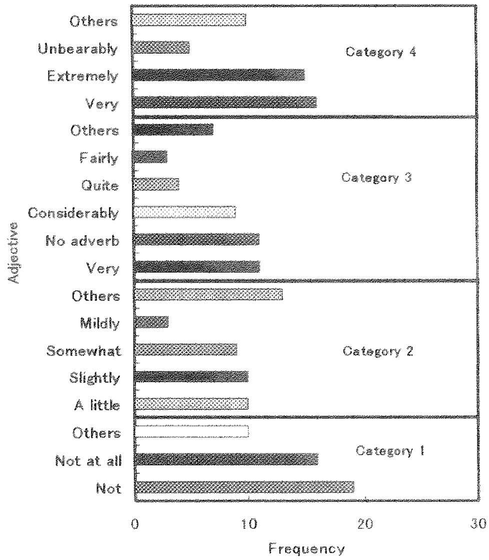

Figure 3 English Adjectives for 4-Point Scale

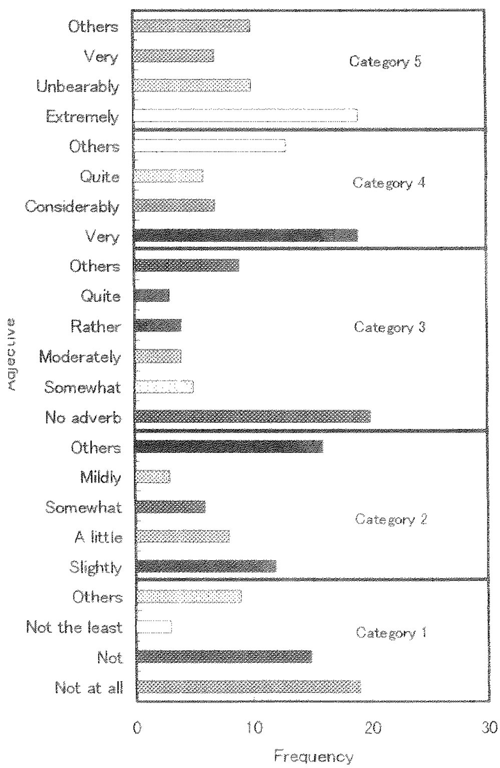

Figure 4 English Adjectives for 5-Point Scale

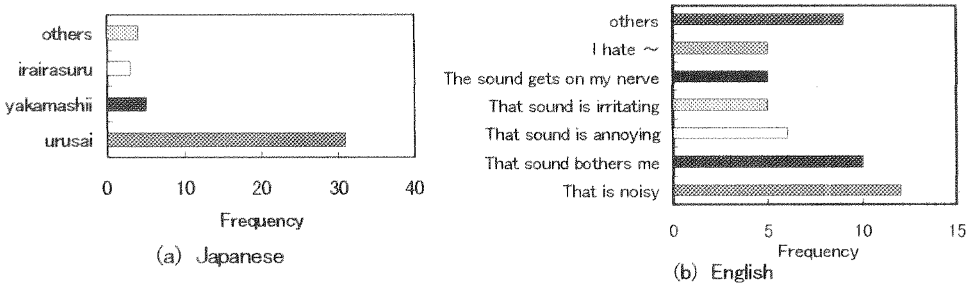

Figure 5 Expressions of the adverse effects of noise

English 4-point scale. They are "not at all" and "not" at the lowest point, "somewhat," "slightly" and "a little" at the second point, "considerably," no adjective and "very" at the third point and "extremely" and "very" at the highest point. However, for the 5-point scale no adjective, "very" and "extremely" were clearly selected at the upper three points as shown in Figure 4. The 5-point scale may be better in the separation of meanings for the English scale than the 4-point scale.

Expression of adverse effect of noise

Figure 5 shows the words that are most frequently used to express the adverse effect of noise. In Japanese, "urusai" is mainly used. However, plural expressions of "noisy," "bothers" and "annoying" are equally used in English. This is consistent with the fact that the expression of "annoyed/bothered" is usually used in English questionnaire [3].

4. CONCLUSION

When the number of scale points both in English and Japanese is greater than six, there is little consensus as to which descriptors should be used for the middle scale points. Accordingly, Japanese and English scales with more than six points are difficult to construct. As the 4-point annoyance scale in Japanese, "mattaku...nai," "sukoshi," "kanari" and "hijooni" are proposed. However, 4-point English scale is difficult to construct, because there is no adjective selected frequently at the upper three points. As the 5-point scale, "mattaku...nai," "Sukoshi," no adjective, "totemo" and "hijooni" are selected most frequently in Japanese and "not at all," "slightly," no adjective, "very" and "extremely" are selected most frequently in English.

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THE USE OF VERBAL LABELS IN NOISE ANNOYANCE SCALES:
THEORETICAL DELIBERATIONS AND EMPIRICAL FINDINGS

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0 Summary

Firstly, criteria for designing response scales and selecting verbal scale point labels for annoyance scales are discussed. Then findings from a psychometric study are presented which can be utilized to refine rating scale construction.

1 The issue: Quantifying annoyance

In social-scientific research on the effects of noise, annoyance due to noise exposure is one of the core topics. Virtually all studies, whether lab experiments or population surveys, employ scales to measure this construct.

Two main types of annoyance scales are: direct scaling, i.e., the respondent expresses her/his degree of annoyance (or disturbance, apprehension, irritation etc) on an accordingly anchored and labeled scale; and scaling via statements, i.e., the respondent assesses to which extent s/he experiences particular described noise effects (usually as intensity or frequency). In psychometric terms, the measurement approach is predominantly category scaling (based on differences), but magnitude scaling (based on ratios) is utilized as well. As considerable context effects occur, some researchers have tried to incorporate well-defined reference levels of noise effects and/or to calibrate annoyance judgments. Quantifying annoyance is indispensable for two tasks: to identify individual levels of noise impacts, and to operationalize the noise problem for populations (e.g., "% highly annoyed" in the vicinity of an airport), and thus requires proper scaling methodology. If cross-national comparability is sought (cf. Rohrmann 1985), the issue becomes very complex.

2 Designing response scales

A annoyance response scale should fullfill psychometric standards of measurement quality as well as practicality criteria, such as comprehensibility for respondents and ease of use.

Within category scaling, verbal labeling of rating scales has become the dominant approach to enhancing usability. The labels are used as "qualifiers, "multipliers", "quantifiers" for particular levels of the issue to be judged (see, e.g., Likert 1932, Cliff 1959, Moxley & Sanford 1993), either for the scale endpoints (e.g., "not-at-all"..."extremely" or "never ... always" for a 0..10 scale); or for each single scale point (e.g., "never/seldom/sometimes/often/always" or "not/ slightly/fairly/quite/very" annoyed). Verbal labeling provides major advantages, such as ease-of-explanation and familiarity (in fact most people prefer verbal responses); it also facilitates to capture normative judgments. The main disadvantage is inferior measurement quality; also, cultural factors might confound the data. Furthermore, cross-national comparability is difficult.

It is therefore essential to design verbalized scales very carefully if equi-distant and unambiguous instruments are to be achieved - if possible based on psychometric data for scale labels. A few authors provide such information (e.g. Jones & Thurstone 1969, Hammerton 1986). Within noise research, Rohrmann scaled 100 (German) expressions for a project on aircraft noise effects in 1966 and replicated the study in 1976. The results were utilized to construct (quasi-) intervall scales (some of them seem still to be in use).

3 A study on verbal scale point labels

In 1997-8, a psychometric study was conducted to clarify the measurement features of (English) verbal scale point labels relevant for questionnaire construction and to develop methodologically sound response scales which are useful for both basic and applied research (Project VQS, Rohrmann 1998). The project deals with rating scale construction in general; however, noise annoyance is the main substantive topic utilized in a series of 6 sub-studies.The research design is as follows:

> *Qualifier dimensions:* Five, i.e.:Frequency (e.g., never, often); *Intensity* (e.g., somewhat, very); Probability (e.g., unlikely, possibly); Quality *(e.g., bad, good);* Response to statements (e.g., disagree, true for me).

> *Number of considered items:* 12+22+16+22+22 = 94 verbal scale point labels (VSPLs), words or expressions, were tested.

> *Scaling tasks:* CAT: Categorial, VSPLs to be placed on a 11-point "equal appearing interval scale" (sensu Thurstone 1929). PREFL: Choosing preferred scale point labels for a 1-2-3-4-5 scale. FAM: Rating familiarity of VSPLs. MAG-N and MAG-L: Magnitude estimations (cf. e.g. Wegener 1983) of VSPLs collected in two modalities, (1) numbers and (2) lines.

> *Contexts for VSPLs:* Noise (e.g.: "I am *<intensity-qualifier>* annoyed by noise; "traffic noise *<frequency--qualifier>* disturbs me; etc); Job satisfaction; and VSPLs presented 'pure' *without* context.

> *Samples:* Students (N=4x30); general population (N=30+30).

A cross-national extension with data collections in Germany (scaling of homologous VSPL's in German language) is currently in preparation.

Selected results - only for noise and the 22 "intensity" VSPLs; only preliminary magnitude scale scores - are summarized in the table below. (Further analyses of the magnitude scaling data, including log-linear transformations and cross-modality matching, are still under way).

SCALING VERBAL QUALIFIERS: SELECTED RESULTS FOR "INTENSITY"

Scaling task	CATEGORIAL (0...10 scale)				MAGNIT-UDE <#>		PREFERED LABEL (% respondents)					FAMILIA-RITY	
Context:	noise		all		all		for annoyance scale level					noise	
	M	*sd*	*M*	*sd*	*M*	*sd*	*1*	*2*	*3*	*4*	*5*	*M*	*sd*
Verbal label													
a little	2.5	1.3	2.5	1.4	10	17		13				7.1	2.7
average	4.7	1.0	4.8	0.9					28			8.8	1.0
completely	9.8	0.6	9.7	0.8	81	161					40	8.5	1.6
considerably	7.5	1.2	7.6	1.1	57	129				21		6.3	1.7
extremely	9.6	0.6	9.6	0.8	76	145					47	8.3	1.4
fairly	5.1	1.3	5.4	1.4	46	113						6.4	1.8
fully	9.2	1.2	9.3	1.3	78	161							
hardly	1.6	1.4	1.7	1.2	9	17		18				7.1	1.8
highly	8.6	0.7	8.6	0.9	68	130						7.4	2.1
mainly	6.4	1.1	6.1	1.4	58	129				18		7.4	1.6
medium	4.8	0.8	4.9	0.8					25			7.3	2.3
moderately	4.9	1.3	5.1	1.1	43	112			37			6.5	2.0
not	0.4	0.5	0.5	0.9	2	3	17					9.4	1.0
not at all	0.1	0.4	0.2	1.0	1	0	70					9.1	1.5
partly	3.5	1.4	3.8	1.4	21	49		14				7.0	1.8
quite	6.1	1.5	5.9	1.5	38	81						6.5	2.4
quite a bit	6.4	1.7	6.5	1.6	45	97							
rather	5.9	1.7	5.8	1.6	46	113						5.7	2.3
slightly	2.5	1.4	2.3	1.5	12	17		27				6.9	1.8
somewhat	4.3	1.7	4.5	1.7	27	49						5.3	2.7
very	8.0	0.9	7.9	0.9	63	129				16		9.2	0.8
very much	8.7	0.7	8.6	1.0	71	145						8.7	1.5

Source: Project VQS, ROHRMANN 1998

The results indicate:

> for some of the tested VSPLs people differ considerably in their allocation of pertinent intensity levels - see items with high standard deviation sd;

> no significant differences between ratings of context-bound (noise) and context-free presented VSPLs;

> rank order of main VPSLs very similar in CAT, MAG-N and MAG-L scaling results;

> when selecting VSPLs for to-be-labeled 5-point scales, most respondents prefer extreme labels at the end (levels "1" and "5");

> most VSPLs are rated as familiar and easy to understand.

4 Utilization of findings

The results enable the systematic construction of scales measuring the degree of annoyance induced by various noise events/situations and approximating interval scale quality. This can refer to the intensity or frequency or probability of effects; the two other response dimensions (quality and response to statements) are useful as well, e.g., for assessments of noise mitigation. The recommended format is multi-modal, i.e., the scale points should be depicted by a combination of numbers, words perceived as equidistant,

and graphical means; thus approximating interval scale level.
Main considerations for choosing a word/expression for a scale point level are:
(1) appropriate position on the dimension to be measured;
(2) low standard deviation;
(3) linguistic compatibility with the other VSPL's of the constructed scale;
(4) sufficient familiarity of the expression;
(5) likelihood of utilization when used in substantive research.
The scale at whole needs to be linguistically coherent and easy to communicate to research participants.

Regarding annoyance scales, a set such as "not/a-little/moderately/quite-a-bit/very" is one possible solutions for a 5-point intensity scale.

The findings of this study are also pertinent for the current discussion within ICBEN-Team-VI (Community Noise) regarding a multi-nationally standardized annoyance scale; cf. Fields 1996, 1998, Guski 1998. The currently considered set, "not-at-all, slightly, moderately, very, extremely" appears to be a reasonable solution (however, there is a rather large gap between level "3" and "4", and using extreme ends can reduce the full usage of a scale).

Finally, it should be noted that the findings from this project are restricted to one language (Australian English) and can not be generalized to English or American or New-Zealand English.

5 The need for further research

To widen the validity scope, three issues seem most relevant: Scaling of labels *within* sets of labels; explicating the impacts of labeling on noise *survey* results; and *cross-cultural* validation (for societal subgroups and across countries). In fact rather complex psycholinguistic research is required to reach the ultimate aim, namely full international comparability of response scales based on verbal scale point labels..

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DEMOGRAPHIC VARIABLES MAY HAVE A GREATER MODIFYING EFFECT ON REACTION TO NOISE WHEN NOISE EXPOSURE CHANGES

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1. INTRODUCTION

On the basis of a recent review of 680 publications from 282 community surveys examining reaction to noise exposure, Fields [1] concluded that "the balance of the social survey data do not support... hypotheses about the effects of demographic variables". Less than half of the relevant reported findings were consistent with the hypothesis that annoyance is significantly influenced by age, gender, socioeconomic status, income, education, or home-ownership.

These findings may owe at least in part to the sampling of residents almost exclusively from areas exposed to steady state noise. The vast majority of studies on which Fields' [1] conclusions are based assessed the relationships between demographic variables and noise reaction in areas where no change in noise levels was reported. However, the relationships between demographic variables and reaction may be influenced by noise level *changes*. For example, older residents may be no more annoyed than younger residents by steady state noise, but could have more difficulty adjusting to recent increases in noise. Similarly, in areas where noise levels have long been constant, home-owners may be no more distressed by noise than renters. In contrast, where noise levels increase, home-owners may be concerned by reduction in their properties' value and so react more negatively to noise than renters. Recent decreases in noise levels may not produce parallel dissociations. For example, whilst home-owners' noise reaction may be alleviated more than renters' by decreases in noise levels, the alleviation of older and younger peoples' noise reactions may be similar.

Anticipation of noise level change influences reaction [2], and this influence may be modified by demographic variables.

Two early studies which considered the relationship between demographic variables and reaction to noise in areas where noise levels had increased found that reaction was not influenced by age [3,4], education or socioeconomic status [3]. However, because noise increases occurred very gradually over 6-8 years these areas may not be representative of areas with recently or suddenly changed noise levels. Fidell et al [5] reported that reaction was not affected by age or gender in areas where aircraft noise exposure was reduced due to runway repairs by up to 18Ldn. However, other demographic variables were not considered, and these data provide no insight into relationships in areas where noise levels increased. Further, changes due to repairs may be viewed as temporary, and factors like property value may not be involved.

The present paper reports relationships between demographic variables and reaction to noise exposure under a range of noise-change conditions. As a result of changes to Sydney (Kingsford Smith) Airport, four types of noise-change area were created. Some areas with initially high levels of noise exposure underwent reductions in noise exposure as a consequence of the changes while others were unaffected. Similarly, some areas with initially low noise exposure underwent increases in noise exposure as a consequence of the changes while others were unaffected. In the present study, associations between the demographic variables and reaction were assessed separately in each area, before and after the flight-path changes.

2. METHODS

Subjects and Sample Selection

1232 residents in the vicinity of Sydney (Kingsford Smith) Airport were sampled to produce a 2x2 design; initial noise level was either "high" or "low" and noise level either changed (decreased or increased) or remained unchanged, due to flight-path changes. 1012 subjects were interviewed before noise level changes and 220 after. The four noise-change areas- "high-to-high" (H-H), "high-to-low" (H-L), "low-to-low" (L-L), "low-to-high" (L-H)- were approximately equally represented in each sub-sample.

From random starting points, every 7th residence along a predetermined path was approached, and one respondent selected using the "last birthday" technique, without replacement.

Materials

A structured interview (based on previous socioacoustic surveys [6,7] and pilot results) assessed reactions to noise (dissatisfaction, affectedness, annoyance), demographic variables (age, gender, education, occupation and home ownership), noise sensitivity, health, noise-induced disturbance and attitudes to the noise source.

Subjects also completed the Grossarth-Matticeck health risk personality questionnaire (70 items) and the POMS Depression, Anxiety and Anger scales (19 items).

Procedure

First, a letter was sent to each selected residence announcing the investigation. Then trained interviewers door-knocked at these residences and asked to speak to the person over 18 living at the residence who last had a birthday. If a suitable individual agreed to participate, the structured interview was conducted before completion of questionnaires.

The study was conducted in two separate stages according to this procedure: before flight-path changes, and again after flight-paths had changed.

3. RESULTS

Relationships of annoyance (2 items) and general reaction (dissatisfaction and affectedness) with age and years of education were assessed by correlational analysis and analysis of variance (ANOVA). The categorical variables- gender, occupation (home duties, blue collar, white collar, unemployed), and home-ownership (own, paying off, renting)- were used as grouping variables in ANOVAs on annoyance and general reaction. All hypothesis tests were 2-tailed (alpha=.05). Analyses were conducted within each of the four noise change areas, for the before and after samples, separately.

Table 1: Associations of general reaction (Gen. R.) and annoyance (Annoy.) with age (r-value), gender (t-value), education (Educ.) (r-value), occupation (Occ.) (F-value) and home ownership (Home-own.) (F-value) in each noise change area, before runway changes (p-values in brackets, *=significant at alpha=.05, **=significant at alpha=.001).

	L- H		*H- L*		*L- L*		*H- H*	
	Gen. R.	*Annoy.*	*Gen. R.*	*Annoy.*	*Gen. R.*	*Annoy.*	*Gen. R.*	*Annoy.*
Age	-.046 (.463)	-.057 (.367)	-.039 (.541)	-.010 (.880)	-.123 (.052)	-.196 (.002)*	-.066 (.298)	-.062 (.323)
Gender	-3.20 (.002)*	-2.12 (.035)*	1.41 (.159)	0.87 (.388)	0.43 (.669)	1.30 (.196)	-2.27 (.024)*	-2.97 (.003)*
Educ.	.105 (.092)	.128 (.040)*	-.017 (.793)	.007 (.916)	.081 (.201)	.121 (.055)	.078 (.218)	.079 (.210)
Occ.	.424 (.736)	.930 (.427)	.754 (.521)	1.101 (.350)	.174 (.914)	.708 (.548)	.199 (.897)	.301 (.825)
Home-own..	16.011 (.000)**	14.579 (.000)**	1.912 (.150)	2.989 (.052)	.707 (.494)	.030 (.970)	.421 (.685)	.092 (.912)

Before flight-path changes, in areas where noise was not expected to change (with either initially high or low noise) reaction was not significantly related to occupation, education level or home ownership [see Table 1]. Females reacted significantly more negatively than males in high noise areas only. Older people had significantly less noise reaction than younger people in low noise areas only.

In areas with initially low noise exposure where exposure was to increase home-owners had a significantly more negative reaction to noise than renters, and females reacted more negatively than males. There was also a significant positive correlation between education level and reaction.

In areas with initially high noise exposure where exposure was to reduce, no significant associations were observed.

Table 2: Associations of general reaction (Gen. R.) and annoyance (Annoy.) with age (r-value), gender (t-value), education (Educ.) (r-value), occupation (Occ.) (F-value) and home ownership (Home-own.) (F-value) in each noise change area, after runway changes (p-values in brackets, *=significant at alpha=.05, **=significant at alpha=.001).

	L- H		*H- L*		*L- L*		*H- H*	
	Gen. R.	*Annoy.*	*Gen. R.*	*Annoy.*	*Gen. R.*	*Annoy.*	*Gen. R.*	*Annoy.*
Age	-.043 (.467)	-.061 (.304)	-.054 (.354)	-.040 (.494)	-.128 (.031)*	-.187 (.002)*	-.044 (.458)	-.039 (.507)
Gender	-3.12 (.002)*	-2.08 (.039)*	0.16 (.869)	0.02 (.984)	0.36 (.720)	1.25 (.214)	-2.25 (.025)*	-2.91 (.004)*
Educ.	.102 (.085)	.119 (.044)*	-.063 (.280)	-.045 (.437)	.056 (.349)	.080 (.183)	.041 (.485)	.047 (.428)
Occ	.417 (.741)	.829 (.479)	.950 (.417)	.807 (.491)	.087 (.967)	.299 (.826)	.668 (.572)	.614 (.607)
Home-own.	15.720 (.000)**	14.498 (.000)**	1.561 (.212)	2.462 (.087)	.275 (.760)	.003 (.997)	.456 (.634)	.168 (.846)

An almost identical pattern of significant correlations and differences was observed in the post-change sample [see Table 2].

4. DISCUSSION

The finding that demographic variables were not consistently related to reaction in steady state noise areas is consistent with previous findings [1].

Nonetheless, in low noise areas expecting no change, older people were found to react less negatively to noise than younger people, and the direction of the correlation between reaction and age across the four noise-change areas was strikingly consistent (though failure to detect significant relationships is unlikely to reflect insufficient statistical power, given the sample size). Indeed, more studies reviewed by Fields [1] supported the hypothesis that older people are less annoyed by noise than supported the opposite hypothesis (29% versus 19% of reviewed studies, respectively).

Associations between demographic variables and reaction were observed in areas where noise was expected to increase, but not in areas expecting noise decreases (5 versus 0 significant results). When noise is to increase, home owners react more negatively to noise than people who are renting. This may reflect the impact of concern about reduction in property value as suggested in the introduction. Years of education was positively associated with reaction, perhaps because more educated people are better informed regarding the anticipated noise increases and so react more negatively.

The more negative reaction of females than males was observed in all areas where high noise was anticipated. This may relate to females' greater time spent at home, because 40% of studies reviewed by Fields [1] support the hypothesis that residents who are at home more are more annoyed.

The failure of demographic variables to correlate with reaction in areas expecting noise decreases perhaps indicates that these variables have an impact on adjustment to negative but not positive outcomes.

In sum, the relationship between demographic variables and reaction is most apparent in areas were noise is expected to increase or has recently increased. The results provide further evidence of the importance of psychological variables in mediating reaction. Most relationships of demographic variables with reaction could be interpreted in terms of the impact of these demographic variables on awareness of, and attitudes toward, noise exposure changes. However, causation is not implied by correlation and further research is required to establish causal mechanisms

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SOUNDS FROM WINDTURBINES - CAN THEY BE MADE MORE PLEASANT?

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1. BACKGROUND AND AIM

Noise may be one critical factor for the public acceptance of wind turbines. The knowledge of perception and annoyance from wind turbines is however scarce. Previous field studies [1] indicated that the extent of annoyance was weakly related to the equivalent noise level (LAeq). This was furthered confirmed by [2] that showed that the extent of annoyance was mainly determined by whether the noise from the wind turbines was perceived and by the viewing angle, while the LAeq level only explained a small proportion or 4% of the variance.
Findings from a previous experiment [3] showed that test-subjects were able to differentiate between different wind-turbine noises with aspect to annoyance, relative annoyance, how long time they were aware of the noises and acoustical characters even though the dBA level was the same. Calculations of traditional psycho-metric parameters such as sharpness, loudness, roughness [4] could not explain the annoyance response. Through subjective descriptions of the noises psycho-acoustic profiles were obtained, which subjectively described the most and the least annoying acoustic parameters. The psycho-acoustical descriptions given the average value of barely annoying or higher were "swisching", "lapping", "whistling", "uneven", "grinding" and "low frequency" character. Of those "swisching", "lapping" and "whistling" were found among the most annoying wind turbines, "grinding" and "low frequency" were found among the second most and least annoying wind turbines while "uneven" was unrelated to annoyance.
This paper gives the results of phase II of an ongoing study, with an overall aim to increase the knowledge of annoyance and perception of acoustical characters, in order for the industry to optimise wind turbine constructions. In Phase II the hypothesis that different psycho-acoustical characters in the noise

not fully detected by the equivalent level, is of importance for annoyance and noise perception.

2. METHODS

The exposure room was a 4x5m large room furnished as an outdoor environment. On entering the room and always in the pause between the noises, recorded bird song was played as background sound. The sound exposures were emitted from two loudspeakers hidden behind thin curtains.

As sound exposures were chosen the two recorded wind turbine sounds that in the previous experiment [3] were judged as most annoying (sound A) and least annoying (sound B). With the object to make the sound as pleasant or as least unpleasant as possible, the subjects were asked to interactively vary different parameters in sound A and B by turning a knob on a panel. The knob had no perceivable start or endpoints. The variations of the parameters were carried out using an interactive sound processing system (Aladdin, Nyvalla DSP). The model was built up in such a way so the resulting sound always had a constant dBA level. The following parameters were varied: *the shape of the frequency spectrum, the amplitude modulation frequency of an added sinusiodal tone* and *the tonal frequency of an added sinusiodal tone. The shape of the frequency spectrum* was changed by letting the subjects vary the centre frequency of a second order resonant filter with a slope of 12 dB/octave. Three bandwidths (500, 1000, or 2000 Hz) of the filter was presented in a randomised order by the experimental leader. The centre frequency could be varied from 500 to 4000 Hz. *The amplitude modulation frequency* of one of three randomly presented sinusiodal tones (500, 1000, or 2000 Hz) was evaluated by varying the modulation frequency of the tone from 1 to 40 Hz. Finally, *the tonal frequency* of an added tone was varied from 50 Hz to 800 Hz. The shape of the frequency spectra was varied in order to alter the perception of "swisching", "whistling" and "low frequency". The variation of the modulation frequency was done to evaluate its influence on the perception of "uneven". The variation of tonal frequency was of more general interest, as the tonal compound in wind turbine noise is believed to be a cause of annoyance.

The test subjects were 12 women and 12 men, with normal hearing < 20 dB HL and with an average age of 24 years (sd=3.76). Each subject took part in four experimental sessions, each lasted about 1.5 hours.

The reliability of the method was tested in a pilot study where the design allowed repeated measures of the same parameter with an interval of 7 to 10 days. The analysis showed that the agreement between the two occasions was very good.

3. RESULTS

Table 1 gives the results for the tonal frequency and the amplitude modulation frequency

Table 1. The average value (M), standard deviation (sd) and standard error (se) for the tonal frequency and amplitude modulation (AM) of the tones, for sound A and sound B.

Sound	A				B			
Parameter	Tone	AM 500	AM 1000	AM 2000	Tone	AM 500	AM 1000	AM 2000
M	94Hz	21Hz	20Hz	22Hz	115Hz	20Hz	20Hz	18Hz
Sd	58	12.7	13.6	13.8	87	11.9	12.8	12.1
Se	12	2.6	2.8	2.8	18	2.4	2.6	2.5

The subjects preferred a low frequency tonal component as compared to a tone of higher frequency. There was no significant difference between the sounds. The average value of amplitude modulation of the added tone for the most pleasant sound, was in the range of 18 to 22 Hz. The frequency was rather similar between the sounds and conditions. Table 2 gives the results from the evaluation of spectra shape.

Table 2. The average value (M), the lower limit (LL) and higher limit (HL) of the 95% confidence interval for the centre frequency for the different filter bandwidths and sounds.

Sound	A			B		
Band width	500 Hz	1000Hz	2000Hz	500 Hz	1000Hz	2000Hz
M	861	834	785	931	1009	1104
LL	674	608	530	658	688	730
HL	1099	1142	1162	1318	1479	1670

The average values of the centre frequency for the most pleasant frequency-spectra were in the range of 785 to 1104. A general observation was that the subjects chose a somewhat lower centre frequency for sound A as compared to sound B. However, there was a tendency to a significant difference only for the bandwidth of 2000 Hz ($t=-1,86$, $p=0,075$).

Figure 1 shows the average chosen value for the different filter bandwidths for sound A and B in relation to the original sound.

In figure 1 it can be seen that compared to the original exposure sound the subjects choose a sound with a higher content of low frequencies or a lower content of high frequencies, as the most pleasant sound. This was more pronounced for sound A, which in the previous experiment was given a higher annoyance rating for the descriptions of "swisching" and "whistling".

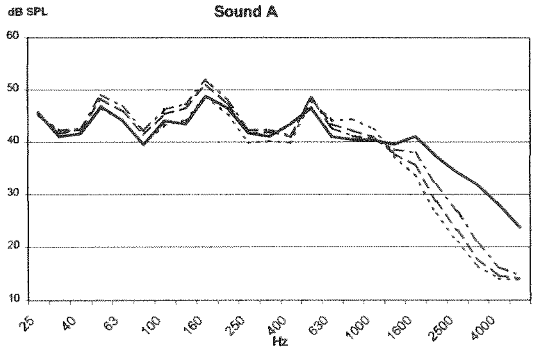
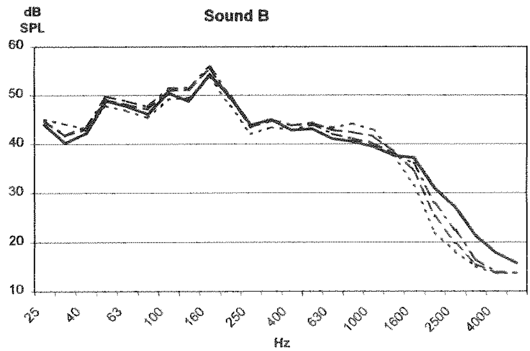


Figure 1. The average chosen value for the different filter bandwidths (Bw) for sound A (above) and B (below), in relation to the original sound.



**(The original sound ———
Bw 500 ··········
Bw 1000 - - - - - -
Bw 2000 -·-·-·-)**

4. CONCLUSIONS

The choice of amplitude modulation was largely in accordance with previous studies of perception and annoyance [t ex 5], in so far that a lower amplitude frequency in the region of 1-5 Hz has been found to be more easily perceived. The choices of tonal frequency and frequency spectra are in accordance with the previous experimental findings [3] where the psycho-acoustic description "low frequency character" was found among the least annoying wind turbines and the characters of "swisching" and "whistling" (indications of high frequency content) was found among the most annoying wind turbines. Further studies will be aimed at identifying the psycho-acoustical description of lapping.

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LOW FREQUENCY NOISE: EFFECT OF EXPOSURE TIME ON LOUDNESS VS ANNOYANCE

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1. INTRODUCTION

There has been much interest recently in the choice of a room noise criterion assessment method, particularly with respect to low frequency noise problems. This follows on the inclusion of both the RC and NCB criteria methods in ANSI S12.2-1995. The main divergence between the two criterion curves occurs at low frequencies, i.e. below 100 Hz. The reason for this divergence is that the NCB curves are based on the assumption that loudness and annoyance are equivalent while the RC is empirically based and reflects the assumption that, at low frequencies, in particular, loudness and annoyance are not equivalent [1,2]. With respect to low frequency noise assessment, one of the issues that arises is how people respond to low frequency noise disturbance on a longer term basis ie how does a rating of loudness and annoyance change with time and are they the same.

Hellman et al [3], used the method of successive Magnitude Estimation (ME) to determine the change in loudness perception with time (test duration was 6 minutes). Below we report the results of testing of loudness and annoyance perception over a 1 hour test period using the method of successive ME. This testing was part of a pilot study conducted during the initial phase of the ASHRAE sponsored research project "The Determination of the Relationship Between Low Frequency HVAC Noise and Comfort in Occupied Spaces - Subjective Phase". The testing, in this instance, was for the purpose of determining how the annoyance and loudness rating of low frequency noise changes with time, if at all.

2. NOISE STIMULI

For the purpose of this psycho-acoustic testing, 4 noise samples of HVAC noise with dominant energy at 25, 31.5, 50 and 63 Hz, as shown in Figure 1, were used. These stimuli were based on samples of over 70 HVAC noises that were collected during Phase 1 of the ASHRAE sponsored research [4] and had been identified in an earlier pilot study as causing the highest Annoyance-to-Loudness rating ratio (A/L) [5].

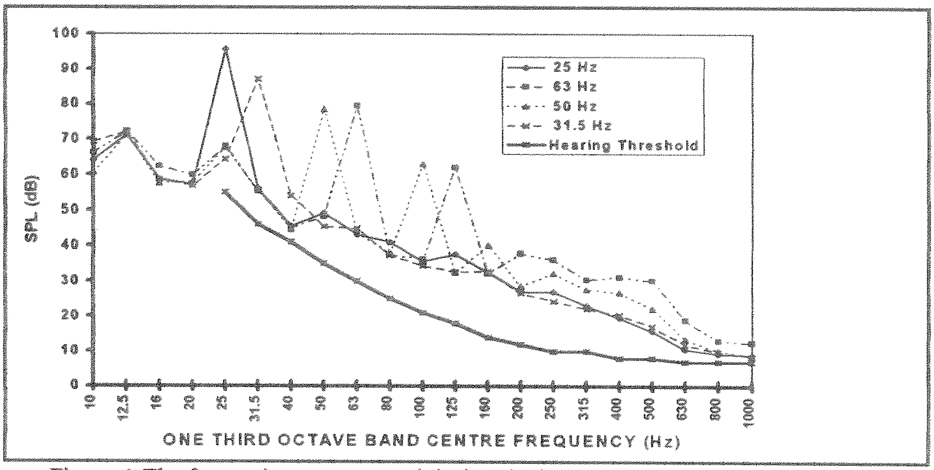

Figure 1 The four noise spectra used during the long term psycho-acoustic testing

3. RESPONSE RATING

To determine the subjective response of subjects for both loudness and annoyance, the Magnitude Estimation (ME) method was used without a designated standard. In this psycho-acoustical method, the subject assigns a rating number to the perceived loudness or annoyance without the use of a reference. This method has been used previously to characterise perception of loudness eg [3]. In the method of successive ME, the response to a stimulus is continuously monitored. For the current testing, the subjective ratings of both Loudness and Annoyance were recorded by Subjects at each of the following intervals during the 1-hour test session: at 5 seconds, 10s, 15s, 30s, 60s, 2 mins, 5 mins, 10, 15, 30, 45 and 60 minutes.

4. TEST METHOD AND SUBJECTS

The subjects were seated in the ASHRAE test room. This room has a double wall construction and is floated on isolators so as to minimise any noise intrusion from the outside. The room is 6700 long by 3100 wide by 2350 high and is a reasonably sized meeting room. The noise stimuli were played back to the subjects via two loudspeakers, each one located above a diffuser located in the ceiling on either side of the room width-wise. One subject was tested at a time. To aid in the response rating, a cue light located on the desk came on when the noise rating was required. At this time, the subjects filled in the response ratings. In this way, no stimuli were missed.

For this testing, 6 Subjects, 3 males, 3 females (average age 26.7 years) were used. Two were relatively new at the rating task while 4 had had previous experience. All subjects had normal hearing.

5. TEST RESULTS

The rating results were normalised using a geometric mean analysis. This analysis accounts for the different range of numbers used by each subject [6]. The mean loudness and annoyance ratings for each of the noise stimulus were calculated and plotted versus time. Figure 2 shows the results obtained. From Figure 2, it can be seen that the adaptation rates vary with frequency. Table 1 shows the Sensation Level and the Loudness and Annoyance Adaptation Quotients (i.e. degree of adaptation) after 3600 seconds for each of the four noise stimuli tested. It can be seen that the Adaptation Quotients increase with decreasing Sensation Level and with decreasing frequency. The data also suggests that adaptation occurred to the greatest extent for the 25 Hz and 31.5 Hz stimuli, most likely due to the reduced Sensation Level at these frequencies.

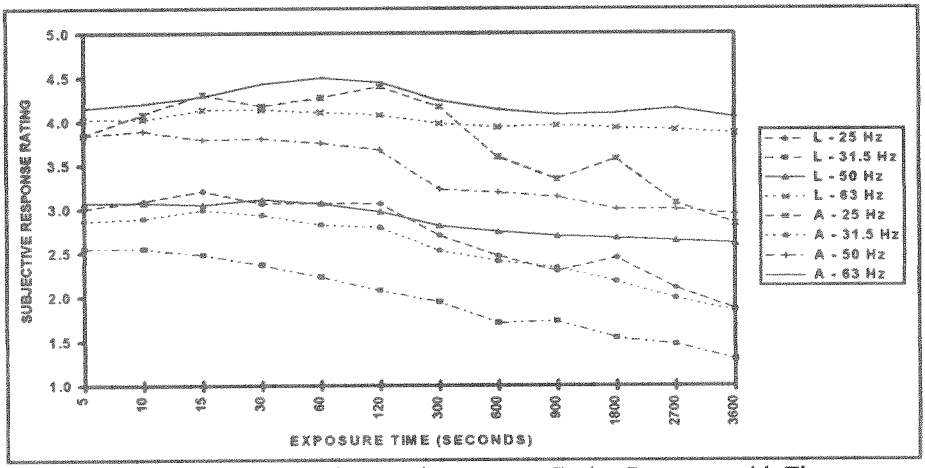

Figure 2 Change in Loudness and Annoyance Rating Response with Time

Table 1 Percentage Adaptation for Given Low Frequencies and Sensation Levels and the Annoyance/Loudness Ratio

Dominant Frequency (Hz)	Sensation Level (dB)	Loudness Adaptation (%)	Annoyance Adaptation (%)	Annoyance/Loudness Ratio at 3600 seconds
63	43	7	2	1.05
50	40	16	24	1.13
31.5	30	48	36	1.42
25	26	40	26	1.51

Figure 3 compares the ratio of the Annoyance-to-Loudness response (A/L) and shows that for 63 Hz, this appears to be relatively constant with time. For 50 Hz, the ratio decreases with time but is always greater than 1. For both 31.5 and 25 Hz, the A/L ratio increases with time - at 3600 seconds, a ratio of the order of 1.5 occurred.

6. DISCUSSION

Given the large inter-subject variability typically observed in psychophysical and physiological data, the initial results obtained appear interesting. It would appear that Loudness and Annoyance are not regarded as too different for spectra dominated by energy above 50 Hz. For 63 hz, the ratio is basically constant while for 50 Hz, the ratio decreases somewhat with time, but both are always greater than 1.0. At lower frequencies, the Loudness and Annoyance are considered to be different and that the A/L ratio increases with time. Thus, even though these lower frequency noises became softer with time, these low frequency sounds have an attribute that causes the Annoyance to decrease less rapidly than the Loudness.

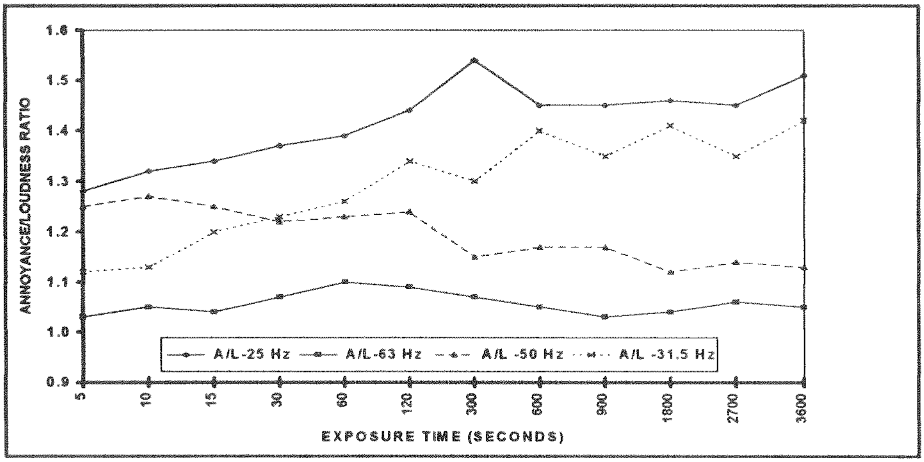

Figure 3 Annoyance/Loudness Ratio versus Time for the four low frequency noise stimuli

7. CONCLUSION

The implication of these results is that, for HVAC noises with rumble, the loudness and annoyance cannot be assumed to be the same. While the loudness may decrease with time for low frequency noise less than 50 Hz, the annoyance does not decrease as rapidly. The RC Mark 2 method of assessing HVAC noise accounts for the Annoyance being greater than the Loudness while the NCB curves at low frequencies (below 100 Hz) do not. More testing needs to be conducted.

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9. ACKNOWLEDGMENT

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ROAD TRAFFIC NOISE ANNOYANCE IN RELATION TO THE INDIVIDUAL NOISE DOSE

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1. BACKGROUND

Noise from vehicles is one of the most important environmental pollutants affecting man's health and well being. Control actions to decrease the effects of noise thus have high priority in work to decrease the effects of the environment. An important factor for this control to function is that the noise dose is highly related to the effect and that the control to be undertaken is easy to implement and to understand. The dose must be clearly defined, and the control measures must give priority to the factors that are most important for the effect.

Environmental noise is usually expressed as the average of all noise events over a certain time, usually 24 hours, equivalent noise level LAeq. The unit is difficult to put to practical use as it is unclear how the two components: numbers and levels relate to annoyance. It is used primarily as a planning instrument.

Earlier studies on aircraft noise exposure have demonstrated that the number of noise events and the maximum noise level independent from another are important factors related to the annoyance reaction.

As regards road traffic noise, the validity of these principles has not been assayed in detail. One study reported a similar relationship when the number of events was expressed as the number of heavy vehicles and the noise level as the average of the three highest noise levels during a one-hour measuring period.

To further investigate annoyance caused by road traffic noise, a field study was performed in collaboration between a Japanese and a Swedish research group. The goal of the investigation for the Japanese group was to evaluate possible differences in the extent of annoyance that were related to housing conditions (flats, semidetached houses, and villas). The goal of the Swedish group was to investigate the relation between the extent of annoyance and different noise exposure indices. This presentation describes the findings from the Swedish investigation.

2. MATERIAL AND METHODS

A random sample of 60–178 persons, aged 18-75 years and having lived in the area for at least one year was chosen from each of the investigated areas using population registers. The selected persons received an information letter and a questionnaire containing about 40 questions on general sources of annoyance in the area, questions on family status, occupation, general satisfaction with the environment and specific questions on annoyance caused by different environmental noise sources. The respondent was asked whether she/he noticed a particular noise source and, if so, if they were annoyed (little annoyed, rather annoyed, very annoyed).

In each area, a measuring caravan was placed on a representative site, and a microphone (Brüel&Kjær type 4165) was placed 1.5 meters above the ground. This was connected to a noise analyser (Brüel&Kjær 4427). The measurements were made continuously for 24 hours during a weekday. Maximal noise levels were registered continuously, and equivalent (LAeq) was calculated for one-hour intervals. The measured levels were corrected to the free field level at the house facade. The maximum noise level for an area was defined as the highest level occurring at least three times per 24 hours.

The numbers and types of vehicles in each area were counted manually during the noise measurements. The observers also noted extreme noise events such as broken noise mufflers and squeaky braking. These events were later coupled to the registration of maximum noise levels and were excluded.

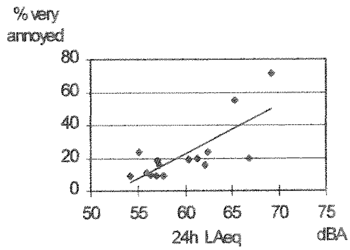
For each person in the study, the noise level was corrected from the value for the area taking into consideration the distance to the road and the floor level for the persons. The correction was based on field measurements of surface and distance reduction.

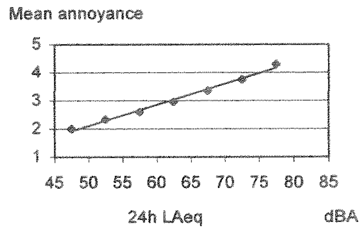
For each area, a calculation was made of the percentage of respondents who indicated that they were very annoyed by the traffic noise.

When the individual noise exposures had been calculated, the respondents were grouped into noise exposure categories in 5 dB intervals. The noise exposure categories were based on numerical values for the annoyance expressed (very annoyed=5, rather annoyed=4, little annoyed=3, notice noise but not annoyed=2, does not notice=1), and an average annoyance for each 5 dB category was calculated.

3. RESULTS

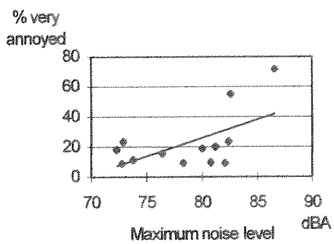
The following figures show the dose response relationship between the noise level expressed as LAeq and the extent of annoyance. In the left figure are the response based on the percent very annoyed in each of the15 different areas. The right figure shows the response based on the individual noise dose in 5 dB groups.

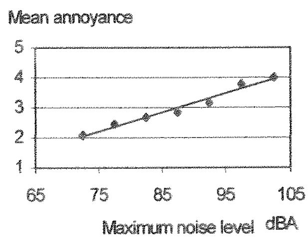




The left figure shows a weak correlation between percentage very annoyed and LAeq (r_{xy}= 0.5769). The dose response relationship in the right figure based on mean annoyance score in 5 dB groups shows a better relationship (r_{xy}= 0.9886)

The next two figures show the dose response relationship with the noise dose based on the maximum noise level. The left figure shows the response based on the percent very annoyed in each of the 15 different areas and the right figure based on the individual noise dose in 5 dB groups.





The correlation for the dose response relationship in the left figure based on percentage very annoyed is rather low (r_{xy}=0.3382) whereas the relationship based on individual noise dose gives a good correlation (r_{xy}=0.9713).

4. DISCUSSION

This investigation calculated the individual noise dose, correcting for distance to the road and floor level. Earlier investigations have determined the noise exposure as an area value, measured in a representative spot. This technique is more adequate for aircraft noise, which exposes the area in a relatively uniform pattern. Road traffic noise, on the other hand, is more variable within an area.

The relationships between noise exposure calculated as individual exposures and annoyance demonstrated some important features. The relationship for LAeq was very strong as was the relationship for Lmax. This demonstrates that the number of vehicles was not an important contributor to annoyance.

The result from this study concludes that the most relevant action to reduce the extent of annoyance is to decrease the maximum noise levels, which practically can be done by prohibiting the noisiest vehicles. It has earlier been shown that these comprise only a few percent of the total number of vehicles in city traffic. Actions to decrease the number of noisy vehicles could thus be of a not very drastic nature in relation to the whole traffic pattern. Additional studies need to be undertaken to support this hypothesis.

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NOISE EFFECTS ON LOCAL SCHOOLS IN THE MADRID REGION

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1. INTRODUCTION

The results that are shown in the present work, are included within a work that consisted of the obtainment of a Noise Map in the Madrid Region, this work was made from May 1995 to July 1997. There were made experimental measures to know the spatial and temporary variation of different indices of environment noise evaluation in 17 towns of the cited region whose population was varying from 3.000 to 180.000 inhabitants.

On the other hand, another subjective study was done of the noise effect on the residents of these locations, as well as the opinion of the Town Hall technical personnel and finally a survey in the Local Schools, this last study makes up the present work.

2. THE SURVEY

The number of Local Schools in which the survey was realized was 50, with a total number of polled pupils of 2109. Also it was considered convenient to know the opinion of the teachers, therefore they were also polled, and there were collected 398 teachers surveys.

3. RESULTS

There are presented below the results obtained in the educational centers from the different towns, the percentages from each questions correspond to the average of the region. The answers of the teacher are separated from the ones of the pupils.

The results show the opinion of the teachers and pupils about the noise in their schools, the acoustics conditions of the classrooms, library, etc.; the internal and external noise sources in the center, the noise effects, etc.

The acoustics conditions of the classrooms are classified like normal by most of teachers (47%) and pupils (47,3%); the rest consider them wrong (25,9% teachers and 23,7% pupils). There are deviations respect the average, since in some of the locations 64,7% of the teachers and 59,1% of the pupils consider them wrong, while in others 62% of the pupils consider that the acoustics conditions are good.

The noise level in the classrooms is medium or high for most pupils (51,6% and 35,3% respectively), as well as teachers (34,4% and 44,7%), only a 12% of pupils and a 16% of teachers consider low the noise level in the classrooms (figure 1).

There is a deviation again from the average in the same town in which the acoustic of the classroom was considered wrong. Now they said (64,7%) that the noise level was high, and in the same way the polled people that consider the noise level low were 33,3% teachers and 18,2% pupils.

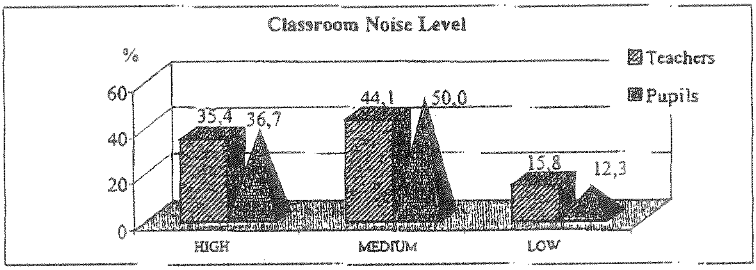

Figure 1

As the result of the previous answers both, teachers (70,1%) and pupils (60%), consider that the acoustics conditions of classrooms have to be improved. We can see how in the school that they consider that their classrooms have good acoustics conditions the answer of the teachers (54,2%) and pupils (43,2%) indicate that this improvement is not necessary.

According to the teachers, the principal noise sources in the classrooms are inside them (55,3%), while 44,2% consider that they are external. On the other hand the pupils believe (61,5%) that the noise in the classrooms proceed from the outside.

Talking about the deviations from the average, in one of the locations close to an airport, 100% of the teachers and 88,4% of the pupils consider that the noise sources are external.

The external noise sources in the classrooms change depending of the town. In the small ones the most important source is people, in the big ones they are traffic or airplanes (figure 2).

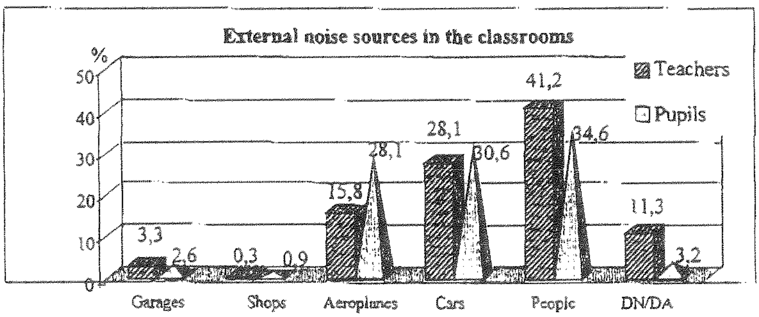

Figure 2

The main internal noise source is people and this people are the students (88,4% teachers and 86,8% pupils). In different local schools a similar answer has been obtained therefore there are not deviations in the answers.

Teachers suffer in similar percentages the different effects of noise (figure 3): interfere in the hearing (83,2%), disturbs the attention and the concentration (80,7%) and affects to the nerve state (68,6%). Two of the towns are less affected by noise pollution (always less than 70%). In the other schools teachers suffer it in a higher percentage.

Pupils are also affected by the noise in classrooms, but in slightly lower percentages to those of the teachers. The loss of concentration (82,7%) and the interference with the hearing of the teacher (78,3%) are the most common effects.

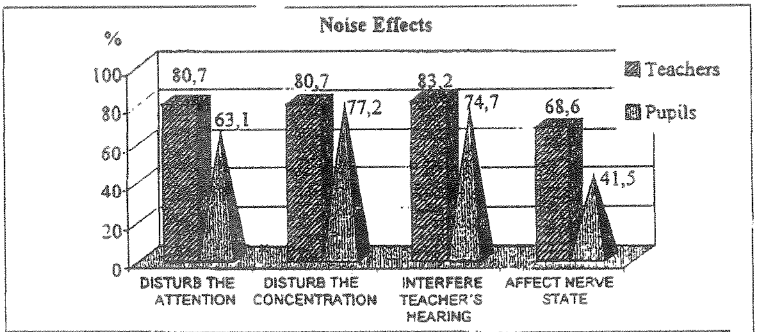

Figure3

The noise problem concerns to most of teachers (76,9%) and pupils (58,3%), while in the schools where the effects are smaller it worried them quite less (36% yes and 28% no).

The most annoying time corresponds to spring and summer (91% teachers and 84,3% pupils).

If they were able to choose the situation of their center, most of the teachers would like (63,8%) a center located in an area with few noises, instead of a school close to their houses. The percentage of pupils that have elected the same option is smaller (a 52,2%).

Also in this case there are deviations from some schools to others, according to the environmental noise existing.

When it comes to criticize the current legislation in noise matters, teachers consider the laws should be more strict (83,7%), while the percentage of pupils is reduced to 51,9%.

The noise environment that exists in the library is good enough for 54,8% of the teachers and 48,5% of the pupils, also these opinions present deviations according to the noise environment that exists in the school.

All the polled people agree that the suitable noise environment for studying is the silent one (82,2% teachers and 66,7% pupils, there are not differences from one school to the others).

Regarding to the origin of the noise inside libraries there is no general opinion in the schools. The answers are distributed as external (41,2% teachers and 44,7% pupils) and internal noise (41,5% teachers and 36% of pupils), existing large deviations of some towns to others, according to the external noise environment.

The most important noise source inside libraries is the pupils themselves.

In the survey there were some questions just for teachers, they answered that there were some classrooms with better acoustics conditions than others (68,1%), only in two of the locations this affirmation were not maintained.

Concerning the effects that noises produce to the teachers, 75,4% tend to raise their voice to mask the noise, suffering throat nuisances (62,3%) and additional stress (73,1%).

Also in this case there exists deviations with respect to these mean values, mainly in one of the locations.

4. CONCLUSIONS

As a consequence of the previous results there follows some affirmations:

1. It is observed that pupils answer with more homogeneity than teachers.
2. Teachers, as a normally, are more critical than pupils.
3. A great percentage of teachers consider that it is necessary to improve the acoustics conditions of classrooms.
4. The differences in the answers between teachers and pupils, in regard to the principal noise sources in classrooms, are mainly because pupils are the principal source of noise inside the classrooms, and most of the pupils did not consider so.
5. Noise is the source of many disorders and concerns to all the polled people. If we consider that part of the noise proceed from the inside of classrooms, in fact from the pupils, the solution goes through adopt a most respectful and considerate behavior, educating students so that they will be more conscious of the fact that the solution to the noise problem in schools comes from their willing to end with the problem.
6. Pupils are normally less concerned about the noise problem than teachers.
7. Most of the teachers and pupils believe that is very important a workplace with a silent environment or with little noise.
8. Pupils are not so critical with the current legislation and a great percentage did not answer this question, while teachers consider necessary a modification of the legislation.

ANALYSIS ABOUT OCCUPANT AWARENESS REGARDING THE MULTI-FAMILY HOUSING SOUND ENVIRONMENT

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1. INTRODUCTION

Since the 1960s there has been a rapid increase in the construction of reinforced concrete multi-family housing, the predominant type of housing in Japan. Recently, there has been a great need to improve the habitability of multi-family housing, and because of this situation, there has been an aggressive push to establish a social and administrative system for the evaluation and the display of performance. To achieve a better living environment from an architectural point of view, there is a need to clearly grasp the awareness of problems held by dwellers in their everyday lives, and through the experiences they share in common regarding the recognition-of-the-sound-environment point of view.

Here, in contrast to conventional ways of evaluating noise such as 'annoyance' or 'noisiness', we have been paying attention to a new "Satisfaction Level Evaluation" with regard to the sound environment for dwellers. Through this study we have been able to ascertain the process by which the awareness structure of dwellers is formed, and an attempt has been made to bring together the effect of the evaluation of the satisfaction level of the sound environment and to show the cause and effect relationships between the various elements.

2. AN OUTLINE OF THE ANALYSIS

The Data:

Up until now we have surveyed residents living in public condominiums and in private condominiums with preset questions in questionnaires as well as open-ended questions with regard to the sound environment (1)(2)(3). An outline of the main objects of research, are given in Table 1. As the sound insulation performance of each unit (122 buildings in all) with regard to the floor

Table 1. An Outline of Housing Complexes used in the Survey

Condominiums		Year completed	Units maintained (number)	Questionnaires returned (%)	Open-ended questionnaires returned (%)	Location
Private	A	1983	546	64.7	33.4	Suburbs
	B	1986	673	34.5	47.1	Centrally
	C	1983~	1185	21.4	54.3	Centrally
	D	1994	163	55.8	29.7	Suburbs
Public		1980 ~ 1992	2528	66.9	37.4	Suburbs

Table 2. Estimated Level of Sound Insulation Performance for Floor

Condominiums		Floor impact sound insulation		Slab thickness	Floor finish
		Heavy weight	Light weight		
Private	A	L_H-60	L_L-50	150mm	Carpet
	B	L_H-55	L_L-45	180mm	Carpet
	C	L_H-50	L_L-40	180mm or more	Carpet
		L_H-55	L_L-45	180mm	Carpet
	D	L_H-60	L_L-45	150mm	Carpet
Public		L_H-60	L_L-65	150mm	Wood flooring

impact sound insulation performance, the feature of the section of the finished floor and the estimated L_H, L_L are shown in Table2. Compared to the current reinforced concrete multi-family housing standard structural performance of public housing, private condominiums, the object of this research, would rank better than 1-2 in L_H, 3-5 in L_L. From our data we learned that the ranks for dwellers of multi-family housing, the object of our investigation, is varied.

The Path Model:

In path analysis, based on the information (2) regarding the dwellers' attitude of the sound environment in multi-family housing, we made a cause and effect model for evaluation of the level of satisfaction toward the sound environment, with final results as given in Table 3. The criterion variable is the "Level of Satisfaction with the Sound Environment" (Y10) as shown in Table 4,

Table 3. Data used in Predictor Variables

Predictor variables	Data used	
X1: Past dwelling experience	Q	Is the sound environment 1) Better than before, 2) The same, or 3) Worse than before?
X2: Sound Insulation Performance LH	C	Heavy-weight floor impact sound estimated level
X3: Having or not Having Children	Q	Are there any infants in your home? Children from 5 to 10 years old?
X4: Surrounding Environmental Noise	Q	Of the 6 items given as reasons for dissatisfaction with the sound environment, was 1) "Is there a terrible noise problem with surrounding noise?" given as one of the answer? Yes or No?
Y5: The Actual Situation with regard to the Sound Environment (Feeling like you are a Victim)	O	Overall score for the actual situation of the sound environment
Y6: Evaluation of the architectural performance	O	Having or not having the desire for architectural improvements
Y7: Feeling like you are victimizing others	O	Feeling or not feeling that one is victimizing someone
Y8: Human relations, manners, morals	O	Overall score for dwelling
Y9: Restrictions on Dwellings	Q	The number of items out of 17 that fit with regard to considerations about living

Q: Questionnaire items
O: Open-Ended answer (Scoring based on points)
C: Calculated value

it is set up so that as the value increases the level of satisfaction decreases. The total number for the data used in path analysis comes from all 942 responses given to the open-ended questions. The path coefficient and the path model used in the analysis are both shown in Figure 1. The explanation rate in this analysis was 0.539.

3. ANALYSIS RESULTS

The Influencing Elements:

From the path coefficient attached to Figure 1, each of the elements influencing the "Level of Satisfaction with the Sound Environment" have a direct effect, indirect effect and a general effect. The estimated results are shown in Table 5. From these results, a direct effect gives a large coefficient: "Surrounding Environmental Noise", "Sound Insulation Performance (L_H)", "Restrictions on Dwellings", "Past Housing Experience". As for indirect effects, they can be seen with "Sound Insulation Performance (L_H)" and "Having or not Having Children". Large variables on the general effect were "Surrounding Environmental Noise", "Sound Insulation Perfor-

Table 4. Data used in Criterion Variable(Y10)

1. Very satisfied because of the very quiet environment.
2. Satisfied with the environment as multi-family housing.
3. Can't say that I'm am completely satisfied but, since there is no direct threat to my lifestyle this is okay.
4. Fairly satisfied as this is the standard level of housing performance (I expect of) multi-family housing.
5. I can't say that I am satisfied, but this is about the level (I would expect of) multi-family housing, so I'm resigned to it.
6. I am definitely not satisfied, but I can put up with it.
7. Though there are some obstacles to daily life, this is about all I can stand.
8. Even if I have to spend some (of my own) money, I'm thinking of improving this (situation).
9. It is so terrible I am thinking about moving

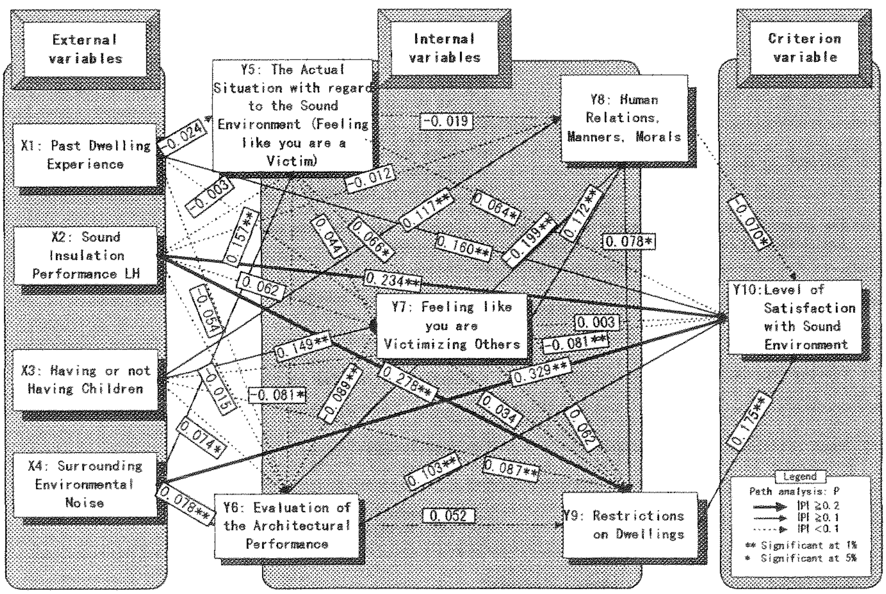

Figure 1. Result of Path-analysis

mance(L_H)", "Restrictions on Dwellings", and "Past Housing Experience".

In Table 5, external elements are given when compared with the general effects on "Level of Satisfaction with the Sound Environment", we can understand that the level of satisfaction with the sound environment has much to do with the condition of "Surrounding Environmental Noise" and "Sound Insulation Performance" of the building itself. Further, "Level of Satisfaction with the Sound Environment" are not only awareness of the present sound environment, but decisions and evaluations based on the degree of change with regard to the previous sound environment are also important.

Table 5. Various Elements and Effects affecting the Level of Satisfaction on the Sound Environment

Predictor variables	Direct effect	Indirect effect	General effect
X1	0.160	-0.002	0.158
X2	0.234	0.048	0.282
X3	-0.081	0.031	-0.050
X4	0.329	0.021	0.350
Y5	0.064	0.003	0.067
Y6	0.103	0.020	0.123
Y7	0.003	0.001	0.004
Y8	-0.070	0.014	-0.056
Y9	0.175		0.175

When comparing internal elements, with regard to the general effect of "Restrictions on Dwellings", "Evaluations with Regard to Architectural Performance" were more important. This fact shows the awareness for dwellers to desire improvements in architectural performance through such things as the sound-proofing of the floors and windows, points out that the "Level of Satisfaction with the Sound Environment" is easily influenced by dwellers' awareness.

The Main Flow of the Awareness:

From the size of the values of the path coefficients, if we pay attention to the main flow of the awareness of the dwellers, 1) the flow of awareness from "Sound Insulation Performance" to "Restrictions on Dwellings", and further to "Level of Satisfaction with the Sound Environment", 2) and we find that flow increases from "Having or Not Having Children" to "The Feeling of Victimizing Someone", and further "Human Relations, Manners, and Morals".

From 1), in order to supplement the architectural performance, dwellers themselves think about their living conditions and accept "Restrictions on Dwellings", and from these regulations, it has become clear that there is a flow of awareness which is evaluating the "Level of Satisfaction with the Sound Environment". And in 2) in particular with families that had children, it was very easy for them to develop "The Feeling of Victimizing Someone" with regards to the lower floors because the prevention of noise was impossible. From this we conjectured that this consideration not to make noise and trying to maintain good relations with the neighbors greatly influenced "Human Relations" and "Manners".

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NOISE IMPACT ASSESSMENT IN A LARGE COAL MINING COMPLEX - A CASE STUDY

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1. INTRODUCTION

Noise could be defined as sound without agreeable musical quality or as unwanted sound. The problem of noise has accentuated in the mining industry due to increased mechanisation. Prolonged exposure of workers to high levels of noise beyond 90dB(A) proves harmful and may culminate in noise induced hearing loss. It is also associated with other physiological, psychological and behavioral effects on mine workers.

Before initiating any measures against the noise hazards, noise surveys are essential. They help in identifying the sources of noise problem and quantifying the risk of exposure of workers. Effective antinoise measures can accordingly be formulated and implemented [1]. This paper deals with the determination of noise impact assessment in a large coal mining complex of southern India.

2. NOISE MEASUREMENT

Noise survey was conducted in GDK - 8 incline colony of M/s. S.C.C.Ltd. B&K modular precision sound level meter (Model: 2231) was used to measure the ambient noise level in the residential colony.

To evaluate Noise Impact Index of residential areas, subjective response of the people to the existing noise was obtained by a questionnaire survey . A six point scale was used for annoyance rating . Noise dose analysis of workers was carried out using noise dose meter at different locations in the mine.

Noise Impact Index (NII)

It is a useful tool in the assessment of noise annoyance and was determined using Schultz's Fractional Impact method (Schultz, 1982). It can be expressed as :

$$NII = \frac{\sum LWP}{P_{total}} = \frac{\sum [P(L_{dn})_i \times W(L_{dn})_i]}{P_{total}}$$

where, LWP = Sound level weighted population

$P(L_{dn})_i$ = Population distribution function

$W(L_{dn})_i$ = fractional noise impact in the sub-neighborhood.

$L_{dn} = 10 \log_{10} [1/24 \{ 15(10^{Ld/10}) + 9(10^{(Ln+10)/10}) \}]$

L_d = day time leq, l_n = night time leq.

P_{total} = total base population.

3. RESULTS

The results of ambient noise levels and the socio-economic survey are summarized in "Table 1" . Observations on noise dose readings are presented in "Table 2".The relationship obtained between the MDS and l_{dn} can be given as :

$$MDS = -4.769 + 0.1219 \, L_{dn}$$

"Table 2" Noise dose readings at different locations

Person	Condition	Noise dose, dB(A)
EE dozer section	engine tested	96
Dumper section	openplace tested	95
Maintenance section	normal work	100
Feeder breaker section	outside cabin	87
Dozer	Operating	99

"Table 1" Determination of NII at GDK - 8 incline colony [5]

Location	Size	L_d, dB	l_n, dB	l_{dn}, dB	approximate population in sub-neighbourhood (P_i)	MDS	% HD Population	LWP	$NII = \frac{\Sigma LWP}{P_{total}}$
Shirke Qtrs.	25	59.9	52.4	61.0	4140	2.52	12.00	496.8	$NII = \frac{3335.16}{20313}$ = 0.16
Shirke Qtrs. behind RG-II	29	59.1	53.1	61.1	3798	2.10	6.90	261.93	
Santosh nagar area	20	54.8	46.3	55.4	2646	1.75	10.00	264.6	
T-II Qtrs. (9 incline)	32	56.6	52.9	60.1	2583	3.0	16.67	430.5	
T-II Qtrs. (near OHT)	22	68.6	66.4	73.2	1782	4.05	45.45	810.0	
T-II Qtrs. behind SCC school	19	60.6	53.2	61.5	2088	4.05	31.58	659.37	
Officers Qtrs.	16	59.9	56.0	63.2	711	3.63	25.00	177.75	
Officers Qtrs. (near temple)	12	59.2	56.7	63.6	1089	2.25	1667	181.50	
T-I and C-II Qtrs.	28	59.9	54.6	62.3	1476	2.57	3.57	52.71	
	Total = 203				ΣP_{total} = 20313			ΣLWP = 3335.16	

4. CONCLUSION

Noise impact index is a useful tool in environmental noise assessment. It was 0.16 in GDK - 8 incline colony and was higher than the indicative permissible value of 0.062 [by using CPCB norms for residential areas l_d : 55 dB(A) and l_n = 45 dB(A)].

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AN ENVIRONMENTAL INDEX BASED ON INHABITANTS' RECOGNITION OF SOUNDS

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1. OUTLINE OF SURVEY

1600 subjects of both sexes, 12 years old or above randomly sampled at the rate of 100 subjects per ward from the computerized resident register, getting permission of personal information protect agency of Yokohama City. The survey was conducted from October to early December in 1991 [1],[2]. Distribution and collection of questionnaires were done by mailing, so the recovery rate was worried to be low. However, under the effort of three time requests for replying, a number of recovering finally counted for 1240, with the valid rate of 77.5% showing a favorable result.

2. DEMOGRAPHIC DATA AND LIVING AREA FEATURES

The demographic data (sex, age, hour in home, family composition, residential building, residing duration) were based on the answers of the subjects themselves to the questionnaires. Among the living area features, land use zoning, the distance from main roads (national highway, express way, major local road) and that from the nearest station were decided based on the location of the residence where the subject was dwelling. For a whole population, a number of whole employees, and a ratio of the employees to the population per mesh where the subject was dwelling, the result of the national census taken in 1990 and the mesh data of 250m x 250m of the Yokohama Municipal Industrial Statistics were used.

3. ATTITUDE TO SOUND ENVIRONMENT

The subjects were given 39 particular sounds, and asked to rate them according to the following (I) inaudible, (F) feeling favorable, (N) feeling neither favorable nor annoyed or (A) feeling annoyed. These answers were aggregated per sound. H (= F + N + A) is the number of subjects who chose any one of F, N and A in the total subjects of 1240 and classified as "hearing number" of each sound. (F/H), (N/H) and (A/H) are indexes of feeling favorable, feeling neither favorable nor annoyed, and feeling annoyed for a sound respectively. A set of (F/H), (N/H), and (A/H) represents the attitude of inhabitants whether they feel favorable or not favorable toward a sound. Using three variables of (F/H), (N/H) and (A/H), 39 sounds were classified into three groups through hierarchical cluster analysis. Figure 1 shows (F/H), (N/H), and (A/H) for each of the three groups. The 9 sounds of group1 represent mainly natural sound, such as twittering of birds or murmurs of water streams, for which people will rate (F) or (N). The 18 sounds of group2 represent miscellaneous sounds around residents, so called daily life sound, and indicate mostly (N), with a ratio of 10 ~ 20% of annoying. The 12 sounds of group3 relate to automobiles, stores, factories and construction work indicating (N) or (A).

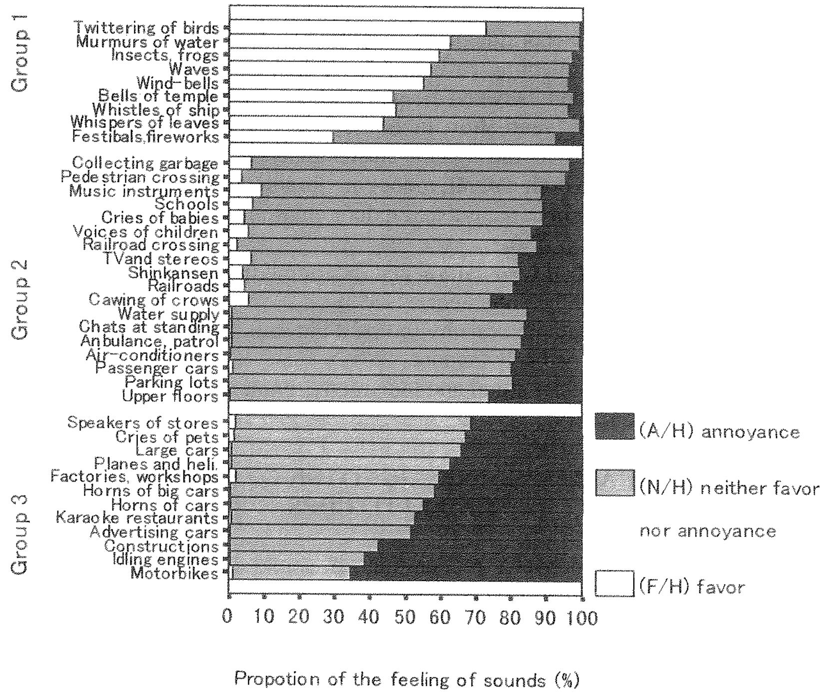

Figure (1) Classification of sounds in surroundings.

The feeling of a subject about individual sound environment can be defined with 6 variables, which are (1g) a ratio of a number of sounds rated (G) and (1na) a ratio of a number of sounds rated (N) or (A) in the 9 sounds of group1, (2gn) a ratio of sounds rated (G) or (N) and (2a) a ratio of sounds rated (A) in the 18 sounds of group2, and (3gn) a ratio of sounds rated (G) or (N) and (3a) a ratio of sounds rated (A) in the 12 sounds of group3. These indicate recognition level of the individual toward sound condition in his surroundings. By using these 6 variables, 1240 subjects were classified into five "sound recognition clusters" through non-hierarchical cluster analysis.

SRC1: low recognition level for every sound. (34%)

SRC2: group1 sound feeling favorable, and had a high ratio of feeling neither favorable nor annoyed for group2 and 3 sound. (22%)

SRC3: heard every sound well but felt neither favorable nor annoyed. (14%)

SRC4: felt neither favorable nor annoyed if hearing group1 and 2 sound, but felt annoyed for group3 sound at a high level. (13%)

SRC5: rarely heard group1 and 2 sound, but felt annoyed by group 3 sound at an extremely high level. (18%)

4.ATTITUDE TO RESIDENTIAL ENVIRONMENT

By using the answers for the questions relating to the satisfaction of the 10 environmental elements except quietness, identified as "places for a walk," "clean air," "amount of greenery," "collecting garbage," "convenience of shopping," "convenience of transportation," "relation between neighborhood," "safety of surrounding roads," "sunshine in house" and "ventilation in house," the subjects were classified into 5 environmental attitude clusters through the cluster analysis.

EAC1: satisfied with both natural, indoor environments and convenience. (26%)

EAC2: satisfied with both natural and indoor environments but dissatisfied with convenience. (22%)

EAC3: slightly satisfied with natural and indoor environments but slightly dissatisfied with convenience. (23%)

EAC4: dissatisfied with natural environment but satisfied with indoor environment and convenience. (20%)

EAC5: dissatisfied with natural and indoor environments but satisfied with convenience. (9%)

5. INDEX OF INHABITANTS' RECOGNITION OF SOUNDS, ATTRIBUTES AND ATTITUDES

When the relationship between recognition of sound and living area features is considered, the SRC2 decreases with respect to restricted urbanization district, exclusive residential district class1 and 2, residential district, neighborhood commercial district, quasi-industrial district, and commercial district, while SRC5 increases in the same respect. As leaving more distance from the major road, the SRC5 decreases, while SRC2 increases. As the number of employees per mesh increases, the SRC5 increases, while the SRC2 decreases. As mentioned above, the increases and decrease of the SRC2 and SRC5 deeply relate to the characteristics of the living area. Hence, the common logarithm conversion value (represented by LSRC5/2) of the ratio of subjects belong to the SRC5 in a certain group to subjects belong to the SRC2 in the group is defined as "an index of inhabitants' recognition of sounds".

In the restricted urbanization district, exclusive residential district classes 1 and 2 and residential district, the LSRC5/2 counts for less than 0.0. In the neighborhood commercial district, quasi-industrial district, it counts for more than 0.0. In the commercial district, it counts for 0.9 or more, where as ratio of the SRC5 to the SRC2 is larger than 8 to 1. At promptly near by the major road, it counts for 0.5, within 100m of the major road for 0.0 or more, and over 100m for -0.3. When the employees per mesh stay below 40% of residential population, it counts for around -0.3, but when exceeds 40%; it counts for more than 0.3. LSHC5/2 well reflects living area features.

Figure 2 shows the relationship between the value of the LSRC5/2 in the groups having various area features and the ratio of the EAC4 and 5, whose attitude to the natural environment is dissatisfied, to total subjects of the same groups. The correlation coefficient exceeds 0.85, showing a strong relationship. At the LSRC5/2 of -0.3, namely at a group where subjects of the SRC5 is half of the SRC2, about 1/4 of the subjects, at the LSRC5/2 of 0.0, namely at a group where the SRC2 mostly equals the SRC5, about 1/3 of the subjects, and at the LSRC5/2 of 0.3, namely at a group where the SRC5 twice the SRC2, about 1/2 of the subjects will belong to the clusters dissatisfied by natural environment in their living area.

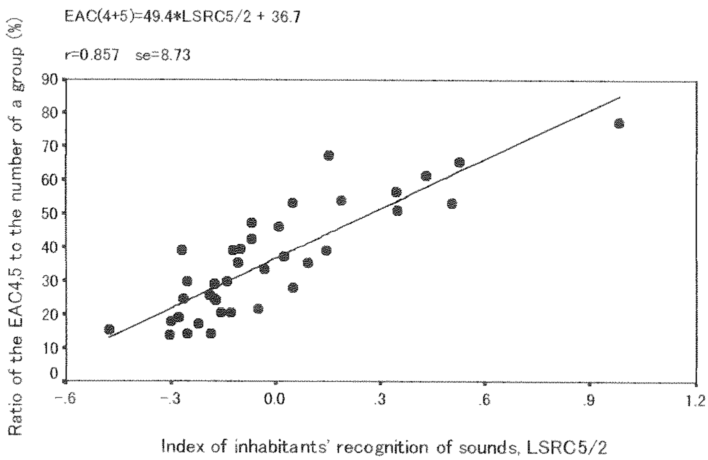

Figure (2) Relation between recognition of sound environment and attitude to natural environment.

6. SUMMARY

The sounds in surroundings can be classified into three groups. Group1 sounds bring the feeling of favor or that of neither favor nor annoyance to people. Group2 sounds bring mostly the feeling of neither favor nor annoyance. Group3 sounds will bring the feeling of neither favor nor annoyance or that of annoyance.

By using these subjective reaction in hearing of the sound of the three groups, 1240 residents were classified into five "sound recognition clusters", SRC1-5. The increases and decreases of the SRC2 and 5 deeply relate to the characteristics of the living area.

The common logarithm of the ratio of the persons of the SRC5 to that of the SRC2 in a certain group, that is to say "an index of inhabitants' recognition of sounds," reflects the living area features of the group and closely relates to the attitude of the inhabitants to the natural environment and sound environment.

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CROSS-CULTURAL COMPARISON OF COMMUNITY RESPONSES TO ROAD TRAFFIC NOISE IN GOTHENBURG, SWEDEN, AND KUMAMOTO, JAPAN, PART I: OUTLINE OF SURVEYS AND DOSE-RESPONSE RELATIONSHIPS

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1. INTRODUCTION

Social surveys on road traffic noise have been conducted all over the world. Some have pointed out the importance of the effects of non-acoustical factors on annoyance in a uniform cultural background. However, community responses to noise may be affected by cultural and climate differences in the areas surveyed. Particular interesting is how to utilize the results of annoyance studies in many countries for the establishment of a general noise evaluation system. To shed light on this problem, Jonsson *et al.* [1] conducted a joint study in Sweden and Italy in 1969 using the unified method. They concluded that the differences in annoyance reactions seemed to be dependent on differences in living conditions, on different requirements and on different evaluations of motor traffic as a part of the physical environment. The present authors [2, 3] have also found differences in community responses in preliminary joint studies in Japan, Sweden and Thailand. The purpose of the present study was to clarify cross-cultural differences in the community response to road traffic noise in Gothenburg, Sweden, and Kumamoto, Japan, using the same questionnaire and noise measurement method.

2. OUTLINE OF SURVEY

Gothenburg is located in the western part of Sweden, which has a comfortable summer temperature and cold winters, while Kumamoto, in the southern part of Japan, has a very hot and humid summer. The culture and the climate of the two cities are very different. Fifteen typical residential areas with both detached houses and apartment houses were selected as the target areas in each city. All the houses surveyed faced roads. The questionnaire comprised 40 questions relating to environmental, housing and personal factors. The key questions concerned annoyance caused by road traffic noise. The answers were given on a five-point category scale, as shown in Table 1. The respondents, from 18 to 75 years of age in Gothenburg and from 20 to 75 years of age in Kumamoto, were randomly selected on a 1-person-per-family basis. The postal method was used in Gothenburg, while the distribute-collect method was used in Kumamoto. Community responses obtained with these two methods showed no significant differences in our previous survey [3]. The total numbers of respondents were 1,142 in Gothenburg

Table 1. Outline of survey

	Gothenburg	Kumamoto
Survey Period	January – June, 1996	May – November, 1996
Number of Respondents	Detached: 436 Apartment: 706	Detached: 378 Apartment: 459
Response Rate [%]	Detached: 73.3 Apartment: 66.4	Detached: 76.0 Apartment: 64.6
Noise Exposure Level LAeq(24) [dBA]	Detached: 46.2 – 73.6 Apartment: 48.5 – 82.3	Detached: 49.0 – 73.5 Apartment: 51.1 – 73.5
Rating Scale for Key Questions 1. Not noticed 2. Not annoyed 3. A little annoyed 4. Rather annoyed 5. Very annoyed		

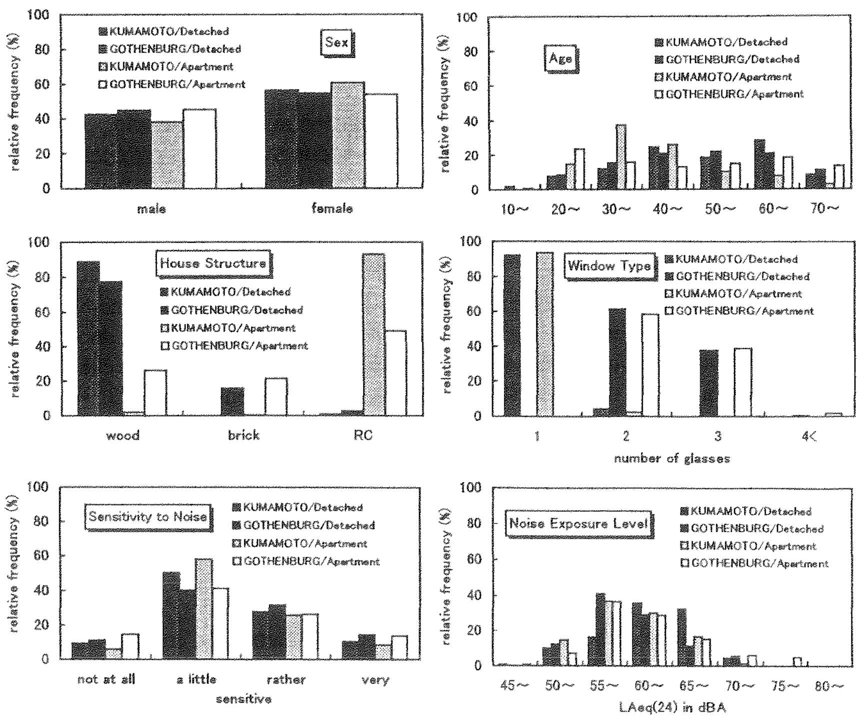

Figure 1. Relative frequencies of responses to questions concerning personal and housing factors and noise exposure levels

and 837 in Kumamoto, and the response rates were 68.8% and 69.3%, respectively. After the questionnaires were completed, two types of physical measurements were made in each area. One was a 24-hour continuous noise measurement at a reference point close to the roadside. The other was a noise reduction measurement at the 5, 10, 20 and 40-meter points on the ground level from the reference point and at each floor level of apartment houses. The noise exposure for each house was determined using these data. The numbers and kinds of vehicles passing in front of the reference point were manually counted during the 24-hour measurement.

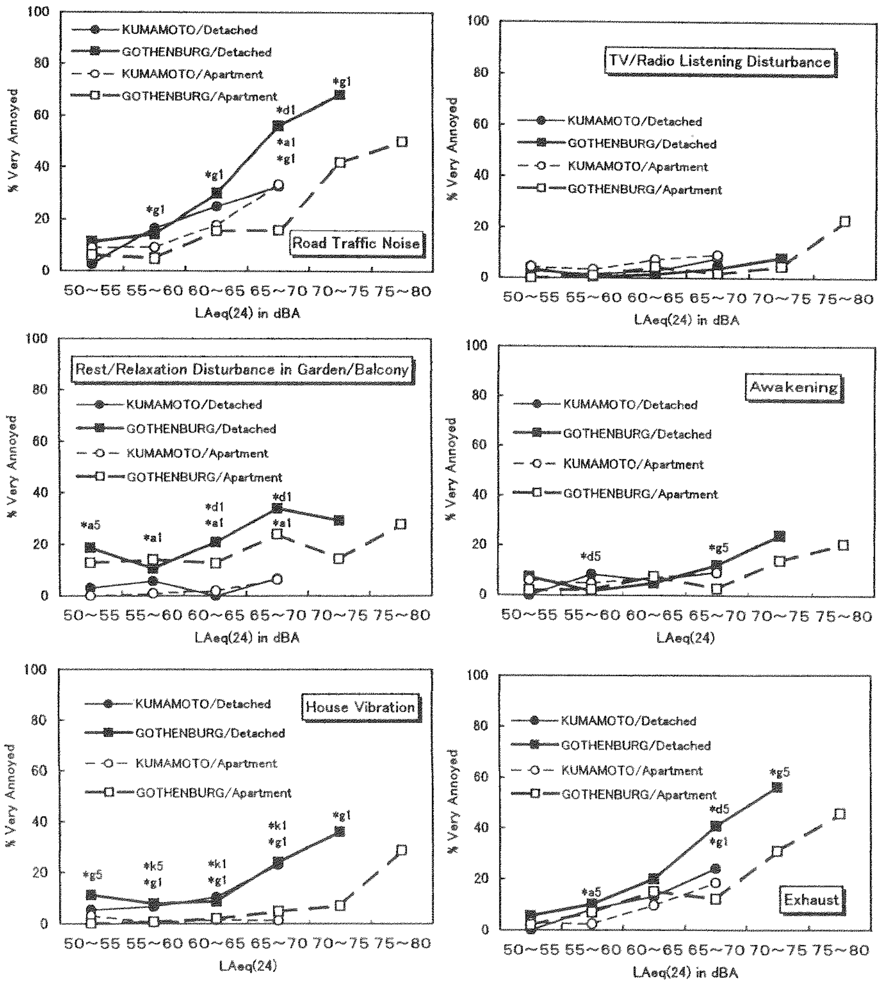

Figure 2. Comparison of community responses to acoustical and non-acoustical factors

"% Very Annoyed" refers to the proportion of people who responded "very annoyed."

*d1, *d5: Significant above 1% or 5% level between Gothenburg and Kumamoto (detached houses)

*a1, *a5: Significant above 1% or 5% level between Gothenburg and Kumamoto (apartment houses)

*k1, *k5: Significant above 1% or 5% level between detached and apartment houses (Kumamoto)

*g1, *g5: Significant above 1% or 5% level between detached and apartment houses (Gothenburg)

3. RESULTS AND DISCUSSION

Figure 1 shows the relative frequencies of responses to questions concerning personal and housing factors and noise exposure levels. The distributions of the responses on personal factors are similar, while the window types are quite different in the two cities. Community responses were compared on the basis of the dose-response relationships, as shown in Figure 2, in relation to "% very annoyed" between the cities and the housing types. People living in detached houses are found to be more annoyed by the same road traffic noise than those living in apartment houses in Gothenburg, while no significant difference is found between housing types in Kumamoto. On the other hand, activity disturbances indoors, such as disturbance in listening to TV/radio or awakenings from sleep showed no systematic differences between the cities, while activities and resting in gardens or on balconies are significantly disturbed in Gothenburg. This probably has to do with differences in the customs between the two cities, such as spending time enjoying outdoor life in gardens or on balconies in Gothenburg. As regards the non-acoustical factors, it is found that people living in detached houses are more annoyed by the house vibration caused by road traffic than those living in apartment houses, which may be explained by house structures. It is also found that people are annoyed by exhaust from road traffic to the same degree as they are annoyed by noise. Exhaust fumes are one of the most serious sources of annoyance in the living environment.

4. SUMMARY

Community responses to road traffic noise in western Sweden and southern Japan were compared cross-culturally on the basis of the dose-response relationships. The main results are summarized as follows: 1) People living in detached houses are more annoyed by the same road traffic noise than those living in apartment houses in Gothenburg, while no significant difference is found between housing types in Kumamoto; 2) As concerns activity disturbances indoors, there are no systematic differences between the two cities, while activities and resting in gardens or on balconies are significantly disturbed in Gothenburg; 3) People living in detached houses are more annoyed by the house vibration caused by road traffic than those living in apartment houses; 4) People are annoyed by exhaust fumes from road traffic to the same degree as they are annoyed by noise.

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CROSS-CULTURAL COMPARISON OF COMMUNITY RESPONSES TO ROAD TRAFFIC NOISE IN GOTHENBURG, SWEDEN, AND KUMAMOTO, JAPAN, PART II: CAUSAL MODELING BY PATH ANALYSIS

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1. INTRODUCTION

Path analysis [1] is a method based on causality to clarify the structural links between many related factors and has been widely used in the field of the social sciences. Taylor [2] first used the method in a noise annoyance study. He proposed an exploratory causal model for aircraft noise annoyance in relation to several acoustical and non-acoustical factors. The present authors also used this analysis in their own studies on the annoyance interaction of noise and vibration [3], the effects of noise barriers on traffic noise annoyance [4] and so on. This paper presents the results of path analysis applied to the data obtained in social surveys in Gothenburg, Sweden, and Kumamoto, Japan, following Part I [5]. The causal relations and the effects of several factors on annoyance are discussed.

2. PATH ANALYSIS

Path analysis was performed to compare the causal models that describe the multiple stratum relationships between road traffic noise annoyance, endogenous variables and exogenous variables. The path model can estimate not only the direct effect of a variable on annoyance but also the indirect effect of the variable via other variables. The exogenous variables, which are not dependent on other variables in the model, were selected from housing, personal and environmental factors, and the endogenous variables were selected from various activity disturbances and related effects, on the basis of the results of discrimination by factor analysis. The endogenous variables are partially dependent on some of the exogenous and the endogenous variables and have direct effects on road traffic noise annoyance. Noting the causal relations, an *a priori* path model was constructed using nine exogenous variables and seven endogenous variables,

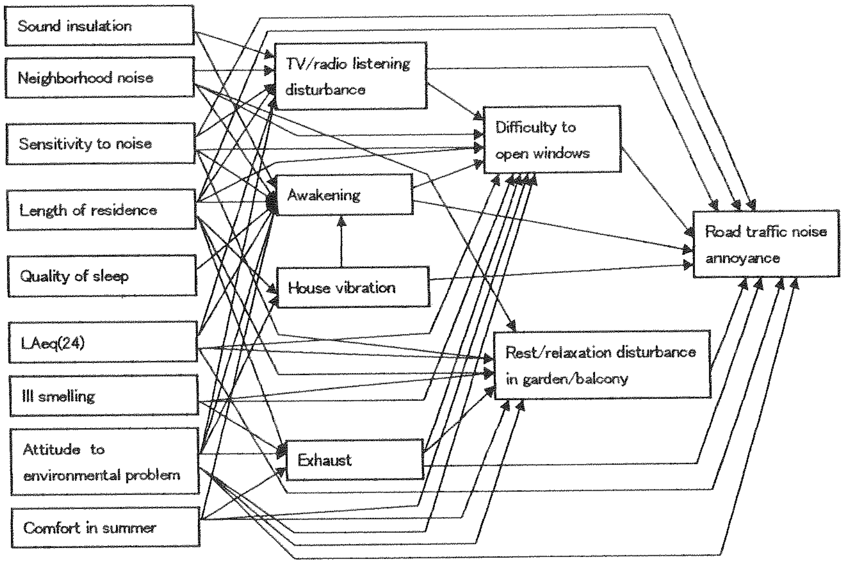
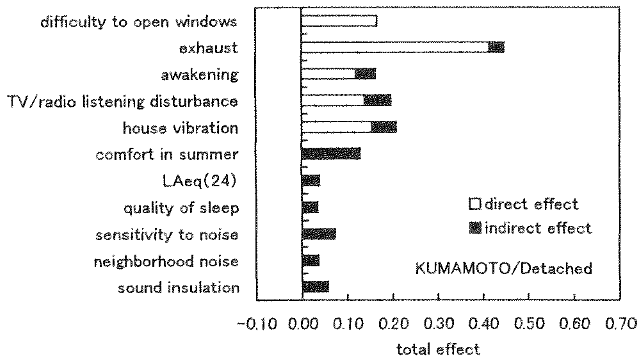


Figure 1. *A priori* path model of road traffic noise annoyance



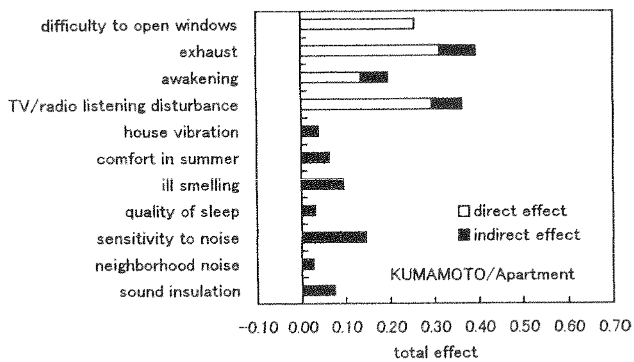
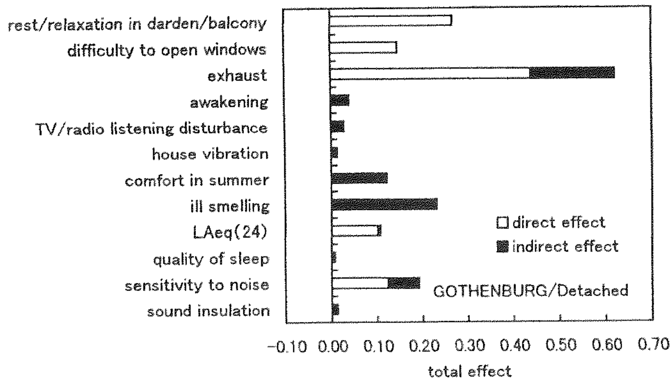


Figure 2. Effects on road traffic noise annoyance for revised model in Kumamoto

as shown in Figure 1. The arrows show the causal relations, cause and effect, between the variables. For example, this model shows that $L_{Aeq(24)}$ affects "road traffic noise annoyance" both directly and indirectly via "TV/radio listening disturbance." The linkage between non-acoustical factors, "house vibration" and "exhaust", and noise annoyance can be interpreted as the result of the subjective attitude against the noise sources of a respondent who is annoyed by vibration or exhaust. According to the normal solution of the path analysis, a series of structural equations were formulated to correspond with this *a priori* model. Most of the variables here are actually of the ordinal scale, but they are commonly treated as those of interval scale. The equations are the same as the multiple linear regression equations, and they are solved by the least square technique. The standardized partial regression coefficients are called path coefficients and show the strength of the linkage between variables. Among the paths in this model, some were statistically proved not to be significant. Deleting the insignificant paths above the 1% level, four revised path models were constructed for each housing type in the two cities. Figure 2 and Figure 3 show the summary of the effects on road traffic noise annoyance for the revised models. In all cases, it is found that exhaust has the strongest effect on noise annoyance. This can be interpreted as the



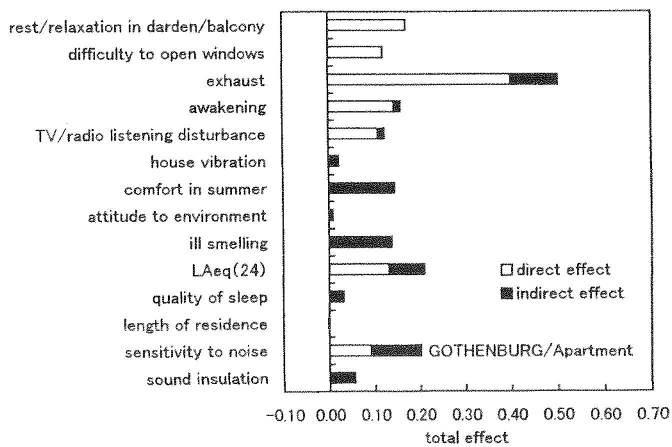


Figure 3. Effects on road traffic noise annoyance for revised model in Gothenburg

result of the subjective attitude against the noise sources. In Kumamoto, activity disturbance indoors, such as disturbance in listening to TV/radio, significantly affects noise annoyance, especially in apartment houses, while activity or rest disturbances in a garden/balcony have a strong effect in detached houses in Gothenburg. This may owe to the different customs in Kumamoto and Gothenburg, such as spending a great deal of time in well air-conditioned rooms in the hot climate of Kumamoto, while the outdoors is enjoyed in gardens or on balconies in Gothenburg. It may be also dependent on housing types. On the other hand, the noise level presented by $L_{Aeq(24)}$ does not have a very strong direct effect on noise annoyance.

3. SUMMARY

The characteristics of annoyance responses obtained by path analysis are as follows: 1) Noise annoyance is most strongly affected by exhaust fumes; 2) In Kumamoto, activity disturbance indoors, such as TV/radio listening disturbance, significantly affects noise annoyance, while activity or rest disturbances in gardens/balconies have a strong effect in Gothenburg, owing to the difference in customs between southern Japan and western Sweden. It is also dependent on housing types; 3) Noise level presented by $L_{Aeq(24)}$ does not have a very strong direct effect on noise annoyance.

From two kinds of analyses in Part I and Part II, it is concluded that the non-acoustical factors, particularly exhaust from road traffic, and the different customs of the people living in different countries and in different types of housing are important for annoyance evaluation of road traffic noise. Further research is necessary to verify the findings obtained here.

4. ACKNOWLEGEMENT

Grateful acknowledgement is given here to the late President Kiyoto Izumi of Muroran Institute of Technology for giving us the opportunity to conduct the international joint study.

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A POLITICAL RESPONSE TO AIRCRAFT NOISE

REES, A

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The decision by members of communities affected by aircraft noise to form a political party was a highly unusual one. The normal community response to an environmental problem is to form lobby groups which seek to influence the major political parties rather than to challenge them directly as electoral opponents. This paper assesses the effectiveness of this political strategy.

In January 1995, two months after the opening of the third runway at Sydney KSA airport, the No Aircraft Noise Party was formed by residents of inner western suburbs to campaign in national, state and local elections. The third runway concentrated aircraft movements north of the airport almost doubling movements over the inner western suburbs overnight.

Many No Aircraft Noise members had been involved in community lobby groups and had experienced problems with the Labor Party attempting to lead these groups. It was fundamentally dishonest for Labor MP's to try to lead community opposition while remaining loyal to their party which was expanding the airport. These MP's were allowed by the party hierarchy to act as phoney independents in order to hold their seats. The Liberal Party is now using this strategy and both parties allowed western Sydney candidates to present completely different positions to the inner city candidates during the 1998 national elections.

In the New South Wales state elections of March 1995, No Aircraft Noise candidates won votes of 23.5% and 19.5% in their best two seats. In the local government elections of September 1995, ten No Aircraft Noise councillors were elected to five councils. Since that time, three of them have served one year terms as mayors of Leichhardt, Hunters Hill and Ashfield councils. In the national elections March 1996, No Aircraft Noise candidates polled 14% and 6.8% in two much larger federal electorates.

The political campaign by No Aircraft Noise resulted in a policy split in the bipartisan position of the two major parties (Labor and Liberal) which had both supported the third runway. After a change of government, the Liberals changed the flightpaths in an effort to share the noise. This has not resulted in a stable political situation and aircraft noise remains a major political issue in Sydney.

No Aircraft Noise has also challenged the terms of the airport debate in Sydney with its call for the closure of the inner city KSA and its replacement by a new airport outside the Sydney basin. While the No Aircraft Noise position has yet to be adopted by either major party, it is now supported by the two minor Senate parties, (the Greens and the Australian Democrats) as well as a coalition of residents and political groups drawn from all areas of Sydney. In the meantime, despite the passage of enabling legislation, the Liberal government has been unwilling to offer Sydney KSA for sale in its airport privatisation program.

While No Aircraft Noise can claim some success in delaying privatisation of KSA and dividing the major parties, it faces the challenges of being effective as a single issue party with a small core of active members.

Before the national elections of October 1998, the No Aircraft Noise Party changed its name to Common Cause - No Aircraft Noise in order to try to break from the single issue mould and to reflect the work of its local councillors who were taking up a series of issues on behalf of inner city residents. New policies were adopted but we were still seen as almost exclusively preoccupied with aircraft noise.

The group had found it hard to gain members in newly noise affected areas and politicians from major parties promoted lobby groups as the way for people to oppose the airport.

Common Cause - No Aircraft Noise remains a viable political group participating in elections in Sydney's inner west, fielding candidates in four electorates as well as the Senate in the 1998 national elections. Our membership and supporters were able to campaign effectively with letterboxing, posters and How To Vote cards. However, in these elections the CC – NAN vote slipped to between 4% and below 1%.

The government had moved to lower noise in worst affected areas where we had our highest support and where people had been angry enough to abandon their traditional political allegiances. In gaining this reduction in noise, we have also lost votes as people returned to more traditional voting patterns.

An announcement by Sydney airport that the air traffic would double by 2010 was delayed until just after the elections. In this statement the authorities said that this traffic increase could not be accommodated with the present seven hour curfew and the capacity limit of 80 movements per hour.

Our future for the moment appears to be at the local government level where we can campaign on the record of our councillors, local issues making the airport our flagship issue. Local government has played a substantial role in the airport conflict with councils organising public meetings and demonstrations at the airport as well as legal challenges.

The No Aircraft Noise Mayor of Ashfield's campaign against the airport was responsible for the resignation of a government MP. The government's noise sharing plan greatly increased noise over this area and the MP felt obliged to resign from the Liberal Party. The former Liberal ran as an independent in the 1998 national elections. He adopted a virtually identical airport policy to CC-NAN and received 15% of the vote, with the seat going to the opposition.

The tactic of taking on the political parties was very effective in the short term, gaining significant concessions and focussing a great deal of pressure on the two main parties. However the long term aim of Common Cause - No Aircraft Noise is to close the present Sydney Airport and replace it with a new airport outside the Sydney basin. Having established a base on local councils the usefulness of these electoral tactics will be tested in the upcoming local elections to be held in September 1999 and in the continuing campaign to move Sydney airport.

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INFLUENCE OF SOUND QUALITY TO ANNOYANCE CAUSED BY ROAD TRAFFIC NOISE

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1. INTRODUCTION

In Japan, road traffic noise is a major source of noise pollution. To reduce annoyance caused by road traffic noise this noise, which is generally evaluated by LAeq (A-weighted equivalent sound level) is regulated by Environmental Quality Standards. To investigate various factors affecting annoyance caused by road traffic noise, we already carried out a social survey[1] . Figure 1, which was the result of these survey, shows the relationship between the noise exposure level in LAeq and the annoyance which is interpreted as *the percentage of highly annoyed people* [2]. It was found in Figure 1 that in cases where LAeq were the same, the resident's degrees of annoyance were varied. As can be seen in Figure 1, the curve reprensenting the percentage of highly annoyed people who can view the road from their house is significantly shifted higher than those of people who can't view the road. As the reasons for these differences, a psychological influence by the visual existence of traffic flow or a psychoacoustical influence by the differences of sound quality between direct propagated traffic noise and

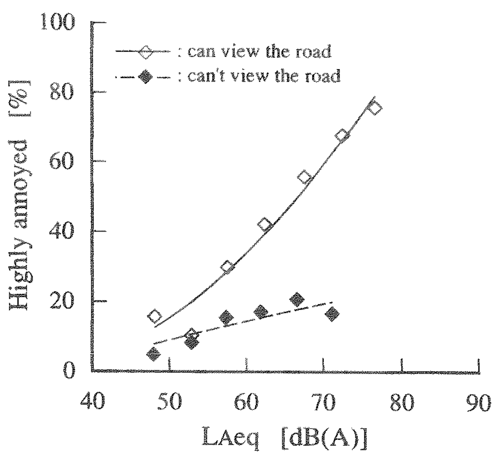

Fig.1 Influence of the visual existence of the roads on the percentage of highly annoyed people

indirect propagated traffic noise may be considered.

This paper describes a laboratory study to investigate the visual influence of traffic flow on the annoyance caused by road traffic noise and the psychoacoustical influence of sound quality of road traffic noise on annoyance. For this purpose, two kinds of subjective evaluation test were carried out using various kinds of road traffic noise .

2. TEST 1:Subjective evaluation test investigating the visual influence of trafic flow

To investigate the visual influence of traffic flow on the annoyance caused by road traffic noise, the following first subjective evaluation test was carried out.

Stimili

30 kinds of road traffic noise recorded on a road side with projection of a video film of the scenery around the road side with and without the visual existence of traffic flow were used as the stimili for Test 1. These test noise ranged from 49-69 dB(A) in LAeq.

Subjects

8 female and 28 male subjects with normal hearing ability participated in Test 1.

Test procedure

Test 1 was carried out in a soundproof room. Test noise was presented in randomized order for 40 seconds with and without the scenary of traffic flow through two loud speakers and a video projector. Subjects were asked to evaluate the annoyance level caused by road traffic noise using five categories (1: not at all, 2: slighly, 3: moderately, 4:very, 5: extremly) along annoyance scale.

Test result

Figure 2 shows the relationship between the annoyance level evaluated by subjects and LAeq of test road traffic noise in each group the stimili with or without the visual existence of traffic flow. As can be seen in Figure 2, the annoyance in the case where the visual existence of traffic flow was not higher than that in non-existence of visual traffic flow. From the comparison of

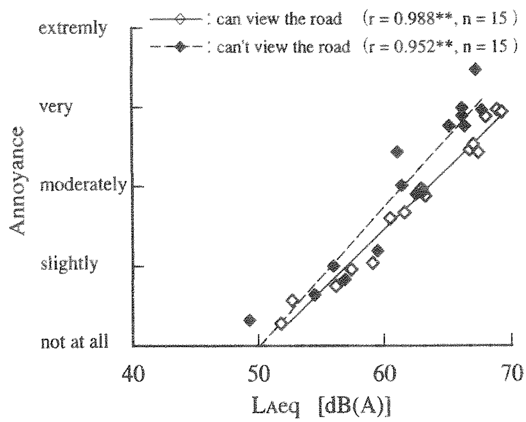

Fig.2 Relationship between the annoyance level and LAeq (** : significant , $P < 0.01$)

Figure 1 and Figure 2, it was concluded that the visual influence of traffic flow on annoyance was not significant.

3. TEST 2: Subjective evaluation test investigating the influence of sound quality of road traffic noise

To investigate the influence of sound quality of road traffic noise on annoyance, the following second subjective evaluation test was carried out.

Stimili

48 kinds of road traffic noise recorded simultaneously at the edge of the road, at the location where direct sound propagation from the main traffic was confirmed and at the location behind the building without direct sound propagation were used as the stimili for Test 2. These test noise ranged from 54-74 dB(A) in LAeq.

Figure 3 shows the differences on the frequency spectra between the direct propagated noise and the indirect propagated noise. Among the frequency spectra of these noise, the differences of the SPL on high frequency components higher than 2.5kHz were significant.

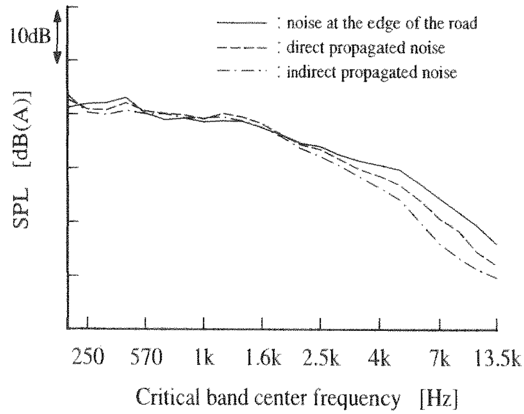

Fig.3 Difference on the frequency spectra between direct propagated noise and indirect propagated noise

Subjects

9 female and 24 male subjects with normal hearing ability participated in Test 2.

Test procedure

This test was also carried out in a soundproof room. Test noise was presented in randomized order for 40 seconds without video film through two loud speakers. Subjects were asked to evaluate the annoyance level using five categories along annoyance scale.

Test result

Figure 4 shows the relationship between the annoyance level evaluated by subjects and LAeq of test road traffic noise in each group, i.e., the noise at the edge of the road, the direct propagated noise or the indirect propagated noise.

From Figure 4, it was found that the annoyances were different between the three groups due to the differences on the high frequency noise while LAeq were the same.

Figure 5 shows the relationship between the annoyance level and fluctuation strength[3] of test road traffic noise. Figure 5 indicates that fluctuation strength has higher correlation than LAeq with annoyance. The differences of annoyance to the three groups of road traffic noise by the influence of sound quality are smaller when annoyance is expressed in fluctuation strength than in LAeq instead.

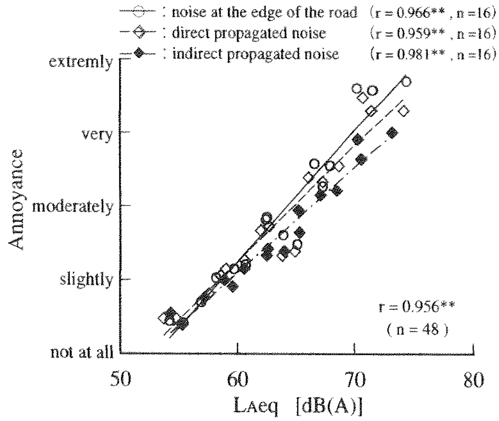

Fig.4 Relationship between the annoyance level and LAeq (** : significant , $P < 0.01$)

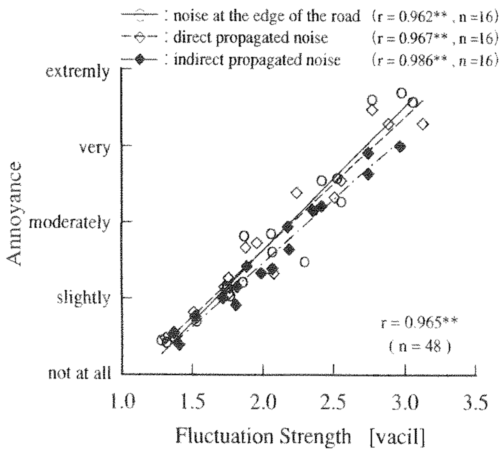

Fig.5 Relationship between the annoyance level and fluctuation strength (** : significant , $P < 0.01$)

Multiple regression model

From the Figure 4, LAeq and other psychoacoustical factors such as roughness[3], sharpness[3] or fluctuation strength may be considered to affect annoyance caused by road traffic noise. To investigate the influence of LAeq and the other factors on the annoyance, the following several multiple regression models were analyzed.

Model 1 : annoyance=f(LAeq, roughness, sharpness)
Model 2 : annoyance=f(LAeq, roughness)
Model 3 : annoyance=f(LAeq, sharpness)
Model 4 : annoyance=f(LAeq, fluctuation strength)

The result of the multiple regression analysis gave the multiple correlation coefficients and partial correlation coefficients between each predictor and the annoyance level in

Table 1 Result of multiple regression analysis

	Partial correlation coefficient				Multiple correlation coefficient
	LAeq	Roughness	Sharpness	Fluctuation strength	
Model 1	0.477 **	0.003	0.320 *		0.961 **
Model 2	0.434 **	0.833 **			0.956 **
Model 3	0.928 **		0.330 *		0.961 **
Model 4	0.097			0.450 **	0.965 **

(** : significant ($P < 0.01$) , * : significant ($P < 0.05$))

Table 1. From Table 1, it was found that besides LAeq, roughness and sharpness significantly contributed to annoyance simultaneously.

Influence of high frequency component

The differences on the SPL of high frequency components between direct propagated noise and indirect propagated noise as indicated in Figure 3 may influence the differences of the annoyance in the case where LAeq were the same. To investigate the influence of high frequency components of road traffic noise on annoyance, the proportion of high frequency noise to overall noise was defined as indicated in Figure 6. Using this parameter and LAeq the following multiple regression model was analyzed.

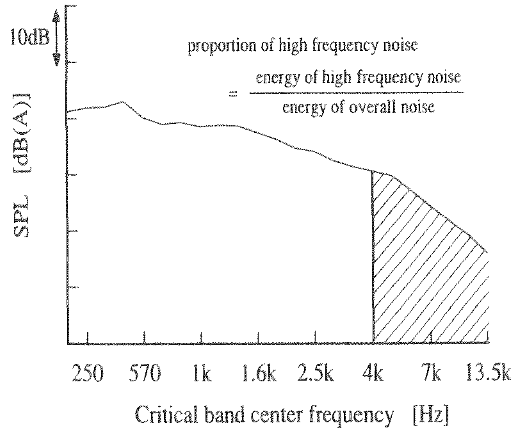

Fig.6 Proportion of high frequency noise to overall noise

Model 5 : annoyance=f(LAeq, proportion of high frequency noise)

Figure 7 shows the multiple correlation coefficients and the partial correlation coefficients between the annoyance level and the proportion of high frequency noise in each case where the lower frequency limit was changed for the calculation in the proportion of high frequency noise. As indicated in Figure 7, besides LAeq, the influence of high frequency noise above 4.8kHz on annoyance was significant.

4. CONCLUSION

To investigate the visual influence of traffic flow and the influence of sound quality on annoyance caused by road trffic noise, two kinds of subjective evaluation test were carried out. As a result, we found that (1) from the first test, the visual influence of the traffic flow on annoyance was not significant, and (2) from the second test, annoyances were different due to the differences on the high frequency noise while LAeq of road traffi noise were the same, (3) fluctuation strength had higher correlation than LAeq with annoyance, (4) besides LAeq, roughness and sharpness significantly contributed to annoyance simultaneously.

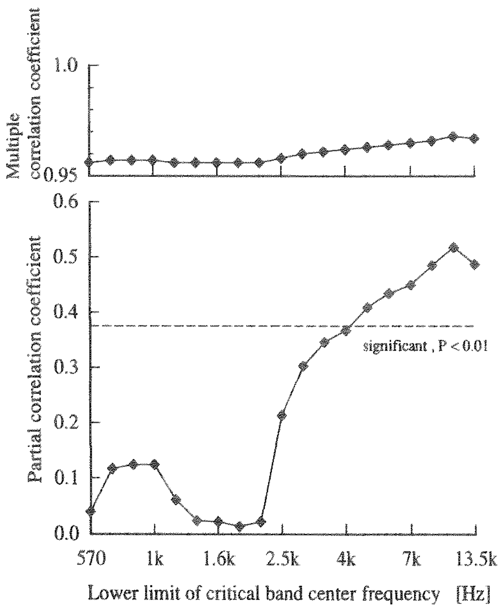

Fig.7 Contribution of high frequency noise to the annoyance (all multiple correlation coefficients were significant, P< 0.01)

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MANAGEMENT OF NOISE IN THE GOOSE BAY MILITARY TRAINING AREA

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1. BACKGROUND

This paper presents the management issues related to potential noise disturbance resulting from military low-level flying on human activity and sensitive wildlife.

Canada provides a 130,000 square kilometre remote wilderness area in Labrador and Eastern Quebec for foreign military training. The prime focus is low-level (terrain masking) training. An average of 7000 subsonic flights are conducted at altitudes as low as 100 feet above ground (or highest obstacle).

A single community (population 800) is within the training area and protected by a buffer zone with a 10 nautical mile radius. Several aboriginal communities neighbour the training area, and practice traditional hunter/gatherer type resource harvesting activities within the training area. The training area also contains several species of endangered, naturally rare, commercially or culturally important wildlife thought to be sensitive to noise. These include the George River caribou herd (800,000 animals - largest caribou herd in the world, Red Wine Mountain caribou herd (threatened), Peregrine Falcons (endangered), Bald Eagles (naturally rare), Osprey, Moose (sensitive during late winter period), Golden Eagles (naturally rare), and Gyrfalcons (naturally rare).

The military training activity was initiated in 1989. The potential environmental impacts that might result from this activity have generated concern both in the scientific community and by the public. In response to these concerns and the potential for expansion of the training activity at Goose Bay, the Minister for National Defence directed that the activity be subjected to an exhaustive public review by an independent panel [1]. This review was completed in 1994. While this panel submitted 58 recommendations, the panel found that "there is little evidence at this time to suggest that the Project will cause significant negative environmental social or health impacts"[2].

2. MANAGEMENT CHALLENGE

Jet overflights generate near-impulse noise levels, with peak values as high as 114db and onset rates of about 26 db/sec at extreme low-levels (Figure 1). The resulting disturbance on exposed wildlife is thought to have both short and long term effects. Short-term behavioural responses to the startle reaction are thought to result in energetic costs to the individual animals, potential injury, breaking of the cow/calf bond, interruption of the incubation cycle, and abandonment of nests. Long-term effects are thought to result in abandonment of traditional (high quality) habitat.

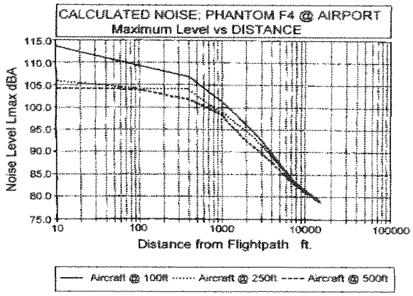

Figure 1

Human response to exposure results in a startle reaction similar to that experienced by wildlife. While the probability of an individual being overflown is quite low, an overflight in a such wilderness environment can be frightening, particularly to children and elders. Potential effects range from annoyance to hearing loss to non-auditory diseases such as cardiovascular diseases, mental and psychosomatic illnesses. Unfortunately, the potential effects are not well understood.

3. MITIGATION APPROACH

The Goose Bay training area is somewhat unique, both in the scale of the activity and the extreme low-levels of training conducted. When the training activity was first implemented, there was little conclusive research into the effects of such activity on humans or wildlife. National Defence adopted a cautious approach to management of the noise problem and mitigating potential effects. Spatial and temporal separation of the flying activity from sensitive areas was adopted as the most practical method to mitigate potential effects. This approach permitted the training activity to be conducted in an environmentally sensitive and sustainable manner, while permitting the effects of the activity to be investigated.

Mitigation for wildlife involves a two-part program consisting of a series of real-time, or near real-time monitoring studies to gather population densities and locations for each of the target species, and the application of a standardized criterion for establishing restrictions to flying activity. In developing these criteria, the best understanding of the species sensitivity, or its perceived sensitivity to noise was applied. As the understanding of noise effects is enriched, these criteria will be adjusted.

Human activity within the training area is generally low intensity and unpredictable. Therefore, protection of human activity areas relies on self-reporting by the affected groups. As information is received, restrictions are established using a criterion similar to that for wildlife.

4. MANAGEMENT OF THE FLYING AREA

Sensitive areas are restricted from military use for the sensitivity period. Based on the human and wildlife data gathered, daily flight restrictions are issued identifying those parts of the training area that are not available for training. The final component of the noise management concept is a compliance monitoring program that includes participation by the aircrew and a Geographic Information System (GIS) developed specifically for this role. Following each mission, aircrews provide detailed flight information including altitude, speed and turning points. For each training day a constraint map is constructed in the GIS, depicting the protected areas for that day. From the aircrew data, individual flight tracks are constructed and overlaid on the constraint map and analysed to verify that protected areas were not disturbed. Figure 2 presents a typical constraint map detailing sensitive areas and the military flight activity for that day.

5. THE WAY AHEAD

Government has been sensitive to the public concerns. At the conclusion of the environmental review, an independent Institute was established. While National Defence remains responsible for the mitigation of potential effects of its activity, the Institute the mandate to conduct effects research and to monitor the mitigation and compliance programs conducted by National Defence. This Institute has a Board of Directors representing stakeholders and a scientific review committee to advise on research initiatives.

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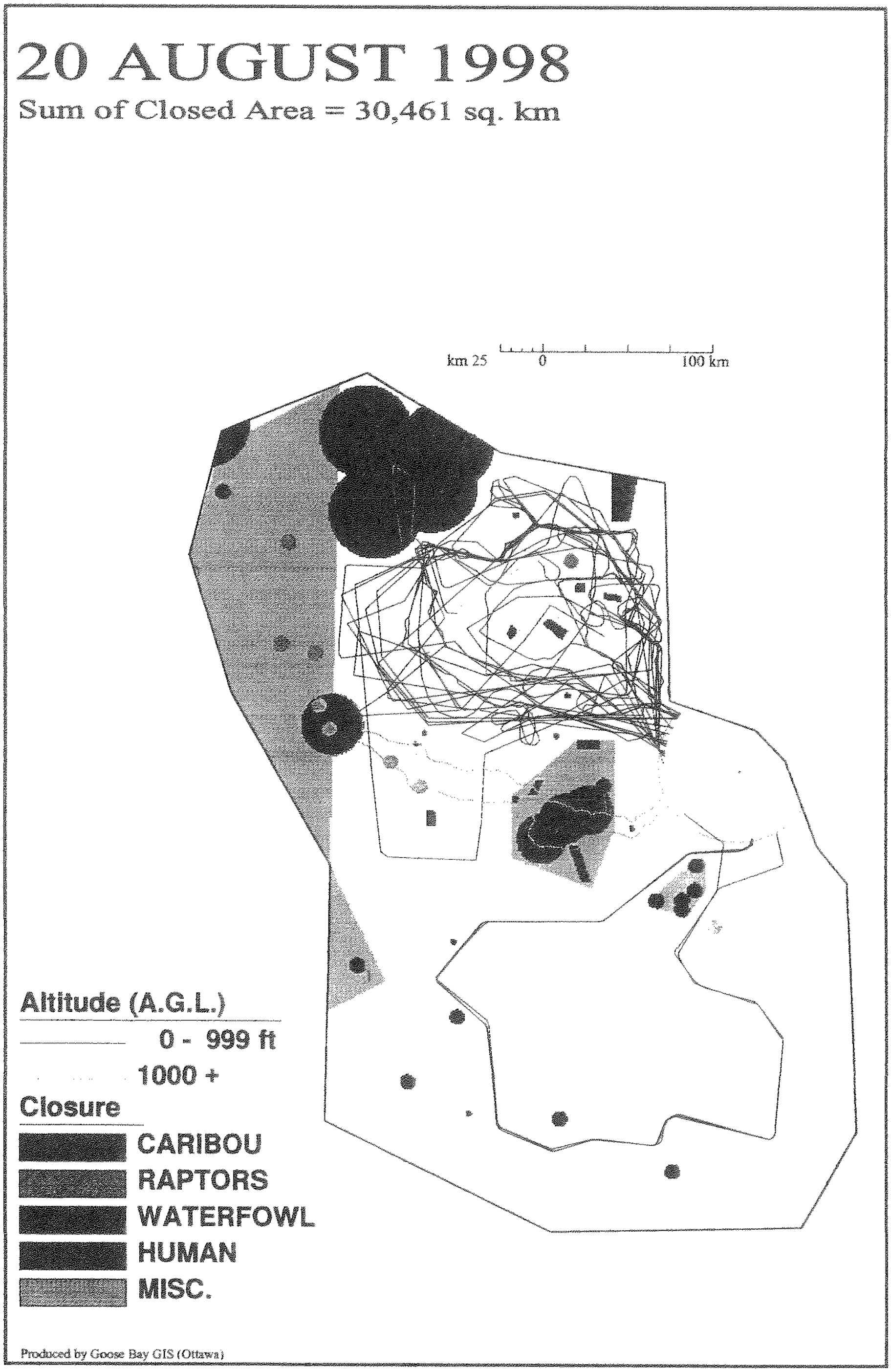
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Sum of Closed Area = 30,461 sq. km
km 25
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HUMAN
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Produced by Goose Bay GIS (Ottawa)

Figure 2

COMPARISON OF RESPONSES TO ROAD TRAFFIC AND RAILWAY NOISES

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1. INTRODUCTION

Community responses to noise from different environmental sources such as road traffic, railway and aircraft have been compared by Schultz [1], Fields et al [2], and Moehler [3]. Though Schultz did not recognize the systematic difference in dose-response relation between noise sources, the others indicated that railway noise was significantly less annoying than road traffic noise. Such results are now reflected in noise criteria in some European countries.

However, community response to noise may be strongly affected by the survey method and cultural aspects such as lifestyle, house structure and so on. Thus social surveys on community responses to road traffic and railway noises were carried out with a common method in the northern part of Kyushu, Japan, which is a warmer area with a distinctly different culture from Europe. The aim was to directly compare the responses between both noises and to investigate the differences in responses between Europe and Kyushu.

2. SOCIAL SURVEY

Social surveys on community responses to road traffic and railway noises were carried out in Kyushu with common questionnaires and noise measurement methods. Table 1 shows the outline of the survey. Respondents, 20 to 70 years of age, were randomly selected on a one-person per family basis from houses facing roads in Kumamoto city or its suburban area and railways from Kumamoto to Fukuoka. The sample sizes are 811 and 464 and the response rates are 79.2 and 79.6 % in road traffic and railway noise surveys, respectively. Annoyance caused by both noises was measured with the same 4-point verbal scale: 1) not at all, 2) a little, 3) rather and 4) very annoyed.

Road traffic noise was measured at a reference point, the road shoulder, for 24 hours with a noise level analyzer (B&K 4435). Short-term measurements for

Table 1 Outline of surveys

	Road traffic noise	Railway noise
Survey site	20 sites in Kumamoto City 2 sites in Omuta and Arao City	Residential area along railway from Kumamoto to Fukuoka
Date	1993.9-1996.6	1994-1995
Traffic volume (vehicles/day)	3,936-44,787	72-414
Sample size	811	464
Response rate (%)	79.2	79.7
L_{Aeq} (dB)	41.1-73.9	33.8-73.7

distance reduction were also conducted at the road shoulder and several points from the road simultaneously. A distance reduction equation was formulated at every site and noise reduction from the road to each house was calculated. Noise exposures to houses were calculated from 24-hour noise indices at the road shoulder and the noise reduction for each house. Almost the same method was used for railway noise except that noise exposures at the reference point were calculated from several measurements for various types of trains and the number of passing trains referring to the timetable.

3. COMPARISON OF DOSE-RESPONSE RELATION BETWEEN ROAD TRAFFIC AND RAILWAY NOISES

Figure 1 shows the distribution patterns of relative frequencies of demographic variables, evaluation of natural environment, sensitivity to noise and noise exposure for respondents in the road traffic and railway noise surveys. There is no systematic difference between both surveys. This means that the responses to noise can be precisely compared.

Figures 2 and 3 show comparisons of dose-response relations for general annoyance and TV/radio disturbance between road traffic and railway noises. Though a systematic difference is found in TV/radio disturbance between both noises, there is no systematic difference in general annoyance. This is quite different from the finding that railway noise is consistently less annoying than road traffic noise in Europe.

4. PATH ANALYSIS OF ROAD TRAFFIC AND RAILWAY NOISE ANNOYANCES

In order to investigate why there are differences in dose-response relations for road traffic and railway noise annoyances between Kyushu and Europe, a path analysis was applied to the road traffic and railway noise data in Kyushu and the annoyance profiles for both noises were compared.

Figure 4 shows an a priori path model of road traffic noise annoyance that was constructed using our previous findings and experiences. This model describes the causal relation between general annoyance and various factors that affect annoyance directly or indirectly. For example, L_{Aeq} affects annoyance not only directly but also indirectly via TV/radio disturbance or awakening. The a priori path model of railway noise annoyance is the same as that of road traffic noise annoyance except that there are not annoyance caused by exhaust, sensitivity to air pollution and road safety in the model.

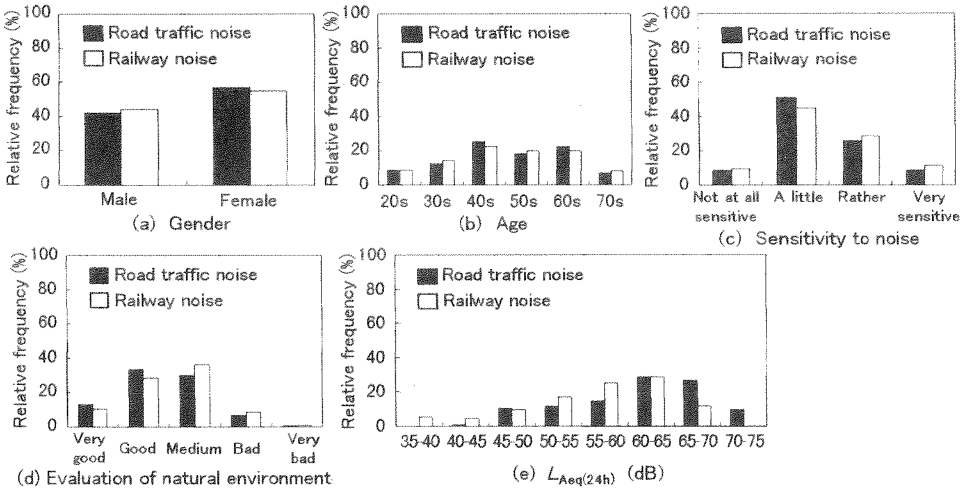

Figure 1 Relative frequencies of demographic, personal factors and noise exposure

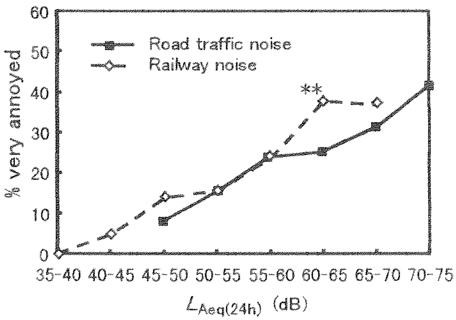

Figure 2 General annoyance

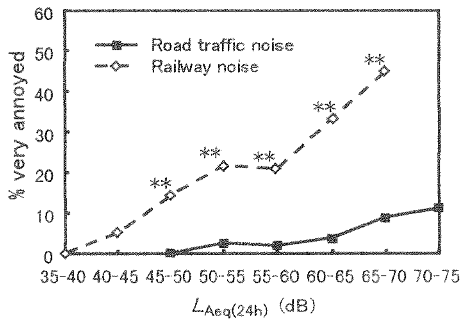

Figure 3 TV/radio disturbance

Based on the linkage between general annoyance/activity interference and various factors, the structure equations were formulated. The standardized partial regression coefficient is called the path coefficient and the magnitude shows the strength of the linkage. The path coefficient showing direct linkage between annoyance and a factor is called the direct effect. The sum of the products of path coefficients from a factor to annoyance via various activity interference is called the indirect effect. The sum of the direct and the indirect effects is the total effect for the factor. The revised path models were reconstructed using only factors with path coefficients significant at the 1-% level. Figures 5 and 6 show the results of path analysis for revised models.

Annoyance caused by exhaust most strongly affects road traffic noise annoyance and TV/radio disturbance strongly affects railway noise annoyance. Such a difference in annoyance profile between road traffic and railway noises may explain the difference in dose-response relation between Kyushu and Europe. Though double pane or more windows are generally found in northern Europe, only single

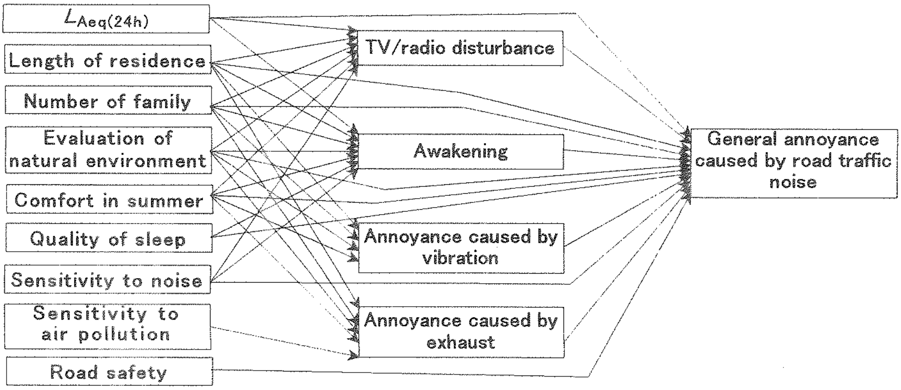

Figure 4 A priori path model of road traffic noise annoyance

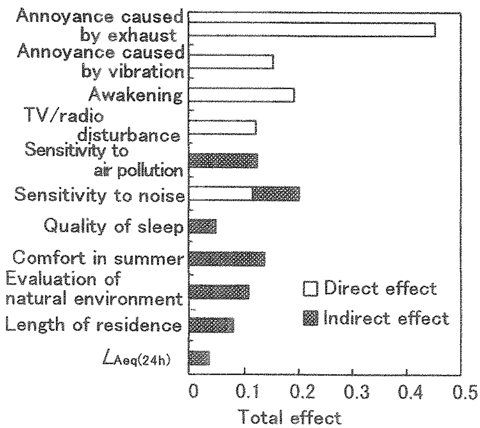

Figure 5 Profile of road traffic noise annoyance

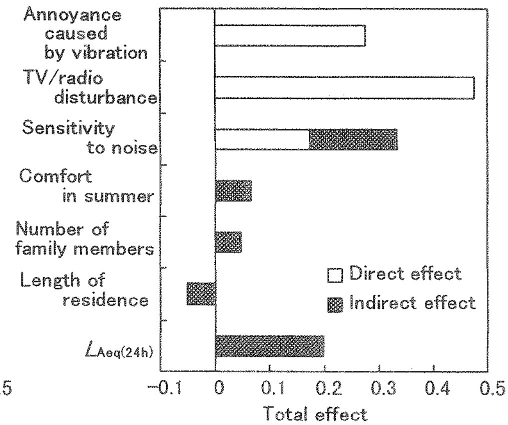

Figure 6 Profile of railway noise annoyance

the difference in listening disturbance and then affect railway noise annoyance. That is, railway noise may be more annoying in Kyushu than Europe. On the other hand road traffic noise annoyance is affected by non-acoustic factor like exhaust and seems to be less affected by window sound insulation. Furthermore, in European lifestyle people take great care to rest in the garden and this is very affected by exhaust. This is probably the reason why road traffic noise is more annoying than railway noise in Europe.

This finding suggests that sound insulation measures are useful for railway noise and that not only sound insulation measures but also exhaust measures are necessary to reduce road traffic noise annoyance. That is, a belt of trees or hybrid/electric cars may be useful for the measures of road traffic noise annoyance.

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Community Response to Traffic Noise along Trunk Roads in Tokyo

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Introduction

The effects of noise on health are related to many noise and individual factors, e.g., noise levels, distance from the noise source, age, sex, history of exposure, etc. The present survey was administered to estimate the influence of traffic noises on the health of inhabitants along trunk roads in Tokyo.

Materials and Methods

The subjects for the survey were a total of 2,500 women aged 20-60 years, extracted by five hundreds from 3 roads, 5 areas, living within 100m from the straight surface to the depth of trunk roads in Tokyo. The survey was conducted during a 3-year period, from 1994 to 1996. Extraction of the above subjects was made using inhabitants' basic registers and housing maps.

1) In terms of the influence on health, the questionnaire was based on mental and physical health conditions, sleep conditions and noise annoyance. The questionnaires, which had been pre-mailed, were recovered at the homes of the subjects by examiners by appointment.

2) Road traffic noise levels were contoured on the basis of noise levels measured at many points, instead of distances from roads; in addition, exposure levels in each household were identified. The selection of points of noise measurement was made on a housing map. Lines parallel to roads were drawn on both sides of roads at 12.5m from the road border, and areas on roads and road borders intersecting these distance lines were selected as candidates.

Results

Recovery rates for questionnaires in 5 areas were 68, 75, 76, 79 and 79%, respectively, totaling 75.2%.

1) Daily life noise annoyance due to road traffic noises showed a dose-response relationship, but no definite casualty regarding hearing impairment or some other disease was observed.

2) In terms of noise level, the range of fluctuation in one day-noise level

according to 10-minute measurements at fixed points and fixed time was higher than 70dB(A) in L_{Aeq} for roads A, B and C, compared with 70dB(A) at night. These noise levels quickly became attenuated for houses one row from the route, and large-sized structures, in particular, underwent a remarkable shielding effect. On the other hand, the noise contour presented a considerably complicated aspect.

Conclusion

In an effort to estimate the influence of traffic noise on human health, a 3-year survey was conducted on women living within 100m depth from the straight surface of trunk roads in Tokyo. As a result, a dose-response relationship was noted between noise levels and annoyance or mental/physical conditions or sleep conditions.

Table 2 Mental and physical conditions/sleep conditions and noise levels

L_{Aeq}	L_{Aeq24h}					$L_{A50(d)}$					$L_{A50(n)}$					Distance from the road				
Year	1994	1995	1995	1996	1996	1994	1995	1995	1996	1996	1994	1995	1995	1996	1996	1994	1995	1995	1996	1996
Roads & areas	A-1	A-2	B-1	A-3	C-1	A-1	A-2	B-1	A-3	C-1	A-1	A-2	B-1	A-3	C-1	A-1	A-2	B-1	A-3	C-1
(1) headache	-	-	**	-	-	-	-	**	-	-	*	-	*	-	-	-	-	*	-	-
(2) morning cough	**	-	**	-	-	**	-	**	-	*	**	-	**	-	*	-	*	*	-	*
(3) too tired	-	-	-	-	-	-	-	*	-	*	*	-	-	-	*	-	-	*	-	*
(4) melancholy	**	*	-	-	**	*	*	-	-	**	**	*	-	-	**	*	*	-	-	**
(5) can't fall asleep easily	*	*	*	-	**	**	**	*	-	**	*	**	*	-	**	-	**	-	-	**
(6) wake up during the night	**	**	*	-	**	**	**	*	*	**	**	**	*	-	**	-	**	*	-	**
(7) bad temper for some time after waking up	-	-	-	-	*	*	-	*	-	-	-	-	-	-	-	-	*	-	-	*
(8) sleep badly	**	*	*	*	**	**	*	*	-	**	**	*	-	*	**	-	**	-	-	**
(9) irritated	*	-	**	-	**	*	-	**	-	**	*	-	**	-	**	*	-	*	-	**
(10) catch colds often	**	-	-	-	**	**	-	-	-	**	**	-	-	-	**	-	-	-	-	**
(11) feel heartbeat or shortness of breath while asleep	-	*	**	-	*	-	-	**	-	*	-	-	**	-	**	-	-	**	-	**
(12) feel oneself unhealthy	-	-	**	-	**	-	-	**	-	**	-	-	*	-	**	-	-	-	-	**
(13) disorders of the stomach	-	**	**	-	-	-	*	**	-	-	-	*	**	-	-	-	*	*	-	-
(14) ringing in the ears	-	-	*	-	-	-	-	*	-	-	-	-	**	-	*	-	-	*	-	*
(15) lack of motivation	-	-	**	-	**	-	-	**	-	**	-	-	**	-	**	-	-	*	-	**
(16) can't think logically	-	-	*	-	*	-	-	*	-	*	-	-	**	-	-	-	-	*	-	**
(17) want to shout suddenly	-	-	-	-	**	-	-	*	-	**	-	-	*	-	**	-	-	*	-	*
(18) no appetite	-	-	-	-	*	-	-	-	-	*	-	-	-	*	**	-	*	-	-	*

**: P<0.01 *: P<0.05 -: ns (P for trend)

Table 1 Age distribution by areas

Year	1994		1995				1996			
Age	Road A-1		Road A-2		Road B-1		Road A-3		Road C-1	
20-29	16	4%	42	12%	35	9%	31	8%	21	6%
30-39	100	25%	74	22%	89	22%	76	20%	88	23%
40-49	123	31%	104	31%	134	34%	114	30%	130	34%
50-59	148	38%	116	34%	136	34%	146	39%	134	35%
60	6	2%	2	1%	3	1%	7	2%	5	1%
Total	393		338		397		374		378	
N of subjects	500		500		500		500		500	
Recovery rates	79%		68%		79%		75%		76%	

ANNOYANCE AND ITS RELATED RESPONSES OF THE RESIDENTS AROUND KADENA U.S. AIRFIELD IN THE RYUKYUS

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1. INTRODUCTION

This study reports the results of the questionnaire survey conducted around Kadena US Airbase as well as Futenma Air Station in the Ryukyus, with respect to annoyance and its related responses of the inhabitants.

2. MATERIALS AND METHODS

The respondents are 5,008 male and female inhabitants randomly sampled from the areas with different levels of aircraft noise exposure expressed in WECPNL, from 75 to 95 or more designated by Defence Facilities Administration Agency (DFAA) of Japan, and 916 inhabitants from the area without noise exposure. The survey was conducted by means of leave-and-pick-up method. They answered the questions asking if they found the aircraft noise annoying, if TV listening and/or receiving are interfered, if they found their rest is disturbed by aircraft noise, if they are horrified by the aircraft noise. The respondents answered in the rating scales of five categories. For the question about annoyance the categories are 1.very annoyed, 2.pretty annoyed, 3.a little annoyed, 4.not much annoyed, 5.not annoyed at all. For the question about the interference with TV listening and/or receiving, the categories are 1.always, 2.from time to time, 3.once in a while, 4.scarecely, 5.not at all.

3. RESULTS

In Table 1 are tabulated the numbers of valid answers for which the age and sex of respondents are known and WECPNL of their homes are identified.

Table 1. Number of Answers

WECPNL	Kadena	Futenma	Sum
70–75		818	818
75–80	958	335	1293
80–85	906	295	1201
85–90	791		791
90–95	741		741
95–	164		164
Sum	3560	1448	5008

In Figures 1 to 6 are plotted the percentage of the respondents who answered 'yes' to some categories as a function of WECPNL. Note that WECPNL -75 in the figure indicates the noise exposure is under 75 exclusive of WECPNL. The response rate is adjusted so that every cell of age and sex matrix in each class of WECPNL has the same percentage of the respondents as the total respondents of the noise exposed areas.

As can be seen in the figures, very clear dose-response relationships are found in all the scales of annoyance and its related items. It is not surprising taking the content of questions and the wide range of the levels of aircraft noise exposure in the study area into account. The percentage of the "highly annoyed" for example starts increasing from the value of WECPNL of 75, gets higher as the level of noise exposure is high and reaches about 95 % at WECPNL of over 95. The tendency is more or less the same for the other questionnaire items. The percentage of the respondents complaining their TV listening are disturbed by aircraft noise, for example, begins to increase at WECPNL of 70 or 75 and gets higher as the level of noise exposure increases reaching to about 90 % at WECPNL of over 95. The time in a day when they are disturbed is basically daytime, but even in the midnight and very early in the morning over 40 % of the subjects living in the areas of WECPNL of 90 and over 95 complain disturbed.

The results shown in the figures reveal prominent difference of the curves of dose-response relationships between the two airfields. Response around Futenma is higher as far as the present questionnaire items are concerned. About 10 points' shift in WECPNL of the curves of Futenma toward right makes the two curves overlap each other. The cause of the difference, which is not small amount, is not very clear, but two theories can be raised. (1) The value of WECPNL having been designated in 1978 by DFAA does not express the recent state of the noise exposure around the airfields. (2) As a rating scale, WECPNL does not properly represent the effect of aircraft noise. It should be pointed out that the Futenma airfield controlled by the Marines are used by helicopters much more than Kadena airfield which is controlled by the U.S. Air Force. As a result the noise around Futenma airfield is of comparatively low level with longer duration, which makes it difficult for the automated measuring instrument monitoring aircraft noise installed around the airfield to identify aircraft noise and results in recording lower level of noise exposure.

Among other things the disturbance of TV reception is considered to represent the flight situation such as the number of flyovers. The discrepancy of the two curves concerning TV reception, therefore, strongly suggests that noise exposure or flyovers around Futenma is more than that around Kadena when WECPNL is equal.

4. CONCLUSIONS

Annoyance reaction and its related responses to aircraft noise around Kadena and Futenma airfields were analysed. Results clearly indicates that the response rate of the people are different between the two airfields. The noise dose around Futenma is likely to be 10 points higher than is designated by DFAA.

ACKNOWLEDGEMENTS

The authors wish to express their gratitude to Okinawa Prefectural Government for its support to carry out the study.

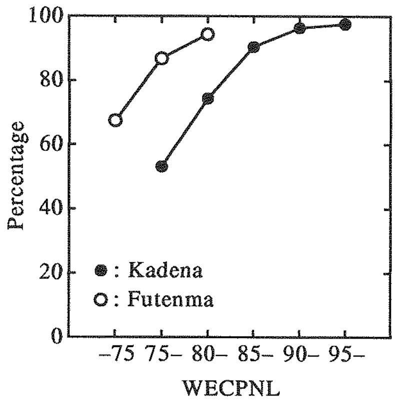

Figure 1. Annoyed.

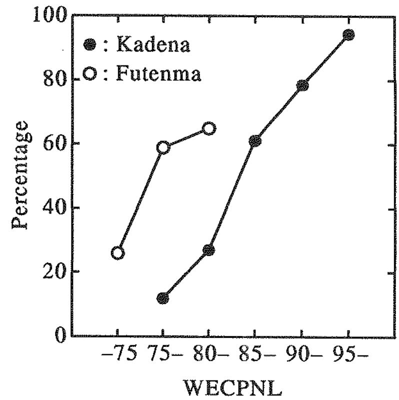

Figure 2. Highly annoyed.

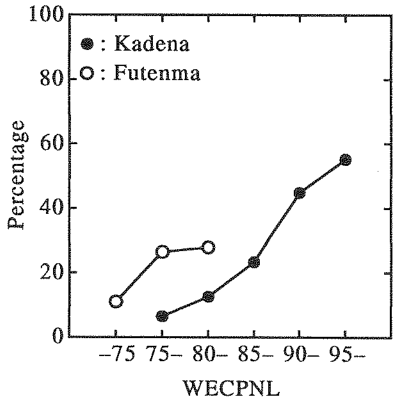

Figure 3. Restdisturbed.

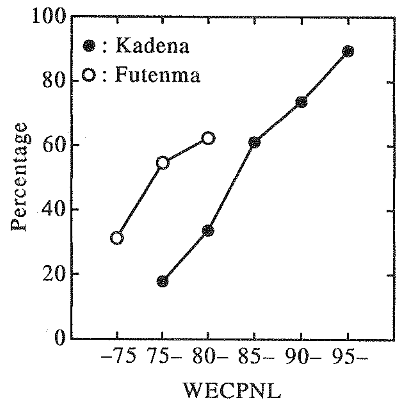

Figure 4. TV listening disturbed.

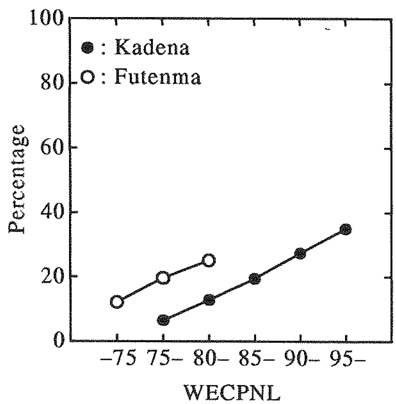

Figure 5. TV reception disturbed.

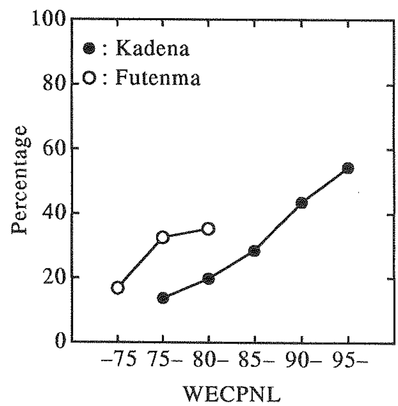

Figure 6. Horrified by aircraft noise.

A CONSIDERATION OF CRITERIA FOR ENVIRONMENTAL NOISE BASED ON DOSE-RESPONSE

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1. INTRODUCTION

The environmental quality standards for noise in Japan were established by a Cabinet in 1971 to protect public health and to conserve the environmental quality. The standards are defined by the median value of A weighted sound pressure level L_{50} according to Japanese Industrial Standard (JIS) on Measurement method of sound level. The value of standards has played important roles to protect the environment as for setting the target value for environmental impact assessment for noise. Many measurements and monitoring of environmental noise have been carried out by many local governments. However, seldom have the measurements been conducted with surveys of residents' reactions to the noise environment.

On the other hand, ISO and almost every country have adopted L_{Aeq} as an index for environmental noise and also JIS on noise were revised to use L_{Aeq}. The Environmental Agency of Japan announced the final report of the new environmental quality standards for noise to estimate them on L_{Aeq} in 1998.

This study aims to lead the criteria for environmental noise by examining the dose-response based on environmental noise measurements and social surveys conducted in Nagoya city. The criteria were obtained from the following ways.

1. cumulative distributions of L_{Aeq} or L_{50} for inhabitants who feel the noise to be loud

2. analysis of dose-response by Akaike Information Criterion (AIC)
3. analysis of dose-response by membership function

2. MEASUREMENT AND SURVEYS

The environmental noise is measured by sound data loggers that record noise levels ($L_{50}1/6$ and $L_{Aeq}1/6$) in every 10-minute interval over all day nearby the houses. All day is divided into morning (6:00-8:00), daytime (8:00-19:00), evening (19:00-22:00) and nighttime (22:00-6:00) and L_{Aeq}'s of each time section is calculated by power average of $L_{Aeq}1/6$ but L_{50}'s by arithmetic average of $L_{50}1/6$. The associated information such as inhabitants' age, housing, surrounding conditions, impression to noise etc. are acquired by a questionnaire since 1987 and collected more than 1000 samples.

3. RESULTS AND DISCUSSION

City areas are categorized into A zoning area (residential area), B zoning area (commercial and industrial area) and roadside area within 20m from trunk road referring to the Japanese environmental standards. The answers on loudness, annoyance and noisiness to outdoor noise show that about 30% inhabitants are bothered. As for above areas, positive reaction (bothered people) occupies 20% in A, 40% in B and 65% in roadside respectively as shown in Fig.1.

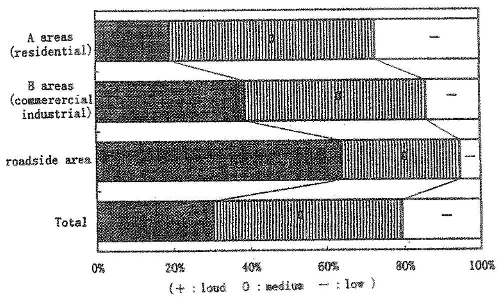

Fig.1 Response ratio for loudness to outdoor noise in different areas.

Cumulative Frequency Distributions

Fig.2 shows the cumulative frequency distributions of L_{Aeq} in different time sections for positive reaction to outdoor noise. The corresponding levels to 30% on the distributions are regarded as the criteria for environmental preservation. The criteria on L_{50} are 50dB in daytime and 40dB in nighttime for general area But 10dB higher in roadside area. These

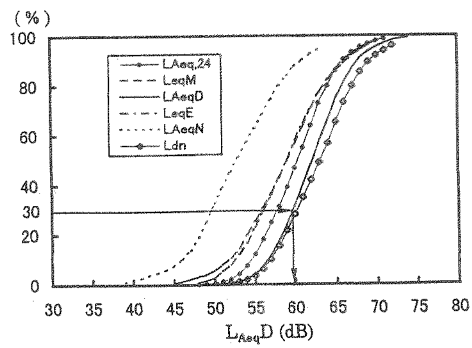

Fig.2 Distributions of L_{Aeq}'s for positive reaction in residential area

ones are consistent with the present environmental quality standards in residential area in Japan. The criteria on L_{Aeq} are 60dB in daytime (shown in Fig.2) and 50dB in nighttime with 10dB higher than those of L_{50}.

Analysis of the Dose-response by AIC

Table 1 Values of AIC between loudness and noise indices

GENERAL AREA						ROADSIDE AREA			TOTAL		
A area			B area								
noise indices	AIC	Number of categories	noise indices	AIC	Number of categories	noise indices	AIC	Number of categories	noise indices	AIC	Number of categories
$L_{50}D$	-69.1	6	$L_{50}D$	-23.7	5	$L_{50}D$	-18.8	3	$L_{50}D$	-203.9	10
$L_{50}M$	-59.6	4	$L_{Aeq}D$	-16.0	4	$L_{Aeq}N$	-18.1	2	$L_{50,}24$	-170.9	6
$L_{50}E$	-57.5	5	$L_{50,}24$	-15.9	2	Ldn	-17.8	2	$L_{50}M$	-165.4	9
$L_{50,}24$	-53.0	5	$L_{50}M$	-15.2	4	$L_{50}E$	-17.7	3	$L_{50}E$	-159.5	7
$L_{Aeq}M$	-47.4	2	$L_{50}E$	-15.0	2	$L_{Aeq,}24$	-16.5	2	$L_{Aeq}M$	-142.9	7
$L_{Aeq}E$	-44.7	2	Ldn	-14.9	4	$L_{Aeq}E$	-15.2	2	$L_{Aeq}N$	-138.1	6
$L_{Aeq}N$	-44.6	6	$L_{Aeq}N$	-13.3	2	$L_{50}M$	-13.7	3	Ldn	-129.8	6
Ldn	-35.5	2	$L_{Aeq}M$	-13.3	2	$L_{50,}24$	-13.6	3	$L_{Aeq}E$	-116.7	10
$L_{Aeq,}24$	-35.2	2	$L_{Aeq,}24$	-12.6	4	$L_{Aeq}D$	-12.5	2	$L_{Aeq,}24$	-113.9	6
$L_{Aeq}D$	-33.0	2	$L_{Aeq}E$	-4.9	2	$L_{Aeq}M$	-11.4	2	$L_{Aeq}D$	-102.8	7
$L_{50}N$	-24.9	4	$L_{50}N$	-3.6	3	$L_{50}N$	-6.0	3	$L_{50}N$	-80.0	6

The dose-response to outdoor noise can be analyzed by AIC. Table 1 shows the values of AIC between loudness and noise indices. The smaller the value is the closer the relation between them. The analysis shows that L_{50} is preferable to daytime and L_{Aeq} to nighttime as indices. Fig.3 shows an example of classifications of $L_{Aeq}D$ by AIC. If we assume to preserve the percentage of positive reaction to noise less than 20%, L_{50} (L_{Aeq}) based on AIC are 50dB (60dB) in daytime and 35dB (45dB) in nighttime. The levels of 50% on positive reactions which are considered the permissible limit are 60dB (70dB) in daytime and 55dB (60dB) in nighttime on L_{50} (L_{Aeq}).

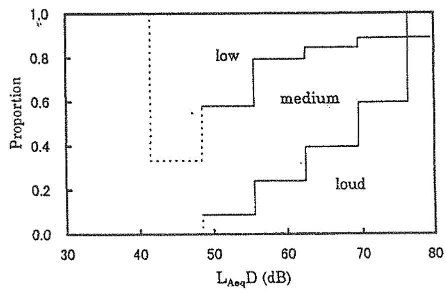

Fig.3 Noise level classification for Inhabitants' reactions by AIC

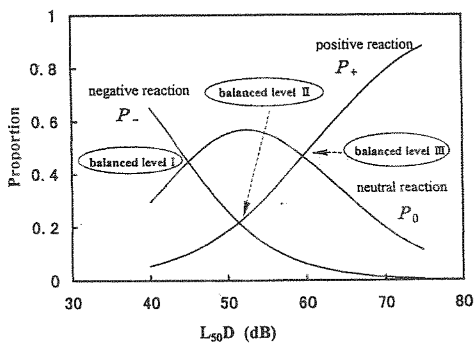

Fig.4 Membership function on L_{50} during daytime

Analysis of Dose-response by Membership Function

The membership function on inhabitants' reactions to outdoor noise is shown in Fig. 4. The negative and positive reaction are balanced when L_{50} (L_{Aeq}) is 50dB (60dB) in daytime and 40dB (50dB) in nighttime. The levels where neutral reaction is dominant might be acceptable considering land use.

4. CONCLUDING REMARKS

The criteria for environmental noise on L_{50} and L_{Aeq} are obtained by examining inhabitants' reactions to outdoor noise. The criteria in residential area are derived from the following ways.

① The 30% values of L_{50} and L_{Aeq} on cumulative distributions for positive reaction to outdoor noise

② The levels against which 20% people respond positively from AIC view point

③ The balanced levels between negative and positive reaction in membership function

These criteria listed in Table 2 show

- The criteria derived from above three methods are consistent with each other.
- The criteria on L_{50} are in agreement with the present Japanese environmental quality standards in residential area.
- The criteria on L_{Aeq} are in agreement with the WHO's guideline and the standards[1] in different countries in residential area.

Furthermore, considering land use such as commercial, industrial and also roadside area, the criteria higher by 5 ~ 10 dB might be accepted. The analyses of dose-response by AIC shows L_{50} is suitable as a noise index in daytime and L_{Aeq} in nighttime. These results of this study give useful information to examine the new environmental standards for noise in Japan.

Table 2 Criteria derived by this study and the standards for noise in different countries (residential area)

(dB)

noise indices	Criteria by different analysis: cumulative distribution	AIC	member-ship function	Japanese stanards (present/new)	WHO guideline	different countries immission values
$L_{50}D$	50	50	50	50	—	—
$L_{50}M$,$L_{50}E$	45	45	45	45	—	—
$L_{50}N$	40	35	40	40	—	—
$L_{Aeq}D$	60	60	60	55	55	45−55
$L_{Aeq}M$,$L_{Aeq}E$	55	50−55	55	—	—	40−50
$L_{Aeq}N$	50	45	50	45	45	35−45

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COMMUNAL NOISE IN BELGRADE, 1993-1997

Ljiljana Pjeroti

1. INTRODUCTION

The Institute of Public Health of Belgrade has been monitoring communal noise in the city ever since 1976. It is performed at 16 measuring points within the city area.

Levels of communal noise are regulated by the Rulebook concerning allowed noise levels in the environment (7), while measuring has been performed in accordance with the contract signed between the Institute of Public Health of Belgrade and Secretariat for the Environment of Belgrade.

Traffic noise is a dominant source of communal noise. It is not determined by time; has a constant impact and incessant oscillations of strength and frequency, which represents a threat to psychosomatic health of the population.

Noise is a stress-related factor; it damages psychosomatic health by causing specific and unspecific reactions within the human body. Noise also causes behavioral disturbances, produces obstacles in communications and work and endangers rest and sleeping patterns (1).

Approximately 25% of the European population is constantly exposed to traffic noise above 65 dB(A) (8).

2. AIMS OF THE PROGRAM OF MONITORING OF COMMUNAL NOISE

Apart from the measures that have been undertaken in order to control the noise in the city, systematic monitoring of levels of communal noise is of special importance. It allows the Institute of Public Health of Belgrade to monitor the trend and undertake concrete measures in minimizing the levels of noise in the city area.

Results obtained by monitoring are also used for the purpose of reconstruction and building of certain city areas and for the construction to be performed in the vicinity of measuring points.

3. METHOD

Measuring of traffic noise levels is performed in accordance with the current Rulebook, with the noise level analyzer (type 4426, manufactured by Bruel and Kjaer). Equivalent levels of Leq and statistical levels of L_1, L_{10}, L_{50}, L_{90} and L_{99} are recorded.

Equivalent level of communal noise is recorded three times during the day and twice during the night. During the day measuring is performed between 9^h-10^{30h}; 14^h-15^{30h} and 18^h-19^{30h}, with measuring interval of 0.2 s. During the night the equivalent level is measured in the same way, in the span between 0^h-5^h. The relevant daytime level is calculated on the basis of obtained equivalent levels of noise measured during the day, while the relevant nightlylevel is calculated in the same manner, only using the levels obtained during the night. The process of calculating them is performed by using Rules concerning summing up of equivalent levels.

4. RESULTS AND DISCUSSION

Results of noise monitoring between 1993 and 1997 show constantly high levels of traffic noise, still significantly above the allowed ones. During 1997 relevant levels of noise in the central area of the city and by major traffic routes were higher by 15 dB(A) than allowed during the day and by 19 dB(A) during the night.

In the residential area of the city relevant levels were higher than allowed by 19 dB(A) during the day and by 23 dB(A) during the night.

Highest levels of noise were recorded in he streets of 29. novembra - 79 dB(A), Main Zemun Street - 80 dB(A) and Vojvode Miši a Street - 80 dB(A) respectively. The night level of noise was also above the allowed values in all thore streets - it was as high as 75 dB(A).

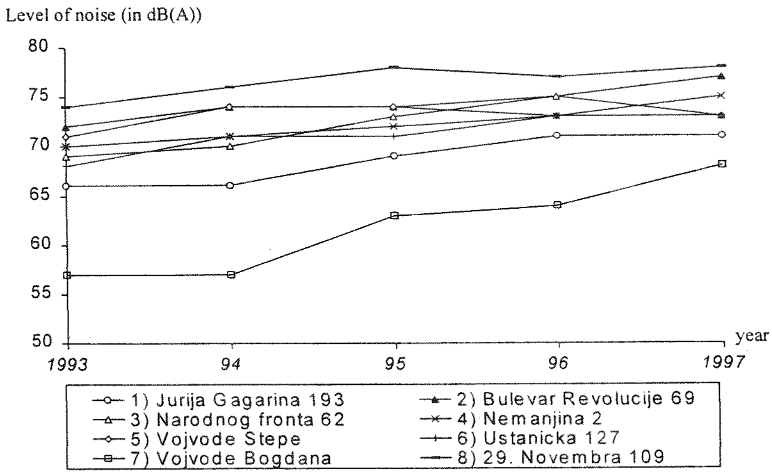
Relevant levels of noise for the day and night (1993-1997) are shown on Figs 1 and 2.

Relevant levels of noise for the day and night were compared with the level of 65 dB(A) ("black spots"), above which harmful effect to human effects to human health are to be expected, according to the findings of the WHO and EU (2). This was done for all 16 measuring points in Belgrade (1993-1997). These results are shown on the Fig. 3.

Results of monitoring of communal noise show that levels of noise during the day greatly overcome the level of 65 dB(A) at 15 measuring points (between 1993 and 1996). The same situation was observed at 16 measuring points in 1997. This brings to a conclusion that noise has been maintaining rather high levels in recent years, with even more unfavorable results being recorded in 1997.

Relevant levels of noise during nighttime were above 65 dB(A) at 5 measuring points in 1993, at 8-9 measuring points between 1994 and 1996. a more unfavorable trend was recorded in 1997 - with the at 11 measuring points relevant level of noise was above 65 dB(A).

Figure 1 Relevant levels of noise measured during the day in Belgrade, 1993-1997



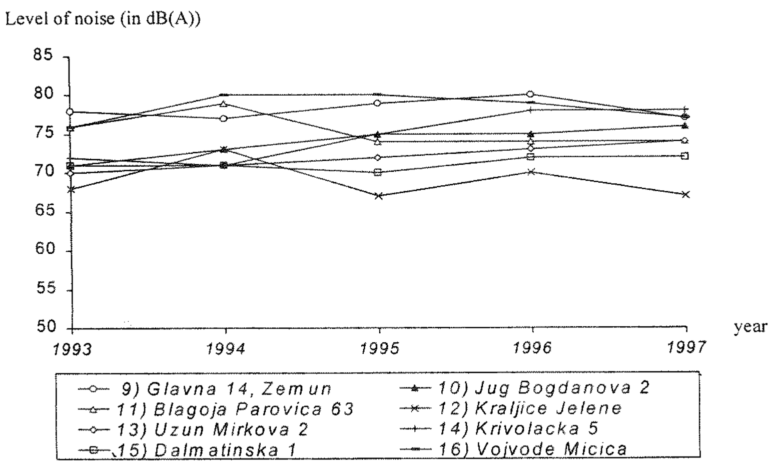
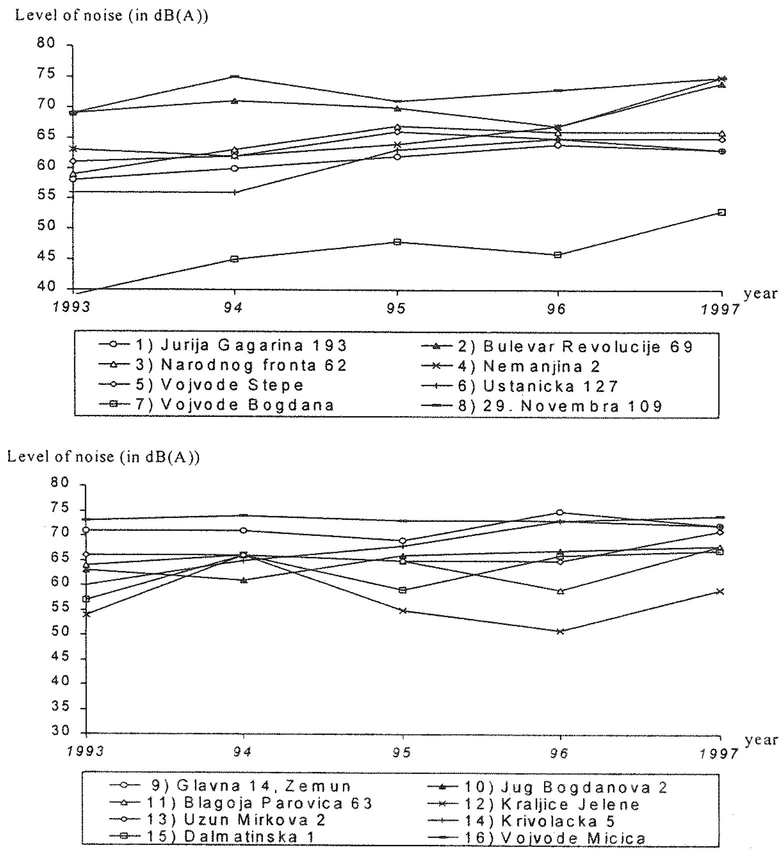
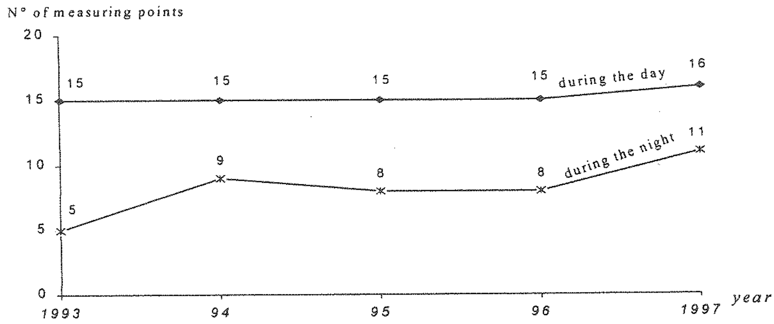


Figure 2 Relevant levels of noise measured during the night in Belgrade, 1993-1997



Numerous studies have shown that disturbed sleep occurs when reaches the level of 35 dB(A). It is necessary for the communal noise to be kept under this level in order to provide optimal conditions for the rest and restitution of a population (3, 4). Sociologic research (5) shows that noise-induced sleep disturbances represent a major problem in urban environments.

Figure 3 Number of measuring points with recorded noise level above 65 dB(A)



5. CONCLUSIONS

Results of monitoring of communal noise in Belgrade (1993-1997) show a high level of traffic noise at most of measuring points above 65 dB(A). During 1997 the state of communal noise has worsened: the level of noise during the day was above 65 dB(A) at all 16 measuring points. The same applies to the nighttime noise at 11 measuring points.

It is obvious that the difference between two noise levels has been gradually decreasing, both during the daytime and night, which inevitably influences conditions for the rest, sleep and relaxation of the Belgrade population. The WHO and EPA recommend the level of 55 dB(A) during the day as a long-term aim (6).

It is necessary to continue to monitor the levels of communal noise; by reviewing projects for industrial facilities of sound-proof insulation; sound-proof insulation in residential buildings (along with technical supervision and approval for use); application of sound-proof insulation materials in construction; barrier-construction; maintenance of roadways; control of the levels of noise produced by motor vehicles (during technical supervision and in traffic). Production of noise levels con also be achieved by removal of heavy traffic from the central zones of the city to the outskirts and by automated traffic-regulation.

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GENERAL HEALTH QUESTIONNAIRE SURVEY AROUND KADENA U.S. AIRFIELD IN THE RYUKYUS -AN ANALYSIS OF THE 12 SCALE SCORES-

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1. INTRODUCTION

A survey on health effects of aircraft noise on residents living around Kadena airfield was conducted using the Todai Health Index. This is a report of the analysis of the 12 scale scores concerning perceived physical and mental health in relation to the level of aircraft noise exposure expressed by WECPNL.

2. MATERIALS AND METHODS

Method and Questionnaire

The survey was undertaken by means of leave-and-pick-up questionnaire method in six municipalities (three cities, two towns and one village) located in the vicinity of Kadena Airport - the largest U.S. airfield in the Far East. The questionnaire used in the present investigation is the Todai Health Index (THI) [1]. THI was developed as a general health questionnaire in 1974 with the purpose of supplementing the Cornell Medical Index (CMI) - Health Questionnaire. It consists of 130 questions regarding subjective symptoms, mental health, personality, health habits, and so forth. Based on the response to 130 questions, twelve scale scores are calculated to reveal the pattern of complaints.

Noise Exposure

Residents living in the surveyed area suffers from high level of noise exposure due to flyovers of aircraft landing and taking-off from the airport [2]. The noise exposure expressed by WECPNL in the area ranges from 75 to 95 or more, which exceeds the environmental standard for aircraft noise around commercial airports [70 for residential area or 75 for commercial area] set by the Japanese EPA.

Subjects

As a noise-exposed group, residents living around the air field was stratified into five groups according to the level of noise exposure expressed in WECPNL from 75~79, 80~84, 85~89, 90~94 and over 95. Questionnaires were delivered to 4,840 residents sampled from the poll book of each group by stratified random sampling. They were also delivered to 1,031 residents, as a control group, sampled from Shimajiri district where aircraft noise exposure was very scarce. The 615 answers of the previous survey conducted in the same area (Chatan Town) in 1992 [3] was also used for the analysis.

Analysis

Twelve scale scores are converted to dichotomous variables based on scale scores of 80 and 90 percentile values or 10 and 20 percentile values in the control group. Multiple logistic regression analysis taking twelve scores converted as the dependent variable and WECPNL, age, sex and their interaction as the independent variables was conducted.

3. RESULTS AND DISCUSSION

The number of valid answers collected from the above 6,486 subjects were 5,172 to 5,255 depending upon the scale. Table shows the observed significance probability of WECPNL for twelve scales scores in the multiple logistic regression analysis. In the table, p_t shows the significance probability of trend test in which linear dose-response relationships are assumed between WECPNL and logarithmic values of odds ratio. Significant dose-response relationships are recognized in the scale scores of SUSY ($p=0.0012$), RESP ($p<0.0001$), DIGE ($p=0.0008$), MENT ($p=0.0061$), AGGR ($p=0.0002$) and NERV ($p=0.0005$). As to SUSY, odds ratios of subjects with the scale score of over 39 inclusive were statistically significant in Group 90 and Group 95 (Figure 1). As for RESP and NERV, significant increase of odds ratio was observed even in the groups with lower noise exposure such as Groups 75, 80 and 85 as well as Groups 90 and 95 (Figures 2 and 6). Odds ratio regarding MENT increases as WECPNL is higher and that with scale score of over 30 inclusive exceeds 2.0 in Group

Table Observed significance probability of WECPNL for twelve scales in logistic analysis

Scale	Score	pt (test for trend)
Many subjective symptoms	≧35	0.0145*
(SUSY)	≧39	0.0012**
Complaints reg. respiratory organs	≧16	0.0000***
(RESP)	≧18	0.0000***
Complaints reg. eyes and skin	≧17	0.6699
(EYSK)	≧19	0.2803
Complaints reg. mouth and evacuation	≧15	0.1090
(MOUT)	≧16	0.1000
Complaints reg. digestive organ	≧14	0.0108*
(DIGE)	≧16	0.0008***
Impulsiveness	≧21	0.1127
(IMPU)	≧23	0.1331
Lie scale	≧14	0.7840
(LISC)	≧15	0.9793
	≧21	0.5769
	≧22	0.4286
Mental instability	≧27	0.2541
(MENT)	≧30	0.0061**
Depressiveness	≧18	0.0652
(DEPR)	≧20	0.0500*
Aggresiveness	≧12	0.0026**
(AGGR)	≧13	0.0002***
	≧17	0.3253
	≧18	0.7487
Nervousness	≧11	0.1224
(NERV)	≧13	0.4428
	≧19	0.1891
	≧20	0.0005***
Irregularity of daily scale	≧22	0.6775
(LIFE)	≧24	0.1434

***: p< .001, **: p< .01, *: p< .05

95 (Figure 4). As to AGGR, odds ratio with scale score of less than 13 inclusive was significant in Groups 85, 90 and 95 (Figure 5).

As a non-specific biological stressor, noise can influence the entire body system via both autonomic nervous system and neuroendocrine system [4]. In this sense, it would be reasonable to consider that prolonged and repeated expousre of aircraft noise adversely may affect health and well-being of people around Kadena airport, making allowance for the serious noise exposure level in the residential area [2] and the high community responses [5, 6] regarding sleep disturbance, disturbance of rest, fear of possible danger as well as annoyance. In addition, sound-proofing as a measure against aircraft noise and air-conditioning which reduce ventilation might cause the spread of air-borne infections and thus increase the complaints regarding respiratory organs (RESP).

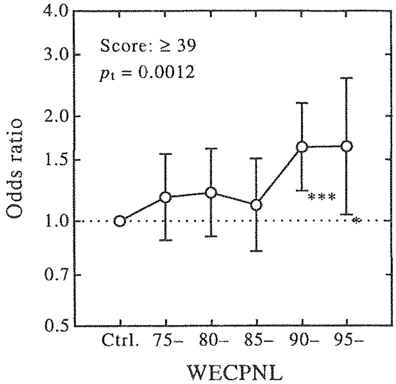

Figure 1. Odds ratio on SUSY

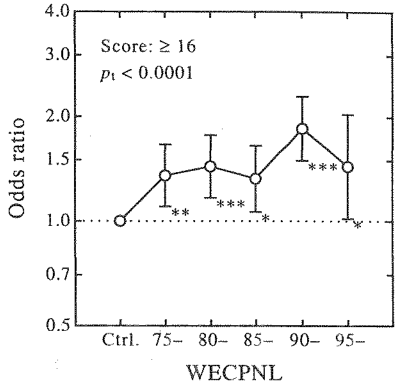

Figure 2. Odds ratio on RESP

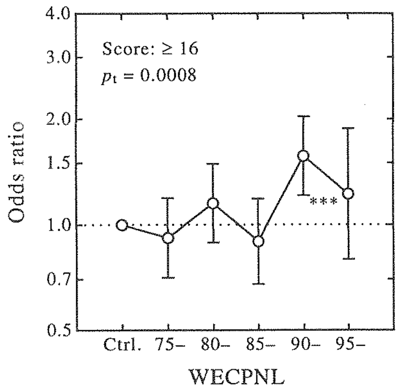

Figure 3. Odds ratio on DIGE

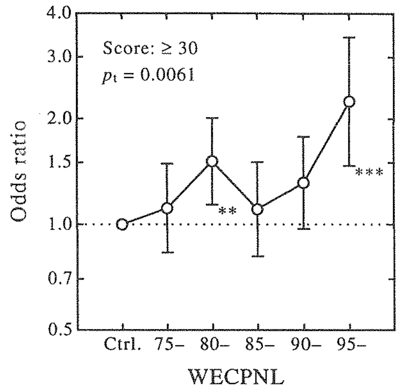

Figure 4. Odds ratio on MENT

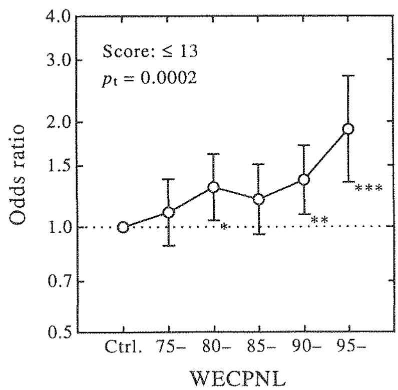

Figure 5. Odds ratio on AGGR

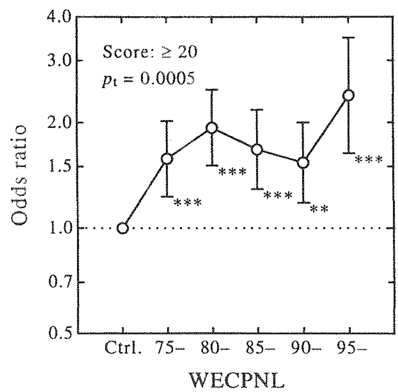

Figure 6. Odds ratio on NERV

Finally, it should always borne in mind that physical health effects of noise may manifest in susceptible subgroup within a population and the sites where various symptoms appear are different among individuals even in the same conditions of noise exposure.

4. CONCLUSIONS

A questionnaire survey was carried out relating to health effects of aircraft noise on residents living around Kadena air field, using the Todai Health Index. Aircraft noise exposure expressed by WECPNL ranges from 75 to 95 or more in the surveyed area. The sample size was 6486 including 1031 from the control group. The results suggest that the residents living around Kadena airfield may suffer from both physical and mental effects due to the exposure to military aircraft noise and that such responses increase with the level of noise exposure (WECPNL).

ACKNOWLEDGEMENTS

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TOLERABLE NOISE INDICES OF $L_{Aeq,T}$ PROPOSED BY RESIDENTS

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1. INTRODUCTION

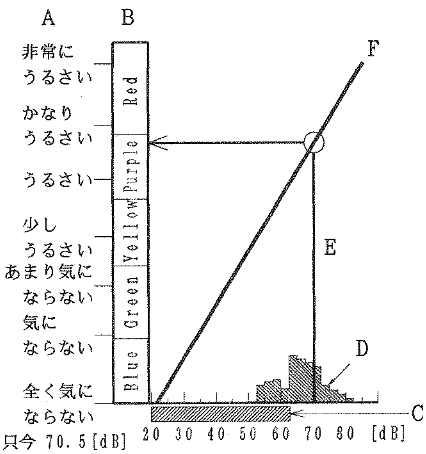
In 1993, WHO published recommendations for desirable and acceptable outdoor noise levels for dwellings (the equivalent continuous A-weighted sound pressure level: L_{Aeq}=50 ~55dB during daytime, 45dB during nighttime). How is the acceptability of a noise determined in a community environment? Social surveys on various kinds of noise sources have been performed in many countries over the past 35 years. The published data up to 1978 were summarized by Schultz [1] and the recent surveys were reviewed and compared by Fidell [2]. For comparison of data obtained in different surveys, a category of "highly annoyed" has been widely used. As an example [3] of the relation between the percentage of people highly annoyed and $L_{Aeq(24h)}$ or L_{dn}, 10% corresponds to about 45~55dB, and 30% to about 60~70dB. However, the labeling of each step and the selection steps affect the response as a function of noise exposure. The relation between "the percentage highly annoyed" and "tolerable limits" for dwellings is not clear.

In this report, using a new type of sound level meter (SLM) devised by us [4], a mean acceptable outdoor noise level of $L_{Aeq,T}$ for dwellings supposed by residents living at seven typical districts in Japan is experimentally discussed. The SLM devised can measure each degree on the two kinds of psychological scales, "urusasa and hues", at the same time as $L_{Aeq(5min)}$.

2. "URUSASA & HUES" SLM DEVISED

In order at the same time to represent both $L_{Aeq,T}$ and "urusasa and hues", the color LCD (TV of 5.6 inches type: SHARP 6E-C1) is used as the display.

Representation method of noise rating scales
A common linear function of F shown in Figure 1 shows the two kinds of noise rating scales with the same gradient. On the vertical axis of its display, the two kinds of psychological scales are displayed in parallel. One "urusasa" scale is shown as A. The



A : "Urusasa" (annoyance) scale

Japanese	English
Hijōni urusai	Extremely annoying
Kanari urusai	Very annoying
Urusai	Annoying
Sukoshi urusai	A little annoying
Amari Kininaranai	Not too annoying
Kininaranai	Not annoying
Mattaku kini-naranai	Not at all annoying

B : "Five-hues" scale
C : A-weighted sound pressure level [dB]
D : Histogram of $L_{Aeq(1sec)}$ [dB]
E : $L_{Aeq,T}$ [dB]
F : Noise-rating scales

Figure 1 The display of "urusasa and hues" SLM.

other "five-hues" scale is shown as B. On the horizontal axis, E shows a perpendicular line of the value of $L_{Aeq,T}$[dB]. C shows the same A-weighted sound pressure level as a conventional SLM. In order to know the degree of the fluctuation of noise sources, D shows a histogram of $L_{Aeq(1sec)}$ divided every 2.5dB.

Relation of "urusasa" and $L_{Aeq(5min)}$. "Hijoni urusai" corresponds to 83dB, "kanari urusai" to 73dB, "urusai" to 64dB, "sukoshi urusai" to 53dB, "amari kininaranai" to 45dB, "kininaranai" to 33dB, and "mattaku kininaranai" to 21dB. Based on fundamental field experiments [5], the seven typical words necessary to represent the level of "urusasa" were selected from 684 words collected from residents in and around Nagano City. The noise rating scale was composed with the method of successive categories [6]. It was also experimentally confirmed that the "urusasa" scale obtained has a good correlation with $L_{Aeq(5min)}$[dB] regardless of the kinds of noise sources (vehicles, machine shops, saw mills, trains, ironworks, construction equipment, etc.) [7].

Relation of "five-hues" and $L_{Aeq(5min)}$. Red corresponds to 80dB, purple to 67dB, yellow to 56dB, green to 41dB, and blue to 26dB. Even for the hue sensibility, Yanagisawa et al. [8][9] found that a five-hues scale (red, purple, yellow, green and blue) correlates well to noise sound.

Consequently, this SLM can directly indicate "kanari urusai & purple" from 70.5dB through its linear function as shown Figure 1.

3. EXPERIMENT

To verify by means of the "urusasa & hues" SLM, a test was carried out whether residents living at seven typical districts in Japan can suppose a tolerable outdoor noise level of $L_{Aeq,T}$ for dwellings.

Cities, subjects and noise sources selected

An investigation was conducted for 600 residents living at Hokkaido (city: Sapporo, the number of subjects: 100), Tohoku (Aomori, Morioka and Fukushima, subjects: 150), Kanto (Utsunomiya, subjects: 50), Hokuriku (Kanazawa, subjects: 50), Chugoku (Hiroshima, Shimonoseki and Yamaguchi, subjects: 90), Shikoku (Takamatsu, subjects: 60) and Kyushu (Fukuoka and Saga, subjects: 100) districts. Those cities selected have some serious noise problems. The common noise sources in all selected cities are highway vehicles. Those subjects were the residents who consented to our request of the actual audio-visual test using the new SLM. The test locations were their houses, parks, underground passages, etc. selected in the surrounding residential areas of each highway.

Procedure

Because of watching the color LCD, the test was carried out at each conspicuous place selected outdoors out of the sun. Each of subjects watched its display and heard the specific noise for five minutes measured. After five minutes, they evaluated the questions into four heads as follows:

Question 1 Whether the "urusasa" scale is a good representation the degree of the psychological effect of noise?

Question 2 Whether the arrangement of the five hues scale is a good representation the degree of the psychological effects of noise?

Question 3 How do you feel that your subjective impressions and the scale displayed correspond?

Question 4 By means of this "urusasa & hues" SLM, a value of $L_{Aeq(5min)}$ corresponding to each degree on the psychological scales can be identified. Therefore, you can relate the value of L_{Aeq} to your tolerable degree on the psychological scales from your impression of the sound heard. What is the value of L_{Aeq} corresponding to your tolerable degree on the "urusasa and hues" scales for acceptable outdoor noise for dwellings?

4. RESULTS

$L_{Aeq(5min)}$ measured

The data of $L_{Aeq(5min)}$ measured ranges from 39.5dB to 79.0dB. The range of from 58dB to 69dB corresponds to 67.2% of data.

"Urusasa" scale

With respect to "urusasa" scale, 99.7% of the number of residents answered to Question 1: "The representative words divided into seven steps on its display are an understandable representation for the degree of psychological effect of noise".

"Five-hues" scale

With respect to "five-hues" scale, 97.8% of the number of subjects answered to Question 2: "The arrangement of five hues and the degree of psychological effects of noise match well"

Table 1 The frequency distribution of the data of L_{Aeq} corresponding to tolerable degree of psychological effects for dwellings supposed by residents living at seven typical districts.

Districts	70.0≧ L_{Aeq} ≧62.5	62.5> L_{Aeq} ≧57.5	57.5> L_{Aeq} ≧52.5	52.5> L_{Aeq} ≧47.5	47.5> L_{Aeq} ≧42.5	42.5> L_{Aeq} ≧37.5	37.5> L_{Aeq} [dB] ≧30.0
Hokkaido	2	17	22	28	20	10	1
Tohoku	5	14	24	58	24	22	3
Kanto	0	5	17	19	6	3	0
Hokuriku	0	2	7	22	12	6	1
Chugoku	1	2	8	26	25	25	3
Shikoku	0	2	7	20	19	8	4
Kyushu	3	13	5	29	34	12	4
Total	11	55	90	202	140	86	16
Percentage[%]	1.8	9.2	15.0	33.7	23.3	14.3	2.7

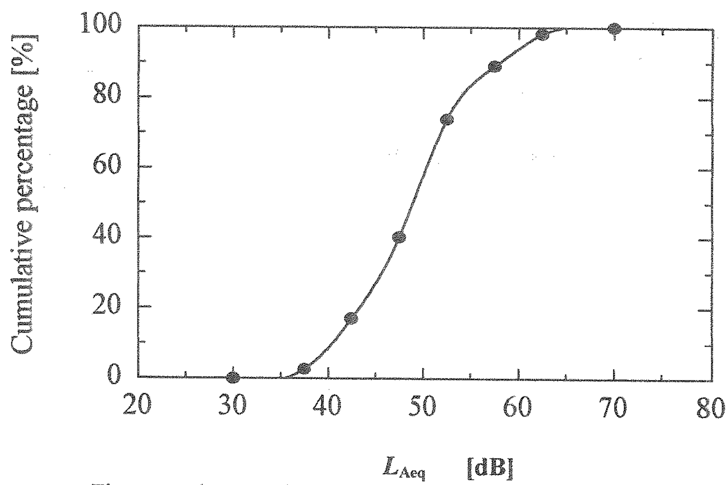


Figure 2 The cumulative percentage of the data (Table 1).

"Correspondence and ease of understanding"

From the results evaluated how degree the correspondence between the scales displayed and the sensuous impressions of the sound heard was, the percentage of the number of subjects likely to be the "highly correspondence" counted in the top three out of seven categories is 80.3%. Where the words representing the seven degrees of understandability selected from typical words which the majority of residents in a community use in daily.

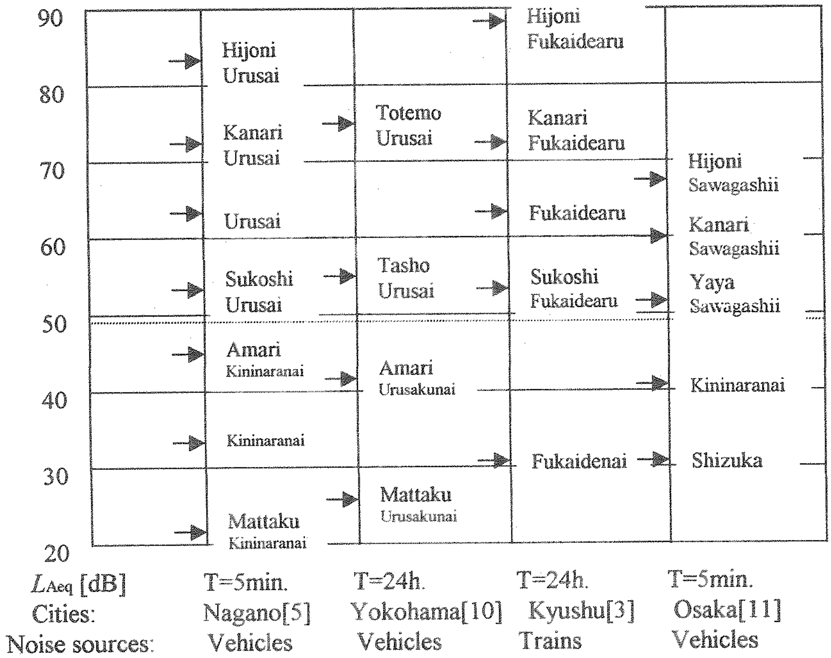


Figure 3 Comparison of four noise-rating scales composed in Japan.

From the results evaluated how degree the "urusasa & hues" SLM could be understood, the percentage of the number of subjects likely to be the "highly understandability" is 84.2%.

L_{Aeq} supposed from tolerable degree on "urusasa and hues" scales

Table 1 shows the data of L_{Aeq} corresponding to tolerable degree of psychological effects for dwellings supposed by residents living at seven typical districts. The mean value is 49.0dB. Figure 2 shows the cumulative percentage curve of the data. From the curve, the cumulative percentage of the number of residents who began to feel psychological effects caused by vehicle noises at 40dB of L_{Aeq} is 10%, at 49dB is 50%, and at 58dB is 90%.

Therefore, it could be said that the instrument, as far as authors have tested, is more effective and useful in the measurement for noise abatement.

5. DISCUSSION

Lastly, Figure 3 gives an indication of four noise-rating scales composed in Japan. These noise-rating scales were composed in common with the method of successive categories. In the two kinds of "urusasa" scales, the left side is our scale [5]. The right side is the noise rating scale composed by analyzing the response of community to vehicle noise sources in Yokohama City using the 4-points "urusasa" scale selected by Kashima [10]. The 5-points "fukaisa" scale selected by Yano et al. [3] shows the results to train noise sources in Kyushu district. The 5-points "sawagashisa" scale selected by Kitamura et al. [11] shows the results to vehicle noise sources in Osaka City.

From the comparison of scale values, it can be said that 49dB of $L_{Aeq,T}$ is a dividing level between whether people begin to feel psychological effects of noise or not.

6. CONCLUSION

Using the SLM devised, which was equipped with both "urusasa" and "five-hues" scales representing the psychological effects of noise, a mean acceptable outdoor noise level of $L_{Aeq,T}$ for dwellings was experimentally discussed. From the results, the mean value of L_{Aeq} corresponding to tolerable degree on the "urusasa and hues" scales supposed by residents for dwelling may be 49dB. In conclusion, the tolerable noise index of $L_{Aeq,T}$ is a dividing level between whether people begin to feel psychological effects of noise or not, and corresponds to about 10% of people highly annoyed.

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THE AURAL RESPONSE TO NOISE FROM LOW FLYING MILITARY FAST JET AIRCRAFT

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1. INTRODUCTION

Noise from low flying military fast jet aircraft is a source of concern for some people regularly overflown during flying training sorties. Possible health risks, especially relating to potential hearing loss, as well as annoyance feature highly amongst comments made by the public particularly after they have been exposed to sudden loud noise. Methods of quantifying any potential risk to health and annoyance could be improved by the use of criteria that are more appropriate.

An important fact to consider is how the sound pressure waveform from an overflight is perceived by the ear, and in particular whether such signals will trigger the aural reflex. It is well known that the aural (or stapedius) reflex is triggered by intense noise levels and causes the middle ear muscles to contract, attenuating transmission through the middle ear and producing a reduction in perceived level at the inner ear. The response of the reflex is governed by the characteristics of the stimulus, for example the intensity, duration and frequency content of the noise. During a typical loud aircraft flyover observed on the ground, the sound pressure level initially rises slowly and then more rapidly as the maximum is approached. It is likely that the reflex will be triggered relatively slowly during this early period provided the reflex threshold has been exceeded. The initial effect of the reflex on noise transmission to the inner ear will be small. However as the noise from the aircraft gets louder, the reflex is likely to respond more quickly and the sound attenuation will increase. This indicates that the response time of the acoustic reflex, and the attenuation of sound through the middle ear during the onset of the event, will not be as dependent on the maximum noise level of the flyover as it will on the pressure/time history.

2. SIGNATURES FROM LOW FLYING MILITARY JET AIRCRAFT

The characteristics of signatures from low flying military jet aircraft have been described in a previous paper [1]. Detailed examination of the pressure waveforms shows that the noise is complex, comprising a series of pressure peaks with rapid return to zero pressure. The amplitude of the pressure peaks increases gradually as the aircraft flies overhead reaching an overall peak pressure after a finite time which is dependent on the speed and height of the aircraft. The amplitude then decays back to ambient levels. The frequency content of the signal varies over the course of the event. In general it can be taken as a broadband noise covering the whole of the human hearing range. The envelope of the noise can show large variations in duration, level and rate of onset. In figure 1 (flight B), simple observation shows that this envelope is not comparable to what is generally understood as an impulsive source. The onset is gradual and the pressure fluctuates around its maximum level for a relatively long period. However, when the aircraft is flying at higher speeds as in figure 2 (flight F) it becomes less clear as to whether the noise ought to be assessed using continuous or impulsive criteria. The onset is faster, as is the rate of decay. Noise was measured during a controlled trial in 1995, when Tornado GR1 aircraft were flown at speeds up to and beyond normal UK low flying limits. At speeds and heights outside those normally flown, but within the regulations, average maximum noise levels do not exceed 125dBA or 140dB wideband peak. The onset rate (using the NPL method [2]) was always <100dB/s for flights within current UK low flying limits and the 20dB down duration of a single event ranged from 665ms to several seconds.

FIGURE 1 - Flight B

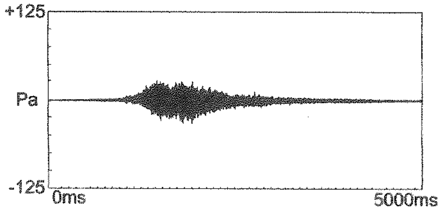
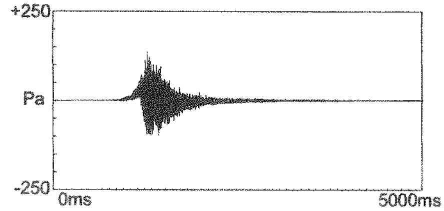


FIGURE 2 - Flight F



3. THE ACOUSTIC REFLEX AND LOW FLYING AIRCRAFT NOISE

Based on existing studies and assuming that low flying jet aircraft noise can be considered a broadband stimulus, the acoustic reflex response can be assumed to take on the following characteristics.

Acoustic Reflex Threshold (ART) may be defined as the lowest level of stimulus that produces a measurable change in the acoustic impedance of the middle ear. ART is dependent on the frequency content of the stimulus, and for short stimuli, (<0.333s duration) on the duration [3, 4]. In the case of low flying aircraft noise, the duration is always greater than 500ms, therefore ART will not be affected by signal duration. From the literature [5, 6, 7], contralateral ART can be estimated at 75dB for broadband noise (or 85dB for people over 50).

Acoustic Reflex Latency (ARL). Contraction of the middle ear muscles occurs with a certain delay after the onset of a sound stimulus (ARL). ARL is the time interval from the start of the stimulus to the first detectable impedance change resulting from middle ear muscle contraction and is dependent on the intensity, frequency and rise time of the stimulus. For an instantaneous, broadband stimulus at levels around 30dB re ART, the contralateral latency can be estimated at 85ms [8]. However low-flying jet aircraft noise is not instantaneous and the maximum level is not achieved until between 0.5 and 2s after the start of the event. Therefore, it may be more appropriate to apply the latency found for less loud stimulus, since the reflex will be triggered when the aircraft noise is at these lower levels. For instantaneous, broadband stimuli at 10dB re ART, latency can be estimated at 105ms [8]. The estimate of latency must also take into account the rise time of the event. A linear relationship has been found [9, 10] between stimulus rise time and latency, therefore ARL must increase with stimulus rise time.

Acoustic Reflex Rate of Growth. For instantaneous stimuli, the response time of the acoustic reflex decreases as stimulus level increases and is generally between 100 and 300ms [9]. However, when considering the noise from low-flying aircraft the problem is complicated because the intensity of the waveform increases over a period of time which can be between 0.5 and 2s. Clearly the response of the acoustic reflex will initially be slow in reaction to the first portion of the event, when the level of the aircraft noise is relatively low. As the noise level increases, the reflex response will react more quickly. The rate of growth of the acoustic reflex will, therefore, not be as dependent on the maximum level of the event as it will be on the onset characteristics.

Attenuation by the Acoustic Reflex. The stapedius reflex attenuates pure tones of frequency up to 2kHz. For 500Hz pure tone stimuli at 30dB re ART, the maximum attenuation has been measured at 20dB [11]. Borg [12] measured attenuation of 12-15dB for 500 Hz stimuli at 20dB re ART. For 2kHz pure tone stimuli the maximum attenuation is lower at 10dB for stimulus levels of 30dB re ART [11]. The dynamic range of the acoustic reflex (the range of intensities over which the reflex magnitude grows before saturating) varies widely between individuals and appears to be related to ART. In experiments to find the dynamic range of the reflex, maximum test levels are generally encountered before saturation occurs for broadband noise. Silman states [13] that the dynamic range for broadband noise stimuli appears to be beyond 120dB (re 20uPa). For the purposes of this paper, it is assumed that for broadband noise, the reflex saturates at 50dB re ART. Therefore for ART = 75dB and a stimulus with maximum rms level of 125dB, the reflex will reach its maximum impedance and provide a maximum attenuation estimated at 20dB. For stimulus levels between 75dB and 125dB the attenuation will increase linearly from 0 to 20dB.

Acoustic Reflex Adaptation. If the activating signal is steady and is presented for several seconds, the middle-ear muscles begin to relax and the impedance begins to fall towards normal impedance. Adaptation for broad band noise is fairly slow; a study by Wilson [14] found the reflex response fall to 50% of its maximum value after around 75s for a 96dB SPL stimulus. The reflex was shown to be within 90% of its maximum for 10 - 20s (depending on stimulus level). This timespan would exceed the duration of the majority of low-flying aircraft events. However, due to the transient character of low-flying noise, adaptation is probably irrelevant as the reflex is reactivated by even slight changes in level and frequency content over the course of the event [15].

4. ESTIMATING THE ACOUSTIC REFLEX RESPONSE

In this section, the information from the previous paragraphs has been applied to an actual recording of a Tornado overflight (figure 2) to predict the effect of the reflex on the noise reaching the inner ear. The short Leq time history of the event (Leq duration 8ms, smoothed using a running average of 40ms to simplify the analysis) is shown in Figure 3. An estimate of the likely impedance change (as a percentage of the maximum possible change) at the middle ear over the course of the event was made by inspecting the waveform's level and rise time over each 10dB section above ART. A tympanogram was produced (Figure 4), and smoothed using quadratic best fit software in three sections; a) the rise of the acoustic

FIGURE 3 - Flight F

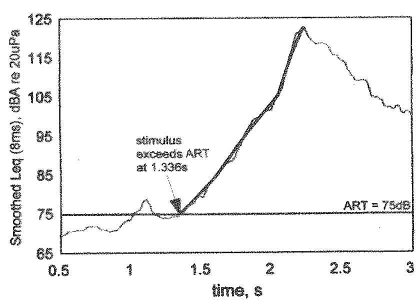


FIGURE 4 - Tympanogram

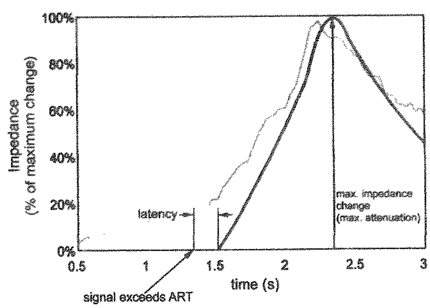
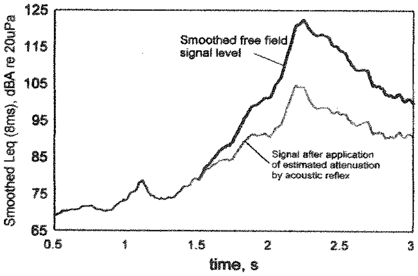


FIGURE 5 - Flight F attenuated by reflex



reflex; b) the transition from rise to maximum impedance and decay; c) the decay of the reflex. Assuming that attenuation is related directly to the impedance change, and that the maximum attenuation for this waveform will be 20dB, the attenuation can be calculated over the course of the event. It can then be applied to the original waveform to demonstrate the probable attenuation effect of the reflex on the level that reaches the inner ear (Fig. 5).

5. CONCLUSIONS

It can be seen from this analysis that the acoustic reflex has a large effect on the noise transmitted through the ear for this particular event. It would be necessary to repeat the procedure for a range of different events to establish the effect of the reflex in more general terms and possibly derive a metric to fully describe the human response to low flying military jet aircraft noise. Any such metric will have to take into account the variation of sound level with time for each event. This cannot be achieved by simple metrics such as L_{Amax} or L_{AE}. It also will be necessary, in future work on this subject, to consider the variability of the reflex action between individuals. Clearly assessing the range of low flying aircraft noise signatures using the above technique will be tedious and the possibility of using cochlea models is being investigated.

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PITFALLS TO AVOID IN NOISE REACTION SURVEY DESIGNS

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1. INTRODUCTION

Knowledge about reactions to environmental noise has been gained through community surveys that relate a social survey of residents' reactions to an acoustical study of noise exposure at their residences. Over 300 such surveys have been conducted since the late 1950's. The success of such surveys depends heavily upon the designs selected for the questionnaire, the sample of residential areas, and the noise estimation program. Although most such surveys have met their goals and provided useful information, most could have been improved with changes in their design. Occasionally a survey has been rendered useless by a major design flaw. This paper identifies a few major pitfalls that have crippled a minority of surveys and lists good practices that would further strengthen most surveys.

2. MAJOR PITFALLS

This section identifies four major pitfalls.

Mismatching the Questionnaire and Acoustical Survey Noise Source

A number of surveys have been rendered useless when there was a mismatch between the object asked about in the survey question and the noise measured (or estimated) in the acoustical survey. Examples of this pitfall include: 1) acoustical measurements of road traffic noise mismatched with a questionnaire about "road traffic annoyance" that never specifies whether it is the noise or danger from road traffic that should be evaluated, 2) acoustical measurements of only the overall community noise environment (often unattended) mismatched with a survey goal of studying reactions to a particular noise source, 3) Estimates of exposure from a surface noise source (road traffic or industrial) that are not adjusted to a uniform position at respondents' dwellings (e.g. most highly exposed facade).

Confusing Perceptions and Reality in Respondents' Answers

Survey questions can be expected to obtain good information about residents' current perceptions, attitudes, and feelings. However, people are notoriously poor observers of past feelings or of the objective characteristics of physical environments. Major confusions that should be avoided include the following: 1) using perceptions of noise levels (e.g., "how noisy is it where you work") to replace measurements of noise levels, 2) using a retrospective report of feelings (e.g. "How annoyed were you last year before the noise changed") to replace how the respondent actually felt, and 3) using perceptions of neighborhood environments (e.g. "Is the road well maintained?") to replace objective observations of the area.

Missing Respondents' Integrated Response

Although detailed questions about specific reactions to separate aspects of a multi-faceted noise environment may be at the core of a social survey, any final judgment about the overall combined impact of these reactions must be provided by the respondent. Detailed questions can ask about annoyance with the loudest events, with average events, at night, on weekends, in the early morning, in the garden, in the television room, while eating, or while talking on the telephone. A survey questionnaire will miss the combined impact of these facets unless at least one question also asks for an integrated, general response to the total noise exposure from the noise source.

The Head-in-the-Sand Approach to Noise Environment/Area Correlations

Many studies are commissioned to determine which characteristics of noise environments or neighborhoods have the greatest impact on residents' reactions to noise. The 1963 Heathrow survey was the first of many surveys that have largely failed to meet such objectives when it found it difficult to separate the effects of numbers and peak levels of aircraft events[1]. This determination needs to be made by contrasting the reactions of residents from neighborhoods that contain contrasting combinations of acoustical characteristics. Obtaining a sufficient number of study areas with the needed contrasting combinations of acoustical and non-acoustical characteristics is difficult for two reasons, 1) the acoustical characteristics are often highly correlated and 2) neighborhoods have unique differences in reactions that introduce error variance into the comparison of neighborhoods with seemingly identical acoustical or other objective characteristics. The solution to this problem is to sample the study areas from strata that are defined by combinations of acoustical and non-acoustical characteristics that will yield low correlations between the study variables. If such areas can not be found, the survey will fail to separate the effects of the characteristics. A Head-in-the-Sand approach that ignores acoustical characteristics at the design stage or that conducts a study even if a suitable combination of environments is not available will not reach its objectives.

3. STRATEGIES AND APPROACHES FOR DESIGNING STRONG SURVEYS

The eight guidelines listed in this section could enhance the value of many combined social/acoustical community surveys. Of course the basic professional social survey and acoustical survey knowledge that are required to conduct and design such surveys can not be summarized in this paper. This paper simply points to issues that are often ignored despite some professional involvement.

Draw on the fundamental principles from all disciplines. No aspect of a combined social/acoustical survey is strictly routine. A strong design comes from researchers who apply and knowledgeably adapt the fundamental principles of each of their disciplines (physical acoustics, psychological acoustics, social survey administration, statistics, social science) to create a combined social and acoustical survey. Some of these principles are implicit in the suggestions in this article. Plans that expect to overcome past weaknesses by devoting their efforts to a single innovation in one discipline without drawing on the fundamental principles of all disciplines are unlikely to succeed.

Design for comparisons within the context of the accumulation of scientific knowledge. Scientific knowledge in any field is gained by accumulating confirmatory evidence from many studies. Guidelines for contributing to this accumulation through publications have been previously published[2]. At the survey design stage the value of a survey can be enhanced by removing methodological barriers to comparisons with previous and future work and by creating linkages that will confirm or contradict previous findings. Such survey design features include: repeating selected questions from previous questionnaires, reproducing previous noise estimation procedures (even if they are not the primary procedure), and conducting small-scale experiments to test for the effects of differences in acoustical or social survey procedures. Such experiments can enable a single new survey to contribute the links that create a larger, unified data base of comparable information.

Design for acoustical and area characteristics. To avoid the Head-in-Sand pitfall described above, it is essential to apportion the study sample to areas that have a combination of characteristics that will make it possible to study the independent effect of major study variables. For example, an ambient noise effect study for aircraft noise must be designed with a wide range of ambient noise levels for different aircraft noise exposure conditions. Statistically sound, probability samples can be used for this purpose if enough areas are selected at random from within each of the types of combinations of conditions.

Consider sample size to be the numbers of neighborhoods, as well as the numbers of interviews. Previous research on community noise surveys has shown that there are random differences between neighborhoods as well as between people[3]. Obtaining a good estimate of the reactions under a particular acoustical or other non-noise neighborhood conditions thus requires enough neighborhoods to average out these neighborhood differences. A counter-intuitive aspect of statistical survey design is that, for a given number of interviews, greater precision in social survey estimates will be achieved through spreading respondents thinly through many areas, than by concentrating them in a few areas. As a rule of thumb, the survey as a whole needs to be spread over at least thirty areas to form a useful estimate of the precision of the social survey results[4].

Measure (social), measure(acoustical), measure(observational). Reactions to noise may be the result of many more factors than can be successfully balanced with even the best-designed, survey sample. In short, some variables are almost certain to be so highly correlated as to be confounded in the survey design. Given finite resources, a supplemental approach to this problem is to use the social survey, acoustical survey and neighborhood observation protocols to measure more variables than can be controlled in the design. In the best case, the variables may be independent. In the worst case, publications can provide full disclosure about the extent to which conclusions about one factor (e.g. effect of noise level) may be confounded with other factors (e.g. distance to noise source). The most frequently neglected measurement aspect concerns measurement by observation of such characteristics as the visibility of the noise source, non-noise impacts of the noise source, quality of the non-noise environment, characteristics of dwellings, and availability of amenities.

Design noise estimation programs to assess the accuracy of acoustical estimates. Even though individual acoustical measurements may be quite exact, estimates of the long-term environments about which respondents form opinions are subject to estimation errors. While the enormous variability in individual respondents' answers can be compensated for through increased sample size and will not bias survey estimates or dose/response relationships, an error in noise estimation (the independent variable) can easily affect conclusions[5]. In the absence of information about the degree of accuracy of noise measurements, it is not possible to assess the validity of findings. For example, a finding that reactions are related to noise exposure at high but not at low noise levels could be generated by a noise measurement program that accurately estimated noise exposure at high but not at low noise levels.

Pretest and assess designs under realistic conditions. Social survey questionnaires should be tested on populations similar to those to be surveyed. Pretests in past surveys have lead to changes in questionnaires when, for example, "quiet neighborhood" was found to be interpreted as an unexciting neighborhood or a request to give the "nearest "cross-street" (needed for mapping a house location to a noise contour) was interpreted as a request for a major road to assist a driver in finding a street. Acoustical survey pretests can lead to realistic assessments of the number of areas that can be studied and of practical difficulties in microphone placement.

Use multiple indicators when possible. Although a single noise reaction question is often valuable for describing individuals' reactions to policy makers, studies in psychometrics show that additional accuracy can be gained by combining respondents' answers to multiple similar questions. This provides more accurate estimates of respondents' relative positions and thus will give additional precision to analyses that attempt to gauge the relative impact of different acoustical and environmental factors on those reactions. Alternative indicators of the acoustical noise environment (e.g. measurements and predicted levels) can provide some additional checks on noise exposure estimates.

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Noise effects research: the importance of estimating noise exposure properly

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Background

Given that the main purpose of most community noise research studies is to establish and develop relationships between the degree of noise exposure and any resulting noise effects, then it is perhaps surprising that, irrespective of any difficulties in measuring effects, standard methods of estimating noise exposure are almost entirely inadequate for this purpose. Fields (1) analysed the effects of various errors on survey results and showed that, for example, after adjusting for noise measurement errors, results indicate a closer relationship between changing levels and changing reactions, and less annoyance at lower noise levels. The recent *'Guidelines for reporting core information from community noise reaction surveys'* agreed by ICBEN Team 6, Community Response to Noise (2) acknowledge difficulties in being able to estimate long term noise exposure from published data and difficulties in being able to compare estimates of noise exposure between different studies. This problem applies not only to general community response surveys but also to the specific field of non-auditory health effects which is attracting increasing attention in Europe (3) and in the UK (4,5).

The problem

Why are existing methods inadequate? The standard method of estimating noise exposure in community noise surveys is to deploy unattended data logging sound level meters outdoors at positions representative of so-called *'homogeneous groups'* of dwellings and for relatively short periods of time. Thus there are problems of spatial and temporal sampling. The shortness of the sample period is the first problem, particularly because environmental noise levels can vary over a large range. The better class of noise survey might employ qualified listeners to identify contributing noise sources at the monitoring point, but many surveys are obliged to omit even this simple quality control precaution, either on grounds of expense, or even because the researchers did not consider it to be necessary. It is not feasible to use attended measurements for extended sample periods in any event, and automatic noise source identifying systems are not sufficiently developed to be able to replace the trained listener for general noise survey work.

Homogeneity

What does a *'homogeneous group'* actually mean? In traditional community noise research, this typically means a residential area where the noise exposure to a single noise source of interest, such as road traffic or aircraft noise, is considered to vary within a range of less than 3 dB. We can ignore the question of whether 3 dB is the most appropriate criterion for homogeneity and move on to the question of how researchers are able to verify this assumption. The available resources cannot usually support being able to check the assumption of homogeneity by any programme of measurement and instead reliance has to be placed on some kind of noise prediction exercise, which is unlikely to be sufficiently accurate to be of any use at all for this purpose.

Individual exposure

An even more serious problem is that, even if the usual homogeneity assumptions were found to be correct, they relate only to noise exposure measured outside dwellings and cannot be considered to reflect any kind of homogeneity of personal noise exposure whatsoever. Individuals vary in the amount of time spent at home, indoors or outdoors, with the windows open or closed, and engaged in various noise sensitive and noise insensitive activities. None of this is taken into account by sample outdoor measurements.

How can researchers check the extent to which individual differences in response or observed effects depend on individual differences in personal noise exposure? The short answer to this question is that without measurements of personal noise exposure, they can't. If we are really looking for exposure-response relationships, then completely ignoring the potential for individual differences in exposure to contribute to unexplained variance in response or observed effects is somewhat remiss.

Identifying acoustic features

What does a data logging sound level meter do? In the good old days a statistical distribution analyser might be connected to a tape recorder for laboratory analysis to derive L_{Aeq} or a range of statistical levels, L_n . The A-weighting is usually decided upon in advance, and although tape recorded data should allow re-analysis using different frequency weighting schemes, again, this would normally be prohibitively expensive. If there were to be any attempt to record personal noise exposure separately, then subsequent laboratory analysis of tape recordings would probably be completely out of the question because of the amount of data that would be involved.

A modern field portable data logging sound level meter system should be capable of recording a wide range of noise indicators. Unfortunately, all of these conventional indicators, although they might appear very different to a beginning student of acoustics, are mostly measuring much the same thing. As such they will generally be quite highly inter-correlated, thus limiting the statistical value of looking at the different indicators separately. The root of the problem here is that no sound level meter system yet developed can identify acoustic features separately without intelligent human intervention. Sophisticated sound quality analysers can be used to determine the objective magnitude of particular time-varying frequency features once they have been subjectively identified, but there are no objective indicators available which can reliably identify even simple features like tonal components, unless they are completely dominant in the frequency spectrum. The main problem here is that human listeners sometimes attend to one part of the frequency spectrum and sometimes attend to another part, depending on which feature within the overall spectrum carries the most relevant or interesting information at the time. In addition, what human listeners are most interested in is the type of source and what it means to them, and they are not directly interested in tonal or impulsive content, per se.

This issue of selective attention to acoustic features must be of particular concern where we are considering possible non-auditory health effects of environmental noise. It is clear that the levels of energy in typical environmental noise exposure are far too low to have any direct disruptive effect on the tissues. If there are any long term non-auditory health effects, then they can only ensue from some maladaptive response of the body to the noise exposure. The stress caused by long term annoyance hypothesis is a simple, if rather unsatisfactory, way of explaining the aetiology of long term non-auditory health effects (quite apart from the problems caused by the fact that the same simple word 'stress' means different things to researchers in different disciplines). The question here is, is there any reason to suppose that it is just the level of noise which contributes to annoyance related 'stress', or should we be considering the different ways in which different individuals might react to different acoustic features within the noise?

Non-acoustic features

Conventional indicators of noise exposure provide no help at all in this area, and if we then move on to consider the question of the so-called non-acoustic features, we know even less. Examples of non-acoustic features include individual perceptions of the amount of effort which noise producers are putting into noise control (which might be wrong, of course), or of the amount of effort they allocate to taking noise complaints seriously. Anecdotal evidence suggests that individuals with a particular concern about a certain type of noise are more likely to be woken by it at night than other individuals who are indifferent to it. Two classic examples of this are mothers and babies, and airport noise. Some of the most difficult noise problems in the UK can arise in disputes between close neighbours.

Residents can be very seriously annoyed by what they consider to be inconsiderate or irresponsible behaviour by neighbours, almost without reference to any absolute level of noise involved. No sound level meter or noise quality analyser can form a judgement as to the perceived intentions of the noise producer, but this is exactly what human listeners do.

Solutions

First of all, there are no easy solutions to any of the problems identified above. However, there are two generic directions in which we could move ahead. First, we could revise our objectives for future research to try to take uncertainty in estimating personal exposure into account and we could reflect this uncertainty rather more when developing methods of assessment as based on that research. Second, we could take steps towards resolving some of this uncertainty.

Revising objectives

We could revise our overall objectives by considering whether estimated personal noise exposure should be the main independent variable in any case. If it is reasonable to suppose that reported annoyance or activity disturbance depends as much on both acoustic and non-acoustic features as it does on the absolute level of noise, then at least as much emphasis should be placed on these aspects as key input variables in any predictive relationships as is currently placed on the long term average A-weighted noise level (L_{Aeq}). Since non-acoustic features cannot be measured by any sound level meter system, and most acoustic features are problematical, this helps to avoid the question of how we might improve the statistical representativeness of outdoor sample measurements, by placing a new emphasis on all those other aspects of exposure which are not measured by the sound level meter at all.

This new approach is reflected in the current draft of ISO 1996 Part 1 (6) which is attempting to standardise practical methods of noise assessment where either specific, residual or total noise are numerically compared in different ways to support different purposes of assessment. The ISO 1996 Part 1 approach to noise assessment recognises that different comparisons might be more or less appropriate in different situations, and that simply comparing measured or predicted noise levels against some defined absolute criterion is often not the most useful procedure. In many situations, the most useful type of noise assessment is that which can inform decisions which need to be made between feasible or viable alternative options, and the most important issue will then be to compare noise impact between the two options, irrespective of any exceedances of absolute criteria or not. In other situations, if reported annoyance or other observed effects can be reduced by attention to acoustic or non-acoustic features, irrespective of whether absolute noise levels are reduced or not, then the effect on absolute noise levels would actually be irrelevant. If this is so, then why do we need to concentrate to such an extent on noise levels at all, when all these variables might be at least as important and in many situations, are probably more important?

Resolving uncertainty

The alternative, and perhaps more traditional approach to resolving uncertainty in the characterisation of individual or personal noise exposure is to increase the sampling fraction. Where a single short series of outdoor measurements is taken as being representative of noise exposure of all individuals resident within a relatively large area, the sampling fraction of all possible measurements which could have been taken is very small. The sampling fraction can be increased very simply by increasing the number of measurement positions and the duration of each measurement. It would be very easy to generate significant cost over-runs by adopting this approach, without necessarily achieving any significant improvement in the sampling fraction. It is difficult to generalise here, but in most situations it is likely that some intelligent combination of noise prediction and measurement could be deployed to achieve significant improvements without incurring excessive cost. In an ideal world, it would be best to avoid actual measurement as far as possible, by using computer prediction techniques. Unfortunately, many computer prediction techniques cannot be relied upon to give accurate results in complex real-life situations unless they can first be calibrated against actual sample measurements. What we would then have would be a complex computer-based predictive model using real sample data for calibration purposes. The main purpose of the sample measurements would be to inform development and refinement of the predictive model, not as primary data collection instruments in their own right.

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NEGATIVE ATTITUDES TO NOISE EXPOSURE HAVE A PURE MODIFYING EFFECT ON NOISE REACTION.

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1. INTRODUCTION

It is well established that variation in reaction to noise is not well accounted for solely by variation in noise exposure [for reviews see 1,2]. A number of variables which modify reaction to a given noise exposure have been identified [for reviews see 1,2,3,4].

Attitude to the noise source appears to have an important modifying influence on reaction [eg see 5,6,7]. For example, individuals who believe that they will never benefit from planes and/or that the airport authorities do not do enough to minimise aircraft noise, are more likely to be annoyed by a particular level of noise exposure than are individuals who do not hold these beliefs.

However, it remains uncertain to what extent attitude to the noise source is a "pure biasing" factor, a "sensitivity" factor, part of the noise reaction itself, or a result of the noise reaction [see 2,4]. McKennell [8] found that "patriotic involvement with Concord" modified reaction to Concord noise in the manner of a pure biasing factor. Subjects were divided into groups with low, medium and high patriotic involvement, and noise reaction was plotted against Concord noise exposure for each of these groups. The equivalence of the observed dose/response gradients indicated that the reduction in reaction produced by increased patriotic involvement is constant across the range of noise exposure levels considered. This marks a pure biasing factor.

In contrast, similar analysis of the data from an Australian study [5] demonstrated that subjects with low, medium or high levels of negative attitude to aircraft noise produced diverging dose/response curves. Thus, the difference in reaction between subjects with high versus low levels of negative attitude increased with noise exposure; the increase in negative reaction with exposure is more rapid for subjects with more negative attitudes. These findings are consistent with the claim that having negative attitudes to the noise source increases sensitivity to noise exposure, or that negative attitudes are a part, or a result, of reaction.

The strong positive correlation of negative attitudes to the noise source with reaction to noise [mean r=.42; 2] is also consistent with attitude being a part or result of reaction.

The present paper examines the manner in which reaction is modified by 3 negative attitudes, corresponding roughly to local concerns, financial impact and misfeasance. For each of the 3 attitudes, general reaction to noise and noise annoyance were plotted against noise exposure for subjects classified as having a low, medium or high levels of the attitude. Parallel dose/response curves would suggest that the attitude is a "pure biasing" factor, whereas diverging dose/response curves would indicate that the attitude may be a "sensitivity" factor, a part of reaction, or a result of reaction.

2. METHODS

Subjects and Sample Selection

523 female and 482 male residents in the vicinity of Sydney (Kingsford Smith) Airport were sampled to produce a 2x2 design; current noise level was "high" or "low" with noise level projected to change (decrease, increase) or remain unchanged, due to flight-path changes. The four areas thus produced- "high-to-high" (H-H), "high-to-low" (H-L), "low-to-low" (L-L), "low-to-high" (L-H)- were approximately equally represented in the sample.

From random starting points, every 7th residence along a predetermined path was approached, and one respondent selected using the "last birthday" technique, without replacement.

Materials

A structured interview (based on previous socioacoustic surveys [6,9] and pilot results) assessed reactions to noise (dissatisfaction, affectedness, annoyance), attitudes to the noise source (local concerns, financial impact, misfeasance), noise sensitivity, health, noise-induced disturbance and demographic variables.

Subjects also completed the Grossarth-Matticeck health risk personality questionnaire (70 items) and the POMS Depression, Anxiety and Anger scales (19 items).

Procedure

A letter was sent to each selected residence announcing the investigation. Then trained interviewers door-knocked at these residences and asked to speak to the person over 18 living at the residence who had last had a birthday. If a suitable individual agreed to participate, the structured interview was conducted before completion of questionnaires.

Aircraft noise was measured at numerous residential sites near flight paths in the vicinity of Sydney Airport. Mathematical noise models for aircraft arrivals and departures were developed from these measurements. These models allowed verification of the Integrated Noise Model (INM) program developed by the US Federal Aviation Administration when applied to Sydney Airport operations. The INM was then employed to produce noise exposure data for the sample areas and sample periods [see 10 for further details].

3. RESULTS

Factor analysis of the 11 items adressing attitude revealed three factors: "local concerns" (eg. pollution), "financial impact" (eg. relevance of airport to the economy) and "misfeasance" (eg. the perception that relevant authorities are not doing enough about the noise) (for details see 7). On each attitude scale, subjects were divided into 3 approximately equal groups: high, medium and low scorers.

Reaction (measured by reliable multi-item scales of general reaction-dissatisfaction and affectedness- and annoyance) was regressed on noise exposure for each attitude group [see Figure 1 for example]. The slopes of the regression lines [see Table 1] were generally similar, or showed a slight tendency to convergence (as evidenced by the greater gradient for subjects with low negative attitude than for subjects with high negative attitude), rather than divergence.

Figure 1: Regression lines and β–values for the relationship between noise exposure and general reaction within the high, medium and low levels of the "financial impact" attitude. The low overall gradients reflect the low possible score range for reaction (0 to 10) versus the higher numbers for exposure).

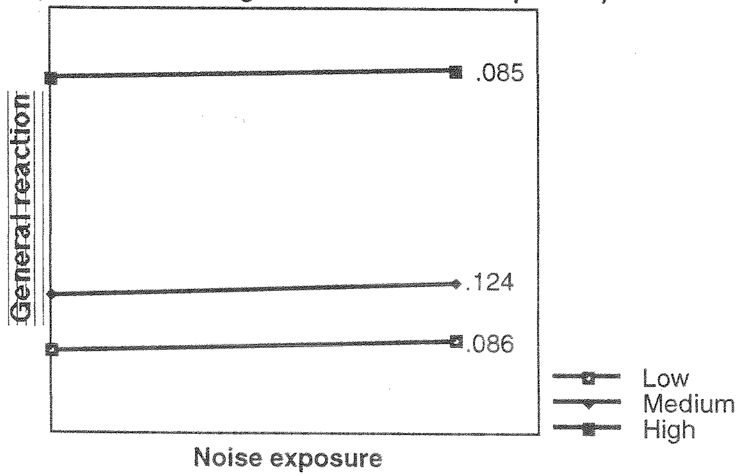

Table 1: Gradients of the noise/reaction regression lines for high, medium and low levels of each attitude, showing generally similar slopes or some convergence, but not divergence.

Reaction measure	Attitude level	Local Concerns	Financial Impact	Misfeasance
General Reaction	High	.085	.085	.086
	Medium	.120	.124	.114
	Low	.120	.086	.085
Annoyance	High	.080	.082	.069
	Medium	.119	.108	.112
	Low	.109	.086	.078

4. DISCUSSION

Subjects classified as having high, medium or low levels of each of three negative attitude factors had noise-exposure/reaction curves with similar gradients, or slight convergence (eg. in the case of local concern). It is unlikely that real divergences between the gradients exist but were not detected. First, the sample size appears to be sufficient to detect any such differences. Second, the data do not suggest substantial divergence. Rather, for five of the six strata the gradients for the low attitude level were higher than for the high attiude (convergence), with the remaining case showing marginal divergence (gradient of .86 versus .85). Although causation cannot be unambiguously identified from correlations, these data, like McKennell's [8], are most consistent with the claim that attitude is a pure modifier of reaction to noise exposure, rather than part of, or caused by, reaction.

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NOISE EFFECTS ON ANIMALS: PROGRESS SINCE 1993

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1. INTRODUCTION

During the *Noise and Man '93* Conference for the International Committee on the Biological Effects of Noise, Kull gave an overview of the United States Air Force studies on the effects of aircraft overflights on wild and domestic animals [1]. Since that report several significant studies have been accomplished to further our knowledge of the effects of military noise on wildlife. Both the US Navy (USN) and the Air Force (USAF) have aggressive programs to address the possible impacts their respective services have on the environment. The main driving forces behind these programs are the increased emphasis on the impact of the Department of Defense operations on the environment and the general public's concern for conserving threatened and endangered species.

Assessing and mitigating the environmental impact of our underwater noise production is not always as intuitively clear as airborne noise impacts might be to us with our air-adapted hearing. The physical properties of water cause it to transmit sound and light differently than air. As a consequence, vision becomes less useful and hearing becomes more useful underwater. Sound is more often "ducted" in water than in air and may travel with little energy loss over hundreds or thousands of miles. As a result many anthropogenic noises, such as low frequency sound from large ships, can affect large areas of ocean. Ironically, our ability to understand and assess the impact of anthropogenic noise on the marine environment is often limited by our own ability to use sound as a tool to "see" underwater: in that realm animals still do a much better job. The reader will find that many assessment techniques commonly used on land are impossible with current underwater sensing technology, and a large amount of our research efforts on this topic are devoted to developing new instrumentation. One more cautionary note is needed before launching into discussions of underwater sound. Traditional in-air and in-water measurements of sound use different reference units, and equivalent input intensities in air and water produce different pressures. A full discussion is beyond the scope of this paper, but the reader is cautioned that considerable confusion about the potential effects of underwater noise has arisen more than once due to the inappropriate

use of numbers without reference units. For an excellent essay on the importance of reference units in discussions of underwater noise see [2].
The intention of this paper is to briefly summarize some of the more significant projects the USN and USAF have accomplished over the last five years regarding the effects of military-generated noise on marine mammals and terrestrial animals.

2. NOISE EFFECTS ON MARINE MAMMALS

The Office of Naval Research (ONR) is the primary Navy command responsible for basic research on underwater noise and its effects, and for the early stages of underwater acoustic technology development. ONR basic research support has focused on three areas: hearing assessment, field assessment of noise impacts, and instrumentation development. Low frequency sound (below 1000 Hz) has been of special interest because it propagates underwater better than other frequencies and thus can potentially ensonify a larger area, and because low frequency sound can affect other physiological functions than hearing, such as the vestibular/balance system, lungs, and nervous tissues. Marine mammals are the main taxonomic group of concern because they have highly developed hearing, many species have been reduced to threatened or endangered status, and they are protected by special legislation, the Marine Mammal Protection Act, in addition to the protections afforded by the Endangered Species Act.

We have little hearing data for marine animals, and that only for a relatively few species of any group. Even basic audiometric data such as a hearing threshold curve or critical ratio data are lacking for most species. Because the technology to make loud low frequency underwater sound is relatively new, and because many species of interest, such as dolphins, are high frequency hearing specialists, we lack data on low frequency hearing for most species. The ONR program has focused on obtaining low frequency hearing thresholds for indicator species, which are readily available for study and already had partial hearing. Low frequency thresholds (below 1000 Hz) were obtained by standard behavioral psychophysical methods for four species of toothed whales (dolphins and porpoises) and three species of seals [3-5]. Not surprising for these high frequency specialists, they all had relatively poor low frequency hearing, with one exception; the elephant seal [4]. This deep-diving specialist appears to have much better low frequency hearing than other seals and sea lions. The reason for this difference is not known, since other deep-divers (sperm whales and beaked whales) do not have similar hearing adaptations, and most of the species of large baleen whales with low-frequency specialized ears are not particularly deep divers.

ONR is expanding on this work with more complex measures of auditory function such as masked thresholds, from which critical ratios and critical bandwidths can be obtained, and temporary threshold shift (TTS) measurements [4, 6, 7]. Preliminary data from one TTS study of bottlenose dolphins indicate that short duration tonal sounds on the order of one second induce just detectable, short duration TTS at SPLs of 192-195 dB re 1 uPa received level in their frequencies of best hearing and slightly higher SPLs around 200-203 dB at 3 kHz and lower [7]. The intensity level at which TTS occurs and the flat shape of the TTS function across the hearing spectrum (elevated slightly at the extreme ends of the animal's audible spectrum) are all comparable to human and other terrestrial mammal TTS functions, with the possible difference that marine mammal ears may possess adaptations to withstand greater sound intensities (greater dynamic range) than terrestrial animal ears. More data are needed before this trend can be confirmed, and that should be forthcoming as this and two other studies enter their second and third years in 1999-2000.

ONR has devoted a portion of its resources to developing remote techniques of hearing assessment such as detailed anatomical studies of the ear and evoked potential measurements of the auditory cortex and auditory nerve [8-14]. These measures are not considered as predictive of acoustically mediated behavioral performance because they lack the critical signal processing input of the brain, but as techniques improve they provide increasingly accurate, and perhaps our only, access to the hearing capabilities of many marine organisms, such as large whales. Significant findings to date include anatomical confirmation that the large whales are low frequency hearing specialists as was first inferred from their vocal output (blue whale signals have their peak energy around 17 Hz and only the higher harmonics are within the range of human hearing). Since most big whales are still at very low numbers following intensive commercial hunting through the early 1970's, their potential vulnerability to loud low frequency noise from human activities puts them at or near the top of our list of "marine animals most likely to be affected by increasing anthropogenic noise", especially since the biggest single source of increased manmade noise is large ships producing low frequency engine and propeller noise.

Evoked potential methods which record electric activity from the auditory nerve or auditory processes portions of the brain are showing promise in tests on dolphins and seals, but our ability to extend the technology for use on large whales and other wild animals in the field has not yet been successfully tested. Evoked potential methods are being applied to groups of animals under human care or in the field to generate large sample sizes needed to assess auditory population demographics. Preliminary data indicate that older marine mammals, especially males, exhibit high frequency hearing loss similar to presbycusis common to humans and many other terrestrial mammals [15,16].

ONR has sponsored studies of beluga whale hearing at various depths to determine if hearing changes as pressure increases; indicating a possible change in the hearing mechanism. The results indicate that beluga whales, and thus probably all odontocetes, hear equally well at all depths (down to 300 meters, or 30 atmospheres ambient pressure) [5]. At depths beyond 30 meters or so, air-filled spaces such as the middle ear would collapse. Studies of the more amphibious ears of sea lions and seals are not completed yet, but there is some indication that hearing in sea lions may degrade at depth, suggesting that the air-filled middle ear may still play a role in their hearing.

Now that we have made some progress in determining the hearing abilities of marine mammals it looks like actual physical damage from underwater noise is probably rarer and more restricted in scope than initially estimated. Behavioral effects, both short and long-term are the more likely consequence of anthropogenic noise exposure, and are more difficult to assess. The most recent, and most ambitious, set of controlled exposure studies undertaken by ONR (in partnership with other parts of the U.S. Navy and the Strategic Environmental Research and Development Program, or SERDP) was the LFA Scientific Research Program. This set of experiments made use of the newly developed SURveillance Towed Array Sonar System, Low Frequency Active (SURTASS LFA) as a controllable low frequency sound source (100-500 Hz with single element source levels in the 190-200 dB re 1 μPa range, and a multi-element coherent beam equivalent to a source level of 230 dB re1 μPa or higher). The SURTASS LFA system or components of that system were used in three experiments to assess the effect of low frequency sound on large whales suspected of being low frequency sensitive. SRP I was conducted in southern California waters among blue and fin whales to assess the response of these whales and their prey during a biologically important activity; feeding. SRP II took place off the central California coast during the coastal migration of gray whales to determine the reaction of animals on a fixed timetable and route when a potentially aversive sound source was introduced in their path. SRP III was conducted near the northwest coast of the island of Hawaii during the breeding season of humpback whales. Singing male whales were exposed to the LFA sound source to determine the source's impact on another biologically critical activity.

In all three SRP's no strong, universal behavioral reaction was observed. Animals did not clear a large zone around the source or dive abruptly and move away quickly, or cease vocalization entirely. At the range of exposure levels, 110 dB to 155 dB re 1 μPa, there was some expectation that the higher exposure levels would indeed produce strong behavioral reactions, but that was not the case. What was observed in all three studies was a tendency of some individuals, but not all, to avoid close proximity to the sound source, as recorded by aerial surveys and ship or shore-based observations. In Phase I there was no apparent change in vocal or feeding/diving behavior by blue whales, and only a small fraction of fin whales showed short, temporary interruption of vocal activity, and perhaps frequency shifts, correlated with "pings" from the sound source [17]. In Phase II migrating animals tended to avoid the source when it was in their path, with avoidance beginning at received levels around 120 dB re 1 μPa. But they appeared unaffected by the same source when it was moved just 2 km further offshore, even at exposure levels of 150 dB re 1 μPa or higher [18]. In Phase III a small percentage of monitored singing whales ceased singing when the sonar was activated and some also changed direction and moved away at slow to moderate speeds, but resumed normal singing and/or social behavior within less than an hour of exposure. The exposure levels that produced such changes were as low as 120 dB re 1 μPa, but other individuals were exposed to levels up to 155 dB re 1 μPa without any apparent change in singing or other behaviors [18].

ONR also supports research to develop new sensors. A variety of devices have been developed to attach to marine mammals, including ARGOS satellite telemetry tags, recoverable dive dataloggers which may also include swim velocity, water temperature or other data, ECG monitors, feeding event (stomach temperature) monitors, and acoustic dataloggers or "dosimeters" [e.g. 18-19]. The combination of large body mass and almost constant movement at speeds of 3 to 20 miles per hour makes it hard to keep

devices attached against the drag imposed by a medium so much denser and more viscous than air. The longest-lived devices are either surgically attached to dorsal fins or embedded in the blubber layer with only an antenna or small data package protruding, but even these only stay attached for a few weeks (current maxima are in the 90-120 day range). For shorter periods up to a day or two, devices may be attached by suction cups or dorsal fins saddle packs.
Considerable effort has been devoted to adapting underwater listening technology developed for anti-submarine warfare or physical oceanographic research to detection and tracking of acoustically active marine animals. One of the largest efforts offers the best possible illustration of some the most challenging problems of the marine environment. This effort involves the monitoring of networks of deep ocean listening stations called SOSUS. This system has enabled us to monitor the approximate regional abundance and migratory movements of several large whale species which move annually through entire ocean basins [20]. These whales emit very loud low frequency sounds, most below the level of human hearing, and these sounds are picked up hundreds of miles away by the very sensitive SOSUS stations. Using the SOSUS system the movements of whales across entire ocean basins the size of continents can be tracked, as can the tracks of individual whales that can cover over a thousand miles in a week [21]. Such data would be impossible to obtain in any other way, and it greatly improves our understanding of how the largest animals the world has ever known use home ranges that may cover tens of millions of square miles of open ocean.

Other new technologies are slated for exploration in the near future, including infrared and ultraviolet sensors, radar, and active sonar. The goal in all cases is to improve sensing of individual animals and of habitats where marine mammals or other marine organisms are likely to be found. Improved sensing will lead to improved understanding of the ecology and life habits of marine animals, which in turn will lead to improved ability to assess and mitigate the impacts from anthropogenic noise sources. ONR is also sponsoring development of a web-based, graphical user interface (GUI) system called the Living Marine Resources Information System (LMRIS) to provide a means of combining data sets on marine animal habitats, distribution and movements with predictive impact assessment tools [22]. LMRIS will be used by Navy activities planners to minimize impacts on the marine environment.

3. NOISE EFFECTS ON TERRESTRIAL ANIMALS

For many years there have been concern for the effects of high speed, low altitude jet aircraft on terrestrial animals, especially birds and mammals. In 1988 the USAF set out to assess possible effects by pursuing several comprehensive studies, of which many were reported to ICBEN at the Noise and Man '93 Conference [1,24-26]. Bowles developed an interim model to predict reproductive effects of military low altitude overflights to raptorial birds. Beginning in 1994, researchers set out to verify whether aircraft overflights might affect peregrine falcons in Alaska as Bowles' model predicted [27]. During the four-year study researchers observed over 112 peregrine nests for productivity and at least 258 overflights with altitudes less than 400 meters from the aeries. During the tests 111 overflights registered at least 85dBA. Of the 111 observed overflights, eight males reacted by taking flight; no females responded by taking flight. They concluded that the interim model, recognizing that it was developed as a conservative predictor, does seem to over-predict the effects of noise on peregrine falcons.

Planned flight testing of the USAF's newest fighter, the F-22, raised the US Fish and Wildlife Service's concerns of noise and sonic boom impacts on the Desert Tortoise, *Gopherus agassizii*. In order to respond to this concern, the US Air Force contracted a study to 1) determine the response thresholds of the desert tortoise to noise and vibration, 2) determine if TTS can be detected after worst-case exposures to simulated F-22 aircraft noise and sonic booms, and 3) determine whether desert tortoises respond behaviorally and physiologically to F-22 noise or sonic booms [28-31]. Hearing tests, using Auditory Brainstem Response (ABR) procedure was used. Bowles et. al. [30] found that on average tortoises' hearing threshold was 34dB SPL at 250 Hz (the most sensitive frequency) at preferred temperatures (28-32°C). No TTS was found after exposures to 20 subsonic overflights over a 40 minute period (levels ranging from 94.6 to 114.2 dB CSEL) or to a single simulated focus boom of 10.5 pound/ft^2 (psf). However, TTS was observed for over 45 minutes after being exposed to 10 simulated sonic booms at 6 psf. Tortoises did not exhibit startle response (including urination or defecation) following any aircraft noise event [29]. However, startle responses were observed when animals were touched unexpectedly. Bowles reports that the worst behavioral response was freezing, sometimes for more than 60 minutes, to subsonic aircraft noise. Tortoises appeared to habituate to overflight events after successive days of exposure. No significant changes in heart rate or activity were observed in response to sonic booms, yet naïve tortoises did exhibit a decrease in heart rate of 7.6% for about an hour after 45 minutes of subsonic aircraft overflight noise [31]. Eckert stated that their data indicated tortoises freeze during overflight activity resulting in a reduction of energy consumption. Bowles et. al. [28] concluded that the F-22 would not cause any acute effects in desert tortoises, however, chronic effects could not be ruled out.

Delaney et. al. [32] investigated the possible impacts of helicopters and chainsaw noise on the Mexican Spotted Owl (*Striz occidentalis lucida*) in the Lincoln National Forest, New Mexico. They documented owl behavior during noise events using HH-60G helicopters and chainsaws as the sources. Forty-nine events occurred during the owl's nesting season, while 112 events were performed during the non-nesting period. Delaney et. al. [32] did not find differences in reproductive success between test and control nest sites. Even though flushing frequency increased as distance from the source decreased regardless of the stimulus, no flushes occurred at a distance greater than 105m. Chain saws consistently produced higher response rates than helicopters at comparable distances. During the nesting season, spotted owls did not flush when the SEL for the helicopters was <92 dBA (102 dB for special owl-weighting, designated as dBO) and an $L_{eq\ 10\ sec}$ of <46dBA (<59 dBO) for chainsaws. For the non-nesting period the levels below which flushing did not occur were <92 dBA for the SEL (<104 dBO) and <51 dBA $L_{eq10sec}$ (<65 dBO) respectively. Delaney et. al. [32] stated that distance was a better predictor of spotted owl response than sound level. They estimated the potential threshold distance for a "sub-flushing, negative impact on prey deliveries was 96m."

They also concluded that chain saws at comparable distances were more disturbing to owls than helicopter overflights and that short duration, single pass overflights had little impact on spotted owls and recommended a 105 m hemispheric radius protection zone around nests to minimize impacts.

The US Army has observed an increase in the number of successful nests of Bald Eagles (*Haliaeetus leucocephalus*) at Aberdeen Proving Ground (APG), Maryland. Russell et. al. [33] reported eight active bald eagle nests in 1990, while in 1995 there were 14; 24 nests observed in 1996. Russell et. al. [33] examined possible influence of weapons testing on the nesting success of the eagles. Behavior data was recorded before and after noise events. Control nests off the installation were also monitored. During the two-second period after the noise events, 92.7% of the time no change in eagle activity was observed; 0.7% of the events observed head turns. Winter roosting sites were also monitored and similar observations were made. Comparisons of nesting success, numbers of young per occupied territory, young/active nest, and young/successful nests on APG versus the control sites indicated no difference from 1990 through 1995. Russell et. al. [33] concluded that bald eagles at APG showed no significant behavioral reactions to weapons-testing at nests or roosting sites.

Bowles et. al. [24] presented initial results of a study on the effects of aircraft noise on predator-prey ecology of the kit fox and its small mammal prey. McClenaghan and Bowles [34] were not able to determine if slight differences in exposed versus control plots of small mammals were the result of increased predation or differences in vegetation diversity. They did conclude that "effects of lifetime exposure to intermittent aircraft noise on animal demography (if any) are likely to be small and difficult to detect." As part of this study researchers measured the sound attenuation of jet noise in small mammal and kit fox burrows [35]. Though they did not sample several types of burrow configurations, relatively straight and shallow burrows for both small mammals and kit fox did not afford much protection of the jet noise. Small mammal burrows attenuated little below 1500 Hz and reduced the level 10-15 dB above 1500 Hz. The kit fox den attenuated sound 20-40 dB between 1000 and 4000 Hz [35]. Francine and Bowles [36] also measured the hearing of kangaroo rats on their control and exposed plots. They found a 3 dB difference in hearing sensitivity of animals from the sites. However, in one animal from the exposed site, a profound hearing loss was detected. Since the animal was in good health, researchers believe the hearing loss did not result from aircraft noise exposures.

The Air Force also performed a study on the effects of low-altitude aircraft overflights on domesticated ratites (flightless birds). This study will be presented at this symposium, so it will not be discussed here. Another study currently in progress is to determine the effects of aircraft overflights on pronghorn antelope. A special annotated bibliography focused specifically on this topic [37] and the results of the auditory brainstem response (ABR) portion of the study will be reported at this Congress.

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EFFECTS OF LOW-ALTITUDE AIRCRAFT OVERFLIGHTS ON RATITES

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1. INTRODUCTION

Traumatic injuries due to all causes (panics, predator attacks, and fights) are the greatest cause of mortality in adult farm-raised ratites (the ostrich [*Struthio camelus*], emu [*Dromaius novaehollandiae*], and greater rhea [*Rhea americana*]; Hallam 1992). Traumatic injuries have occurred after overflights of U.S. Department of Defense (DoD) aircraft, motivating the experiments reported herein. Ratite responses to aircraft were investigated several ways. First, claims against the DoD were collected from bases across the U.S. Second, farmer responses to questionnaires were collected at meetings and by mail. Finally, experiments were conducted at cooperating farms throughout central Oklahoma with air support from the Oklahoma Air and Army National Guard. A total of 73 ostriches, 362 emus, and 218 rheas at 10 farms were exposed. At each farm, 5 experiments were conducted (2 with real aircraft, 3 with simulated overflights). Detailed observations of bird responses in a test pen with 7-15 individuals were collected during each experiment; observations of up to three other pens were also collected when possible.

2. METHODS

Ratites at each farm were exposed to two real aircraft overflights and three simulations. A total of 6 real F-16 and 3 C-130 jet overflights were conducted, associated with 19 and 3 simulation experiments, respectively. A total of 10 real helicopter overflights were conducted (1 UH-60A, 2 UH-1V, 7 CH-47D) with 3 series of simulations (for a total of 9; 4 CH-47D, 5 UH-1). *A priori*, exposures to real overflights were broken into two level categories (L_{max} below 90 dBA, above 90 dBA), with level to be controlled by the speed of the aircraft (30 or 120 kt for helicopters) or power setting (Table 1). Pilots were generally instructed to fly at 500 ft AGL (exceptions were the experiments at the first and fourth farms). F-16 fighters were controlled using GPS navigation and made a single pass over the test farm. However, helicopters and C-130 transports made their final approach visually, even when aircraft were equipped with GPS navigation, so there were occasional near-misses. In these cases, the pilots made 1-3 passes in search of the target pen.

Table 1. Summary of real aircraft overflight exposures conducted during the study.

Farm	Aircraft	Date	Passes*	Time	ASEL (dB)	Duration (s)	Reported Altitude (ft AGL)	Photo Distance (ft)	Trakker Distance (ft)	Trakker speed (kts)
OSU	F-16	9/5/96	1	14:35	101.2	71.0	1082	1236.1	-	-
	UH-60A	9/8/96	1	09:59	80.8	38.8	545	1304.5	-	-
Jones	F-16	9/19/96	1	14:10	110.6	30.3	500	-	417.6	363.1
	CH-47D	9/24/96	3	12:03	94.2	28.5	500	396.3	357.4	46.3
Ada	F-16	10/2/98	1	14:41	108.9	64.8	500	1545.2	1476.4	414.2
	CH-47D	10/4/96	3	10:29	95.4	46.6	500	418.5	455.6	57.2
Francis	F-16	10/15/96	1	10:19	88.4	21.1	2500	-	-	-
	CH-47D	10/18/96	2	15:01	88.8	25.6	500	757.0	-	-
Paul's	F-16	10/24/96	1	10:21	95.2	89.9	1000	1201.8	1079.8	269.5
Valley	CH-47D	10/30/96	1	15:08	96.2	17.4	500	935.7		
Duncan I	F-16	11/4/96	1	15:34	96.5	18.3	500	558.2	-	-
	CH-47D	11/7/96	1	16:10	83.4	34.0	500	1182.0		
Duncan II	UH-1V	11/21/96	2	15:18	91.3	50.9	500	522.1	506.0	32.0
Chickasha	C-130H	12/10/96	2	12:08	97.8	22.4	500	637.9	721.23	186.6
	CH-47D	12/12/96	3	16:03	99.3	33.3	510	556.8	590.1	138.9
Meeker	CH-47D	7/17/97	1	17:43	97.7	41.3	510	478.4	-	-
	C-130H	7/22/97	1	11:15	90.7		510	1011.1	-	-
Noble	UH-1V	7/25/97	1	14:30	103.2	33.8	500	-	-	-
	C-130H	7/29/97	1	12:44	92.9		510	-	-	-

* Some aircraft made several passes over the test birds. Slant distance was estimated closest point of approach.

Photographic documentation of the point of closest approach was obtained for 15 of the real aircraft passes at 9 farms. All flights were photographed in black and white with a Nikon still camera equipped with a motor drive and 185 mm Nikkor lens. A more accurate video-based system, a Ball, Inc. Camera Trakker, was used to estimate closest point of approach and airspeed during 8 overflights.

Larson-Davis 820 and 870 community noise monitors were deployed at all farms throughout the experimental period to document both overflight levels and ambient noise.

3. RESULTS

Examination of 73 claims and complaints and 22 additional incident reports from 29 bases yielded records of overflights (sometimes farms were exposed repeatedly) involving >2000 birds in 1993 and 1994. A total of 19 birds were killed in these incidents, for a loss rate of 1% of exposed birds. In addition, 7 cases of breeding declines and 2 cases of 'stress' were reported. Out of a total of $570,436 claimed, 22% was paid; over half of this for stress and lost reproductive output (56%).

A total of 27 farmer questionnaires were returned from 11 states reporting responses of >3352 birds to a variety of disturbances. DoD overflights were responsible for 3 mortalities at 2 farms, a leg injury at 1, and minor injuries at 2. The calculated loss rate was 0.1% of birds exposed. If injuries are included, the rate was 0.2%. Both the base complaint records and farmer questionnaires were probably biased in favor of substantive injury reports, so it is possible that the loss rate was actually lower than the calculated values. They therefore represent a worst-case estimate of expected loss rates. Unfortunately, such low probabilities are difficult to measure accurately with a practical experiment. None of the 653 birds exposed during the experimental phase of this program was injured.

Observer reports and Larson-Davis 820 sound monitors deployed at cooperating farms for 2003 hrs showed that ratites were exposed to many noise sources other than the experimental overflights. Thunder was the most intense, with maximum levels in the range from 120-130 dB (peak SPL). Most of the farms visited were exposed to lightning and thunder at least once during the experimental period. Farm machinery also produced high noise levels, ranging from 92-104 dB ASEL. Finally, ratites were exposed to light aircraft, trains, shotgun blasts, truck traffic, jetliners (near a major airport), and noise from cattle. Average equivalent sound levels (L_{eq}) at farms during the experiments ranged from 47-70 dB. Levels were below 70 dBA for 95% or more of the period at each farm.

Real aircraft overflights varied up to 10 dB ASEL from planned levels (Table 1), but produced relatively uniform exposure in all areas of the pen. As an example, high amplitude F-16 overflights planned for a level of 105 dB ASEL ranged from 96.5 to 110.6 dB ASEL, but varied < 10 dB and often < 3 dB across the test pens. Simulated sound levels had roughly the same range (high amplitude F-16 overflights had a range of 100 to 120 dB ASEL), but varied considerably in different areas of the pen (> 20 dB).

Ratites reacted to noisy disturbances, including overflights, with controlled species-typical aggressive and defensive behaviors. Most commonly, exposed birds of all three species ran, congregated (formed a group), and looked for the source of the sound. They oriented (turned in the direction of) the incoming sound accurately even when an aircraft was not visible, *i.e.*, during simulations, in overcast weather, or when tree cover obscured their view. The range of behaviors gave an indication of response intensity, ranging from tall alerting, to running (usually to congregate), to orienting (usually after congregating), to mild aggressive gestures, to evasive movements designed to throw off predators, and, finally, to running in a flock along the borders of the pen at high speed (flock running).

Ratites did not panic in response to overflights, i.e., blind running and uncontrolled collisions with fences were never observed. However, they did react with behaviors that could have resulted in accidents. The most intense of these, evasive running and flock running, were observed in every species. Flock running in emus was aroused once by a UH-1 helicopter at a range greater than 3000 ft, but the incidence of risky behaviors was highest when overflights were directly overhead at low altitude.

The longest bouts of flock running and evasive running were observed among large flocks in big pens. However, birds controlled their movements in the vicinity of barricades, usually slowing or stopping before hitting them. The collisions that caused greatest concern occurred in pens too short to allow birds to run freely.

Ratites also congregated defensively during overflights, and, while congregated, oriented aggressive behaviors at one another. These brief aggressive encounters could potentially have caused injuries, particularly aggressive chases by emus.

Five behaviors (tall alerting, running, congregating, evasive running, and dropping) were quantified for emus and rheas during and immediately after overflights. In both species, running and congregating had low thresholds – the birds ran as readily as they alerted (Table II). Alerting, running, and congregating constituted over 95% of the behaviors observed in both species. However, the incidence varied by species, aircraft type, experimental condition (real or simulated), and exposure level.

Responses of Emus

High amplitude overflights. Viewed in terms of incidence (number of behaviors per experiment), the responses of emus did not differ much between experiments with jets and helicopters (54/expt F-16 *vs.* 42/expt UH-1 *vs.* 51/expt CH-47D). However, emus ran, alerted, and congregated less often when exposed to simulated *vs.* real overflights. The difference was smallest in the case of jet aircraft overflights. For F-16 overflights, rates of alerting, running, and congregating were only 18% smaller during simulated overflights (54/expt real *vs.* 44/expt simulated). For UH-1 helicopter overflights, alerting, running and congregating occurred twice as often during real overflights (42/expt real *vs.* 16/expt simulated). No emus were exposed to Chinook simulations. The difference in response between real and simulated overflights was almost double during experimental C-130 overflights as well, but overall response incidence was much smaller (5/expt real *vs.* 2/expt simulated). High intensity evasive running, flock running, and dropping were never observed in response to simulations.

Emus occasionally ran into fences during close approaches by real aircraft. In one case (a pair held in a 100'x35' pen), an emu hit a fence hard during a bout of evasive running (non-focal pen) after exposure to a pair of F-16 aircraft at 500 ft.

Low amplitude overflights: Alerting, running, and congregating occurred in roughly equal proportions among emus after exposure to real F-16's and helicopters at low exposure levels (unfortunately, no simulations of helicopter exposures at low levels were conducted). Low exposure levels yielded lower rates of behaviors (11/expt F-16 *vs.* 9/expt CH-47D). Evasive running and dropping were not observed in response to low level exposures.

Table (1). Responses of emus and rheas to aircraft overflight experiments (A – high amplitude exposures; B – low amplitude exposures). Number of experiments and rates of the three most common behaviors (alerting, running, congregating) are indicated in the columns. Real and simulated overflights are summarized separately.

A. Experiments with high level of exposure

Species	Emus				Rheas			
Aircraft	Real		Simulated		Real		Simulated	
	Expt	Rate/ Expt	Expt	Rate/ Expt	Expt	Rate/ Expt	Expt	Rate/ Expt
F-16	3	54	9	44	4	10	8	10
CH47D	3	51	0	-	5	14	2	19
UH-1, UH-60	2	42	8	16	0	-	0	-
C-130	8	5	8	2	2	20	3	27

B. Experiments with low level of exposure

Species	Emus				Rheas			
Aircraft	Real		Simulated		Real		Simulated	
	Expt	Rate/ Expt	Expt	Rate/ Expt	Expt	Rate/ Expt	Expt	Rate/ Expt
F-16	4	11	13	9	4	9	13	1
CH47D	4	9	0	-	3	6	0	-
UH-1, UH-60	0	-	0	-	0	-	0	-
C-130	0	-	0	-	0	-	0	-

Responses of Rheas

High amplitude overflights. Rheas did not congregate as easily as emus and exhibited a generally lower rate of alerting, running, and congregating. Responses to real jets and helicopters were similar (10/expt F-16 *vs.* 14/expt CH-47D), with the incidence of response 1/3 of that observed in emus. In rheas, responses to C-130 transports were markedly stronger than those of emus (20/expt *vs.* 5/expt).

No differences were seen in responses to real *vs.* simulated aircraft overflights in the rhea. For the F-16 experiments, the rates were indistinguishable (11/expt real *vs.* 9/expt simulated). There was an increase in response to simulated Chinook helicopter overflights (14/expt real *vs.* 19/expt). There was also an increase in responses to simulated C-130 aircraft overflights (20/expt real *vs.* 27/expt). Evasive running was observed during both real and simulated overflights, although the behavior was not common (0.2-1.7/expt). Rheas were never observed flock running in response to overflights, nor did they collide with fences.

Low amplitude overflights. Rhea responses to low amplitude F-16 overflights did not differ much from responses to high amplitude jets (10/expt high *vs.* 9/expt low). However, there was a marked difference in responses to real and simulated low amplitude overflights (9/expt real *vs.* 1/expt). Congregating, rare during high amplitude exposures, disappeared during low amplitude exposures (3.2/expt *vs.* 0.3/expt; 2 congregating incidents were observed during 20 experiments, both during simulated jet overflights). However, unlike the case for the emu, evasive running was observed during exposures at low levels. No helicopter experiments were conducted at low exposure levels.

Responses of Ostriches
The data for ostriches were insufficient for meaningful comparisons. One case of flock running was observed in a large, open pen in response to oblique approach by a UH-60A helicopter.

4. CONCLUSIONS

The results of these measurements suggest that simulated overflights do not model real exposures well, particularly not when aircraft are at a distance. However, the reasons for this difference are still not clear. Three hypotheses have been advanced. First, observers noted that birds were motivated to localize the source of aircraft noise and were able to orient on an incoming aircraft as soon as they were audible (human observers and ratites detected incoming aircraft at the same time). Since the simulations did not (and could not) mimic the approach of an aircraft from a long range, the birds may have detected abnormalities in the perceived location of the sounds. Second, the simulated overflights were much shorter in duration as measured from the moment of first detection to the moment they disappeared into the background. Finally, birds in different areas of the pen received different levels from a simulation, whereas the sound field was relatively uniform during real overflights. This meant that fewer birds were likely to receive the highest sound levels during simulations.

The low incidence of injuries and the controlled behavior of the birds lend support to the hypothesis that most traumatic injuries occur when ratites make mistakes rather than when they panic *en masse*. Because noise-induced panics could not be elicited experimentally, it is difficult to say whether aircraft can cause panics. Certainly, the aircraft would have to be at low altitude and in the vicinity of birds for several minutes before such a result could be expected. However, even when movements are controlled, highly energetic behaviors such as flock running or even congregating have the potential to cause accidents [2]. Flock running was observed in response to helicopters at ranges as great as 1 km (3280 ft).

The likelihood of traumatic injuries during overflights can be reduced by habituating birds gradually to noisy sources (the more, the better), providing them with room to run, and designing fencing that reduces risk of injury during accidental contacts. In addition, group sizes should be kept small and rivals should be separated [Aircraft support was provided by the Oklahoma Air National Guard and Army National Guard; funded by the U.S. Air Force, Contract No. F41624-95-C6014-DO-C9].

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A PROGRAM TO MEASURE SUBTLE EFFECTS OF NOISE ON BIRDS

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1. INTRODUCTION

Noise generated by human activities such as aircraft, traffic and machinery, is generally assumed to harm animals, especially those that depend on sound for mating and social cohesion. Nevertheless, evidence to support that assumption is very sparse. There is no plausible way for noise levels found in urban or industrial environments to cause direct damage to animals or their young. The assertion is that noise harms animals indirectly by generating stress. The popular point of view that noise intrusion in formerly unexposed areas reduces animal well-being or quality of life falls outside of science because such vague concepts are unmeasurable; we simply cannot ask the animals if they are unhappy about the noise. Even so, noisy human activity may indeed affect animals negatively. For example, if noise were to mask vital communication signals, the animals' normal activities would be disrupted. When noise is essentially constant, animals and especially birds could be excluded from the habitat because their signals would be masked by noise and they could not communicate. [1]

Over the past several years, studies have been conducted to determine the effects of anthropogenic noise on avian species. These studies were conducted on small passerine species living in the coastal sage scrub plant community including the threatened coastal California gnatcatcher (*Polioptila californica californica,* CAGN, gnatcatcher), and the endangered least Bell's vireo (*Vireo bellii pusillus*, LBV, vireo) which lives in riparian habitat.

Currently, we are working on a study that was designed to determine the effects of noise generated by helicopter operations on the above mentioned federally listed bird species at two military facilities in San Diego, California in the southwestern corner of the United States of America. This project involves monitoring the acoustic environment and reproductive success of these two species over five years. We consider reproductive success of the birds to be the best measurement of the effects of environmental influence on a population.

Marine Corps Air Station (MCAS) Miramar, hereinafter referred to as Station or Miramar, is located near the west coast of San Diego County and is surrounded by urban development. On the Station, the California gnatcatcher has been studied for the past several years [2,3]. These previous studies have centered around gathering data on reproductive performance, predation, habitat characteristics and measurements of military aircraft noise. The habitat of Miramar is generally a coastal sage scrub plant community comprised of moderate xerically adapted species. There are large areas of southern mixed chaparral and there is some riparian habitat that is associated with a more mesic environment. Southern mixed chaparral and riparian vegetation communities do not serve as habitat for the target species, CAGN.

Marine Corps Air Base Camp Pendleton, hereinafter referred to as Camp Pendleton, is located in northern San Diego County, approximately 30 miles north of Miramar. On Camp Pendleton, the least Bell's vireo lives in riparian habitat and the reproductive success of this species has been studied for many years by a variety of biologists [4]. The study area on Camp Pendleton is dominated by the Santa Margarita River. The riparian vegetation is dominated by willows (*Salix sp.*) and serves as habitat for one of the largest populations of the LBV in southern California.

The basis of the current study is that the acoustical environment for the birds on Miramar and Camp Pendleton will be changing. Previously, Miramar was a Naval Air Station and air traffic consisted of fixed-wing jet aircraft, including F-14 and F-18, and a variety of other aircraft. In 1998, the Marines began to transfer helicopter operations to the Station. Future air traffic will include fixed-wing jets and helicopters. Pendleton has had both helicopter and fixed wing operations for several years, but there will be increased numbers of helicopters using the air station.

The current study is designed to allow for more subtle changes to become evident. A higher number of nests will be monitored over a longer period of time than has been done in past studies. Noise contours derived from these measurements will enable us to predict the sound exposure level experienced by passerine species. These data then can be used to determine any correlations between the reproductive performance of the birds and the sound pressure level (SPL) at the nesting site.

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2. METHODS

This and previous studies involved field measurements of the acoustic characteristics and nesting success at specific nest locations to determine the noise characteristics in passerine nesting areas. On Miramar, the sound measurements are taken at each CAGN nest location. On Pendleton, the measurements are taken in a grid that is systematically shifted throughout the study area. Systematic sampling of the study area which is determined by presence of LBV nest locations may result in a sound level meter within 10 meters of a nest. In addition to acoustic characteristics, an effort to analyze the possible effects of masking was undertaken. Calls of the birds were recorded and the call characteristics were determined and compared to recordings of ambient noise. This should show if call characteristics are masked by introduced, manmade noise.

Larson Davis model 720 community noise analyzers were used to record a variety of acoustic parameters in the field. These are battery-operated sound measuring instruments that consist of an integrating sound level meter, a digitizer, a microprocessor for analysis, and memory to store the resulting data. The Larson Davis model 720 meets American National Standards Institute (ANSI) S1.4-1983 type 2 specifications for general noise measurement [5].

The noise analyzers summarize all sound data collected during every one week period sampled by all permanent and movable noise analyzers. Data include the hour, in international time, that the Larson Davis 720 started to record data and the total time that the noise analyzer collected data (also referred to as the sampling period). For each hour and for the entire sampling period, the analyzers calculate the average sound pressure level (L_{eq}), the sound exposure level (SEL), a measure of the total sound energy during a time period (see glossary for equation), the maximum and minimum fast sound pressure levels and the A-weighted and unweighted maximum instantaneous peak sound pressure levels. The analyzers also compute the sound levels exceeded n% of the total time (L_n) and our templates extract its converse, the percent of the run time that the sound level was equal to or greater than some level.

In our application, the microphone was mounted in a weatherproof holder 1.6 meters (four feet) above the ground atop a metal pole that was driven into the earth. Each microphone was covered with a 17 cm (6.7 in) diameter acoustical foam windscreen. After some data were lost because heavy rain saturated the windscreens and wet the microphones, the windscreens were enclosed in close-fitting, thin (15 μm) plastic bags to seal out rain. Tests showed that this reduced effective microphone sensitivity to fixed- wing aircraft noise by 0.6 dB. The microphone cables were encased in flexible metal tubing to shield against electromagnetic interference (*e.g.*, radar and high-voltage power lines) and damage by animals. To prevent overheating, the weatherproof enclosure for the analyzer and its battery were placed under reflective sun shields, which protected them from direct sunlight.

The calibration of the noise analyzers was checked with Larson Davis model CAL150 acoustic calibrator number 0490 (94/114 dB) before they were placed in the field, and rechecked halfway through the season. When required, meters were sent to Larson Davis for calibration. Once in place, the analyzers were left running for a full seven days, starting and ending at midnight, to gather acoustical data. After one week, each noise analyzer had its memory contents transferred to a portable computer, then its memory was cleared and its battery was replaced. The permanent reference analyzers were set to run for another week and the others were moved to new sites. All data collected in the field were transferred to a computer at Hubbs-Sea World Research Institute for processing. Templates were constructed in Microsoft *Excel*© to convert raw data from the analyzers into finished tables and graphs.

Standard A-weighting was applied to all SPL measurements except for unweighted peak sound pressure levels. A-weighting reduces the sensitivity of the system to low frequencies in a manner analogous to that of the human ear. The integrating sound level meters in community noise analyzers can calculate the time-averaged sound level (L_{eq}) during a set time period. This average is not the arithmetic mean of individual sound levels in decibels. Simply averaging decibel levels gives incorrect results - all levels must be converted to squared sound pressures, and the average of those pressures then reconverted to decibels [6].

Summary graphs are produced to display the percent of the total time that the A-weighted sound pressure level was at or above each level and the variation in maximum, minimum and one-hour average sound levels for every hour of the day over the one week sampling period. They also show the twenty-four hour average sound pressure level for each day and the one-week average sound pressure level for every week.

In an effort to determine if manmade noise masks passerine calls, the source sound pressure levels were recorded. Each call was recorded with two ACO 7013 type 1 precision sound level microphones onto the two channels of a digital tape recorder. At least once in every recording session, a 1 kHz 94 dB tone from a Brüel & Kjaer 4230 sound level calibrator was also recorded. Recordings of the songs and attendant ambient noise were analyzed with a Unigon Spectrograph for general song characteristics and with a Spectral Dynamics SD380 FFT analyzer for quantitative measurements of sound pressure and spectral characteristics.

In order to determine reproductive success, the two key response variables measured were the number of nest attempts and the number of fledglings produced, both of which have a finite number of levels. Strict protocols for nest monitoring were followed in order to decrease predation as a function of visiting the nests. Nests were observed from a distance of approximately 10 meters to ascertain if the nest was active with eggs or nestlings or if the young had fledged. If this information could not be ascertained from a distance, the nest was approached when the adults were not on the nest or in the area.

Statistical tests and spatial analysis will be used to determine if helicopter noise has an effect on CAGN and LBV breeding success. To determine the probability of a response as a function of the sound level, logistic regression will be used. To determine if the response was solely due to sound level, other confounding factors will be considered such as predation, habitat, weather, disturbance and year of study. These factors will all be accounted for in the statistical analysis.

3. RESULTS

The current studies on Miramar and Camp Pendleton are in the initial stages and at this time we have not began to analyze the data. All results discussed in this section pertain to past studies.

During the fixed-wing aircraft study on Miramar, fast sound levels have ranged from a minimum of 29.6dB to a maximum of 123.3dB and one week average sound levels ranged from 45.6dB to 81dB. The western section of the Station, where the aircraft land and take off, experienced one-week average sound levels that averaged 72.5 dB. The central section is an approach corridor for landing and one-week average sound levels averaged 70.1 dB. In the eastern section, aircraft were either absent or at high elevations and the one-week average sound levels averaged 56.9dB. Neither ANOVA on ranks or regression analysis shows a clear and consistent pattern of differences in reproductive production among the three sections of the Station.

There was a low correlation between fixed-wing aircraft noise level and CAGN reproductive performance, explaining less than 10% of the variability in any of the seven different reproductive performance indicators. The total number of nest attempts and the total numbers of eggs show a negative trend, but neither trend is statistically significant. The negative trends that imply that CAGN reproductive performance declines slightly with increasing noise level, are consistent with the common observation that birds are more easily affected by disturbance before they have invested heavily in a clutch of eggs than afterward.

The number of chicks and fledglings per pair did not differ consistently among the sections, as they should if the trends were real and important. One week average sound levels measured at 81dB were not enough to discourage pair formation and success of fledgling chicks in the noisiest part of Miramar. They commonly fledged chicks when the 1HL maximum reached 80dB and were successful when it approached 90dB.

CAGN calls are quiet in comparison with most bird calls. The source levels of the calls we recorded were all around 50 dB. The overall source sound level of a LBV song recorded at Pendleton was 63.8 dB. Other songs by the same male ranged as much as 10 dB higher. Mockingbirds, in contrast, often exceed 90 dB. We measured call attenuation in coastal sage scrub and estimated that a gnatcatcher should be able to detect another's call about 90 m away under good conditions

4. DISCUSSION

There are only a limited number of ways to scientifically measure the effects of sound on animals. Three major effects that noise can have on avian species are 1) masking communication noises, 2) causing stress in individuals which changes their behavior and 3) causing hearing loss. Any of these effects can create a general loss of vitality in birds. Since it is difficult to quantify stress and hearing loss, masking is the focus of most studies. There are numerous responses that birds can have to elevated levels of noise in the environment. These include alterations in location of home ranges, singing behavior, calling rate and other behaviors to mitigate the effects of the noise.

Whether a particular noise will prevent an individual animal from hearing a signal depends on the hearing characteristics of the listener and the spectrum levels of the noise and the signal. In order to mask a signal, the total power in a band of frequencies, termed the critical band, around that of the signal must be at least as high as that of the signal. Width of the critical band is determined by frequency and by the structure of the inner ear. Noise prevents an animal from hearing a signal only if the sound power in the critical band containing the signal exceeds the sound power of the signal. Noise at frequencies outside a critical band interferes little with hearing the signal [7]. Physics, behavior, anatomy, and physiology are important in establishing the masking distance. Important masking factors also include duration and the time-of-day of the noise [8).

An animal's ability to detect signals in the presence of background noise also depends on its ability to determine the direction of sounds and its ability to discriminate sounds of different levels and frequencies. Such factors as wind, and interactions between sound waves and barriers, surfaces, soils, etc., also affect the masking distance, but calculating how to compensate for them is essentially impossible because they are so variable and because signaling between animals is dynamic. The wind is seldom constant, so repeated signals will come at times when the wind dies down as well as when it is blowing, and animals, especially birds, tend to call most at times of the day when wind is minimal. Animals usually are highly motivated to attend closely to the signals of others and can turn their heads or move to improve signal-to-noise ratios. No simple equation can model this behavior, so the practical course is to assume that animals act to optimize their communication and not encumber ourselves with complexity unless we have good evidence that it is necessary.

When examining the effects of highway noise on the CAGN communication signals, we found that passerine communication signals can be masked but not for a period of time that disrupts breeding. We also examined the hypothesis that birds compensate for higher ambient noise levels by increasing their call repetition rate by recording in places with flat weighted ambient sound pressure levels ranging from below 50 dB to over 75 dB. Only the song sparrow showed a significant correlation between sound pressure level and singing rate and even there the regression explained only 21% of the variance. The scatter in the data implies that compensating for higher background noise levels is at best a minor reason why birds vary their calling rates.

Since previous studies have not focused on the subtle effects of noise on passerine breeding success, it was evident that a larger, more comprehensive study would be required to detect these effects. The Miramar and Camp Pendleton studies are based on the idea that productivity of the birds is the fundamental measurement to determine subtle effects. The studies will provide data on a minimum of 220 CAGN pairs and 800 LBV pairs and account for confounding variables such as vegetation, weather, predation and disturbance. By collecting adequate data and using appropriate statistical models, we should be able to precisely differentiate between the effects of aircraft noise and other environmental factors on bird breeding.

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EFFECTS OF INTENSIVE AIRCRAFT ACTIVITY ON THE BEHAVIOUR OF NESTING OSPREY

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1. BACKGROUND

In response to a concern for the potential effects of aircraft noise on nesting raptors [1], a Monitoring and Mitigation program for raptors has been conducted in the Low-Level Training Area (LLTA) of Labrador and northern Québec since 1991. Active nest sites were identified during this program and subsequently excluded from Low-Level Flying (LLF) aircraft by a 2.5 nm radius area for the duration of the breeding season. While this strategy has permitted the Department of National Defence (DND) to maintain training activities and mitigate the potential disturbance on species such as Osprey (*Pandion haliaetus*), the behavioural response to such disturbance had not been investigated.

In 1995, we examined the 2.5 nm exclusion requirement for nesting Osprey, through a behavioural effects study of their reactions to high noise level jet activity on the Naskaupi River of Labrador [2]. Controlled low-level CF-18 jet aircraft passed by active nests (n=5) at distances ranging from 2.5 nautical miles to directly overhead at speeds of 400-440 knots. Maximum noise levels varied from 52-101 dB according to topography, distance and other factors. Over 240 hours of direct observations from blinds investigated responses to overflights by examining nest attendance, exposure of young or eggs, and feeding [3] and defence of the young. Similar observations were completed at control nests (n=2). Low-level (100 feet above ground) overflights occurred only when observers were present. No significant difference in nesting behaviour was observed as a result of overflight distance, noise level or nesting period as a result of 139 individual overflights. Nesting behaviour was similar to the control nests. With the exception of nestlings crouching low in the nest, no reactions of agitation or startle effect were observed despite rapid onset rates of aircraft noise (26 decibels/second) and all attempts to minimize possible habituation. Agitation, temporary nest abandonment and other extreme reactions by Osprey possibly influencing nest success were observed only in association with slower fixed-wing aircraft, other Osprey or raptors entering territories, and observers entering/exiting blinds [2].

As controlled overflight distance and associated noise level were not correlated with the behaviour of nesting Osprey, we attempted to determine if repeated uncontrolled overflights would elicit a significant response. In 1996, the same study area and experimental nests from 1995 were reused with increased noise stimulus. The objective was to determine if disturbance (described by the noise metric L1) caused by repeated jet aircraft overflights interfere with reproductive activities of Osprey through behavioural changes associated with nest attendance. If valid, this behavioural change could eventually result in a decrease in productivity and reduced abundance.

2. METHODOLOGY

The LLTA is a 130,000 km^2 area wilderness area within Labrador and northeastern Québec. For the purposes of this study we examined reactions to LLF within a 350 km^2 area along the Naskaupi River. The climate is subarctic with severe winters, heavy snow accumulation and short summers [4]. The area consists of undulating upland topography and a productive forest of black spruce (*Picea marianna*), balsam fir (*Abies balsamea*), and white birch (*Betula papyrifera*) forest types. Annual precipitation is between 1,000 to 1,100 mm with an average snowfall of 4 m. The Naskaupi River area was selected due to its proximity to Goose Bay, alignment and position regarding entry/exit of LLF aircraft between the LLTA and 5 Wing Goose Bay, and availability of nest sites with suitable points of observation.

Our initial experimental design involved seven nesting pairs (five treatment nests and two control nests). In late May 1996, observation blinds were constructed at the same locations on the Naskaupi River used in 1995. From 21 April 1996, approximately two weeks before the first individuals were observed in the area, until the first day of field observations on 3 June 1996, an exclusion to low-level flying of 2.5 nm radius was placed over the study area. Observation blinds were also constructed at the same control nest on the Kenemich River and at a new site on the Kenamu River (1995 nest collapsed) approximately 40 km east of Goose Bay, outside the LLTA. A Bell 206L helicopter was used to transport observers near the respective blinds, arriving about 30 minutes before the first overflight of each day.

Overflights were completed by a variety of jet and propeller military aircraft (F-4, F-16, F-18, Tornado and Transaal) conducting training at 5 Wing Goose Bay. Detectable overflight distances from the nests varied from directly overhead to >2.5 nm. Overflights were permitted without restriction from 3 June 1996 until the end of the season. Similar to 1995, observations occurred at two week intervals: 3-4 June; 17-18 June; 3-4 July; 15-16 July, and on 20 August. Two 1.5 h sessions were also completed at active control nests during each observation period. Noise levels at the blinds were recorded by automatic monitors throughout the experimental period.

Data Recording

Observations were made using tripod-mounted spotting scopes (10-40X). The maximum noise level (L1) was recorded automatically using palm top data loggers connected to a Bruel & Kjaer Model 2231 or 2236 sound level meter. This equipment was contained within watertight containers mounted 2 m above ground and powered by a 12-volt battery. Sound level meters were calibrated for the expected noise levels prior to each field measurement. Using synchronized digital stopwatches, observers at each blind recorded Osprey behaviour at the nest continuously. Emphasis was placed on three experimental variables: (1) the number of egg exposure events, (2) the duration of egg exposure during each event, and (3) the number and sex of adults at the nest. Observations continued until 30 minutes following the final overflight of the day. Noise calibration flights from August 1995 [2] were used to calculate the actual noise level at each nest from the noise levels taken at the blinds during the recorded overflights experiments.

Data Analyses

To examine differences in behaviour between 1995 and 1996, we compared those parameters objectively determined for an entire observation period: incubation rates and number and sex of adults at the nest. The following hypotheses were tested:

H_0: no difference in incubation rates between 1995 and 1996

H_A: there is a difference in incubation rates

For incidents relating to nest attendance and whether nest contents were left unprotected:

H_0: no difference in the percentage of the time that at least one adult was present at the nest between 1995 and 1996

H_A: there is a difference in the percentage of the time that at least one adult was present at the nest

The 1995 behavioural data (in seconds) had been arranged by two 15 minute periods preceding an overflight (pre-overflight) and following an overflight (post-overflight). The data in these periods were considered separately and as 30 minute (experimental) periods. Other periods included the non-experimental (normal) and the entire period of observation (total). With multiple and consecutive overflights in 1996, 15 minute periods pre- and post-overflight were often interrupted by additional overflights and therefore not applicable.

3. RESULTS AND DISCUSSION

Flight track recording data indicated up to 170 low-level aircraft noise events (occasionally consisting of 2 or more aircraft) on the Naskaupi River during June and July 1996. Background noise level and maximum noise level associated with individual overflights remained similar to 1995 [2] values (around 88 dBA) at each nest. Single Event Levels, representing the total acoustic energy of the aircraft event, were 90-121 dBA (usually 97 dBA, n=61). However, Equivalent Sound Level (Leq) values increased (<5 dBA) as flight track recording and field observations confirmed the increase of up to 17 overflights daily, versus a maximum of 16 per month in 1995.

We found no difference in behaviour between 1995 and 1996 experimental and control periods of observation throughout the study. As in 1995 [2], we observed no overt reaction as a result of a LLF jet overflight. Reactions of adult Osprey during low-level overflights varied from alertness, to adjustments in incubation posture. Adult Osprey appeared to perceive the approach of an aircraft before it was audible (to the observers). This behaviour has been described in seabirds as the orienting response (OR) indicating increased readiness and heart rate [5]. Adult Osprey reacted strongly whenever other Osprey or raptors approached the nest, fixed-wing aircraft approached within 3 km of the nest, or an observer appeared outside the observation blinds. Adult birds continued to be agitated and display aggressive behaviour to these non-experimental stimuli throughout the two years of study. Young nestlings crouched following any disturbance (including jet overflights). Usually, overt behaviour diminished within 5 minutes of the event (e.g. observers arrival at blinds, following departure of intruding Osprey or other raptors).

Incubation rates during observations were typically greater than 95% (mean value of 97.3% over 25 observation periods) and did not differ significantly from 1995 values (P=0.684) (Table 1). Osprey eggs remain viable when maintained between 29 and 36 ^{0} C [6]. While others [7] have found that successful nests were incubated 99.5-100% of the daylight hours, our results were occasionally less for total observation periods during both years but still above 90%. Unpublished data from Nova Scotia has indicated that researchers could routinely handle eggs in Osprey nests for up to 15 minutes without any measurable affect on hatch success (R. Bancroft, *pers. comm.*). Regardless of the overflight activity, we did not observe exposures of a duration significant to affect hatch or early nestling success in 1996 and only a single event not attributed to an overflight during 1995.

Table 1. Summary of experimental data, 1995 and 1996.

Osprey Nest	% Time Incubating		% time no adults at nest		# Overflights June-July	
	1995	1996	1995	1996	1995	1996
1	96.665	98.439	1.8	0	27	157
2	97.206	98.251	0	0.2	27	130
3	97.244	96.717	0.3	0.4	27	149
4	98.879	94.734	0	0.1	27	131
5	99.682	97.603	0	0.1	27	170

The second parameter tested, attendance of the eggs or young, was defined as the time that at least one adult was present at the nest. Throughout the incubation period, instances in which a nest was left unattended were rare and did not exceed 2% of an observation period (Table 1). Following hatch and for those nests which remained active during the nestling period, these temporary nest desertion values remained less than 6% until fledging (*i.e.* 35.5% at Nest 3). Observers also noted similarities in other aspects of behaviour for the same nesting pair. Female Osprey spent most of the time at the nest during incubation and early nestling periods and males were absent except to deliver food, to defend against a perceived threat or to briefly assume incubation duties.

We did not observe any of these reactions as a result of low-level jet noise, represented by different L1 values (influenced by various propagation conditions and overflight distances including direct overflights) throughout the nesting period. However, we recorded several instances of alarm by a nesting pair when red-tailed hawks (*Buteo jamaicensis*) or northern ravens (*Corvus corax*) entered nesting territories. These and other predators such as Great Horned Owl (*Bubo virginianus*), may predate the nest particularly if the adults were temporarily absent. As observed in other studies [8], we recorded several instances when the adults were away from the nest immediately prior to fledging. The high percentage of nest attendance by at least one adult indicated that the nest was rarely left undefended. Situations in which nests were left undefended during incidental slower fixed-wing aircraft overflights were noted again in 1996.

Other studies of Osprey nesting behaviour [8,9,10] have reported instances of alarmed adults being repeatedly flushed from their nests (by a variety of stimuli) exposing eggs or nestlings to extreme heat or cold, predators, or premature fledging - all of which could lead to decreased nestling survival and production. Factors affecting noise perception in Osprey could be similar to that of humans and include the spectral content (the range of acoustic frequencies) and amplitude (loudness) modulation in the noise time history. Osprey reactions may be dependent on interactions between the physical perception of the sound energy in the ear and the mental interpretation of that sound. In addition to noise associated with each overflight, we were also able to address the visual stimulus of the aircraft, a shortcoming often identified with simulated noise effects research [11].

This study was designed to determine if a threshold of LLF existed with measurable effects on Osprey behaviour that would lead to decreased reproductive success. The investigation was completed in association with ongoing Osprey population (100-200 nests annually) monitoring inside and adjacent to the LLTA [12]. Since 1993 when analyses began, no relationship of nesting success or reproductive output has been detected in relation to LLF. Osprey on the Naskaupi River and elsewhere in the LLTA have undoubtedly been exposed to overflights in previous years and may have previously habituated. Nevertheless, reactions to controlled overflights at 2.5, 1.25, and 0.75 nm [2] and the above average overflights associated with this study, indicate that Osprey are able to conduct nesting activity without being significantly disturbed by the ongoing LLF program. The extreme reactions noted during infrequent overflights of fixed-wing aircraft suggested that visual aspects (*i.e.* speed and not noise or the duration of the noise) may act as a stronger stimulus. Other factors such as weather [6,7,13] and food supply [3,7,14] appear to have greater influence on Osprey productivity and may mask subtle effects of jet aircraft disturbance.

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THE RESPONSE OF SEA BIRDS TO ACOUSTIC AND VISUAL STIMULI IN EXPERIMENTS SIMULATING AIRCRAFT OPERATIONS

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1. INTRODUCTION

Brown [1] reported the response of Crested Tern (*Sterna bergii*), to acoustic stimuli simulating overflights of fixed-wing aircraft. The experiments involved presentation of pre-recorded aircraft noise, with peak over-flight levels of 65 dB(A) to 95 dB(A), to sea bird colonies nesting on the Great Barrier Reef. Sea bird responses in the exposed colony were videotaped and these tapes were subsequently analysed by assessing the behavioural response of each bird in the colony. Results of the trial indicated that the maximal responses of preparing for flight, or escape, were restricted to exposures greater than 85 dB(A). A scanning behaviour was observed in nearly all birds at all levels of exposure. An intermediate level of response, an alert behaviour, demonstrated a strong positive relationship with increasing noise level.

Most previous investigations of bird response to aircraft overflights had been based on observations of response to uncontrolled, or limited controlled, stimuli. Further, often only gross disturbance responses such as flushing or escape had been observed. It was argued [1] that both careful control over the stimulus and detailed measurement of response were pre-requisites for the investigation of the effects of aircraft noise on wildlife.

This earlier work has been extended by the experiments reported in this paper. The new experiments examine sea bird responses to helicopter noise (the initial work used noise from a fixed wing DHC-2 Beaver float plane) and responses to visual stimuli simulating the approach of low-flying aircraft. The reason for the latter was that, in the previous investigation, trials of free balloon flights over the sea bird colonies had suggested that there may be effects on bird behaviour from an overflying visual stimulus. The significance of the contribution of the visual component to bird disturbance needed to be resolved in this work that relies on simulated aircraft noise to assess the effect of aircraft flights on wildlife.

2. STUDY SITE

The study site was Eagle Cay in the Cairns-Cormorant Pass section of the Great Barrier Reef Marine Park. Colonies on this cay had had no prior chronic exposure to aircraft overflights or to other forms of human disturbance. The species of sea bird examined was the Crested Tern (*Sterna bergii*). It is a colonial nester, found mainly in open habitat among low grasses and herbaceous vegetation, and breeds in large numbers, up to several thousands, in the summer months. The eggs are laid on the bare ground in hollow scrapes [2]. Because it nests in open areas, this species could be videotaped relatively easily, allowing detailed measurement of the behaviour of individual birds in the colony.

The experiment was conducted over two colonies (Colony 1 and Colony 2) of which only portions on the periphery, about 20 to 35 individual birds present at any one time, were observed in the experiment. When the experiments started the birds were in the late stage of the incubation period. In Colony 2, hatching occurred during the course of the experiment. Experimentation was terminated in this colony as soon as chicks started to form crèches. Hides were established at 15 - 20m distance from the edge of the colonies and these provided shelter to research staff and were the locations from which the stimuli were controlled and bird behaviour filmed.

3. NOISE EXPOSURES

The acoustic stimuli consisted of instrumentation quality, mono tape recordings of Kiowa helicopter operations recorded at various distances from an alighting point. The aircraft operation consisted of approach and descent to the alighting point, a brief pause on the ground with motor and rotor idling, then lift off and departure. This operation simulates a tourist activity ferrying passengers to locations on the Great Barrier Reef. The Kiowa is a military equivalent of a Bell Jetranger helicopter, commonly used for tourist activities on the Reef. The recordings were conditioned to represent six "alighting" treatments where the peak level in the helicopter alighting operation ranged from 70 dB(A) to 95 dB(A) in five 5 dB(A) increments. In the field these recordings were amplified and replayed through a column loud speaker. No birds were located between the speaker and the part of the colony under observation. A microphone located in the column monitored the level of every simulated alighting operation to confirm that the correct treatment level had been delivered. These aircraft signals were superimposed on an acoustic background of bird calls from within the colony and the sound of wave action on the shores of the cay. The simulated alighting recordings were of some 80 to 90 seconds duration.

Colony 2 was exposed to five replications of each of the six helicopter alighting treatments and a control (no acoustic stimulus) over a period of four days. Treatments were applied in random order within each of the replications. Replications were separated by a minimum of four hours, most by 24 hours. Individual treatments were separated by at least 10 minutes.

4. VISUAL STIMULI

The simulation of the visual stimulus of an aircraft overflight was not as sophisticated as that of the acoustic stimuli. It was achieved by towing a target on a fixed wire towards and above the colony. The wire was fixed to a 12m high mast which had been erected at the edge of the colony and also to a point on the ground some 60m distant from the colony, the latter hidden behind bushes. The target was towed rapidly to the top of the mast by winding the tow wire on a reel. The target would have been first observed by the birds in the colony when it emerged above bushes some 40 to 50m from the colony and at an angle of approximately 5° above the horizon. Four target sizes were used and each had the wing and fuselage shape of a fixed wing aircraft. Wing spans were 280mm (Target A), 409mm (Target B), 602mm (Target C) and 948mm (Target D). At the point at which they could first be observed by the colony, these targets would have subtended angles of between 0.4° and 1.4° at a bird's eye.

Colony 1 was exposed to nine replications of each the four visual targets and a control (winding the tow rope along the target wire, but with no target attached). Treatments were applied in random order within each of the replications. Replications were separated by a minimum of two hours; individual treatments by at least 10 minutes. The experimentation was completed over a period of seven days. The first five replications were undertaken with the mast positioned so that the target reached the mast 14 m short of the colony. Subsequently the mast was relocated so that the target passed across the colony. Results from these two different mast positions were similar, and all replications have been combined in the results below. All targets were towed at the same, uniform, velocity.

5. OBSERVATION OF RESPONSES

Bird behaviour during each noise and target treatment was filmed on videotape, and laboratory viewing of this videotape was used to score bird behaviour. Laboratory analysis was undertaken by repeated replay, with the behaviour of a single bird observed over each replay of the same segment. The maximum response behaviour of the observed bird was scored and the segment then replayed to observe the next bird. Categorisation of the hierarchy of responses used has been previously reported [1]. In summary, these were:

- Scanning behaviour: head turning, tilting, appearance of "looking" for disturbance.
- Alert behaviour: neck extension, carriage erect/tense; re-orientation or stepping on spot.
- Startle/avoidance behaviour: incomplete intention movement to fly up or escape. wing flapping, possibly leaving eggs or chicks exposed momentarily.
- Escape behaviour: flying up, nest exposed for a longer time.

It should be noted that these behaviours could also result, not just from the simulated stimuli, but from routine interactions with other birds in the colony and also from the presence of predators. Behaviours that could be attributed clearly to such interactions were discarded and only those behaviours that could not be attributed to such causes were used in this analysis. If responses that could be attributed to interaction were observed before another that could not be attributed to interaction or predators, a conservative approach was adopted by excluding the latter from the analysis.

6. PILOT STUDY RESULTS

The results of the five replications of the helicopter alighting experiment are shown in Figure 1. The figure shows the mean proportions of the birds that exhibited a particular (or greater) behavioural response. It is clear that bird response depends on the level of helicopter alighting noise. Over three-quarters of the colony exhibited a scanning (or greater) behaviour for all levels of the helicopter alighting stimulus. Escape, and startle (or greater), behaviours were also observed at all levels of the noise stimulus, with between 16% and 36% of the colony reacting in this way. These proportions increased slightly with increasing helicopter noise levels. The proportion of the colony exhibiting alert (or greater) behaviours increased more steeply with increasing maximum helicopter noise levels. There were some small, and unexplained, behavioural responses to the control stimulus, but response to the noise stimuli were always greater than for the control.

These findings reinforce those of the previous fixed wing experiment [1] that there is an observable behavioural response to all levels of aircraft noise that can be heard above the background sound levels of the cay. Background sound levels are highly variable depending both on wind speed and hence wave action on the shore, and bird activity in the colony. Background levels on the cay were recorded as high as 65 dB(A).

The results of the nine replications of the visual experiment are shown in Figure 2. The figure shows the mean proportion of the observed birds that exhibited particular behavioural responses to each size of visual targets (Target A was the smallest target, Target D was the largest). There was no measurable response to the control. The largest target (near 1m wingspan), was the only stimulus to result in any of the higher orders of behavioural response in the colony. The scanning (or greater) response was observed for much lower proportions of the colony than observed for the noise stimuli.

7. DISCUSSION

The results of the helicopter alighting noise simulation experiments conform broadly to those found by Brown [1] for the fixed wing DHC-2 Beaver float plane. For both helicopter and fixed wing sources, Crested Tern demonstrate an observable behavioural response to aircraft noise at all levels of noise exposure audible above the background sound levels. Escape or startle responses are exhibited by only a small proportion of the colony, whereas for the fixed wing noise source these behaviours were restricted to the higher noise level exposures of 90 and 95 dB(A). There was no similar threshold for the helicopter noise source. Overall, the noise of helicopter alighting generated greater levels of escape or startle behaviours than did the noise of fixed wing aircraft. For both noise sources, the most prominent relationship between level of noise and proportion exhibiting a particular response was for the alert (or greater) behaviour – though the gradient of the relationship was not as strong in the helicopter results as it was for the fixed wing results.

While the peak noise levels to which colonies were exposed were the same in the treatments for the fixed wing and the helicopter experiments, the difference in bird response to the same peak noise levels is notable. It may be possible to attribute the somewhat greater response to different frequency and temporal components in the noise sources. In particular, it may be the variability in the levels of sound produced by a helicopter as it hovers, alights, idles and takes off, relative to the somewhat more "predictable" signature of an overflying fixed wing aircraft, produces a greater response in the colony. These results suggest that a cautious approach should be taken in the control of helicopter movements when these are operating near wildlife

The results of the visual stimulus experiments suggest, at least within any limitations of the current simulations, that the acoustic component of aircraft overflights near sea bird colonies may be far more important in generating behavioural responses than the visual components. There clearly is a response to visual stimuli, but of a much lower magnitude than to acoustic stimuli. This result means that simulating aircraft overflights by means of replay of recorded sound of aircraft movements is not overly confounded by the absence of a visual component of the stimulus. This finding is of considerable value. It means that it is possible to design experiments to determine operating limits for aircraft near wildlife which expose just small parts of a colony to disturbance using simulated noise operations, rather than exposing the whole of the colony, as would be the case if using real aircraft overflights. There is still a need, of course, to validate any findings obtained through simulation experimentation using actual aircraft.

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9. ACKNOWLEDGEMENTS

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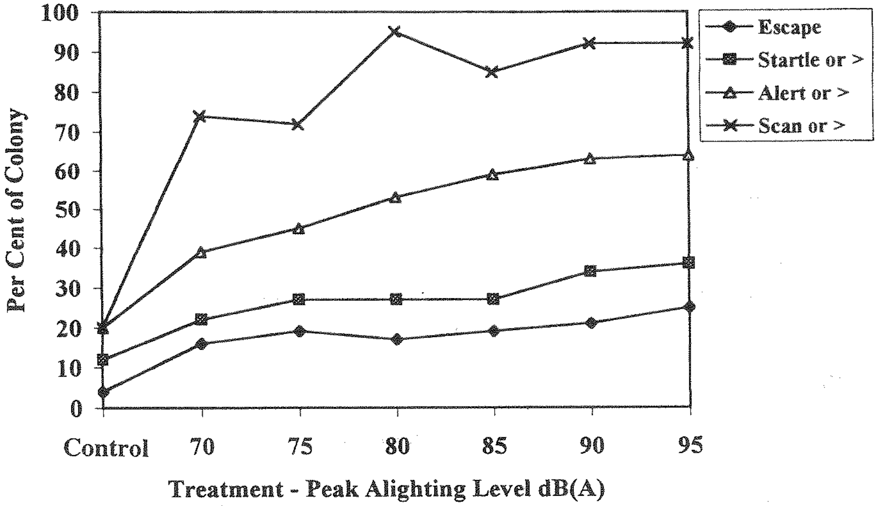

Figure 1. Mean Proportion of the Crested Tern colony exhibiting different behavioural responses to helicopter noise stimuli.

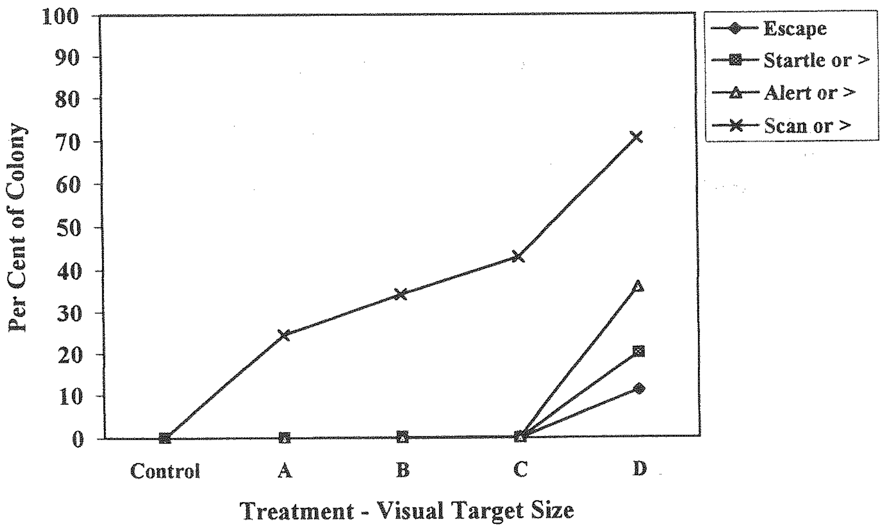

Figure 2. Mean Proportion of the Crested Tern Colony exhibiting different behavioural responses to visual stimuli. (Increasing target sizes A to D).

Effects of hearing loss between type A and type B reactive rats for long-term noise exposure

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Abstract

BACKGROUND: At previous studies, the rats could be divided into A and B types by reaction of electrocardiogram (ECG) for noise exposure. Type A reaction is to decline heart rate and elevate ECG ST segment during noise exposure. Type B reaction is stable on heart rate and ECG ST segment during noise exposure. It was observed blood pressure elevated after long-term noise exposure in type A rats, but no significant changes in type B rats. This paper hopes to know if the hearing changes same as blood pressure for noise exposure in the two types of rats. **MATERIALS AND METHODS**: Twenty of type A rats and twenty-two of type B rats were selected from 129 male Wistar rats. They were randomly divided into four groups, type A with noise (10), type B with noise (12), type A without noise (10) and type B without noise (12). Noise exposure groups were exposed to 105 dB(A) stead state white noise four hours per day, from Monday to Saturday, eight weeks. Control groups were sent into a laboratory at same times with environmental noise lower than 55 dB(A). Hearing threshold was measured after more than sixteen hours of noise exposure by averaged brainsteam reaction with click sound on right ear. **RESULTS**: The hearing thresholds of four group rats had not significant difference before noise exposure. The hearing thresholds of noise exposure groups were significantly elevated more than ten to thirty dB than control groups at 1st, 2nd, 4th and 8th week of noise exposure. The hearing threshold of type A and noise group was slightly higher than that of type B and noise group at 1st, 2nd and 4th week. The former (40 dB) was significantly higher than later (30 dB) at 8th week of noise exposure. The hearing thresholds of control groups were stable during the eight weeks with means of ten to twelve dB. **CONCLUSION**: Above results showed that the type A rats do not only sensitive to noise exposure on its' cardiovascular system, but also sensitive on its' hearing system. It likes some persons with 'glass ear' in feature. It is a possible animal model to research the susceptibility mechanism of bio-effects for noise exposure.
Key Words: susceptibility, hearing threshold, noise, rat, type A reaction, type B reaction

At previous studies, it was found that the rats could be divided into two types[3], type A and type B, by different reaction of cardiovascular changes to noise exposure. The typical type A reaction is the heart rate declines and electrocardiogram (ECG) ST segment elevates during noise exposure. Gao Hong[2] found that the blood pressure of type A rats was elevated after long-term noise exposure, and that of type B rats was not significant changes. An interesting question is if the hearing has different changes in the two kinds of rats.

MATERIALS AND METHODS

The type A and B reaction rats was selected from 129 healthy male Wistar rats, weighted 163.1   22.1 grams, by short-term noise loading test. Each rats was exposed to 105 dB(A) steady state white noise one hour with a computerized ECG scanning system. The reaction type of each rat was defined as changes of heart rate and ECG ST segment[3]. Twenty of typical type A rats and twenty-two of typical type B rats were selected from all 129 rats. They were randomly divided into four groups, type A with noise (10), type B with noise (12), type A without noise (10) and type B without noise (12). Noise groups were kept in a sound barricaded room and exposed to 105 dB(A) stead state white noise four hours per day, from Monday to Saturday, eight weeks. Control groups were sent into a laboratory at same times with environmental noise lower than 55 dB(A).

Madson ERA 2250 system was applied to measure the brainsteam reaction (ABR) in a sound barricaded chamber. The rat was fixed at a special frame after anesthesia. Record electrode was fixed in top of head, reference electrode in right mastodeum, ground electrode in left mastrodeum. Click sound was output by earphone to out channel of right ear of rat by a sound tube. The smallest sound pressure level of click, which induced appearing of main wave of ABR, was defined as hearing threshold. Hearing threshold was measured at before, 1st, 2nd, 4th and 8th week Sunday (not exposed to noise more than 16 hours) of the experiment.

RESULTS

Figure 1 showed the means of hearing threshold were very near in four groups of rats before noise exposure. During eight weeks, hearing thresholds in both type A and type B without noise exposure groups did not significant change. In noise exposure groups, hearing thresholds were significantly elevated during noise exposure with higher for prolongation of noise exposure. In trend, hearing threshold of type A with noise exposure group was higher than that of type B

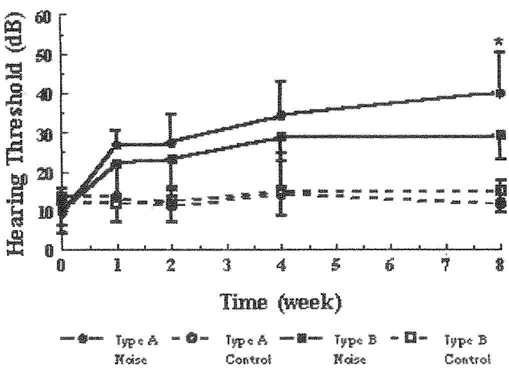

Figure 1. Hearing thresholds of type A and type B reaction rats for 105 dB(A) noise exposure

during all 1st week to 8th week. At 8th week, hearing threshold of type A group (40 dB) was significantly higher than that of type B group (30 dB), P<0.05. These results suggest that the auditory system of type A reaction rats was more sensitive for noise exposure than that of type B reaction rats.

DISCUSSION

It is long time to have stories of 'glass ear' and 'iron ear' from occupational field investigators. It means some susceptibility on human being present in part of general population to noise exposure on their hearing damage. Unfortunately, no animal model is fit for this kind of feature which was found in human being. At previous studies, we found rats could be divided into type A and B reactions by ECG changes during noise exposure. The type A reaction rats were susceptibility on their blood pressure for long-term noise exposure. This kind of reaction is very like the blood pressure behavior in part of human being. A reasonable question is if type A reaction rats are susceptibility to noise on their hearing?

This paper showed that the type A reaction rats do not only susceptibility to noise exposure on their cardiovascular system, but also susceptibility on their hearing system. The result could be used to explain why more hypertension cases were found in senior hearing loss workers[1].

We select 'typical' type A reaction and type B reaction rats from more than thousand rats. In this procedure, we found most of rats site between type A and type B reaction rats. This feature is very like the hearing susceptibility to noise exposure in human being[4]. It was found that the susceptibility distribution of hearing for noise exposure in human being is a single bell with light left shift. It suggested that the susceptibility of hearing on each subject, both human being and animal, to noise exposure differs from each other. A reasonable question is what substances cause susceptibility for noise induced hearing damage and cardiovascular impairment. Development of molecular biology and 'human genome project' give us a chance to looking for genes which associated with susceptibility for noise induced health problems. This animal model on the paper might be useful for our future noise-gene researches.

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EXPOSURE TO GENUINE INDUSTRIAL NOISE INDUCES PROLIFERATION OF SUPPORTING CELLS AND GANGLION CELLS IN THE CHICK'S INNER EAR.

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1. ABSTRACT

The aim of the study was to assess pathomorphological changes and cell proliferation following exposure to industrial noise, depending on the level of exposure. The chicks were exposed to broad-band industrial noise at the intensity of 110 dB(A) or 125 dB(A) for 4 hours or 8 hours a day, for 5 consecutive days. The fine structural changes in basilar papilla and neural elements during post-traumatic regeneration was assessed by light and electron microscopy. The proliferation of cells was studied by immunohistochemical labeling of Proliferating Cell Nuclear Antigen (PCNA).

Our results confirm that the proliferation of supporting cells starts immediately after exposure to noise. Apart from supporting cells, the strong PCNA-like immunoreactivity was observed in the ganglion cells, suggesting their role in the regeneration process. The proliferation of cells was observed either in the region damaged by noise or in the regions without any damage, and was dependent on the level of exposure.

2. OBJECTIVE

Acoustic overstimulation produces a loss in the auditory epithelium. In postembrionic mammals the loss of auditory cells is thought to be permanent. In birds, however, degenerated auditory epithelium may be replaced by new hair cells, which prob-

ably originate from the supporting cells of basilar papilla [1, 2, 3].
The aim of the study was to assess pathomorphological changes and cell proliferation following exposure to industrial noise, depending on the level of exposure.

3. DESIGN OF THE STUDY

In total fifty seven 1 day-old White Leghorn chicks (Gallus domesticus) were included in the study. Thirty nine birds were exposed to broad band industrial noise, while 18 chicks served as a control. The exposure was either 110 dB(A) of noise for 4 hours a day, for 5 consecutive days (24 chicks) or 125 dB(A) of noise for 8 hours a day, for 5 consecutive days (15 chicks). The fine structural changes of basilar papilla and neural elements during post traumatic regeneration was assessed by light and electron microscopy. The proliferation of cells was studied by immunohistochemical labeling of Proliferating Cell Nuclear Antigen (PCNA). The structural changes and PCNA expression were assessed on days 1, 3 and 5 after completing the exposure to noise.

4. RESULTS

The results are presented for the control group and then for each of the experimental groups in sequential order of survival time after exposure.
The normal chick's basilar papilla has a crescent shape and displays an orderly distribution of over 10.000 hair cells. The normal sensory epithelium consists of hair cells, which are located at the lumenal surface and the supporting cells which extend from the basilar membrane to the lumenal surface. Each hair cell is surrounded by five or six supporting cells. The hair cells are characterised by the presence of stereocilia, a cuticular plate, dark staining cytoplasm, and nuclei located in the centre or at the lower part of a cell. They do not have contact with the basilar membrane. The stereocilia of long hair cells are embedded in the tectorial membrane. Supporting cells are identifiable by their lighter staining cytoplasm. They have contact with the basilar membrane and separate the hair cells from each other.
In chicks exposed to noise at the level of 110 dB(A), the light microscopy did not reveal a hair cell loss in auditory epithelium at any time after noise exposure. In the electron microscopy, however, a moderate injury to hair cells was observed. Immediately after the end of the exposure disarrayed stereocilia and protrusion of hair cell cytoplasm toward the subtectorial space were often seen. On the day 3,

and particularly on day 5 after exposure, an increase in metabolic activity in nerve fibres and binuclear cells with the electron lucent cytoplasm (like supporting cells) was observed (figure 1). The supporting cells had well developed Golgi apparatus associated with numerous clear and dense cored vesicles.
Immunohistochemical study did not show immunoreactivity for PCNA in the basilar papilla on day 1 and 3 after exposure. On day 5, however, weak immunoreactivity was observed in both supporting cells and ganglion cells in the exposed-to-noise birds. PCNA positive nuclei were located in the middle portion of the auditory organ. In the control group no PCNA-immunoreactivity was observed at any post hatching day of observation.

Figure 1. Electron micrograph of the basilar papilla in a chick exposed to noise at the level of 110 dB(A). 3 days after exposure. Binuclear supporting-like cell. 6.000x.

In chicks exposed to noise at the level 125 dB(A), the light microscopy revealed damage to the sensory epithelium, particularly to the short hair cells, located close to the hyaline cells (figure 2). The changes were observed immediately after completing the exposure to noise.
The electron microscopy confirmed the necrosis to some hair cells, but also to the supporting cells separating the hair cells. The nerve endings at the base of hair cells were swollen. The supporting cells located beneath the hair cells revealed signs of proliferation – falciform nuclei, condensed intranuclear chromatin. They contained many vesicles and wider (enlarged) cytoplasmatic membranes. The maximum intensity of the above changes was observed 5 days after the end of exposure to noise.

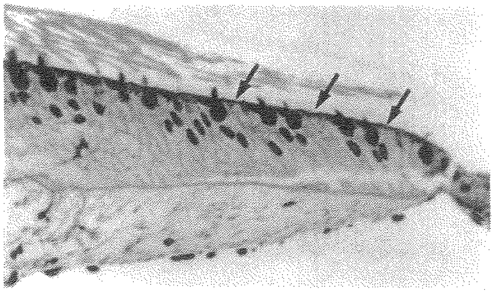

Figure 2. Micrograph of the basilar papilla in a chick exposed to noise at the level of 125 dB(A). 1 day after exposure. Arrows point to the places of loss of short hair cells. 250x

Immunohistochemical study revealed PCNA positive nuclei in supporting cells located just below hair cells along the entire length of basilar papilla. Thus, the cell proliferation was seen in the region damaged by noise, but also in regions without any damage. Apart from supporting cells, a strong immunoreactivity was observed in the ganglion cells of the auditory organ. The maximum intensity of the proliferation was observed on day 5 after the end of noise exposure.

5. CONCLUSION

Our results confirm that in alike cases of exposure to pure-tone or octave band noise, the proliferation of supporting cells starts immediately after exposure to genuine industrial noise, reaching a peak level on the fifth day during the period of recovery from noise. Apart from supporting cells, the strong PCNA-like immunoreactivity was observed in the ganglion cells suggesting their role in the regeneration process. The proliferation of cells was observed either in the region damaged by noise or in the regions without any damage, and was dependent on the level of exposure.

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COMBINED EFFECTS OF CITY NOISE AND BRIGHTNESS OF COMPUTER DISPLAY ON IMMUNOCYTES AND PHYSIOLOGICAL STATUS IN VDT WORK

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1.INTRODUCTION

There has been widespread use of computers in the workplace for about 20 years and from very early in their use, employees have experienced a number of health problems. Many working conditions jointly influence the VDT user. A good working environment (social and physical) can affect employee comfort, but a harmful environment leads to stress responses. Recently, reports of harmful stress effects on immune functions are increasing. It is well known that noise is a physical stressor that can directly alter physiological processes. In the city, some VDT workers are exposed to traffic noise in their working places.

The present study was performed to make clear the combined effects of city noise and brightness of the computer display on immunocytes and physiological functions in human subjects.

2. MATERIALS AND METHODS

The subjects were six healthy male students between the ages of 21 and 23 years. They were tested randomly under the following four experimental exposure conditions for 60 minutes: (1) a calculating task using a VDT with brightness of 90 cd/m^2 without city noise, (2) a calculating task using a VDT at 20 cd/m^2 without city noise, (3) a calculating task using a VDT at 90 cd/m^2 with city noise, and (4) a calculating task using a VDT at 20 cd/m^2 with city noise.

The sound to which the subjects was exposed were road traffic noise recorded by a digital audio tape recorder at the roadside. The sound level of the city noise was 69.7 dB(A) Leq. The workload was 60 min of mental arithmetic performed in a seated position using a VDT unit in a soundproof room (background sound level 50 dB(A), air conditioned chamber at 22 ± 2℃, and 50-60 % relative humidity). All experiments were conducted between 9 and 13 o'clock in order to avoid the effects of diurnal variations of physiological functions.

Evaluation of combined effects on physiological functions was determined by heart rate (HR), blood pressure (BP), critical flicker fusion frequency (CFF)[1], a visual reaction test (VRT)[2], subjective symptoms of fatigue determined by questionnaire (The committee on Industrial Fatigue of the Japanese Association of Industrial Health 1969) and measurement of blood catecholamines, as well as subsets of circulating white blood cells (WBC). Blood was collected 30 minutes before, just after and 30 minutes after the calculating task. T cells, B cells and natural killer cells (NK cells) were measured using flow cytometry with immunofluorescent antibody (CD3, CD19 and CD16) staining of mononuclear cells. Blood catecholamines were measured by high-pressure liquid chromatography with an electrochemical detector (HPLC-ECD).

3. RESULTS

Changes in VRT, CFF, norepinephrine (NE), and epinephrine (EPI) caused by the four experimental conditions are shown in Table 1. The mean value of VRT (VRT-M) increased significantly 30min after the task of conditions (2) and (3). The S.D. value of VRT (VRT-SD) increased significantly just after the task of condition (3). CFF showed a significant decrease just after and 30min after the VDT task of condition (3). Plasma NE showed significant increases 30min after the task in conditions (1), (2) and (4). There was no significant difference among the four experimental conditions with respect to calculation performance and incorrect answers rates (data not shown).

Table 1. Changes in VRT, CFF, NE and EPI in the four experimental conditions

condition		pre	just after	30 min after
VRT-M	(1)	15.72±3.09	17.60±5.52	19.03±5.42
	(2)	9.41±0.11	10.22±1.51	10.25±0.21*
	(3)	16.86±6.36	18.97±7.26	19.05±6.72*
	(4)	13.56±0.99	14.17±0.98	16.03±1.86
VRT-SD	(1)	34.14±8.95	37.56±16.56	47.04±17.30
	(2)	6.84±1.83	11.69± 4.18	11.79± 1.80
	(3)	21.59±8.60	30.02±11.13	36.58±12.73*
	(4)	26.19±3.12	31.49± 3.95	38.44± 8.25
CFF (Hz)	(1)	43.28±0.63	42.57±1.25	42.28±0.82
	(2)	42.62±0.46	42.12±0.71	42.26±0.72
	(3)	42.30±0.62	41.48±0.71*	41.57±0.58*
	(4)	42.57±0.63	42.12±1.45	42.05±0.75
NE	(1)	355.1±32.9	368.4±34.1	431.3±39.3*
(pg/ml)	(2)	255.4±23.8	278.0±17.4	383.0±30.2*
	(3)	335.7±62.4	373.5±40.2	402.4±80.9
	(4)	315.6±44.3	339.5±53.7	403.5±26.8*
EPI	(1)	38.6±10.7	53.8±14.4	59.7±11.6
(pg/ml)	(2)	30.8± 8.9	132.5±46.8	63.8±37.6
	(3)	56.6±12.8	42.8± 6.7	96.9±33.6
	(4)	44.4±16.8	43.0±15.9	122.5±53.7

mean±SE *p<0.05 vs pre (paired t-test)

The respective self-rated subjective symptom scores are shown in Figure 1. There was a significant increase in the score just after the task of conditions (3) and (4) in category Ⅲ. Changes of immunocytes are shown in Figure 2. The numbers of WBCs increased just after and 30min after the VDT task of conditions (1) and (2). Numbers of neutrophils increased 30min after the task only for condition (1). Numbers of lymphocytes, T cells and NK cells did not show significant changes throughout the task in any condition.

Numbers of B cells increased significantly 30 min after the task of condition (4).

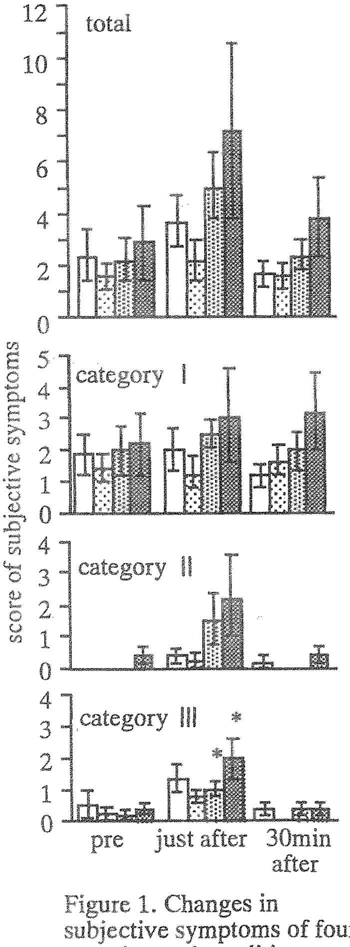

Figure 1. Changes in subjective symptoms of four experimental conditions. *p<0.05 vs pre (Mann-Whitney U test)

□ bright+quiet ⁝ dark+quiet ▦ bright+noisy ■ dark+noisy

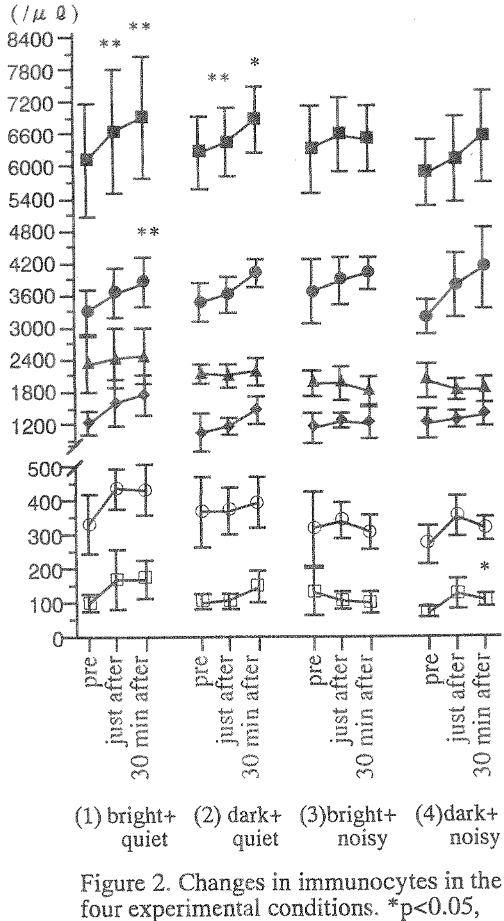

Figure 2. Changes in immunocytes in the four experimental conditions. *p<0.05, **p<0.01 vs pre (paired t-test)

WBCs, Neutrophils, lymphocytes, T cells, B cells, NK cells

4. DISCUSSION

In the present study, the methods used for evaluating fatigue such as VRT and CFF showed significant changes when conditions were not quiet and bright. VDT work thus fatigues workers, although there was no significant difference between quiet and noisy conditions or bright and dark conditions by two-factor ANOVA.

The number of WBCs and plasma NE showed significant increases after VDT work in quiet conditions. It is said that serum levels of catecholamines are directly associated with various indicators of immunity [3]. In our present study, NE increased significantly in the quiet conditions after the VDT work. It seemed that changes of plasma catecholamines had some effects on the total numbers of WBCs. However, our data do not explain why the number of WBCs increased in quiet conditions without noise.

The self-rated score of category III, which shows the symptoms of "projection of physical disintegration", increased significantly in noisy conditions. It is thought that traffic noise was stressful to VDT workers. This suggests that subjective symptoms indicate combined effects of city noise and brightness of the computer display on VDT workers.

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THE INHERENT CONTEXT OF ANNOYANCE RATINGS ON COMBINED NOISES

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1. INTRODUCTION

A field study on community noise annoyance followed by two associated laboratory studies has been carried out for a two-year period. The context of assessments on noises was validated definitively to be taken into account for measurement procedures [1]. The need becomes obvious too for a sufficient measurement to provide insight information that would enhance the understanding of the complex processes being the cause of annoyance and disturbance, and are inherent in assessments on noise, especially on noise of combined sources [2,3]. It is the goal to estimate the subjective relevance of the emissions in daily residential-and living areas. Noise events will be analyzed regarding the aspect of effects in reference to disturbance and annoyance and to implement an adequate methodological procedure.
While the field study was carried out in the northern part of Germany as well as one of the two laboratory studies, the second laboratory study took place in Toronto with an approach to explain noise annoyance by assessing components of noise events using the CIS-method judging the unpleasantness of the noises presented.The presentation here will focus on the first results of the Toronto study which intercultural aspects strongly point out the input of the context. The results of the field study as well as the results of the lab studies demonstrate the complexity and the complicated context behind annoyance and disturbance assessments.

2. METHODS

The question is focussed on noise annoyance and disturbance in three residential areas, differing by their social structure features as well as by their quantity of noise from different sources. Over the two year period there have been developed interdisciplinary approaches methodically to analyze single and synergetic noise effects of road, rail-road and air traffic in residential areas.

Qualitative-explorative and objective-standardized measurement-procedures have been applied in the field study as well as in the two laboratory studies.

3. RESULTS

From the two laboratory studies in Oldenburg (Germany) and Toronto (Canada), the Toronto data will be presented in detail. Results from the field study have been presented at Internoise 97 validating noise annoyance and disturbance as a high leveled context sensitive variable. Laboratory experiments on noise annoyance have to take this phenomenon into account when carried out.

The laboratory studies

The associated *laboratory studies* on loudness in Oldenburg and unpleasantness assessments in Toronto are focussed on the noises recorded in the environmental areas, where the German interviewees are living in.

In the laboratory study at the University of Oldenburg, Germany the set of 15 air traffic, road- and railroad noises has been judged by loudness. Involved have been 14 subjects: 10 m and 4 f. 8 subjects are living in the area where the noises were recorded, 6 subjects are living in a different area in Germany, but took part at the field investigation too. The summary of the results here: The context sensitivity is stable for the laboratory situation. Experiences with the noises as well as the identification of the noises are dominant for the noise assessments in the laboratory.

In the laboratory study at the Institute of Environmental Medicine, Toronto, Canada the same noise set has been judged by unpleasantness. Involved have been 25 subjects: 15 m and 10 f, all living in the Toronto area.

Each of the subjects was judging the noises by the CIS-method using a five–category-scale (Rohrmann), from not at all unpleasant to very unpleasant (**CIS**-C: categorical scaling). At the end of each presentation they were asked for an overall estimation by the scale as well as to write down the thoughts that entered their mind while listening to the noise events (CIS-I: Intermittent thinking aloud). After the assessment procedure there was an interview based on the comments giving during the assessment procedure (CI**S**-S: Subsequent thinking aloud) and a questionnaire outside the laboratory.

There was a 4-step procedure for the assessment sessions: the subjects had to come for four different assessment sessions, in each session the procedure of judging was identical but the noises presented changed by filtering: in session g1 the noise set was the same as for the subjects in Oldenburg, but in session g2 the noises were filtered from 0-600 Hz, in session g3 from 600 Hz to 2000, and in session g4 from 2000 Hz to 10000 Hz.

The difference of the assessments for the sessions g1, g2, g3 and g4 is significant [Fig 1]. Regarding to verbal comments there is an associative context in each of the comments by the subjects. For judging the noises they are looking for similar noises from their own environment or memories of an environment they had experiences with those noises.

But there are results different from the ones evaluated with the German subjects: the judgments on unpleasantness differ by one category compared to the loudness judgments. The subjects from Toronto have a different understanding of noises being unpleasant.

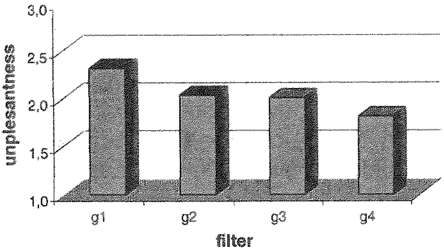


Fig 1

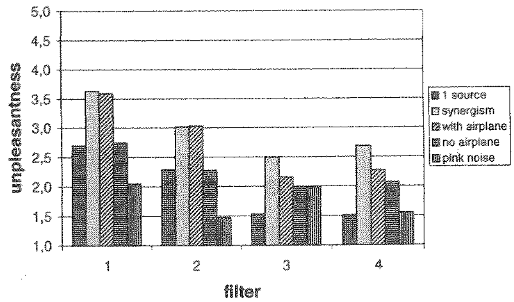
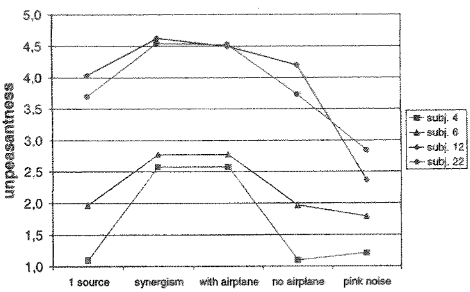


Fig 2

Fig.1: mean values of the subject's assessments in the 4-step procedure averaged over all the noises presented in each of the sessions

Fig 2: mean values of the judgments by 4 selected subjects to the noises clustered regarding the four different situations g1 to g4

When filtering the noises in g2 and g3 the judgments on unpleasantness change to less unpleasant, but for the situation g4 the unpleasantness of the synergistic noises as well as for the cluster with and without airplane are higher compared to situation g3, except for the pink noise. For the pink noise in g3 the unpleasantness judgments are ranked half a category higher compared to g2. All the judgments in g1 are judged on higher unpleasantness levels for the noise events clustered by an analysis in noises from one source, synergistic noises, synergistic noises with and without airplane and pink noise [Fig 2].



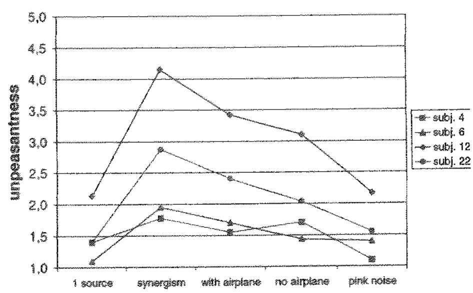


Fig 3

Fig 4

Fig 3: mean values of the judgments of each of the four selected subjects for the noises clustered in the four step procedure, here the situation g1 (no filter)

Fig 4: mean values of the judgments of each of the four selected subjects for the noises clustered an in the four step procedure, here the situation g4 (filtered from 2000 to 10000 HZ)

Comparing the mean values of judgments for the 4 subjects regarding the 5 clusters there is a two group procedure for the situation g1 and g4, but especially for the noise cluster 'noise from one source' and 'pink noise' in the situation g4 the judgments are very similar [Fig 3 and 4].
The analysis of the comments regarding the five noise-clusters strongly point out the relevance of the associated context as well as if people are usually annoyed or afraid of health problems by a typical noise source they will judge on higher categories to unpleasantness if there is the feeling the noise set includes such that noise source. For the noises which have been judged in the situation g1 with being unpleasant up to category 5, they change their judgment to a lower category if this noise source is not to identify anymore as it happens in g4.

4. SUMMARY

The results of the presented laboratory study demonstrate the complexity and the complicate context behind assessments on unpleasantness of noises.
In the field study carried out the noises are precisely described by effects on disturbance regarding activities or daily routines in interviews and acoustical journals. There is no identification in general of a noise of first importance too [1,3,4]. The description of combined noises is to be seen against an individual background of experiences with noises in daily life. The subjective judgment on annoyance correlates with those parameters they are relevant for the living situation of each subject. For the laboratory experiments the context is defined by associations evoked by the noises presented. Definitively the context influences judging the loudness or unpleasantness using a categorical scale.
For annoyance measurements there is the need to validate that judgments on loudness and/or unpleasantness have an identical meaning like assessments of disturbance and annoyance in non laboratory situations.
Regarding the assessments on the different situations by the 4-step-filtering as it was carried out in the Toronto-study the data set has to be analyzed whether the judgments on unpleasantness rely on the noise characteristic or are a feedback to the situation that the noise source can not be identified anymore. But: both of the laboratory studies point out the context sensitivity of any judgment as well as the measurement procedure guarantee a detailed characterizing of the noises. They strongly demonstrate the need of combined measurements including the context.

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ENVIRONMENTAL NOISE REGULATION: A PUBLIC POLICY PERSPECTIVE

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1. INTRODUCTION

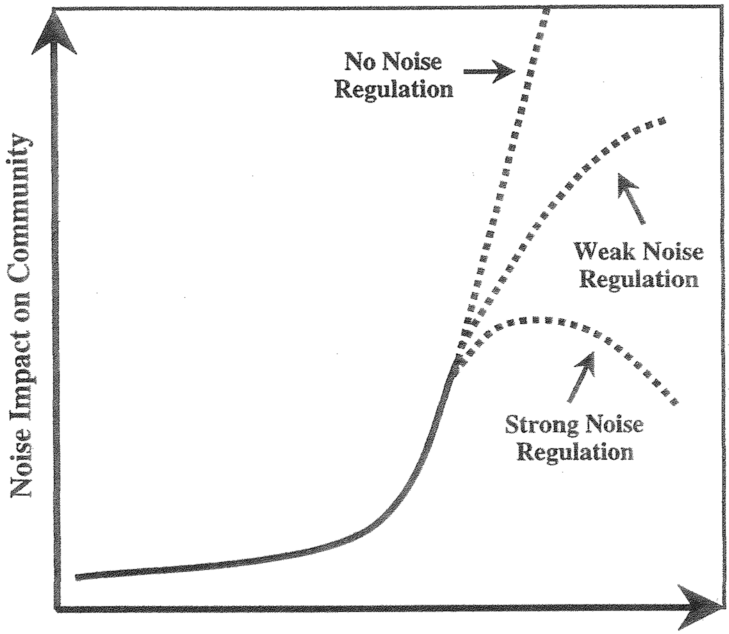
'Noise as a public health problem' poses a universal challenge for public policy. Every country throughout the world faces the task of controlling noise so as to protect the health and well-being of its citizens. Governments have the responsibility for formulating and implementing noise control regulations. The process they use is generally described as the public policy process. Noise regulations do not simply appear out of a 'black box' of political and bureaucratic activity that is impervious to scrutiny. As with any governmental policy, noise control legislation and regulation can be subjected to policy analysis in order to expose and unravel the dynamics of the processes involved. The present paper aims to analyse environmental noise regulation from a public policy perspective. Specifically, it aims to provide a framework for comparing noise regulations across countries, not in terms of their technical specifications but rather in terms of the processes used to derive and implement them. The paper presents several current case studies from Australian jurisdictions that illustrate different aspects of the noise policy process.

2. ISSUES IN NOISE REGULATION

Before considering the public policy process involved in noise regulation, it is worthwhile reviewing a number of issues about noise, its community impact and its control. Noise control no doubt dates back to pre-historic times when cave-people first used organised political action to restrict late-night rock chipping and other sleep-disturbing activities. It is reasonable to postulate that noise becomes an increasing environmental and health problem as a society progresses through the various stages of civilisation and industrial development. However, it is not until a society embraces full industrialisation and mass transportation that noise problems emerge as a predominant factor affecting the amenity of whole communities such as those around factories, airports and freeways.

We can model this progression in the detrimental effects of noise with an exponential function as depicted in Figure 1. Without noise regulation a society will face ever-increasing uncontrolled noise eventually impacting adversely on every member of that society. Depending on the strength and effectiveness of noise control regulations implemented in a society, the level of adverse impact on the community can be contained and can even be reduced (see Figure 1). The level of community impact that is regarded as 'acceptable' will vary across societies according to the value that is placed on the well-being of its members relative to other priorities (e.g., access to transportation, land use, economic growth, etc.).

Figure 1. Effect of noise regulation on growth in noise impact with industrial development



Challenges in Noise Regulation

When governments address the challenge of noise control they have to contend with the fact that different noise sources: 1) have different physical characteristics, 2) are assessed using different exposure indices, 3) vary in their impact on communities, and 4) require different controls. The major types of environmental noise typically covered by control regulations are: 1) transportation noise (aircraft, road traffic, railway), 2) industrial noise (factory, construction), 3) shooting noise (military, sporting), 4) entertainment noise (discos, concerts), 5) recreational noise (vehicles, crowds), 6) neighbourhood noise (parties, barking dogs, lawnmowers, domestic motors).

Various types of controls are implemented for different types of noise depending on the approach and commitment of the relevant authority. Noise control regulations typically involve: 1) setting limits on noise emissions, 2) specifying minimum distances, 3) requiring noise barriers, 4) restricting hours of operation, 5) imposing penalties on noise events, 6) requiring acoustic insulation of buildings, 7) issuing noise cessation or attenuation orders, 8) requiring labelling of noisy equipment, and 9) providing incentives for noise reduction. In addition, most advanced societies use planning controls to restrict developments which cause noise impact on residential and other communities (e.g., schools, hospitals).

One of the difficulties for noise control in most societies is the spread of responsibilities across levels of government (local/county, state/provincial, national) and across agencies within a government. Different jurisdictions and agencies in the one country often adopt different approaches making inconsistencies inevitable [1, 2]. However, there is often a lack of coordination across jurisdictions and agencies which results in less effective noise control. Added to this are the complexities of community reaction to noise which further cloud the requirements for public policy on noise.

Noise Regulation and Human Reaction

Human reaction to environmental noise is generally described in terms of 'annoyance'. However, research has shown that community reaction is composed not only of the annoyance individuals experience but also of activity disruption, sleep disturbance, complaint propensity, fear and even startle reactions [3]. The relationship between noise exposure and community reaction is relatively weak with noise dose explaining only 10-20% of the variation in individual response across many studies [4]. A major determinant of human reaction to noise is the person's attitude towards the noise and the noise-maker – attitude serves to moderate the effect of the noise itself such that a low noise dose can cause a serious reaction in those who strongly dislike the noise whereas those who have positive attitudes towards the noise may experience little or no reaction to very high noise doses [5].

This weak dose/response relationship in the case of noise makes it difficult for regulators to specify an 'acceptable' level for control purposes. First, they have to decide how much disturbance to what proportion of the community they will allow. In many countries a convention has developed subtly over the past few decades that an acceptable level of noise is that which causes 10% to be highly annoyed (or seriously affected). This convention, in fact, is based on subjective judgments about the costs and benefits of noise control, about quality-of-life values in the society and about the politics of complaint. Second, regulators have to choose an index to measure noise exposure. For any noise source there are many different indices in use by different regulators, and different acoustic professionals will argue for different indices on the basis of different research findings. Third, regulators have to select a dose/response curve from which to determine which noise level corresponds with the allowable community reaction level for their chosen index. A problem here is that different studies vary by as much as 10+ dB(A) in where the reaction curve is plotted against noise dose [6, 7].

Even when regulators have selected an allowable level on a specified index, they have to contend with the fact that the criterion will be widely misinterpreted to mean that at lower levels (i.e., at 'acceptable' levels), there is no noise problem and no one will be affected (or has any right to be affected!). This occurs particularly when noise exposure contours are drawn on planning maps to show noise affected areas. In the minds of many (including politicians, bureaucrats and even land-use planners), contour lines become fictitious boundaries definitively marking where a noise problem starts and stops. They typically confuse noise exposure and noise impact. They seem not to realise (or they forget) that the exposure/impact relationship is a continuous function and that outside a noise exposure contour corresponding with a particular impact level (e.g., 10% highly annoyed), the impact will only gradually decrease with increasing distance from the noise source [8].

3. NOISE REGULATION AS PUBLIC POLICY

The process by which governments develop public policy is usually seen as occurring in stages [9, 10] or as a cycle [11]. A useful categorisation of the stages as they relate to noise is as follows:

- agenda setting (noise problem identification),
- problem analysis (noise impact assessment),
- policy formulation (noise control options),
- policy adoption (decision on noise regulation),
- implementation (operation of noise regulation),
- policy evaluation (evaluation of noise regulation).

The noise policy process is acted out by a range of policy players, namely:
1) politicians, that is, members of the country's law-making assembly or legislature, 2) political advisers employed to serve politicians particularly government ministers, 3) policy analysts in the bureaucracy, 4) 'technofficials', that is, technical experts within the relevant government agency, 5) noise researchers in various institutions, 6) acoustics professionals, 7) interest groups representing noise-makers and those noise-affected, and 8) the general community or individual citizens. Let us briefly review the policy stages and the players who are involved in each.

The first stage is *agenda setting*. The two most common mechanisms by which a noise problem gets on the policy agenda are individual complaints to politicians about noise nuisance and group representation by those with an interest in the issue. Alternatively, technofficials may identify a noise problem and may initiate action to put it on the agenda. The second stage, *problem analysis*, involves determining how serious the noise problem is and how it impacts on the community. This is usually undertaken by technofficials but may also involve researchers and acoustics professionals. At the *policy formulation* stage, various noise control options are compared by those driving the policy development, usually technofficials.

The *policy adoption* stage involves formal decision-making about the noise regulation by the government minister who is charged with the relevant portfolio or by the executive (e.g., cabinet) of the government of the day or by the relevant law-making assembly (e.g., council or parliament). The *implementation* stage of the policy process for noise involves putting the regulation into operation. This may be carried out by technofficials assigned as noise inspectors or noise control officers. The final stage is that of *policy evaluation* which may occur as a separate project after some month/years of operation of the noise regulation or else may be designed in as an ongoing monitoring process to gauge the effectiveness of the regulation.

The Role of the Technofficial

Noise is one area of public policy where the policy process can be completely dominated by technofficials. Because the area is highly technical and complicated, it is relatively easy for technofficials to consider themselves the only ones capable of understanding the complexities of community reaction and of different noise control options. They can easily forget that in most governmental systems, bureaucrats are expected to provide impartial advice to elected (or appointed) representatives who are responsible for determining policy. Noise technofficials can sometimes take it on themselves to completely control the policy process so as to ensure that the 'best' noise regulations are adopted.

In cases where technofficials are in total control, researchers, acoustics professionals, the community, and even politicians are often devalued in terms of their contribution and are excluded from the policy process. Although motivated simply by a desire to see technically 'correct' regulations in force, technofficials may be tempted to confound politicians with excessive technical detail so that they accept the single option previously worked out by the technofficial. Where technofficials control the noise policy process, the evaluation stage is often omitted. Policy breakdown occurs when implementation problems are ignored and eventually the noise problem becomes political, returns to the policy agenda and a new cycle of noise policy formulation commences.

The Role of Research

Researchers typically play a minor role in the development of noise regulations yet their work is crucial to the effectiveness of those regulations in controlling noise. A common misperception is that research findings directly determine policy choices. Researchers confuse their role if they operate as policy analysts at the same time. It is important to see the research and policy processes as quite distinct. We can summarise the key differences as shown in Table 1:

Noise Research	Noise Public Policy
Empirical	Political
Scientific	Non-scientific
Rational	Non-rational
Value-independent	Value-based
Assesses dose & impact	Controls dose & impact

Table 1. Comparison of features of noise research and noise policy

Thus, researchers should concentrate on the scientific assessment of noise and its effects, communicating their findings to policy analysts but leaving it to the analysts to translate these findings into policy choices. For example, it would be appropriate for a researcher to advise on a suitable exposure index for assessing noise as this meets the features of noise research (see Table 1). However, if the researcher gets into setting criteria and specifies an 'acceptable' level of noise for a particular situation, they are exercising a value judgment which is inherently political, non-rational and non-scientific. This is not to say that researchers should not play a role in the development of noise policy, only that they should remain clear about their role as researchers not analysts.

Regulations versus Standards

There is a fundamental difference between noise regulations and noise standards. Regulations, on the one hand, are developed and implemented under the authority of legislatures. Standards, on the other hand, are adopted by panels of experts and promulgated by non-government bodies including the International Standards Organization (ISO) [12]. When standards begin specifying acceptable levels of noise they become de facto regulations which bypass the normal processes and safeguards of public policy. Technical experts are not authorised in most societies to perform the essentially political and legislative role of determining policy. One could question, for example, the appropriateness of the Australian Standard on aircraft noise (AS-2021) with its table of acceptable exposure levels for different land uses. Regulators in Australia have specifically demanded that standards be confined to technical matters. The body representing the environment ministers of the nine Australian federal, state and territory governments (ANZECC) has sought to prevent Standards Australia from including environmental protection criteria and goals in their standards.

4. CASE STUDIES IN NOISE POLICY

Let us now consider some examples of the noise policy process. The following cases are from different jurisdictions in Australia but should illustrate points relevant to most countries which have some form of democratic political system.

Case 1: Comprehensive Noise Policy 1997

The State of Queensland adopted its noise policy as subordinate legislation under the *Environment Protection Act 1994*. The policy process commenced in the late 1980s with technofficials in the environment department developing an initial comprehensive noise policy covering all types of noise to replace guidelines that had previously been developed for different noise sources. In mid-1991 a Noise Policy Advisory Committee was established with representation from government departments, local councils, the acoustics profession, industry and academe. The committee was required to evaluate a Draft Provisional Noise Policy, to consult with relevant organisations, and to review public comment on the provisional policy. This committee was disbanded in early 1992 and the policy was virtually shelved for the next four years although it was worked on internally by technofficials with occasional consultation with external representatives.

The policy was resurrected in mid-1996 when a draft noise policy and explanatory documents were widely distributed resulting in 910 personal response questionnaires being returned as well as 373 detailed submissions. There were 25 public meetings and also 49 meetings with 'key-stakeholders'. After the first round of consultations, a further four rounds were held in late 1996 and early 1997 by circulating revised drafts and related information to those who responded to the previous round. The final round of 54 stakeholders included most state government departments and the representative bodies for local government, industry, business, environment, trade union, Aboriginal and other interest groups. Politicians were presented with a detailed 'regulatory impact statement' which provided a cost-benefit analysis of the proposed noise policy. There appear to have been extensive modifications to the policy as a result of political input. The final policy was adopted by Parliament and promulgated in late 1997 [13].

While very protracted, we see in the development of the above policy a number of features of an effective policy process. Clearly, the process was driven by technofficials but many other policy players were given an opportunity to influence the policy's provisions. While the content of the policy is not relevant to the present analysis, it is notable that an over-riding objective was to ensure that noise in Queensland is limited to a level that causes 10% of the population to be highly annoyed. The process seems to have had considerable political input which has, no doubt, complicated the process for the technofficials. Interestingly, with a new government elected in Queensland in mid-1998, it appears that the noise policy is back on the agenda for modification, again to accommodate political considerations.

Case 2: Road Traffic Noise Policy 1998

This case involves a policy under development for road traffic noise in the State of New South Wales. A joint task force was set up in 1989 by the two ministers responsible for environment and for roads. The task force reported to a steering committee of officers from the two relevant authorities. A number of working groups were established to investigate various technical issues including road design, vehicle emission controls, planning and development controls, and traffic management. In late 1991 the task force issued a progress report and conducted a community consultation workshop. Because of concerns raised at this workshop about community representation, the task force membership was expanded beyond government officials to include some community representatives. Further limited consultation was conducted over the next two years while the working groups collated findings for a final report which was publicly released in late 1994 [14].

The next step in the policy process was the establishment in late 1995 of the Road Traffic Noise Committee (RTNC) comprising representatives of various government departments and authorities (environment, roads, urban affairs, local government, transport, housing, rail, and cabinet office – the latter two with observer status). The only external stakeholder invited onto this committee was the body representing local government authorities which was initially given observer status but later became fully active on the committee. The committee set out to implement the noise control options recommended by the task force and released a progress report in 1996. Up to this stage, we see that the policy process has been facilitated by technofficials with fairly limited involvement from other policy players. The next step was the preparation of a draft policy again conducted by technofficials with some input from acoustics professionals. The draft policy specifies an exposure index and sets criteria for proposed road and residential land use developments. A formal round of public consultation began in mid-1998 with the release of the draft policy and a call for submissions [15]. A number of consultation seminars were held with local government officers and one with the general public. A report on the consultation process will be presented to the RTNC before the revised policy is submitted to the two ministers for adoption as government policy. It remains to be seen how much the policy is changed as a result of political input prior to adoption.

Case 3: Aircraft Noise Sharing Policy 1997

This case concerns the operation of Sydney (Kingsford Smith) Airport since the opening of the third runway in 1994. The Commonwealth of Australia is the relevant policy jurisdiction. The new runway lies parallel to the main North-South runway and intersects the shorter East-West runway. The third runway had been a hot public policy (i.e., political) issue for many years prior to and during its construction, but has escalated into a major ongoing controversy since its opening. At the core of the controversy is the policy question of how aircraft noise should be distributed so as to minimise impact on residential and other communities. Initially, the East-West runway was virtually closed and aircraft overflights were concentrated to the north of the airport using the main and third runways. A Senate Select Committee was established soon after the runway opened and it received 5,200 submissions, an unusually high number for Australia. The committee commented that there were two basic approaches, namely, concentrating the noise over fewer residents who would each be more seriously affected (which was the policy then in operation) or sharing the noise over more residents each of whom would be only moderately affected [16]. The committee concluded that the noise burden should be shared rather than concentrated.

This concept of sharing aircraft noise became a key plank of the then Federal Opposition's election policy in early 1996. They campaigned against the then Labor Government's regulations which they claimed concentrated noise in narrow corridors and they committed a Coalition Government to a policy of distributing the noise from the airport in a way that was fair and equitable. Clearly, the noise sharing policy originated with political players responding to strong community representation. It appears that the politicians drew on advice behind the scenes from acoustics and environmental professionals. Soon after they came to government in March 1996, the Coalition directed that a long-term operating plan be developed for Sydney Airport. A task force was established as well as a number of subordinate technical sub-committees. The task force which operated in the latter half of 1996, comprised mainly technofficials but also included two community representatives. More than 1600 submissions were received before the plan was finalised. In addition, a community forum was established as a consultative body which held six public meetings attended by 2600 people overall. The long-term operating plan was adopted by ministerial direction in mid-1997.

In adopting the policy of noise sharing by directing the implementation of the long-term operating plan, the Minister cited a determination that an environmental impact statement was not required [17]. This determination was recently challenged in the Federal Court by three aircraft noise affected local government authorities and that court's decision is still pending (as of August 1998). Thus, the noise sharing policy has been subjected to thorough legal as well as political scrutiny. Its future is still uncertain, though now both sides of politics accept noise sharing rather than noise concentration as the underlying principle.

5. SUMMARY AND CONCLUSIONS

This paper has demonstrated how noise regulation can be considered from the perspective of public policy. It has shown that the concepts of policy stages and policy players are relevant to the analysis of noise regulation. We have seen that noise policy can be controlled by technofficials, that is, technical experts in the bureaucracy who may engineer the process to the exclusion of all other players including acoustics professionals, researchers and the community. We have also seen that the research process is best considered quite distinct from the policy process and that researchers should be clear about their role. Finally, technical experts who are responsible for developing noise standards need to confine themselves to technical matters rather than creating de facto noise regulations which are the prerogative of the legislature.

The three Australian case studies presented focus on the development and adoption stages of the policy process, specifically, noise problem identification, noise impact assessment, evaluation of noise control options, and decision-making on noise regulation. These cases illustrate differences in the involvement and interaction of the various policy players. The first two cases are typical of noise regulation in democratic societies these days with a concerted effort being made to allow the various policy players, particularly the community to have an input into the process. In both cases, nevertheless, technofficials played the central role. The third case is distinctive in that it has been highly controversial with a major involvement by politicians. In most countries noise is currently a relatively low-profile public policy issue typically overshadowed by more pressing political concerns such as the economy, defence, education, industry, social welfare and employment. Even in the environment portfolio, issues such as air quality, greenhouse gases, water quality, and waste minimisation usually occupy the policy centre stage. Rarely do politicians take such a keen interest in noise policy issues as they obviously have in the case of noise sharing around Sydney Airport.

The present public policy approach could be used to compare noise regulations across different countries. Rather than simply focusing on content (e.g., which exposure index is used and which levels are regarded as acceptable), we can compare how different countries address the various policy stages and how the various policy players contribute to each stage. We can also use this approach to derive a normative model which exemplifies the best way of developing and implementing noise regulations. Such a model would set limitations on the role of the technofficial. Ideally, technofficials would play a facilitative role ensuring that teams of policy players contribute as appropriate to each stage of the policy process. Mechanisms would be established to prevent technofficials from giving only token recognition to the input from the other policy players particularly the general community. It is only by instilling in technofficials an understanding of and respect for collaborative policy-making that we can ensure they play a facilitative rather than a controlling and excluding role. Only then can we be sure that society is able to effectively address and counter the growing health problem posed by environmental noise.

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HEALTH CONCEPTS AND NOISE EFFECTS

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1. Concept of Health

Health means a state of complete physical, mental and social well-being and not merely the absence of diseases or infirmity. The highest attainable status of health is a fundamental right of everybody regardless from race, religion etc. These two statements can be found in the beginning of the preamble of the Foundation Act of WHO. The second statement means a reduction of the complete well-being of the first statement into an optimal one. Applied to the questions of noise effects on human health it is necessary with regard to complete well-being to establish and to develop criteria and characteristic guidelines to prevent health effects caused by noise.

It is necessary to recommend specified and proven noise effect guidelines for complete and for optimal well-being which can be used for well-founded noise abatement regulations and strategies in different areas (countries) and situations (traffic, homes etc.)

The physical (medical) well-being is the base for health. It is characterized by equilibrium of the physiological functions and functional systems of the human organism within standard deviations which have differentiated measures in resting and working situations.

Diseases are occurring when measured values (blood pressure, combination of hormones etc.) are exceeding the area of standard deviations. Disease means an irregularity of physiological functions and the treatment of these irregularities. Healthy or ill reactions can be assessed by two different methods (see fig. 1).

The upper limit of healthy reactions and the beginning of pathological reactions overlap so that a physician always has to decide according to harmfulness or harmlessness of a reaction in respect of disease. This type of assessment is a characteristic in curative medicine whereas in social medicine the method of percentage assessment has to be applied.

The establishment for community guidelines has to follow chronically the schedule:

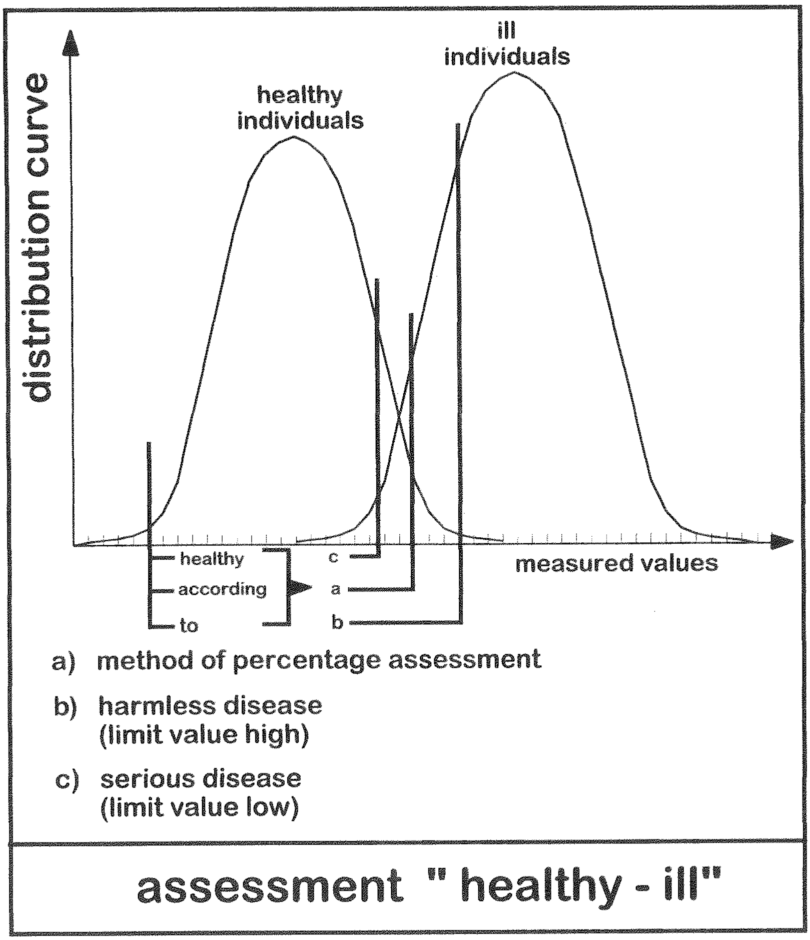
A: measurement of values of noise exposure (stress)
B: recording of physiological reactions (strain)
C: assessment of healthy or ill reactions
D: establishment of guidelines

The mental (psychological, psycho-sociological) well-being is indicated by an equilibrium of emotions, mental activities, state of tension and relaxation. Analogous to a physical equilibrium mental equilibrium has to be differentiated in resting and working situations as well.

Thus, physical and mental well-being are characterized by stable and labile equilibrium. Health is not an objective and static concept; it is indicated by dynamic conditions. Additionally individual and social attitudes are influencing the optimal well-being. This means that not only medical findings but annoyance of individuals and groups are relevant for health disturbances.

2. Assessments of Noise Effects

When establishing noise effect guidelines two extreme positions have to be taken into account: (1) jeopardy of physical health (disease) and (2) complete health (high quality level of life and comfort). Between these two positions an area of decreasing health and increasing disease is existing (see table 1)



Reviewing scientific investigations and reality experiences it is possible to identify health limits (1) and borderline values for jeopardy: LAeq 8h = 85 dB(A), Lmax (SEL) = 99 dB(A) (overstrain of vegetative regulations). In the same way it is obvious (2) that noise loads of LAeq = 30 dB(A) and Lmax = 45 dB(A) are representative for complete well-being which can be achieved only at few places and in a few situations in our civilised and technically dominated world.

Health risking by noise must be prevented in any case; this is possible by reducing the guideline of noise level for jeopardy by 10 dB(A). This means that LAeq = 75 dB(A) during daytime should be regarded as a tolerable limit for physical health. Long-term disturbances by noise induced considerable annoyance were observed by levels of LAeq = 65 dB(A); this means that serious annoyance is occurring when people are exposed to these levels. From this it was concluded that noise exposure should not exceed LAeq = 65 dB(A) to prevent negative psycho-physiological heath effects.

It has to be considered, too, that sleep is interfered by noisy events. Laboratory studies have shown that changes in sleep patterns (sleep stages) occur already at levels of Lmax = 35 dB(A). The subjective sleep quality estimation shows influences already at outside levels LAeq, night = 40 dB(A); on the contrary by studies around airports medical recordings showed awakening reactions with levels of Lmax = 80 dB(A) (outside). The assessment of all reported results leads to the conclusion that awakening reactions are meaningful for noise induced health disturbances. Inside levels of more than Lmax = 60 dB(A) may cause awakening reactions; this has to be regarded as a pathogenic factor.

Below the guideline of L_{Aeq} = 65 dB(A) a great variety of psychological and social reactions (like speech interference, annoyance etc.) has been observed. But there is no evidence for causal relationship for negative health effects in the pathogenic sense. Nevertheless, requirements for noise reductions are necessary especially with noise sensitive situations or groups (e.g. learning in school etc.). The threshold for annoyance and communications was found at LAeq = 55 dB(A) (0-20% annoyed) and at short time exposures of 55 dB(A) for 99% speech intelligibility. Noise levels during evening and night should be 5-10 dB(A) lower than during the day.

As already mentioned above complete well-being (complete health) (1) is to be expected when inside levels of LAeq = 30 dB(A) respective Lmax = 45 dB(A) are existing. In residential areas the outside levels should not exceed 55 dB(A), better is 50 dB(A). Otherwise slight psychological and/or recreational disturbances are occurring.

In hospitals the inside LAeq = 30 dB(A) respective Lmax = 45 dB(A) should not be exceeded though it is known by measurement in rooms with intensive treatments that these levels are often and highly exceeded.

Concluding from all these results and facts it is recommended especially to WHO to follow a gradation of noise effects on human health:

Gradation of Noise Effects on Human Health

H (Healthy state):	complete well-being comfort high quality of life	LAeq = 30 dB(A) (in) Lmax = 45 dB(A) (in)
IHD (increasing heath disturbances):		
1	slight disturbances, negative influence on creative work, etc.	LAeq = 50 dB(A)(out)
2	threshold of annoyance, vegetative reactions during sleep	L_{Aeq} = 55 dB(A) (out) L_{max} = 55 dB(A) (in)
	communication disturbances	short time LAeq = 55 dB(A) (in)
3	serious annoyance awakening reactions	LAeq = 65 dB(A) (out) Lmax = 60 dB(A) (in)
D (diseases):	jeopardy ↓ hearing loss extraaural overstrain	LAeq ≥ 75 dB (A)(out) LAeq = 85 dB(A) (in) Lmax = 99 dB(A) (in)

These classifications of noise effects might serve as a base for a human oriented noise management.

3. Noise Management

An optimal noise management is to anticipate the noise nuisance. This means that strategies or a prevention of noise nuisance have to be developed. Based on the assessment of noise effect as described above, IHD (stage B 2) LAeq = 55 dB(A) is a centre value for requirements for town and country planning and for all other noise abatements. The planning guidelines of every initiative in planning new plants etc. should remain below this value or not exceed it. It is not possible to give any detailed forecasting models of future noise development but there are existing standards and guidelines for town planning, land use, plant design etc. in various countries (Austria, Germany and others). For noise control at the receiver's sites there are existing regulations for maximum sound levels in front of buildings. For commercial buildings the LAeq = 65 dB(A) during day and LAeq = 55 dB(A) at night, whereas corresponding values for residential buildings in suburbs and rural areas and schools are 50 dB(A) respective 40 dB(A). For hospitals and spas the levels are 45 dB(A) and 35 dB(A).

As conditions of environments, noise susceptibility, circumstances and population-specific behaviour differs from continent to continent, from state to state and from region to region considerably it is a matter of course that no generally accepted rules are existing for application of the noise reduction or preventing in individual cases. But some possibilities should be considered carefully in advance of situations that are likely to give rise to noise problems. It might be, for instance, possible to site noise processes and equipment away from noise sensitive areas. Traffic should be smoothed by transferring the main traffic outside villages or settlements of dwellings. Most effective can be the information or education of people about purpose and use of noisy equipment during construction of streets or plants.

Concerning existing or predicted noise situations it is most important to know the strategies of noise control procedures: 1. control at the sources, 2. control along the paths and 3. control at the receiver. The control at the receiver is most decisive. Depending from the outside level of noise the required sound insulation for facades and windows differ between 32 and 52 dB. By means of sound insulation it might be possible to reach reduced noise levels as described and recommended above in the gradation schedule.

Measures to limit the noise emission at the source are generally most effective. This can be demonstrated best by means of technical construction of quieter vehicles for traffic noise loads. The European countries as well as some countries in other parts of the world have regulations for maximum permissible sound which have been revised several times during the last decades and years so that new vehicles have become quieter. But not only technical measures but also organisational regulations may cause noise reductions. The speed limit of 30 km/h in central parts of cities may result in reduction of maximum sound level up to 7 dB(A). Also the driver himself can raise the maximum sound level up to 10 dB(A). Well-educated drivers are therefore very important in noise control.

The emissions of aircraft noise have been reduced during the last two decades significantly; this is due to ICAO-Requirements which define maximum permissible sound level limits. The use of low noise aircraft may be enforced by setting noise related charges for take-off and landing. Likewise the introduction of noise reducing procedures around airports have resulted in a reduction of aircraft noise in settlements in the vicinity of airports. The increasing air traffic and the increasing density of residential areas around airports lead to the conclusion that noise zones around airports should be calculated based on the prognosis of movements in the year 2010.

4. Recommended actions:

1. Limit noise emissions of sources
2. Enforce town and country planning
3. Establish noise control programs
4. Establish sound insulation requirements
5. Establish and promote advisory groups and scientific institutes to work in the fields of acoustics and noise control
6. Encourage ISO, CEN and other national and supranational bodies to work together in establishing human-oriented guidelines for regulations
7. Promote scientific research in noise fields and in the fields of noise effects

STANDARDS FOR PROTECTING COMMUNITY HEALTH: AN UPDATE ON THE NEEDS OF THE LEGISLATOR

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Standards for the protection of community health are rare. International organisations seem unwilling to set standards specifying levels of noise that should not be exceeded in a community; believing, no doubt, that the responsibility for this rests with each individual country and that it is not prudent for an international group to advise and set standards on such matters.

More often than not, a similar situation is found in the individual countries, with central government delegating the responsibility for protecting health to regional government. Inevitably regional government further delegates the responsibility to local government, with the result that those upon whom the responsibility has been placed have little background knowledge of what is going on internationally, no standards to which they can refer for direction, no international network of colleagues to whom they can turn for guidance, and little if any help from national resources. These people are the new breed of legislators. They have a hard task in front of them. Often they face great opposition from powerful bodies who wish no control that might hinder their operations. The legislators need help that at present often seems non-existent.

It is not only the system that is to blame, but some of the fault must rest with us and the rather confined way in which our scientific community works.

Only in very exceptional circumstances will local government have the expertise to produce standards for the protection of community health from noise, and will look to regional government for guidance and standards on how to manage the noise environment. Similarly, regional government will look to central government for this advice, and so the ball rests back in the hands of central government who, if to be seen to be producing such a performance standard meets with political approval, will produce a discussion paper that will be circulated to selected parties. Usually these parties will consist of representatives of the major noise producing industries and certain medical officers of health, both of whom, perhaps for different reasons, will point to the lack of published scientific evidence (in the journals they read) and international standards to justify such a radical step. More likely than not, the matter ends there and central government goes on to other things, even if, on the rare occasion, technical expertise is to hand. So we have the legislators urgently requiring standards that are not available.

If, by chance, central government feels such a standard would be very useful, and politically expedient, an approach to interested organisations often produces a surfeit of those supporting the noise makers and a dearth of those with community interests at heart, resulting in the standard being stopped or the performance requirements removed. An approach to international organisations for such a standard usually follows the same path with the same result. To the author's knowledge, no international performance standard for the protection of community health from noise has successfully passed this stage.

It may be appropriate at this point to examine what has been published and readily available during the last five years since ICBEN met at Nice in 1993, and what the legislators now have to work from. The answer is: Very little!

The community noise document [1] has been published but only as a university publication and apparently with very limited circulation and availability, which does not give it the credence necessary for government world-wide to accept the recommendations. The one thing that does stand out, however, is that the editors have had the courage to make recommendations at the very start of the document and this is to be commended. Converting the findings of scientific research into benefits for the community at large is not easy for rarely do the two sides meet to discuss what is needed, what is available and what can be done. The scientist's livelihood often depends on government funding to whom policy is everything and not necessarily implementation – for that is local government's task and that of the health professionals who often feel entirely left out of the picture. It is very difficult for the health professional to talk to the scientists and discuss needs, and this is an area where the resources of ICBEN should, it is suggested, come into action.

The Health Council of the Netherlands has published its Gezondheitsraad [2] which is an excellent document but again with limited circulation and advertisement. The document analyses results of much research, gives tables of long term effects of exposure to sound, and gives an estimate of numbers of people in the Netherlands affected by noise in different environmental situations. Although it gives threshold levels for the effects and a large amount of excellent information, it does not set out the information in a form that local government can adopt as a regulatory instrument.

Performance standards are an urgent need for the legislator. It is here that ICBEN can make its mark if it is willing to do so. It is suggested that ICBEN take on board the portfolio of producing these international standards that are so critical for the protection of community health from noise. And for this we need not only the dedicated working group members to compile the standards but also the researchers willing to produce criteria that to the best of today's knowledge will provide sufficient protection without being too conservative or too radical that its implementation becomes non-productive or nonsensical. These standards should then have wide circulation and be easily accessible to the legislators to whom the information and guidance is so important but, to date, has been so difficult to find.

So what do the legislators need and what do we as scientists have to offer?

The legislator's task, in this context, is to develop rules for the protection of community health from noise in an environment where noise is a daily biproduct of social and economic development. For many years the noise of transportation has formed the major component of the noise environment. This remains the major problem but other, more insidious components are daily invading our lives and their effect may be of lasting significance to our overall health status.

The major noise problems facing local government include:

1. How to manage the noise from transportation with the tools that are available.
2. What limits to set for the noise from recreational activities and how to enforce them.
3. What constitutes a damaging noise exposure and how to protect people from self inflicted excessive sound.
4. What are damaging noise levels for young children and how to protect them from such levels.
5. How to justify setting limits to noise emission, and introducing mitigation at some cost, when there is no guidance to the value of such mitigation in terms of life expectancy, and no daily value put to human life.
6. How to protect from sleep disturbance and how to justify any means taken. How does sleep disturbance relate to human health and what cost can be put into ensuring such disturbance does not take place in a freely moving society?
7. What is the cause of the low frequency hum heard by some thousands of people world-wide, but not by others, and how do we solve their problem?

Most of the problems contain the same two recurring questions that have plagued acousticians for so many years, but are still mainly unanswered:

- From the point of view of health: What are the noise measures that should be used, and then what is the amount of noise that a person should reasonably be expected to tolerate?
- If noise is excessive and affects health, how do we price the health disbenefit?

Transportation

Legislation to protect health from transportation noise emissions has always been difficult to formulate. Central government usually holds the power over what uses its transportation routes, and over any restrictions that may be imposed with regard to weights, speeds, vehicle integrity and vehicle emissions. The main concern is with safety and free flow of traffic. Noise immissions in bordering land are of secondary importance and not a matter for central government. In most cases, local government has to guess the amount of noise immission and plan its land use accordingly if the health of the community is to be protected. Most often this is too hard a task and housing development is permitted right up to the transportation route, or terminus, with no protection from the noise. Indeed a well tried planning strategy is to put low cost, high density housing in such areas to act as a buffer between the noise source and more affluent residential areas. One may question the ethics of doing this, but with little or no evidence before the planner to say that this is wrong, it is hardly a question of ethics - more one of expediency. The planner has few tools to help in this matter and as noise, to the general public, is simply an annoyance and not a concern at all with regard to health, there would seem to be no problem in having such a human buffer. The noise immission is treated simply as part of the socio-economic value of the neighbourhood.

It is not that the noise emissions cannot be controlled. Transportation noise management is not difficult technologically - indeed it is no more difficult to manage than industrial noise emissions. The difficulty is that the transportation industry is very powerful, compared to other industry, and the management of noise immission depends on setting limits to growth, density and individual emission levels, all of which are contrary to the industry's aims and those of central government. Against almost overwhelming odds a national standard on the management of airport noise for the protection of community health was developed in New Zealand [3], has achieved national recognition and acceptance, and is working very well. By the adoption of the standard in a district plan, the local residents are protected from excessive noise and know just how much noise to expect from the airlines using the airport. Similarly the airport knows where it stands and is protected from any incursion by new residential development in the area. It is believed, however, that the industry does not like the standard and would prefer there to be no likelihood of any restrictions to the choice of aircraft they would like to use or to future flight densities, and there are indications of moves afoot to try to get it withdrawn. An attempt to produce an identical international standard has met with the most extreme opposition from air transportation groups world-wide, though not from aircraft manufacturers, and the standard is unlikely to proceed unless environmental and health groups can lobby to be equally included in the discussions. In the large working group that was set up to look at development of the standard, there was only one representative from public health - all but one of the others appointed to the group were affiliated in some way to the air transport industry. Unless more effort is made by health and environment groups to be involved in such matters, it is unlikely there will be any international (performance) standards to protect community health from the adverse effects of excessive noise.

Transportation too is changing. More and more people own their own light aircraft or microlight, aircraft are operated like buses, helicopters are replacing ambulances and police cars, are in common use by farmers (to round up their stock) and by hunters (to access the highlands for game), and motorised watercraft are in abundance wherever there is water. So the sounds in the environment are changing in pattern and spectrum, and the legislator is faced by a bewildering array of different noise sources to consider, with little or no help from anyone. With transportation now personalised more than ever before, and the occupants believing in the divine right to go where they like, when they like, and how they like with no one having the right to complain about them, noise problems are once more on the increase and the noise in the environment no longer on the decrease - as it was in 1993.

Recreation and leisure

Modern society in the developed world is highly mechanised and times of recreation and leisure no longer are quiet periods of rest. Exacerbating the situation are modern employment contract regulations that place many workers on long hours in noisy and stressful workplace situations. Most countries have occupational noise regulations in place, based on an eight hour work day and a five day working week. Such regulations, designed to protect between 90 and 95 percent of those exposed, assume the noise in the workplace is the only exposure to noise, the remaining 16 hours per weekday and all the weekends being sufficiently quiet to allow the body to recover from the effects of the sound immission. The environmental conditions during this recovery time are very important and the health of the worker is inextricably linked not only to the occupational conditions but also to the environmental conditions experienced out of work hours during the time that recovery should be taking place. To complicate matters, the environmental noise received out of work hours is a combination of self imposed sound during recreational activities and often unwanted intrusion of noise from neighbours' activities, transportation and local industry. And at present there are no legal limits for sound received by choice, even if the recipient does not understand or is unaware of the dangers. Our leisure hours are filled with noise and the effects on health are noticeable, but little is being done to mitigate or correct the problem.

Based in extensive audiometric experience [4] it is estimated that about 40 percent of the workers in New Zealand have a noise induced hearing loss of at least 10 dB (equating to 25 to 30 dB Hearing Threshold Level (HTL) dependent on initial audiogram) and about 25 percent of young people under the age of 18 have an elevated HTL in the region of 30 dB or more. How much can be blamed on the use of personal cassette players or on car radios at high volume is not known, but it is not uncommon to hear sounds from a personal cassette player several seats away over the internal noise of public transport, or to hear a car radio before the sound of the car itself. George T Singleton [5] described the worrying situation of hearing loss among high school students in Florida in the early 1960s. Today, almost 40 years later, the situation has not improved. Indeed it is likely to have worsened. There are even reports of our schools using loud music to keep the children happy during play time. As a responsible body of physicians, scientists and engineers, one wonders how we could have let this happen.

New Zealand also experiences a large number of single car accidents each year, many caused no doubt by the driver's lack of concentration. Again how much can be blamed on the use of car radios at high volume is unknown, but there is the distinct possibility that such noise does play a significant part in the proceedings. In August of 1998 there was rally of car stereo enthusiasts in New Zealand. In the rally was a competition for the loudest car stereo. In-vehicle sound levels in excess of 150 dB were measured!

For more than 10 years now the low frequency beat of "rock" music has been one of the most annoying components of the sound environment in our residential areas. A new comer to the scene is the throb from neighbouring spa pool pumps. This latter does not form part of the enjoyment for the neighbours and silencing, when requested, has not been a technical or social problem. Quietening the beat from stereos is a totally different matter with no solution in sight. The ability to make noise, without redress, is still regarded as power, and the demand to quieten considered an infringement of human rights. Until we have the evidence of its effects on health, a definitive set of limiting criteria to use, and a proven method of compliance measurement, we are unlikely to solve this problem. Again one must ask what we as a responsible body are doing to solve this. Surely, if we try, we can present the necessary evidence and the limiting criteria to use - and a "rock-music filter" ought to be very easy to produce, for the frequencies are in a fairly narrow range. Why do we have no solution in place?

The home environment

The results of one epidemiological study involving 145,000 cases in a city [6] showed that every third person suffering from neurosis and every fifth person suffering from a mental disorder, developed illness as a result of exposure to noise, and that the long term effects may be a reduction in life span by 8 to 12 years. The validity of research that produced such startling results may well be questioned, but the numbers are too high to be ignored. The study may well not have been replicated, but other studies show similar effects, albeit perhaps to a lower level. The majority of people live in towns and cities in some form of building, yet we know little about the role of the building itself in modifying or producing the environment in which people may spend more than half their life. From an investigation of the conditions surrounding just under 400 cases of unexplained infant mortality, it was postulated that the size of sleeping rooms, and the enhancement of certain natural frequencies, may well be an environmental stimulus in cases of sudden infant death syndrome [7]. Unfortunately, there seems to be little interest in following up such studies. Building authorities go to some lengths to control the environment in buildings in terms of heat and light to protect the health of the occupants, but the natural acoustical properties of buildings seem to have been ignored. There was some derision [8] when in 1973 it was reported that a low level throbbing sound in the environment, heard by a very few people in some buildings, may adversely affect health. Some 25 years later, there are thousands of sufferers world-wide, no country seems immune, and no-one has come up with an answer to the problem that has caused suicide, neurosis and early death.

In the space permitted it has not been possible to discuss all the problems that still face the legislator with reference to the management of the noise environment. The few that are mentioned form only a small part of the many problems facing the modern day legislators. They have an almost impossible task and have need of the help of performance standards giving definitive limiting criteria for managing noise in the environment. ICBEN is one of the very few bodies with the technical expertise to produce such standards, and has the added advantage of not being governed or restrained by political boundaries. It is recommended that this become part of the portfolio of ICBEN and possibly the work of Team 9 during the next five years, so that we may enter the next millennium with the knowledge that our descendants will not suffer from noise because of our lack of responsibility.

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INTERNATIONAL COMPARISON OF STANDARDS REFERRING TO OUTDOOR AND INDOOR NOISE

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1. INTRODUCTION

In the last five years international comparisons of noise regulations referring to outdoor and indoor noise have been published (e.g.[1]-[5]). The background has mainly been the establishment or revision of national regulations, but also the new noise policy of the European Commission [6] towards regulations for noise exposure has stimulated investigations. The interest has been mainly directed to the way noise is assessed and to what extent noise exposure is considered as tolerable by the responsible authorities. The publications mentioned above present detailed information about the applied noise indicators and the established immission values in various countries. In this paper the main findings of these comparisons and recent developments will be reported.

2. BASIC CONSIDERATIONS

Immission values have been established in terms of environmental quality standards (target values), guide values that shall not be exceeded, or limits with legal consequences when they are exceeded. They are applied for various sources (road, rail, aircraft, industry) and situations (land-use planning, licensing of new installations for industry and transportation, remedial measures). Immission values can only be compared directly when the noise indicators to which they refer are identical and the measurement or calculation procedures for the determination of the noise exposure are comparable. Important factors that have to checked are e. g.:

- the receiver location (e. g. near facade or free field),
- reference time intervals (24 h, daytime, night-time),
- emission situation (e. g. yearly average, 6 loudest month),
- transmission situation (e. g. downwind, long-term average),
- - with calculation procedures - the sound prediction models.

Concerning sound prediction models comparisons of data from various countries [7] have shown large differences between the results even for comparatively simple situations (straight roads, no reflections, no walls or berms). For road traffic noise e. g. the differences amount up to 8 dB(A).

It turns out that the factors to be checked often vary in regulations for different sources within one country. The necessary information to check these factors has not always be available in the publications mentioned above. Therefore, conclusions from comparisons of immission values can only be drawn after a thorough examination of the conditions.

3. OUTDOOR NOISE REGULATIONS

Road traffic noise

Comparisons of regulations from various countries show that L_{Aeq} is the preferred noise indicator. In some countries adjustments are applied to the L_{Aeq}-value, e. g. in the USA (L_{DN}) an adjustment of +10 dB for night-time exposure (23:00 to 7:00), in Germany (L_r) an adjustment up to 3 dB near traffic lights for increased annoyance, in Switzerland (L_r) an adjustment down to -5 dB for low traffic volume.

Some countries use percentile levels as noise indicator, e. g. United Kingdom L_{10} (level that is exceeded in 10 percent of the reference time interval) or Japan L_{50}. But in these countries the development goes towards L_{Aeq} with new or revised regulation, too. In the British Planning Policy Guidance L_{Aeq} is already applied, and in Japan the Central Environmental Council has recommended to adopt L_{Aeq} as noise indicator [8].

Considerable differences exist for the reference time intervals. They range from a 24h period over two separate periods for day and night to three separate intervals for day, rest period, and night. In general, the immission values for daytime are 10 dB higher than immission values for night-time, and 5 dB higher than those for rest periods. It is often discussed whether noise indicators for a 24h reference time interval are suitable for an appropriate protection against noise at night-time or whether it is necessary to consider two separate reference time intervals [9].

Table 1:
Limitation of $L_{eq,D}$ at daytime and $L_{eq,N}$ at night-time when noise indicators for a 24h reference time interval meet the guide value, as compared to separate guide values for daytime and night-time, parameter is the difference between $L_{eq,D}$ and $L_{eq,N}$. All levels in dB

noise indicator	guide value	$\Delta L=L_{eq,D} - L_{eq,N}$					
		4		8		12	
		$L_{eq,D}$	$L_{eq,N}$	$L_{eq,D}$	$L_{eq,N}$	$L_{eq,D}$	$L_{eq,N}$
$L_{eq,24h}$	60	60.9	56.9	61.4	53.4	61,6	49.6
L_{DN}	60	57,0	53,0	59.2	51.2	60.6	48.6
$L_{eq,16h}$ $L_{eq,8h}$	60 50	54	50	58	50	60	48

It can simply be shown how the sound level at daytime $L_{eq,D}$ and night-time $L_{eq,N}$ respectively are limited on one hand by 24h-indicators and one guide value or on the other hand by two indicators for daytime and night-time and two separate guide values. Table 1 presents results for $L_{eq,24h}$ and L_{DN} (for simplicity night-time is taken from 22 - 6:00). The guide value is 60 dB for the 24h indicators and 60/50 dB for the two separate reference time intervals. Parameter is the difference $\Delta L=L_{eq,D} - L_{eq,N}$ which typically varies between + 4 dB (highways) and + 12 dB (residential streets).

For ΔL-values of 8 to 12 dB nearly the same degree of protection can be get if the guide values for L_{DN} ($L_{eq,24h}$) would be about 1(2.5) dB lower than the guide value for $L_{eq,D}$. For ΔL= 4 dB the corresponding guide values would have to be considerably lower (3 or 7 dB resp.). It turns out that L_{eq24h} is only suitable to guarantee the necessary protection against noise at night for all types of roads when the guide value is considerably lower than the guide value for daytime in case of two reference time intervals. For L_{DN} the assessment for night-time is comparable to the assessment by means of separate daytime/night-time intervals when the guide value is about 2 dB lower.

The differences in the requirements for the protection against noise are enormous between countries. Planning values for new developments along roads vary from 50 to 70 dB. For new and altered roads the margin of immissions values is about 8 dB with most countries setting limits at about 60 dB for residential areas. These values are considerably higher than the environmental quality targets of 50 to 55 dB being proposed by an experts' group appointed by the WHO [10].

In some countries there are regulations at existing roads. Noise reduction measures are carried out when the noise exposure typically exceeds 65 to 70 dB.

Railway Noise

As with road traffic noise L_{Aeq} is the preferred noise indicator. Some countries apply maximum levels as the only or additional indicator. The variation of reference time intervals correspond to the situation with road traffic noise. But for comparisons of indicators it has to be taken into account that $\Delta L = L_{eq,D} - L_{eq,N}$ can be 0 or even negative at railway lines with mixed passenger and freight traffic. In this case, the guide value for L_{DN} would have to be 6 dB lower than the guide value for daytime when two separate reference time intervals are applied to get a comparable protection against night-time exposure.

Immission values for new railway lines in residential areas roughly vary between 60 and 70 dB with an emphasis on levels between 60 and 65 dB.

In some European countries the requirements for railway noise are smaller than those for road traffic noise. In Austria, Denmark, Germany, and Switzerland the difference is 5 dB, in The Netherlands 3 dB. This difference is called *railway bonus*. It is based on scientific findings from social fields surveys indicating that at the same L_{Aeq}-level the general annoyance of residents living near railway lines is smaller than the annoyance of residents of roads. This effects is more pronounced at higher levels.

The railway bonus is nowadays criticised by residents of new and existing railway lines, especially in Germany. It is questioned whether the results of the former social surveys are still valid because the frequency of trains, esp. freight trains at night, and the speed of passenger trains have become considerably higher in the meantime.

To date new social surveys are carried out in Germany to investigate if a railway bonus is still well-founded. First results will be reported at this congress [11]. It is worth mentioning that in the German noise regulation for the high speed magnetic train Transrapid the railway bonus is restricted to speeds up to 300 km/h [12]. Laboratory studies had yielded that the perception and assessment of passages differ considerably at different speeds. At high speeds (≥ 300 km/h) the transrapid is rated as louder and more unpleasant than a conventional train. Furthermore it is stronger associated with danger, threat, and aggression. [13].

Aircraft Noise

International comparisons between aircraft regulations are still difficult because noise indicators differ considerably between countries. Direct mathematical conversions of exposure data are not possible, but some information is available from model calculations with various noise indicators [14].

To date some countries strive for a harmonisation of noise indicators for different sources esp. air traffic. For The Netherlands see chapter 5. In Switzerland, the *Commission for the* *assessment of noise limits* has proposed to replace NNI by rating levels based on L_{Aeq}-values [15].

The analyses of regulations have shown that nearly all countries apply a 24h reference time interval. Therefore, there is a broad public discussion in many countries about the necessity of an additional noise indicator to assess the effects of aircraft noise at night-time. Several criteria on the basis of L_{AFmax} or L_{AX}-values have been proposed (see e. g. [16][17][18]) and partly used in licensing procedures of new and altered airports. But also criteria based on L_{eq} as indicator are applied. In The Netherlands a night-time limit of 26 dB (L_{Aeq}) within bedrooms has been adopted [19]. In Switzerland, the Commission mentioned above has proposed limits for night-time exposure on the basis of hourly L_{Aeq}-values.

Industrial noise

Industrial noise is generally assessed by means of rating levels according to ISO 1996. The rating level is calculated from L_{Aeq} and adjustments for special characteristics, mainly tonal components and impulses. These adjustments vary considerably between countries as concerns their determination and values (see e. g. [3]). E.g. the maximum value of the impulse adjustment differs by about 7 dB between countries. To date working group ISO TC 43/SC1/WG 45 is revising ISO 1996. It is especially dealing with the specification of adjustments. WG 45 has already elaborated a procedure for the determination of impulse adjustments on the basis of recent research results [20].

Additional differences between regulations concern reference time intervals, the consideration of most disadvantageous hours within reference time intervals, and rating procedures (comparisons with given guide values and/or with background or prevailing levels). For details see [1]-[5]. Immission values for residential areas for most countries amount to 45 to 55 dB(A) at daytime and 35 to 45 dB(A) at night-time. These values are in agreement with the target values recommended to the WHO [10].

4. INDOORNOISE

Many countries have enacted regulations to protect people inside their dwellings, too. There are two ways of setting requirements. Target values either for the indoor sound level or for the necessary sound reduction of the enclosure of buildings (walls, windows, and roofs) are laid down.

International comparisons [5] have yielded that different indices are applied to describe the requirements for sound insulation (standardised level difference D_{nT}, sound reduction index R', weighted apparent sound reduction index R'_w). By this, comparisons of indoor noise standards become more difficult. But at least approximate comparisons seem to be possible.

Regulations for the sound insulation of new houses and dwellings are of special importance in noisy areas where new dwellings are to be approved exceptionally (e. g . in the surroundings of airports or along busy roads). The indoor values to be tolerated in various countries vary considerably. At daytime the difference between the highest value of 45 dB(A) (Canada, USA) and the lowest value of 30 dB(A) (Nordic countries) amounts to 15 dB(A). At night-time, the differences are even higher. The immission values vary from 22 dB(A) (Austria) to 40 dB(A) (Canada). In some Nordic countries, the maximum level L_{Amax} is limited in addition to L_{Aeq}. By this, the protection of sleep can be considerably improved in cases where only a few noise events occur during night-time.

The comparisons demonstrate that in some countries only minimum requirements (prevention of health hazards) for sound insulation at new dwellings are laid down while other countries aim at undisturbed human activities (communication, recreation, sleep) indoors. It is often argued that the authorities shall regulate only the minimum requirements for healthy living conditions and that client is responsible for additional sound insulation as he must pay the cost anyway. But it has to be taken into account that the client does not always live himself in the exposed building, that the inhabitants very often recognise negative effects of noise too late, and that remedial measures are very expensive. Therefore, the target values for indoor noise which guarantee undisturbed living conditions as far as possible are strongly recommended [5].

In some countries, regulations have been enacted to support sound insulation in highly exposed areas (remedial measures) or with the construction or considerable alteration of transportation when measures at the source are not possible or too expensive (precautionary measures). Especially in case of precautionary measures the requirements should meet a high standard because of the deterioration of the the outdoor situation. To date comprehensive, legally binding regulations only exist in The Netherlands and Switzerland. In other countries, e. g. Germany, legal regulations only exist for some noise sources.

5. FUTURE DEVELOPMENTS

The harmonisation of rating procedures is an important prerequisite to make noise abatement more comprehensible for the politicians and the public. In some countries, steps towards harmonization are taken, e.g in The Netherlands and Switzerland which have already comprehensive legal noise regulations for all sources and situations noise. In Switzerland, a proposal has been elaborated to include noise at airports into the general rating system for noise immissions [15] with L_{Aeq} as noise indicator. In The Netherlands the National Health Council has proposed a uniform environmental noise metric on the basis of L_{DEN} (rating level consisting of L_{Aeq} and adjustments for special characteristics and exposure during the evening and night-time) [19]. In Germany, the harmonisation of noise indicators is discussed in the framework of the revision of the Aircraft Traffic Act.

To prepare the future noise policy the European Commission has established a working group which shall work out a proposal for a harmonised noise indicator till February 1999. This indicator shall be applied in EU-directives concerning noise exposure.

While L_{Aeq} is introduced more and more into national noise regulations international experts' groups (e. g. ISO) have started discussions about a replacement of level related noise indicators for the description of noise exposure because they may lead to confusion (emission values/ immission values) and numerical procedures are hard to understand for the public [21][22]. Instead, it is proposed to use SI-units (sound exposure in Pa^2s) to characterise the noise situation. It has to be stated that this change only affects the presentation of exposure data. Both kinds of data are in principle equal as rating levels can directly be converted into sound exposure values and vice versa.

Other proposals aim at an additional source related adjustments to rating levels (or sound exposure values) which shall take into account that different noise sources may lead to different amount of annoyance at the same level [19][23]. By this, the noise indicators are directly related to noise effects.

It is suggested that the ICBEN committees should discuss these proposals to work out recommendations for a possible improvement of future noise regulations which should be more comprehensible and convincible for the public and politics.

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CEN-STANDARDS AND REGULATIONS REFERRING TO NOISE EFFECTS

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1. INTRODUCTION

CEN (the European Committee for Standardisation) and its counterpart CENELEC (the European Committee for Electrotechnical Standardisation) work in partnership with the European Commission to support the internal market of the European Community. The role that CEN/CENELEC can play, with ISO, IEC and ITU-T, to facilitate international trade, develop the information society and protect the environment was highlighted last year by Commissioner Martin Bangemann.

Noise and its effects are important areas for European Standards in respect of health and safety, the environment and trade issues. An audit in 1997 of European Standards containing "noise" clauses identified 118 draft or approved standards being developed by 23 CEN technical committees (TCs).

The scale of work within CEN in the area of noise and its effects is, indeed, substantial. It could also be said to be fragmented in nature, with the attendant risks of inconsistency and duplication of effort.

Although much of the work takes place under the auspices of TC211 "Acoustics", with related and co-ordinated work in other TCs in the fields of ergonomics (TC122) and personal protective equipment (TC159 hearing protectors), for example, many sector-specific TCs in fields such as machinery design or toys are also active. Establishing a dialogue between groups developing noise clauses is a necessary, albeit somewhat time-consuming, activity and the audit carried out by TC211, as referenced above, provides a valuable starting point.

2. REGULATORY BACKGROUND

The driving force behind this considerable activity is the regulatory framework of the European Union, in the form of Commission Directives. These Directives provide, in each case, a single set of shared rules for the EU, to replace national laws. They define the broad requirements that products must meet and the checks that the manufacturer must have carried out before the product can be placed on the market. CEN may be mandated by the Commission to develop standards within agreed timescales in direct support of Directives. The Commission has supported the development of standards by funding pre-standardisation research projects in its third and fourth Framework Research Programmes, within the Standards, Measurement and Testing plan.

Among the several Directives which refer to noise are the Noise at Work Directive (soon to be succeeded by the Physical Agents Directive), the Machinery Directive, the Toy Safety Directive, the Construction Products Directive, the Personal Protective Equipment Directive and the Use of PPE Directive. Motor Vehicles (Cars, Lorries and Buses), Motorcycles and Air Transport are also covered by a series of noise limits contained within Directives, as are Lawnmowers.

All Member States of the European Union are required to implement Directives by means of appropriate national legislation within agreed timescales, such as, in the case of the Noise at Work Directive, in the UK, by the Noise at Work Regulations 1989.

3. THE RELATIONSHIP BETWEEN DIRECTIVES AND STANDARDS

Many Directives are concerned with the sale and use of products within the EU, for example the Personal Protective Equipment Directive 1989, which covers products such as safety helmets, respirators and hearing protectors. Under the "New Approach to Technical Harmonisation and Standards" agreed in 1985 by Ministers of EU Member States, such Directives set out "essential requirements" (for safety, for example), written in general terms, which must be met before products can be sold in the EU. Products meeting these requirements are given the CE Mark. Taking hearing protectors as an example, in the case of the PPE Directive, the Directive does not set quantitative performance requirements for hearing protectors itself and such statements, covering areas such as minimum attenuation, sizing and durability are left to the associated CEN Standards. When a new CEN Standard is adopted by Member States, following a two stage enquiry and (weighted) voting process, it is known as a Harmonised Standard and its implementation is then mandatory in all EU Member States.

To continue with hearing protectors as an example, it is illegal to offer for sale in the EU a hearing protector without a CE-Mark. CE-Marks can only be granted by accredited certification bodies operating within one of the Member

States, who will normally base their assessment of the hearing protector on the results of tests made by an accredited laboratory in accordance with CEN Standards (EN 352-1 for ear-muffs, EN 352-2 for ear-plugs, EN352-3 for helmet-mounted ear-muffs, for example).

4. CERTIFICATION AND CONFORMITY ASSESSMENT

Where a Directive requires products or systems to be independently tested, certified or inspected, this must be done by a body approved for that purpose by a member government of the EC. These Approved or Notified Bodies might be test laboratories or certification/inspection bodies. Conditions for licensing and accreditation of both certification bodies and test laboratories are rigorous, as judged by UK experience, and the demands of maintaining accreditation are not insignificant. The author can speak with direct experience of such matters as the Director of the UK's only accredited test laboratory for hearing protector attenuation testing at Salford University and as the Chairman of the independent Board of Governors of a licensed certification body.

There are systems for communication and comparison of experience both within a specific area of assessment such as hearing protector assessment ("vertical committees) and across a more diverse field such as all type of PPE ("horizontal" committees) and the systems of accreditation of laboratories across all Member States is itself being harmonised through EOTC (European Organisation for Testing and Certification) to ensure equality of technical performance.

5. PRINCIPAL NOISE STANDARDS AREAS

As indicated above, CEN TC211 is the main "noise" Technical Committee. Much of its work programme is delegated, under the Vienna Agreement for co-operation between CEN and ISO, to the corresponding ISO committee TC43. The secretariat for both committees is provided by the Danish Standards body. TC211's scope is broad, encompassing methods of measuring acoustical phenomena, the generation, transmission and reception of sound, all aspects of the effects of sound on man and his environment and methods of noise reduction. As at last year, it had more than eighty current work items covering statistical methods for determining noise emission values, determination of sound power, audiometry, measurement of the attenuation of hearing protectors, silencers and ventilation noise, design of low-noise machinery and enclosures, vibro-acoustic transfer properties of resilient elements and, importantly, guidance for the drafting of noise clauses in (specific) safety standards. Since its technical work is undertaken chiefly within ISO TC43, which is the subject of a separate paper to this conference, the details of its work programme will not be discussed further here.

Among the other TCs with an interest in noise are TC113 (air conditioners), TC114 (fluid power systems), TC142 (woodworking machines), TC143 (mechanical presses), TC144 (agricultural and forestry machinery), TC145 (rubber and plastics machines), TC146 (packaging machines), TC151 (mineral extraction machines), TC153 (food preparation), TC186 (thermoprocessing machines), TC197 (pumps), TC198 (printing and papermaking), TC200 (tannery machines), TC201 (footwear), TC202 (foundry machinery), TC214 (textiles machinery), TC232 (compressors and vacuum pumps), TC255 (handheld tools), TC256 (railbound equipment), TC271 (coating plants), TC274 (aircraft ground support) and TC313 (centrifuges). This list illustrates just some of the many diverse areas in which there has been a need to develop noise requirements within standards.

6. FUTURE EUROPEAN NOISE POLICY AND STANDARDS

Finally, looking ahead to the development of a cohesive environmental noise policy within Europe, as proposed by the Commission's Green Paper of November 1996, there will be increasing action in a number of standardisation areas. The Green Paper addresses the development of a Directive providing for the harmonisation of methods of assessment of noise exposure and the mutual exchange of information and specific actions in respect of road traffic, rail and aircraft noise. A framework Directive encompassing a range of outdoor equipment, including construction machinery and garden equipment, will incorporate the seven existing Directives in this area. It is clear that there will be an important role for CEN to play in the development of a new generation of European Standards concerned with noise and its effects.

7. ACKNOWLEDGEMENTS

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ASSESSING THE EFFECTIVENESS OF NOISE CONTROL REGULATIONS AND POLICIES

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1. INTRODUCTION

Most of the developed countries throughout the world have been concerned about the effects of community and occupational noise exposure on their populations and have implemented national and local noise control regulations and policies over the past 25-30 years. For example, the National Environmental Policy Act was enacted in the United States in 1969, followed by the Noise Control Act of 1972. The US Environmental Protection Agency published its "Levels Document" [1] in 1974, among other significant noise policy documents which were published in the same decade [e.g., 2, 3, 4]. In addition to implementing noise exposure regulations and policies, however, governments also need to conduct Noise Policy Assessment (NPA) programs to periodically assess the effectiveness of these regulations and policies in actually controlling noise exposure. The purpose of this paper is to advocate coordinated, international NPA programs, using a common data collection technique to allow for comparisons of results between countries. It provides a general approach to NPA, but does not describe the detailed methodology for conducting such research.

If it can be shown that noise control policies actually reduce noise exposure over time and improve the general health and welfare of the affected population, this would be the best argument for persuading government policy-makers to continue to adequately monitor noise exposure and to fund required noise control efforts. Alternatively, data collection efforts may show less than anticipated benefits of noise control policies, in which case NPA data would provide the impetus for additional, but necessary, improvements in noise exposure regulations. Noise exposure monitoring and impact assessment must be done, of course, with the support of appropriate scientific and other professional organizations.

Noise policy assessment is also necessary because of the economic impacts of funding, as well as not funding, adequate noise abatement projects. For example, the European Commission Green Paper on Future Noise Policy [5] recently estimated the cost of just transportation noise exposure alone in the European Union at between

0.2% and 2.0% of GDP. Using the lower of these two figures, the annual cost to society was estimated to be, at a minimum, over 12 billion ECU. Gottlob [6] reported that German studies have found that the annual costs accruing from noise in general in that country amounts to over 25 billion Deutsche marks. Economic cost/benefit models, when linked with adequate NPA data, can provide critical information to assist policy-makers in making noise control policy decisions. However, we need to be able to show the benefits that would accrue from effective noise management policies, as well as the costs of inadequately managing noise, such as average national costs from noise-induced hearing impairment claims in industrial settings.

The key to effective NPA is a uniform assessment methodology, whose results can be compared across countries or can be combined in the eventual development of an international database. This requires inclusion of comparable emission and imission data for various noise sources, receivers, and environments. This has never been attempted as a coordinated international effort to allow the results of studies in different countries to be compared. All of the other International Commission on Biological Effects of Noise (ICBEN) Teams address the specific effects of noise. Team 9, Noise Regulations and Policies, should provide a forum for transitioning research results into effective regulations and policies, and for the assessment of their effectiveness. Such programs would benefit greatly from international coordination and oversight. It is recommended that ICBEN Team 9 take the initiative in promoting and coordinating such programs, with the organizational and financial support of a sponsor such as the International Institute of Noise Control Engineering (I-INCE) or the World Health Organization (WHO). It is also recommended that an international Working Group be established to develop the detailed research methodology for implement NPA research programs.

2. APPROACH TO NOISE POLICY ASSESSMENT (NPA)

An effective NPA program would be composed of three separate surveys, each of which should be implemented periodically. The first (Survey A) would consist of a cataloging of *noise sources* and their respective *noise policies*. The second (Survey B) would involve periodic noise measurements, combined with noise modeling predictions, to determine how *noise exposure* is varying over time. The third survey (Survey C) would determine the various *objective and subjective effects* of noise exposure for individuals, selected groups, and populations over time. The information obtained from these surveys would then be compiled and analyzed to determine what effects are observed from changes in noise policies. All three types of surveys need to be made every five to ten years to evaluate the effectiveness of existing noise Standards and regulations. They would provide the data required to accurately describe and compare various home, occupational, community, and recreational noise environments in different countries. The questions that need to be addressed include:

(1) How effective are our various noise control regulations and policies, are they being complied with, and how is their effectiveness changing over time? For example, the paper by Steensburg [7] at this Congress provides an examination of the effects of thirty years of community noise policy in Denmark from a public health perspective.

(2) How much does each type of regulation and policy contribute to management of the overall noise environment? Is it possible to collect data to describe the relative

contribution of each part (including both noise regulations/policies and technical noise abatement efforts) to the whole?

(3) What is the cost-effectiveness of each approach to noise control?

Survey A - The basis for a NPA program would be a survey to catalogue the predominant noise sources and their relevant exposure regulations and policies (Survey A). Gottlob [6], in his comparison of international community noise regulations, and Lambert and Vallet [8], in a similar effort for the European Commission, provide examples of how this might be done. Most emission Standards (such as for automobiles and machinery) and architectural Standards (such as those for noise barriers) are covered by individual ISO and IEC Standards. However, there still remain noise policy differences both between and within individual countries which must be taken into account in implementing NPA programs. Nielsen and Sorensen [9] provide a comprehensive description of the relevant Standards development work of ISO TC 43 - Acoustics and TC43/SC1 – Noise. Much of the information in these Standards can be incorporated into a NPA methodology.

Survey B – One of the key components of implementing long-term assessments of the effectiveness of noise control regulations and policies is to conduct periodic noise monitoring programs in both community and occupational settings (Survey B). Such programs should include an accurate, reliable noise measurement methodology, using an appropriate sampling technique with the measurements repeated either continuously (ideally) or, at the least, every five or ten years. Noise control has three choices for where noise monitoring can be conducted: the traditional "source, path, and receiver" alternatives. The long-term goal would be to describe the overall "total noise environment", including estimates of individual, group, community, and total population exposures. The most important noise sources would include home and leisure activity noise exposures, workplace exposures, and general community noise. For individuals, data on their average daily noise exposure, how this is composed of various individual emission sources, and their time-varying impacts are required. Residential, community, and workplace noise exposure levels need to be measured using state-of-the-art area measurement capabilities and an agreed-upon sampling technique. NPA programs need to use commonly accepted acoustics terminology, such as the equivalent continuous sound exposure level (L_{Aeq}) or its variant, the day-night average sound level (DNL), to describe noise exposure. Although there are many technical issues to agreed upon in developing a detailed NPA methodology, many of these are addressed in relevant ISO Standards. For both individuals and groups, average yearly noise exposure levels would be of most interest.

Early estimates for the average daily exposure for various population groups were advanced in 1974 in U.S. Environmental Protection Agency's (US EPA) "Levels Document" [1], but only partially verified by subsequent large-scale measurement efforts. In an early report for the US EPA, Galloway *et al.* [10] provided estimates of the national population distribution as a function of outdoor noise level, establishing population density as the primary predictor of a community's noise exposure. Other significant early works include those of Sutherland *et al.* [11], Schori and McGatha [12], Eldred [13], Fidell [14] and Bolt, Beranek and Newman, Inc. (BBN) [15]. More recently, Eldred [16] reviewed the long-term trends of noise exposure in the US. This ICBEN Congress presentation estimated noise exposure levels, their impacts over a 30 year time span starting in the early 1970's, and noise exposure forecasts for the year 2000. Several recent examples of large-scale noise assessment projects are also available from outside of the US. For example, in an assessment of alternative exposure limits for road traffic noise, Kihlman and Kropp [17] compared estimates of this type of noise exposure for several international cities, including Los Angeles, Hong Kong, Stockholm, Paris, Melbourne, Munich, and Amsterdam. The European Commission Green Paper on "Future Noise Policy" [5] recently estimated that 22% of the European population (80 million people) are exposed to outdoor levels higher than 65 dB(A) $L_{eq(24)}$ and more than 45% (170 million people) are exposed there to levels between 55 and 65 dB(A) $L_{eq(24)}$.

Survey C - The third type of periodic survey (Survey C) would include monitoring the objective and subjective effects of noise exposure, such as changes in community annoyance and sleep disturbance, changes in hearing levels of individuals (including both children and workers), and changes in people's perceptions about their noise environment. The latter might be accomplished through the use of "Soundscapes", which can also provide valuable input to city and community planning professionals. TNO Preventive Health Care in Leiden conducted national noise impact assessment surveys in 1987 and 1993 and have published the results on their Web site, including estimates of annoyance by noise from a variety of sources and distributions of dwellings in six noise level categories for both road traffic noise and railway noise. In Germany, Gottlob [6] reported the results of a 1994 survey in which it was determined that 70% of that country's residents were annoyed by road traffic noise and that 22% of these are seriously annoyed. For air traffic, 40% of the respondents indicated that they were annoyed by aircraft noise and 20% were annoyed by rail traffic and industrial noise. Such studies as these are important and revealing.

One example of NPA at the global level is described in a recent I-INCE draft report [18] involving tracking road traffic noise regulation policies and noise measurement data over a 25-year period. Another new I-INCE draft report [19], provides an example of how to conduct an assessment of a specific noise control technology; in this case, for noise barrier walls. The weakness of existing methodologies for assessing the effectiveness of both noise control regulations and noise control technologies, however, is that the effectiveness of only one type of change is estimated and its impact on individual, long-term, overall exposure is not assessed.

3. UNIFORM NOISE EXPOSURE GUIDELINES

The baseline for large-scale NPA efforts (Survey A, above) would be a compilation of the noise-related regulations, policies, and Standards for the country or smaller geographic area in which the data are to be collected. In this context, regulations and policies refer to government directives that control the level of noise exposure, typically for a specific source and a particular type of receiver environment. To ensure international agreement, it would be desirable for the World Health Organization (WHO) to take the lead and publish a noise exposure policy report using information from various authoritative publications currently in existence. Sources such as the reports on "Noise" [20] and on "Community Noise" [21], which have already been prepared for WHO, provide extensive descriptions of community noise and its effects on people. Other valuable documents include the extensive summary reports being published in The Netherlands [e.g., 22], particularly those of Passchier-

Vermeer [e.g., 23], and the comprehensive noise effects overview article by von Gierke and Eldred [24]. Together with the three-part ISO Standard 1996, "Description and measurement of environmental noise" [25], which is currently under revision, we would then have most of the tools required to study how noise control regulations and policies are affecting people's overall environmental noise exposure.

For the work environment, the International Institute of Noise Control Engineering (I-INCE) [26] recently published a draft report entitled "Technical Assessment of Upper Limits on Noise in the Workplace". Although still in draft form, this report provides a set of guidelines for occupational noise exposure and recommendations for protecting worker's hearing through a series of actions including product labeling, noise control measures, audiometric testing, and the use of hearing protector devices. In parallel with the ISO Standards in the 1996 series specifically addressing occupational noise exposure [27, 28], these two documents provide excellent guidance on occupational noise exposure policies. Finally, it is recognized that the level of technology and specifically, noise abatement technology, that exists in any society during a given period of time has a very large effect on individual and group noise exposure, regardless of what governmental directives set out as goals or requirements. Thus, it will also be necessary to track progress over time in areas such as industrialization, population density, noise control technology, etc. to accurately attribute any changes observed in noise exposure to a specific cause, such as a government regulation or policy, rather than to other causes, such as technology improvements or population shifts.

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A NEW APPROACH: THE AUDITORY HAZARD ASSESSMENT ALGORITHM (AHAA)

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1. THE PROBLEM(S) WITH IMPULSE NOISE HAZARD ASSESSMENT

For more than ten years those concerned with assessing the hazard from intense sounds (usually impulses with peak pressures above 140 dB) have been aware that they are like individuals with one foot on a dock and the other on a boat with the gap between them widening. We know that the world's assessment methods are not adequate; yet no satisfactory alternative has been available. NATO Research Study Group 8 on Impulse Noise (1987) reviewed all the available data and concluded that the current standards were not accurate, especially for sounds with a lot of low-frequency energy, and that a new formulation for a damage-risk criterion (DRC) was needed. We believe that two aspects of the DRCs required attention: (1) their fundamental validity and (2) the utility of their formulations.

Validity

Data are now available that clearly illustrate the validity problem. The data that formed the basis for the existing DRCs were largely threshold shifts in human subjects wearing no hearing protection as they had been exposed in the free field to small arms impulses. The standards had been developed from these data on a largely empirical basis. Because of differences in formulations, direct comparisons between the different DRCs are not really possible; but in general they agree that perhaps 5 to 10 impulses from a rifle might be acceptable for occasional exposures. A-weighted energy has proven a useful metric of hazard and is used internationally for many noise assessments (is the basis for the French DRC); consequently we can employ it to illustrate problem of DRC validity. The A-weighted energy at the firer's ear in a typical rifle impulse is about 1 J/m^2 and current criteria would agree that an acceptable exposure would contain an energy of about 10 J/m^2 (L_{AEQ8HR}= 85.5 dB). Recent work supported by the U. S. Army provides a very different perspective on the ear's susceptibility. Protected human ears were exposed to impulses up to 195 dB peak in the free field. Under the muff, peak pressures were lower, of course; but A-weighted energies under the muff of as much as 3000 J/m^2 were acceptable ($L_{AEQ8HR} > 110$ dB (Johnson,1994; Patterson et al. 1998; Patterson and Johnson, 1994). These exposures are also well above what any current impulse noise DRC would allow (Patterson and Johnson, 1998). Obviously, there is a basic problem of accuracy with the current standards.

Formulation
The heart of the problem here is that (1) we need to predict hazard for situations that differ from the test conditions that provided the data on which the standards are based and (2) the standards themselves are not theoretically formulated. The lack of theoretical formulation means that once any aspect of the exposure situation changes, the predictive capacity of the standards is questionable. Yet we need to be able to deal with exposures from a wide range of impulse sources, where different hearing protectors are worn, where the wavefront is approaching from a particular angle, where the environment is reverberant or non-reverberant (or somewhere in between), where a non-linear attenuating device is worn, etc. Current standards fail to meet these needs.

2. A NEW APPROACH: AHAA

We propose that the problem of the ear's response to intense sounds and the requirement to assess hazard in complex conditions can best be addressed with an integrated mathematical model of the ear (Price and Kalb, 1991; 1998) and hearing protector systems (Kalb and Price, 1998; Price and Kalb, 1998). Developed and tested first with the cat ear, a parallel human version has been developed (Auditory Hazard Assessment Algorithm – Human or AHAAH). As this is being written, AHAAH's assessment of hazard matches the existing human data well and it is being proposed as the basis for a new DRC for intense sound. In this paper we focus on the new possibilities for evaluation and analysis it offers because of its formulation as a theoretically based model. We also note that AHAAH runs on PC level computers and given the omnipresent computer chip in modern instruments, it could in principle be integrated into sound level meters. In such a configuration AHAAH offers the user many new features.

Allowances for Azimuth
In a sound field which has direction, the angle at which it encounters the head has a large effect on the energy actually reaching the inner ear, the site of damage. AHAAH includes a model for this interaction and where appropriate it can be applied to a measurement made in the free field to correct for an exposure situation in which azimuth is an issue. For instance, the right ear of a right-handed rifleman is at lower risk because it is pointed away from the muzzle.

Allowances for Complex Sound Fields
In some conditions, such as the passenger compartment of a car in which an airbag deploys, the sound field contains components coming from many directions and characterizing such an environment with a model would be prohibitive in its complexity and questionably accurate as well. In such conditions, AHAAH provides for the use of an artificial head as a physical corrector. Sound pressure measurements

at either the ear canal entrance or at the eardrum position of the test fixture are inserted into the model at the appropriate location and calculation commences under the appropriate circumstances.

Allowances for Middle Ear Muscle Activity

The middle ear muscles can have a profound effect on energy transmitted through the middle ear; however their action is not linear with respect to frequency or time. AHAAH includes algorithms which allow a middle ear muscle contraction to take place either as an evoked response (a latency and time constant for contraction effect mimic the muscles' response to sound) or as a pre-existing contraction, such as would be appropriate for a "warned" ear or the second and later impulses in a series. AHAAH in effect stiffens and adds resistance to the stapes suspension, reproducing the effect of a contraction of the stapedius muscle which tilts the stapes and puts stress on the annular ligament.

Allowances for Hearing Protectors

As hearing conservation programs succeed, exposure to really intense impulses is most likely to occur while some hearing protector is being worn. AHAAH allows for a variety of approaches to hazard assessment under these circumstances.

Measures under the protector. With circumaural protectors, pressure histories can be measured under the protector while it is being worn or while on a test fixture. For an ear plug, measures behind the protector are practical only for an artificial head. But in either case, AHAAH allows insertion of the measured waveform at the appropriate location and the effect of the protector is properly accounted for. This is especially significant for non-linear protectors where other approaches are either difficult to execute or non-existent.

Calculation of protector effect. If the waveform under the protector is not available, two alternative methods of assessment are possible. First, a mathematical model of the protector itself could be generated and AHHAH would use the calculated waveform under the protector. This is an elegant procedure; but difficult for the modeler and impossible for the non-modeler. Alternatively, if we assume that there is only one basic path of conduction into the ear from the protector and we know the attenuation of the protector, then AHAAH uses a minimum phase filter to calculate the protector's effect on the waveform. Hazard calculation can then proceed.

Creation of an Analytical Display - a Movie

Finally, AHAAH provides a dynamic display of the evolution of hazard, i.e. it makes a movie showing the cochlea, the waveform driving it and the growth of damage. For some purposes it is enough just to know that a particular impulse is safe or hazardous; but the designer's goal should be to eliminate the problem. By coupling the loss and stimulating conditions in a single display, the engineer can gain insight into the processes that are producing damage. Trials with AHAAH and a variety of waveforms indicate that the outcomes of this exercise are non-trivial e.g. high peak pressures are often <u>not</u> the most damaging elements, zero crossings in the stapes displacement are critical moments, eliminating small amounts of energy in particular frequency regions at particular instants can have dramatic effects. There is no assurance that all problems can be designed away; but a door to possibilities is now open.

3. SUMMARY

Existing DRCs for impulse noise are neither accurate nor do they provide for analysis in any but the simplest conditions. A mathematical model of the ear, conformal with its structure, has been proposed as a new form of DRC. AHAAH, which is theoretically based, allows assessment of hazard as a function of azimuth or in complex sound fields, has algorithms reproducing middle ear muscle activity, and permits assessments with all types of hearing protection. At the same time it provides a visual display of the evolution of hazard as a function of events in the exposure waveform. Computational requirements are at the level of the PC and there is no inherent reason that AHAAH could not be integrated as a feature in modern sound level meters. With the insight provided by the movie relating growth of hazard to stimulating conditions, the engineer now has an unparalleled opportunity to solve problems through design.

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The feasibility of linking future noise standards to health effects

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1. INTRODUCTION

Because there are often severe technical, economic and social costs constraining what can be achieved in practice, noise control is not simply a matter of setting targets and then taking action as required. The assumed benefits of noise control action must be carefully weighed against these costs, and this is hard to do when the most widely used indicator of noise effects is simply "annoyance". It is clear that a general change-over to some more tangible indicator of effects such as effects on health, might enable the setting of future noise targets with greater transparency.

It is against this background that the National Physical Laboratory (NPL), together with the Institute of Sound and Vibration Research (ISVR) began a project in January 1998 for the UK Department of the Environment, Transport and the Regions (DETR) to review noise standards used for assessing the health impact of environmental noise. The objectives of the project were, to consider existing information to establish noise levels at which there may be particular effects on the population, and from this, to advise on the feasibility of establishing effects-based standards which could be used to inform the setting of objectives and targets. This paper explains how the work was carried out, summarises the conclusions, and puts forward an approach to using the information acquired in the study

2. WORK STRATEGY

The work was divided into two phases, review and feasibility study.

Phase 1- Review The review phase was split into three stages;

1. A review of literature on the effects on environmental noise, An analysis was made of existing review literature on the effects of environmental noise. In the interests of efficiency of effort and in view of the short time available, our review took as its starting point the report of the Health Council of the Netherlands, published in 1994 under the title Noise and Health (1). A number of key review papers since 1994 were then identified and have been used to varying degrees in the course of this work.

2. A review of current standards and noise criteria/limits in operation in the UK and other EU countries. The aim of the review of noise criteria was to summarise the standards and limits used to control environmental noise, and where possible to find out the origin and justification for the numerical noise limits. The starting point for this review was two key publications. In 1994 Dieter Gottlob of the German Federal Ministry of the Environment presented the results of an extensive review of community noise regulations (2). In 1995 work was completed at NPL on a review of national practices on the assessment of industrial noise (3). For this project, requests for updated and additional information were sent to representatives in EU countries.

3. **A review/critique or "guide to interpretation" of the 1995 WHO Community Noise Guidelines document.** This was used to highlight the difficulties of setting over-precautionary noise limits based on scientific evidence alone.

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Phase 2 - Feasibility study

This phase considered whether effects-based standards can realistically be set in the UK context. The findings are based on: the extent to which there is general agreement on the existence of an effect due to noise, and agreement on the noise-exposure relationships and how reliably these can be used to set threshold indicators for effects; the uncertainties associated with combining separate effects to determine an overall impact on health; and the role of other factors apart from noise exposure level in setting practical, useful and attainable noise criteria.

3. OUTCOME OF THE STUDY

The detailed results of this review study are provided in a report, copies of which are available from NPL (4). The results are reported in three main sections, summarised as follows;

An examination of the scientific evidence for health effects due to noise,

There are a number of definitions and defined requirements for (good) health but it is concluded that a descriptor that can be used to assess the impact on health, and can provide a framework on which to base a method to balance costs and benefits, is the most useful to the decision maker. The literature confirms that there are a number of potential effects of noise on health, although the evidence in support of actual health effects other than those based on reported bother or annoyance and on some indicators of sleep disturbance is quite weak. The available literature tends to be contradictory. In general, it is often the research studies with the least control over bias and confounding factors which show the strongest effects. There are serious methodological difficulties involved in being able to carry out definitive research. This also means that significant effects amongst the most susceptible minority of the population remain scientifically plausible, even if unproven.

On examining existing information on exposure-response relationships based on scientific evidence, we can draw some conclusions from the primary research. Since the evidence in support of potential health effects other than annoyance is either contradictory or controversial , we cannot at present define any precise exposure-response relationships for any effects other than annoyance, and there is some uncertainty even for that effect. There are many non-acoustic factors involved in both annoyance and other effects, each of which undoubtedly adds to the general variability in the data. The scientific evidence suggests thresholds below which it is possible to infer that there are no significant health impacts. Equivalent thresholds at the upper end of the scale above which definite health impacts are likely are much more difficult to determine.

The possible links between observable and mostly short-term effects and longer-term impacts on health are even more problematical. How might one effect modify another? What precise role is played by effects-modifiers and confounding variables such as diet and lifestyle. What makes one individual more susceptible than another? Are there any hidden costs of adaptation remaining so far undiscovered because they have not been previously looked for?

An investigation of the practical noise criteria used to assess environmental noise,

Practical noise targets are a compromise between the desirable and affordable. The desirable relates to the thresholds suggested by the scientific evidence below which no effect is expected. The affordable involves weighing the costs and benefits in monetary and social costs. Practical noise limits are usually set above these lower desirable thresholds.

On reviewing environmental noise regulations and standards in the UK and in other EU countries, we find that existing standards and regulations usually take the results of primary research into account to some extent, but social, political and historic factors are at least as important. It is very important to be clear about the role played by these factors in the development of current standards and regulations and their likely role in future developments.

A guide to the interpretation of the WHO guidelines,

In view of the uncertainties involved in setting standards, there are moves within Europe to adopt a precautionary approach when setting future noise standards and regulations to protect against possible health effects. An example of this is the way in which the recent 1995 WHO guidelines(5) have been interpreted in some quarters. It is necessary to consider the wider consequences of any over-precautionary approach in the context of potentially unacceptable impacts in other areas, such as costs or limits on the freedom to travel. Many individuals might consider a certain amount of noise to be a fair price to pay in exchange for the personal freedom granted by the motor car, yet the quickest way to cut environmental noise levels at a stroke would be to ban cars.

4. FURTHER INTERPRETATION

In this section we suggest an approach to the interpretation of the information arising from the review which might be used to indicate the relative importance of various effects and which could be useful in the process of setting standards. Figure 1 illustrates the general position in the UK in relation to the percentages of the population of England and Wales exposed to different day-time noise levels measured outside their homes (6) and the likely percentages of those populations affected by noise in different ways. Each effects curve is forced to a generic s-shape with the centre, slope and maximum effect varied in accordance with professional judgement. The precise positions of the various effects curves cannot be considered to be definitive at this time for two reasons. There is uncertainty in the literature regarding the shape of the various exposure-effect curves, and there is some uncertainty regarding the units in which each effect is measured. For example, the generic daytime annoyance curves as shown could be considered as representing the percentages describing themselves as either moderately or extremely annoyed. This ought to make a great difference to the political interpretation of any results, yet different researchers continue to measure such effects in different ways. As another example, should the curves represent either the slightest detectable effect or effects of such magnitude that they have a particularly significant effect on an individual's quality of life? The issue of clinical significance is relevant here (7). If the problems of confounding factors could be overcome, then epidemiological research may reveal weak but statistically significant associations between exposure and effect, for example elevated blood pressure and noise exposure outdoors. But this does not of itself mean that these small changes necessarily have any clinical significance. Finally, it is important to note that the available information on some of these effects relates to noise exposure at the receiver and not to the magnitude of the effect when residents are indoors and possibly protected by noise insulating facades at the higher outdoor noise levels.

Figure 1 clearly shows that the relative significance of the different noise effects varies considerably in terms of the percentages of the overall population potentially affected. For example, the generic annoyance curve shows around 20% affected by some degree of annoyance at 60 daytime L_{Aeq} measured outdoors but it is important to remember that this is 20% of the 26% exposed at that noise level (i.e. around 5%) and not 20% of the whole. Moving up the scale, we have possibly less than 5% of exposed persons subject to weak cardiovascular effects at 70 daytime L_{Aeq} measured outdoors, which is less than 1/10 of a percent of the population as a whole. While noise induced hearing loss can constitute a major disability, there would seem to be virtually nobody at risk of even the slightest degree of deafness caused by environmental noise.

It is also clear from the figures how existing guidelines such as the often quoted 55 L_{Aeq} recommendation from the 1980 WHO criteria document (8) fit into the overall scheme of things. Clearly, only a small percentage of the population exposed at 55 daytime L_{Aeq} measured outdoors are affected by annoyance, and virtually none of them are affected in other ways. On the other hand, something over 65% of the population are exposed at this level. This illustrates both the conservative nature of the 55 L_{Aeq} guideline value in terms of effects and also the likely difficulty in being able to do anything about it anyway.

Subject to the general uncertainty regarding the precise shape of the various exposure-effects curves, this analysis leads to the general conclusion that health effects other than reported annoyance, and some relatively moderate degree of sleep disturbance might only be a problem for a small proportion of the overall population. This conclusion does not diminish the importance of those effects for individuals, but it might influence government when establishing priorities for future noise control effort. Of course, the only way to overcome this existing uncertainty is to carry out carefully targeted research. However it is difficult to avoid the conclusion that any such research is unlikely to come up with any more definitive results than in the past unless some considerable ingenuity in terms of both methodology and theory is brought to bear. The case for first attempting to find some way of selecting the most susceptible individuals from the general population before proceeding to any more general research is made all the more clear by this analysis.

5. CONCLUSIONS

Given the present state of knowledge, it would be unwise to base future environmental noise standards and regulations on what are at present hypothesised non-auditory health effects until future research can make the present confused situation clearer. There could be greater transparency in the way in which future standards and regulations are developed so that the public can become more aware of both the strengths and limitations of these standards. An increased emphasis on non-auditory health effects, as opposed to annoyance, as the outcome variable may lead to this greater transparency, although there is considerable doubt at the time of writing as to the magnitude of these effects due to environmental noise. To ensure that non-auditory health effects are included in the development of future standards, research is required. This must be carefully designed, not only in terms of its planning and execution, but also in terms of setting precisely defined and achievable objectives.

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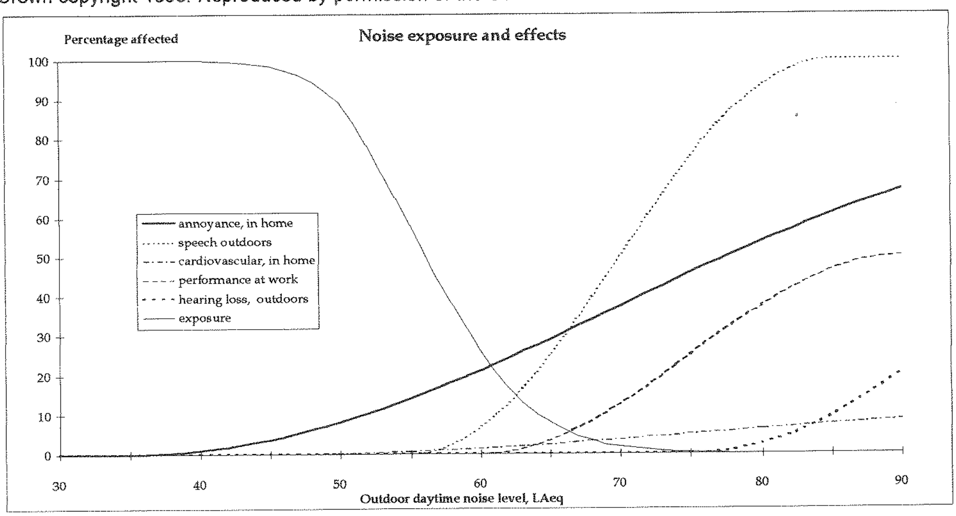

Figure 1. Day-time noise exposure and effects

SOME RESULTS OF AN INTERNATIONAL SCALING STUDY AND THEIR IMPLICATIONS FOR NOISE RESEARCH

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1. INTRODUCTION

International discussion has shown that there is a strong need for at least one shared annoyance question for community noise studies conducted all around the world. This question should be answered using comparable scales. This ensures a better comparability of noise annoyance research results. But before experts reach consensus about the best scale for this purpose, a study should clarify several qualities that the scale should posess: It should be usable in telephone studies as well as in personal interviews, it should be applicable in different nations, and its metric qualities should allow for parametric statistical operations.

In cooperation with noise research experts from 10 nations (and eight different languages) a scaling study about modifiers that describe different degrees of annoyance was performed. The aim was (1) to propose a scale for each nation to the experts, (2) to test the linguistic quality of the proposal in the country it will be applied to, and (3) to develop a final version of the scale to be included in the international agreement. This could be either a four- or a five point scale with equidistant verbal qualifiers.

The participating nations were: Australia, France, Germany, Hungary, Japan, Norway, Spain, Turkey, The United Kingdom and The United States.
We intended to perform the study at least at two different sites (N = 30) per country in order to measure the amount of consistency in usage and meaning of the selected modifiers at different sites.

2. METHOD

At a first step, the experts were asked to select 21 modifiers that describe different degrees of annoyance. Then, subjects (mainly students at most sites) were given five tasks:

1. All modifiers should be ranked by being assigned to one of nine categories which represent increasing degrees of annoyance.
2. The modifier that describes the highest degree of annoyance should be selected.
3. Using a given modifier that describes the lowest degree of annoyance (engl.: *not at all*) and the previously defined modifier that denotes the highest degree of annoyance, the subjects should select those three modifiers that represent the second, third and fourth point of a five point scale with equal appearing distances.

4. Using the lowest and highest degree of annoyance as in (3), the subjects should select those two modifiers which represent the second and third point of a four point scale with equal appearing distances.
5. All modifiers should be scaled individually with respect to their degree of expressed annoyance on a graphical 10cm-scale.

The test modifiers for the English language were:

not at all, barely, insignificantly, hardly, a little, slightly, partially, somewhat, fairly, moderately, significantly, rather, considerably, substantially, very, highly, strongly, importantly, severely, extremely, tremendously

These modifiers should cover the range from "no/lowest degree of annoyance" up to "highest degree of annoyance" evenly, and they should reflect the actual usage of language in each country.

To extract the best suitable adverbs several criteria were determined. Some of them are listed next (the complete catalogue of criteria will be presented by J. Fields at this conference):

Popularity (frequency of selection in the scale-construction task, frequency of combination with other adverbs), ***Scale values*** (low distance from the ideal scale value which would give equal distances between steps), ***Congruency*** (low standard deviation, high inter-rater-consistency, high consistency between sites), ***Correspondence*** (high correspondence between the scaling results from the category task and the graphical task (1 and 5), ***Expert's decision*** (suitability of the constructed scale / linguistic quality of the chosen adverbs / ability to meet future demands / benefit for political and administrative communications.

It would be desirable to apply these criteria to the data of all nations in the same way and to provide a solid basis for a decision for either a 4-point or a 5-point-scale. The verbal qualifiers for each language should not be just translations from the English version. Our aim is to develop scales for each nation which optimally fit the criteria.

This paper focusses on the correspondence and the congruency criteria. Results from those countries are presented, in which we found systematic problems in comparing results for either the ranking of modifiers in the nine categories (Task 1) or scaling the modifiers on the graphic scale (Task 5).

3. RESULTS

From ten participating countries five reached our criteria (at least two sites per country with 30 subjects each), and they were included into more detailed data analysis. The other five reached at least one criterion and were analysed separately.

For all participating countries statistical analyses to test for data quality concerning consistency and congruency were applied to the data. The over all consistency is very high with Ebel's coefficient of consistency [4] ranging from $r = .992$ to $r = .999$ for the category scale and $r = .993$ to $r = .999$ for the graphical scale.

Congruency between the two scaling tasks varies from Kendall's Tau r = .914 to r = .979.

Next, single results are presented which gave us a hint to problems of comparability of the different tasks. In Australia for instance, we found differences in inter-rater consistency between the two sites: In Canberra, average consistency of a single rater was very low with 0.485. Here we found changes in the order of some modifiers per category. Table 1 shows Ebels Coefficient of consistency for the two sites, and for the average score versus average single rater results.

Table 1: Ebels Coefficient of consistency, task 1 and 5

	Sydney		Canberra	
	average score	average single rater	average score	average single rater
category scale	0.998	0.852	0.966	0.485
graphical scale	0.998	0.864	0.996	0.893

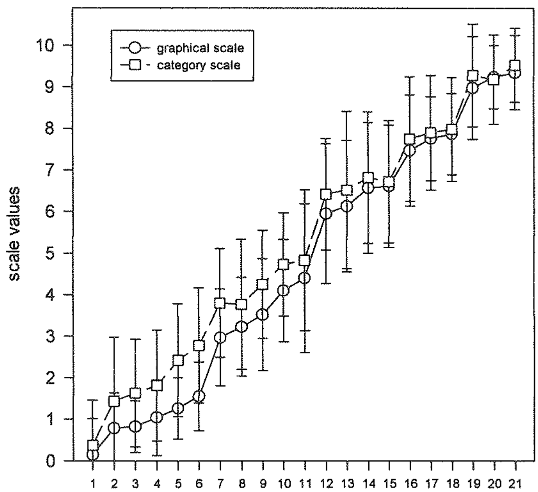

Figure 1: Scaling tasks 1 and 5, mean values and standard deviations (USA data)

Figure 1 shows mean values and standard deviations from analysis of repeated measures on two factors (scale versus modifier). USA data serve as an example to point out sign. differences between the two scales. Here the adverbs describing a low degree of annoyance are rated about one scaling point higher in the category task than in the graphical task (the analysis based upon transformed scales to reach comparability). Altogether, we found differences between the scales in seven countries.

In all countries, the two scaling tasks lead to significant differences in the adverb means. Moreover, we also found differences between the sites within a country. In Spain, for instance, the subjects in Pamplona rated three of the 21 adverbs differently than those in

Valencia. This leads to a significant effect of the site-factor, although scale congruency was quite high, as it is shown in table 2. Unfortunaltely, one of these adverbs was very popular in task 3 and 4. In some other countries we found effects of the site in third order interactions.

Table 2: Correlation between category and graphical scale

Over all (sig. p<.01)		Pamplona		Valencia	
Pearson	Kendall´s tau	Pearson	Kendall´s tau	Pearson	Kendall´s tau
r = .996	r = .976	r = .996	r = .958	r = .994	r = .968

4. DISCUSSION

First of all it is neccessary to point out that this study was performed in cooperation with researchers in 10 countries. Only with their help and support it was possible to select data and conduct the study in less than one year. When the study is finished, we hope to present equidistant annoyance scales for each nation.

At present we see a conflict between applicability of research results and statistical quality. On the one hand a solution of the scale-problem is strongly demanded. On the other hand we cannot neglect statistical problems which oppose against jumping into solutions. The new scales will be used by many experts in noise research for many years. Therefore final versions have not been defined yet. Alternative proposals will be presented at this conference by J. Fields. But before the final versions can be adopted, there should be a decision concerning statistical problems presented here. Then we need the experts´ decisions on linguistic quality of the constructed scales.

In any case we propose to repeat the study once in a while to test the stability, respectively changeability in the use of language. Optimally this will be done with non-student subjects. And, in order to point out further quality checks, we recommend to test the influence of verbal context on the equidistance of the selected adverbs. This will be done in Germany in the near future.

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REQUIREMENTS FOR NOISE METRICS

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1. INTRODUCTION

Noise metrics are used in many countries to assess and control environmental noise. This has resulted in a variety of noise metrics, not only between countries, but even within countries for different noise sources. This variety has negative consequences when it comes to explaining noise standards and their impact to the public or to politicians. The ideal goal would be a single metric to describe noise for all relevant effects and noise sources. In the course of a process of simplification of the Dutch noise regulations, a set of criteria has been developed to choose a suitable noise indicator between a number of possibilities. This set is also used - in a slightly altered form- to make a choice for a uniform noise indicator for the European Union. This work is carried out by the Working group on Noise Indices, one of the 5 working groups appointed by the European Commission to prepare a future Noise Policy for European Union. It is expected that the Working Group will present her report in the beginning of 1999.

2. CRITERIA FOR CHOOSING NOISE INDICATORS

Requirements for noise indicators not only depend on scientific validity , but also on the uses that will be made of the indicator in every day practice and in legislation.
The following criteria can be formulated
- **validity**:

  relation with effects.

  Which effects have be to taken into consideration is to a large extent a political question. From literature a large number of *possible* effects may be derived. For a much smaller number a quantitave relationship has been established: Speech interference, annoyance, sleep disturbance (to some extent: self reported sleep disturbance OK, physical so-so), cardiac diseases (weak)

- **practical applicability**:
  as little as possible difference with standing practice, easy to calculate from available data, use of available equipment. This aspect is strongly costs-related. Technically it is no problem to manufacture new sound meters with different frequency weightings; only the cost of substituting all obsolete soundmeters is prohibitive.
- **transparency**:
  easy to explain, intuitive, as simple as possible, relation with physical units.
- **controllability**:
  use of metric in assessing changes or the exceedance of set limits.
- **consistency**
  the indicators should be line with standards and practices in adjacent fields

Although there is consensus to a large extent on the requirements, there are differences in the relative importance that should be given to each.
The quest for a single, simple indicator is complicated by the fact that the requirements which are seen to be the most relevant, are in part mutually exclusive. Furthermore, the relative importance given to each may be different for different end users.

3. POSSIBLE INDICATORS

A number of recent publications give overviews of noise indicators presently in use[1][2]. Other publications suggest new or altered indicators to be added[3]. For the Dutch situation the indicators currently in use were taken into account, plus those resulting from the work of the Dutch Health Council[4]: the day-evening-night equivalent sound level (L_{den}) , the L_{night} and their effect-adjusted counterparts, the EEL (Environmental Exposure Level) and ENEL (Environmental Night Exposure Level). In total 8 different indicators were considered.
For the European situation the list of indicators in use is slightly longer. The Working group on Noise Indicators decided to group the indicators according to their degree of complexity. This results in 3 groups: basic metrics (like LAeq,T), composite indicators (like Lden) and complex indicators (like indicators for multiple sources, population exposure or quiet areas).
In order to facilitate the final selection, a preselection can be made to limit the number of possible candidates. One important issue is the frequency weighting. There are various possibilities to simulate the frequency dependency of the ear: A, B, or C-weighting, PNL, or Zwicker/Stevens. Most people feel that the more complex PNL or Zwicker weightings are only interesting in a limited number of cases. On the other hand, it requires signal manipulation and calculation not readily available. That is why the Dutch Health Council and the European Commission limits the choice of indicators to A-weighted signals.

indicators for noise: composite metrics							
	validity (long term effects)			**practical**	**transparency**	**controllability**	consistency
	annoyance	complaints	sleep				
$L_{A(night)}$							
$L_{aday(night+10)}$							
$L_{Ad(n+15)}$							
$L_{Ad(e+5)(n+10)}$							
L_{10}							
L_{95}							
EEL							
ENEL							

-- = unacceptable - = unsatisfactory ± = indifferent + = satisfactory ++ = good +? = probably satisfactory
?? = not the faintest idea

In the table the group of composite metrics is shown, together with the criteria. Although the ideal situation would be to end up with only one single indicator, from the information now collected it is clear that this is probably not feasible. One example is the effect that noise has on sleep, as opposed to effects on annoyance. It is difficult to imagine a single indicator that describes both effects equally well. Generally speaking, if the indicator is to be used for very different purposes, chances are that there will be fundamental differences in their build.
The amount information needed to fill in the table is considerable, and in some cases can only be based on expert judgment. Reaching consensus over each and every cell in this table will probably be a long and arduous task, but important if the result must be a noise indicator to be used by all member states of the EU.

4. CONCLUSION

The procedure here described ensures that noise indicators are proposed that will fit their specific purposes. It seems however unlikely that one single indicator will result, but a set of indicators each suitable for a specific purpose.

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MODELED AND MEASURED NOISE LEVELS OF LOW ALTITUDE MILITARY AIRCRAFT FLIGHTS

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1. BACKGROUND

Mitigation of aircraft noise effects on wildlife in the Low-Level Flying Training Range (LLFTR) in Labrador, Canada, requires three components in order to be effective. The first component is a quantitative understanding of the effects of noise on wildlife species inhabiting the range; the second component is a method of predicting noise levels caused by low-flying aircraft during training exercises which can be used to quantify noise impacts on the animals. The third component is the environmental management of the training range in light of the expected noise levels and the resulting consequences for wildlife species.

A program to address the second of these components, the creation of a noise model for low-flying aircraft on the LLFTR, was started in 1991. This model combines noise spectral data of the military aircraft using the range with a ray-tracing sound propagation algorithm [1,2,3,4,5], using parameters based on the physical characteristics of the LLFTR (ground surface characteristics, terrain, weather). Presently, this model can be used to predict noise characteristics at specific ground locations in proximity to aircraft flight tracks. Ultimately, by using it in conjunction with planned aircraft flight tracks over the LLFTR, it could be used to implement immediate mitigation measures for sites inhabited by noise sensitive species with a minimum effect on flight training efficiency. Used with a record of all flight tracks flown in a given time period, it would enable an estimation of the seasonal noise impact due to the low-level flight training program.

The development of the model began with measurements of aircraft noise (Tornado, F-4 and F-16 types) at various locations within the LLFTR. Baseline measurements at speeds and altitudes representative of training range flying were made at the aerodrome at Goose Bay, using controlled aircraft flight tracks and measuring current weather conditions. These data were used to develop the methodology needed to quantify the various parameters in the ray-tracing procedure. The model has now been upgraded with F-18 noise data provided by the Swiss Federal Laboratories for Materials Testing and Research (EMPA), and by adding a limited data base of terrain elevations for the Naskapi River valley in the LLFTR.

During the training period in 1995, the Naskapi River valley was closed to all training flights except for specific flights of Canadian Forces CF-18 aircraft on prearranged tracks and altitudes. The noise levels of these flights were recorded by observers at specific locations in the valley. The noise propagation model was then used to calculate the noise time histories of some of these flights, which were compared with the measured noise histories. In addition, the statistical probability of exceedance of peak noise levels at one of the locations due to all flights over the summer was computed by the model, and compared to the measured probability distribution of peak noise levels.

2. COMPARISON OF MODEL WITH DATA

The designated flight tracks for the CF-18 flights were intended to be at distances of 0.75 nautical miles (nm), 1.25nm and 2.5nm from each of the measurement locations, and at altitudes of 100ft., 250ft. and 500ft. above ground level (AGL). However, in order to maintain straight flight tracks that could be readily followed by the aircraft, these distances were approximate at each location. There was no independent method of determining the actual distance between each aircraft flight track and the measurement location. Additionally, there was no record of the thrust levels of the aircraft during the flight past the measurement location, nor of wind conditions existing between the measurement location and the aircraft flight track. However, aircraft altitude was known, based on the schedule of flight tracks.

The modeled noise time history therefore had to assume distance, thrust level and wind conditions. The distance was defined in the model by requiring the duration of the modeled noise time history to be equal to the duration of the measured time history. The thrust level was set by requiring the maximum noise level of the modeled time history to be equal to the maximum noise level of the measured time history. Atmospheric conditions in the model were set with zero vertical gradients of wind and temperature.

Figure (1): CF-18 NOISE COMPARISON
Naskapi River; 500ft Dist., 100ft AGL

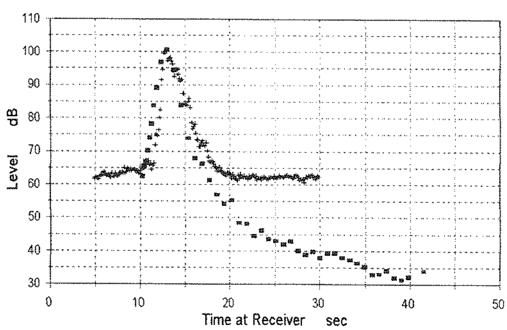

Figure 1 shows a comparison of modeled and measured noise time histories under these assumptions, representing a separation distance (closest approach) of 500ft. and an aircraft altitude of 100ft. AGL.

The measured noise history is well matched by the modeled noise history, particularly in the time before the maximum level. The values of the modeled noise levels beyond about 18 seconds are lower than the data because no background noise was included in the model.

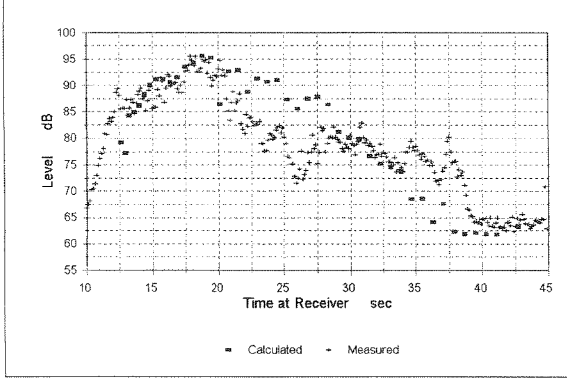

Figure (2): CF-18 NOISE COMPARISON
Naskapi River; 3500ft Dist. 100ft AGL

Figure 2 shows a comparison of the modeled and measured noise time histories at a nominal (closest approach) distance of 3500ft. While the initial segment of the measured time history is well matched by the model, there is some discrepancy in the region immediately after the maximum level.

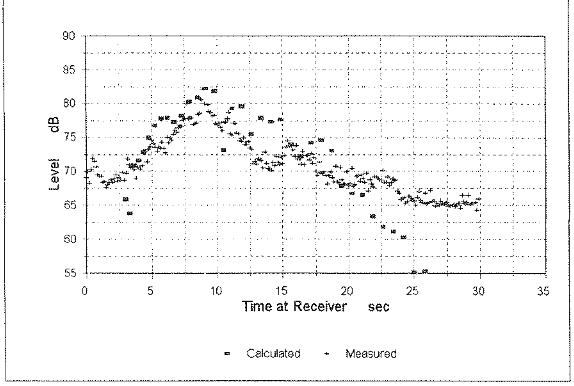

Figure (3): CF-18 NOISE COMPARISON
Naskapi River; 3500ft Dist. 100ft AGL

Figure 3 shows another comparison at the same nominal distance, between the same modeled results but another measured sample. The discrepancies in these figures are related primarily to acoustic shielding effects of terrain features. These discrepancies may be due to an insufficient representation of terrain detail in the model's limited terrain elevation data base, which therefore might not have included all the acoustic blockage on the propagation paths. The discrepancies may also be due to an inaccurate positioning of the aircraft flight track in the model, placing it before rather than behind terrain features which would attenuate noise by propagation path blockage. These figures illustrate the importance of including terrain effects in the acoustic modeling process.

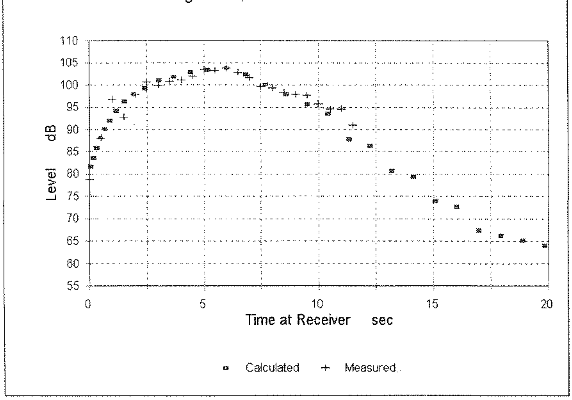

Figure (4): CF-18 NOISE COMPARISON
Snegamook; 3000ft Dist. 100ft AGL

Figure 4 shows a comparison of the modeled noise time history and the measured history for a high-speed CF-18 flight over water (Snegamook Lake in the LLFTR). In this case, the distance (closest approach) was known relatively accurately, as was the aircraft altitude above the water surface. However, as before, the thrust setting was not known, so the noise levels in the modeled results were modified to cause the maximum level in the modeled results to coincide with the maximum level in the measurements. It can be seen that in the absence of terrain blockage effects, the model and the measurements agree very closely.

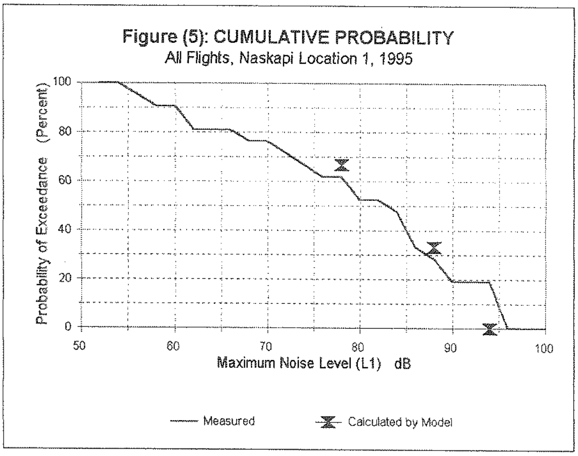

Figure 5 shows the statistical comparison of modeled predictions versus measured results. The comparison in this case is in terms of the probability of exceeding various values of the maximum noise level for all flights past Location 1 at 100ft AGL during the summer of 1995. The maximum noise level of a flight depends on the distance from the aircraft flight track to the receiver, given a fixed altitude and thrust setting. Since the aircraft flew on different flight tracks past the measurement location, there would be a variation in maximum noise level over all measured flights. The solid curve represents the probability of the measured maximum noise level exceeding any particular value. The markers indicate the calculated probability of exceeding the indicated noise level, using the model to calculate the maximum noise level at each of the three track locations, and assuming that all flights were equally divided between each track (1/3 of all flights on each track) as planned.

The model appears capable of providing a highly reliable representation of noise from low flying aircraft, if the factors affecting noise propagation are adequately quantified. Terrain elevations are the most important of these factors, but the effects of wind and temperature gradients in bending sound rays over terrain obstructions are also significant. Improved accuracy from the model will therefore require a detailed terrain elevation data base, and a knowledge of localised and current wind conditions.

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DAMAGE-RISK CRITERIA FOR UNDERWATER NOISE EXPOSURE

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1. INTRODUCTION

Divers are sometimes directly exposed by vibrations and noises radiating from working equipment in water, e.g., water jet tools, rock drills, stud guns and so on. From the viewpoint of ear protection for divers, it is necessary to determine the maximum sound pressure level that the divers can endure against noise exposure in water, that is, a damage-risk criterion for underwater noise exposure is required. Widely accepted damage-risk criteria for noise exposure in air has already existed [1] but not been found in water. In order to establish the criteria for noise exposure, it is necessary to carry out the experiment of temporary threshold shift (TTS) [2,3]. However, many difficulties would be encountered in trying to realize the TTS measurements in water. The more efficient approach is a transposition of the current noise exposure limits from air to underwater. The purpose of this study is to estimate the noise exposure limits in water from the values in air already existing.

To attempt this, we examine the relationship between loudness in water and in air by means of hearing tests within a water tank and show a practical expression which can describe the relation of loudness between in water and in air. Then, noise exposure limits in water will be estimated from the values in air by making use of this expression.

2. HEARING TEST

In order to examine the relationship between loudness in water and in air, two kinds of measurements concerning the loudness levels were carried out by means of hearing tests within a water tank. One is to obtain the sound pressure level in air as a function of the sound pressure level in water when the sound in air was equal in loudness with the sound in water under the condition of a constant frequency (175Hz, 1kHz, 5kHz). The other is to obtain the sound pressure level in air as a function of the

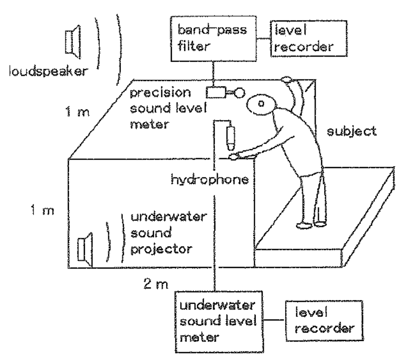

Fig.1 Experimental configuration at the water tank.

frequency when the sound in air was equal in loudness with the sound in water under the condition of a constant sound level (142 [dB re 1 μ Pa]). The experimental configuration of the water tank (1m×1m×2m in size) is shown in Fig.1. Background noise level in the water tank is about 73 [dB re 1 μPa].

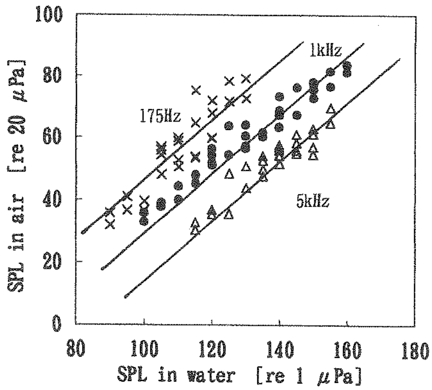

Fig.2 Equal-loudness relation between SPL_A [dB re 20 μPa] and SPL_W [dB re 1 μPa] under the condition of a constant frequency (×: 175Hz, ●: 1kHz, △: 5kHz). Solid lines show the eq.(1); $SPL_A = SPL_W - C_1(f)$.

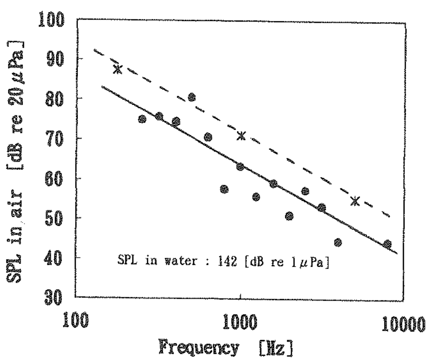

Fig.3 Equal-loudness relation between SPL_A [dB re 20 μPa] and the constant SPL_W [142 dB re 1 μ Pa] with various frequencies f [Hz] . Solid line shows the eq.(2); $SPL_A = -24.6 \log(f/1000) + C_2$.

We employed two male subjects with normal hearing in air. The experimental procedure is as follows. At first, the subject submerged his head into the water, making sure to remove air bubbles from the ear canals, and heard the underwater sound of a pure tone radiating from an underwater sound projector in the water tank. The loudness of the sound was memorized by the subject. Next, he raised his head above the water, clearing the air passage in the ear canals, and heard the sound in air radiating from a loudspeaker. The sound pressure level in air was adjusted by the subject until the loudness in air was equal to that previously memorized in the water. The above measurement was repeated five times per sound pressure level for the various frequencies and a mean value was used as an equal loudness level. The sound pressure levels were obtained by reading the data sheet on level recorders (RION LR-4) calibrated, respectively, by underwater sound level meter (OKI SW1020) in water and by precision sound level meter (RION NA-20 at F-weighted characteristic) in air. Both the hydrophone in the water tank and the microphone in air were set up as close to the subject's ear as possible. As the background noise in air around the water tank was about 50 [dB re 20 μPa] in the audible frequency range, we used a band-pass filter (RION SA-34) with cut-off frequencies little wider than critical band for the measurements in air below 50 [dB re 20 μPa].

3. EXPERIMENTAL RESULTS

Results of the two kinds of measurements are indicated in Figs.2 and 3, respectively. From the first measurement (Fig.2), we can find a linear relation between SPL_A [dB re 20 μPa] and SPL_W [dB re 1 μPa] as,

$$SPL_A = SPL_W - C_1(f) \qquad (1)$$

where $C_1(f)$ is a value depending on the frequency. Straight lines in Fig.2 are the results of best fitting with eq.(1) for each frequency. Here, C_1(175Hz) is 53.0 dB, C_1(1kHz) is 70.8 dB and C_1(5kHz) is 85.9 dB.

From the second measurement (Fig.3), we can also find a linear relation between SPL_A [dB re 20 μPa] and frequency f [Hz] as,

$$SPL_A = -24.6 \log(f/1000) + C_2 \quad (2)$$

where C_2 is also a value unrelated to the frequency but often varies with experimental conditions or subjects. A straight line in Fig.3 is the best fit line with eq.(2) and C_2 is determined to be 63.0 dB.

These linear relations as shown in eqs.(1) and (2) imply that an interior auditory mechanism in man is common both in water and in air, once the sound enters into the internal ear. According to eqs.(1) and (2), on the other hand, it is found that the sound of 142 [dB re 1 μPa] at 1 kHz in water corresponds to the sound of 63-71 [dB re 20 μPa] in air, whereas the sound of 142 [dB re 1 μPa] in water is physically equivalent to the sound of 80 [dB re 20 μPa] in air considering that the standard of sound level and the acoustic impedance are different in each medium. Therefore, it is considered that a transmission loss of 9-17 dB has arisen. This is probably caused by differences in sound propagation process between the two media.

4. DISCUSSION

Practical expression between the loudness in water and in air

In order to estimate underwater noise exposure limits from the values in air, we must indicate in advance a practical expression describing the relation of loudness in water and in air. The expression can be derived from eqs.(1) and (2) as below. Firstly, sound pressure levels in air at three frequencies (175Hz, 1kHz, 5kHz) corresponding to the sound pressure level of 142 dB in water are obtained by means of eq.(1), respectively. When we plot them in the logarithmic function of frequency, the similar straight line with coefficient of -24.6 as eq.(2) is obtained (they are denoted by * and broken line in Fig.3). Thus, we can obtain a sound pressure level in air corresponding to the sound pressure level of 142 [dB re 1 μPa] in water for arbitrary frequency by using this broken line. Once again, by substituting these values into SPL_A in eq.(1), where SPL_W is 142 [dB re 1 μPa], we can determine each value of C_1 in eq.(1) for arbitrary frequency. Then, the practical expression; $SPL_A = SPL_W - C_1(f)$, between the loudness in water and in air can be obtained. The frequency characteristic is consequently reflected on the values $C_1(f)$, as shown by □ in Fig.4 for each 1/3-octave frequency.

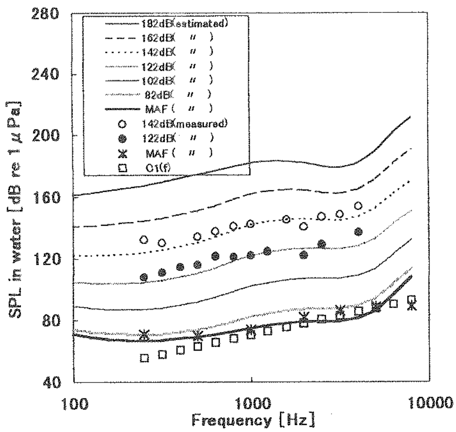

Fig.4 Comparisons of the underwater equal-loudness contours between the experimental values (○,●, *: previously obtained in our work [5]) and the estimated ones (seven lines : obtained in this work). Symbols of □ denote the values C_1 for each 1/3-octave frequency in the practical expression; $SPL_A = SPL_W - C_1(f)$.

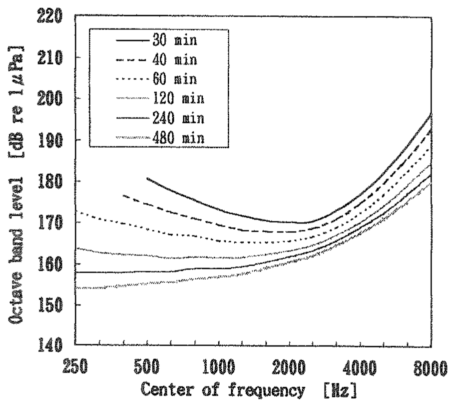

Fig.5 Estimated noise exposure limits for underwater.

To verify the validity of this expression, we try to obtain the equal loudness contours and hearing thresholds in water from the values in air and compare them with the experimental ones previously obtained in our study. The SPL_W is readily obtaied from the practical expression by substituting the values of ISO R226-1961 [4] into SPL_A. The contours thus obtained are described by seven lines in Fig.4 together with our experimental values obtained by hearing tests in the pool [5]. The estimated results are in good agreement with the experimental ones.

Estimate of underwater exposure limits

In air, damage-risk criteria for noise exposure has been recommended by the permission concentration committee of the Japanese Industry Sanitation Society in 1969 [1] and is widely adopted in our country for the purpose of ear protection. On the other hand, a criterion for underwater noise exposure is difficult to find. In this study, we estimate the underwater exposure limits by transposition from air to underwater in the same manner as above. Figure 5 shows the estimated exposure limits for underwater noises in every exposure time in one day. It is found that a maximum permissible octave band level for noise exposure around 1 kHz in 8 hours on a day is about 157 dB in water.

5. SUMMARY

We examined the relationship between loudness in water and in air by means of hearing tests within a water tank. And the noise exposure limits in water were estimated from the values in air by making use of this relationship. It is very important to carry out hearing tests of temporary threshold shift (TTS) in water. However, there are many difficulties to realize in doing so. At least, our results may be used as a guide to the evaluation of noises in water, considering that the damage-risk criteria for underwater noise exposure could not be found until now.

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TRANSPORTATION NOISE ANNOYANCE: AN ECONOMIC ISSUE

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1. KEY ISSUES

Transportation noise can be regarded as a major environmental impact, particularly in residential areas. Its cost could represent close to 0.5 % of GDP in the European Union [1]. Considerable amounts of money are spent each year by the community to prevent or limit noise, through both the enforcement of regulations (emission and immission) and the use of economic instruments (charges, incentives). Unfortunately, the financial resources of the community are limited. Consequently, integrating noise concerns into economic decisions clearly needs more rationality [2]. For the economist, this basic issue raises two main problems:

- How can noise annoyance be evaluated, and by what methods? What are the limits of these methods: theoretical, practical, ethical? Are these methods acceptable to scientists as well as operators and political decision makers? Can monetary values be transferred from one study and used as inputs into other policy-making activities?
- What economic decisions are influenced by the use of monetary values of noise: cost-benefit analysis of infrastructure projects, noise abatement measures or policies, compensation of residents exposed to high noise levels, charging for transport infrastructure and, more generally, internalisation of noise costs.

2. VALUING NOISE IMPACTS

The economic value of noise derives from a *willingness to pay* (WTP). Sometimes WTP reflects impacts to the extent that individuals are aware of them and sometimes the amount of money that society or individuals will agree to pay to reduce or prevent transportation noise. Various techniques are available for valuing noise [Table 1], but the hedonic price and contingent valuation methods are at present the most commonly used [3].

Table 1. Valuation techniques of noise

		Group concerned	*Valuation technique*	*Approach*
Preferences	Explicit	Individual	Contingent valuation	Psychometric
	Implicit	Individual	Hedonic price Expenditures of households	Econometric
	Implicit	Society	Court decisions (results of) Preventive public expenditure	Tutelary

The Hedonic Price Method (HPM)

This technique is based on direct observation of consumer behaviour (revealed preference method). It has almost exclusively been applied to the housing market to evaluate the cost of road traffic and aircraft noise. The basic idea is that WTP for noise environment quality around the home is revealed in the market price (purchase or rental) for houses: houses in noisy areas will be cheaper than the equivalent houses in otherwise quiet streets. House prices or rents are functions of various housing, neighbourhood and environmental quality variables such as noise. An equation (the hedonic price function) is determined from which the implicit price of noise can be estimated for each noise level. After this price has been derived with the social and economic characteristics (income) of each household, WTP for noise improvements can be estimated.

To employ this method presupposes that a large number of theoretical and practical conditions pertain [4]: a free property market which is in equilibrium, noise which must be local in character and display sufficient variability from one location to another, individuals who are able to correctly assess the effects of noise (there is some doubt about the ability of individuals to take into account the full, long term and health effects of noise).

The results obtained either underestimate (failure to include long term effects - lack of knowledge of all the effects of noise by individuals), or overestimate (high correlation with other environmental effects like dust and visual intrusion) the value of noise. A large body of work has been accumulated concerning the effects of noise on property values, particularly in the field of road traffic [Table 2].

Table 2. Loss in property values due to road traffic noise

Study	*Year*	*Noise index*	*Noise depreciation index % per dB(A)*
Colony	1967	Distance	0
Towne	1968	?	negligible
Diffey	1971	L10 (18h)	0
Nelson	1970	LDN	0.88
Gamble et al.	1969-71	Leq	0.26 - 0.54
Anderson et Wise	1971	Leq	0.31
Vaughan-Huckins	1971-72	Leq	0.41 - 0.80
Hammar	1972	Leq	0.8 - 1.7
Bailey	1977	Leq	0.38
Abelson	1977	L10 (18h)	0.5
Hall et al.	1977	Leq	0.5
Allen	1980	L10 (18h)	0.15
Palmquist	1980	L10 (18h)	0.08 - 0.48
Taylor and al.	1982	Leq	0.5
Pommerehne	1985	Leq (6h-22h)	1 - 1.4
Heinonen	1986	Leq (7h-22)	1.06 - 1.39
Soguel	1989	Leq (6h-22h)	0.91
Iten	1989	Leq (6h-22h)	0.90
Vainio	1991	Leq (7h-22h)	0.36
Grue et al.	1995	Leq	0.48 - 0.54
Renew	1995	Leq (24h) L10 (18h)	1.0 1.1

A direct comparison of the results listed in Table 2 has to be undertaken with considerable care as noise levels were measured differently from one study to another, and threshold levels below which noise is assumed not to affect property values differ. Moreover, the care taken in collecting data may considerably influence the accuracy of the results. This may explain the diversity of values generated by these studies and the difficulties in aggregating them. To improve the comparison, a meta-analysis has been undertaken [4] from nine out of the 21 HP studies listed in Table 2. Marginal willingness to pay (MWTP) to reduce road traffic noise has been estimated as follows:

$$MWTP = e^{\left(2.3148+0.509\cdot 10^{-5} m+0.497\cdot 10^{-1} N\right)}$$

where:

N = noise level L_{Aeq}
m = annual income level (US $)

WTP varies significantly with income, which implies smaller valuations for noise changes in poorer areas. Using this result may be undesirable on distributional grounds. However, this result provides useful information and hence would enhance the quality of future benefit transfers [5].

The Contingent Valuation Method (CVM)

In this approach, survey respondents are asked to state (stated preference method) their willingness to pay (WTP) or willingness to accept compensation (WTAC) to obtain or avoid changes in the noise environment [6].

This method involves observing responses to a controlled hypothetical situation. The design and implementation of the survey require great care. Apart from conventional sampling problems, the main difficulty lies in the construction, presentation and understanding of the scenario presented to the survey population. The hypothetical scenario must be plausible and pertinent, the mechanism for payment must be realistic and neutral, and information concerning the effects of the noise abatement measures must be as clear and complete as possible.

Table 3 gives examples of contingent valuation questions for evaluating noise in monetary terms.

Table 3. Examples of CV questions

WTP for an improvement	*WTAC for a deterioration*
Example 1. How much would you be willing to pay each month for living in a quiet environment?	*Example 4.* How much would you accept to continue living in this noisy environment?
Example 2. How much extra rent per month would you be willing to pay to make sure half of the traffic noise was removed from this road?	*Example 5.* How much money would you need each month to just make up for a doubling of traffic noise?
Example 3. How much would you be willing to pay each month to make sure you will no longer be annoyed by traffic noise? (or to avoid health effects of noise)	*Example 6.* Suppose the local authority were to offer you ECU ... per month as compensation for the disturbance you think you may suffer from road traffic noise. Do you think this offer would be adequate or inadequate?

There are numerous forms of bias which may occur in CV studies. Table 4 outlines the main types of bias applicable to CV scenario design and implementation [4]. Therefore a methodological challenge is the elimination of bias.

Table 4. Main types of bias in CV studies

Formulation	*Revelation*	*Analysis*
Information	Embedding effect	Sample
Hypothetical	Initial	Execution
Payment vehicle	Strategic	Inference

Contingent valuation surveys have recently been conducted in Germany [7], Sweden [8] and in Switzerland [9] in the field of transportation noise. The German study provides the following relationship between the monthly WTP for living in a quiet area and the existing noise exposure (daytime LAeq) of the population interviewed:

$$\text{WTP (DM)} = 1.67\ L_{Aeq} - 71.7.$$

Hedonic Price vs. Contingent Valuation Method

Swiss studies carried out between 1984 and 1994 permit a comparison of the findings obtained through the application of the hedonic price and contingent valuation methods [9]. The analysis of Table 5 shows non-contradictory and rather converging results. However, CVM generally gives a higher WTP than HPM [10], which in fact is in accordance with economic theory.

Table 5. Monthly WTP for halving road traffic noise (SFR)

Swiss study	*Hedonic price*	*Contingent valuation*
° Pommerehne	81	75
° Iten	70	-
° Soguel	60	-
- Equation 1		95 - 56
- Equation 2		80 - 67

3. USING NOISE VALUES FOR POLICY DECISIONS

From a theoretical point of view, noise values could be used for numerous types of economic decision related to noise issues: transportation scheme appraisal, compensation, pricing of infrastructure, noise abatement projects or policy, etc. Unfortunately, in practice most of these decisions have little regard to the economic costs and benefits related to noise.

Noise Values Unsuitable for Decision-making

Noise values are most often used to estimate the total costs of transportation noise for a given country. Table 6 gives estimates for some selected European countries [11]. Unfortunately, these estimates are not very useful for decision making. Units costs [1] were derived by distributing total costs among sources of noise (Table 7). However, as for national estimates, these costs are not very useful for decision-making since the cost per kilometre or tonne is very dependent on local factors (density of population, topography, etc). Therefore an average value has no sense for economic appraisal of local projects and is unsuitable for estimating the benefits of noise abatement measures.

Table 6. Costs of road traffic noise in selected European countries

Country	*Year*	*Percentage of GDP*	*Valuation technique*
Finland	1989	0.30	Avoidance cost
France	1994	0.10	Hedonic price
Germany	1992	1.40	Contingent valuation
Norway	1987	0.30	Hedonic price
Sweden	1992	0.40	Hedonic price
Switzerland	1988	0.26	Hedonic price

Table 7. Unit costs of transportation noise

Car	ECU 3 / 1 000 passenger-km
Rail passenger	ECU 5 / 1 000 passenger-km
Road freight	ECU 12 / 1 000 tonne-km
Rail freight	ECU 6 / 1 000 tonne-km

Decisions without Economic Values of Noise

Many decisions are often taken in the field of transportation noise without any economic assessment using noise values: standards (emission, immission), noise abatement projects, compensation. Economic analysis could be very useful for policy decisions as it provides an assessment of the costs and benefits and determines the net present value. Attempts have recently been made concerning the economic evaluation of road traffic noise abatement options [12] and railway noise control legislation [13].

Decisions based on Economic Values of Noise

Noise values are sometimes used by governments in road scheme appraisals, but some of these values are subjected to ad hoc manipulations in their application. Table 8 indicates values for Scandinavian countries [14] and France.

Table 8. Value of noise used in road scheme appraisal in Scandinavian countries and France
(per person annoyed/year - 1993 ECU)

Denmark	*Norway*	*Sweden*	*Finland*	*France*
2 330	1 200	1 020	860	150

4. CONCLUSION

Transportation noise has a cost to society. This cost can be measured through a variety of sophisticated economic techniques based on the concept of willingness to pay (or willingness to accept compensation). Hedonic price (revealed preference) and contingent valuation (stated preference) methods are the most commonly used. They are capable of providing acceptable benefit estimates for reducing noise. These economic techniques have limitations for eliciting individual preferences. They also have a number of theoretical and practical drawbacks. Their implementation raises philosophical, ethical and equity issues. Nevertheless, they can inform the policy maker of the beneficial (in terms of savings in noise damage) and detrimental (in terms of increases in noise damage) consequences of different policy options by expressing these outcomes in the common metric of their value to society. At present, few policy decisions related to noise concerns actually use an economic tool such as cost-benefit analysis, although the economic analysis of noise now has a rather good rational basis. Consequently, in order to introduce a more rational utilization of resources, assessing the value of noise pollution has to be developed and encouraged and its use promoted. The first need is a more rigorous application of existing valuation techniques. There is a further need to expand the research work to encompass other techniques (the damage cost method which attempts to estimate the health effects of noise in particular). Last, but not least, it is necessary that valuation techniques and values provided by these techniques are acceptable to policy makers and the public.

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THE HEDONIC METHOD AND ITS APPLICATION TO ROAD TRAFFIC NOISE

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1. THEORETICAL BACKGROUND

The effects of noise on society are many and various. They have been classified by numerous authors in ways which depend to a great extent upon the particular field of study being undertaken. A useful classification comprises three categories: health related, activity related and cost related. It is the third category, cost related effects, which will be examined in this paper.

Because it has these adverse effects on society, noise can be said to have a social cost, one borne by society as a whole. In general, society is not compensated for suffering this noise through any market mechanism, so that a negative externality can be said to exist. Traffic noise (as well as exhaust emissions, congestion and vibration) can be considered as an externality. It is generated by road users and causes negative effects such as a lowering of property prices, but the community as a whole pays for them.

Berglund and Lindvall [1] divide social costs into two types, primary and secondary. They include in the primary costs category the societal costs for noise-induced illnesses and disabilities and the losses due to falls in productivity. Secondary costs are related to a lowering of the quality of life, including considerations of discomfort and annoyance, depreciation of house values, population segregation and general deterioration of residential areas. Cost benefit analysis provides the techniques for determining these social costs. In a major report on the evaluation of transportation impacts on the environment, Lambert and Lamure [2] discuss several techniques for evaluating environmental costs. Included are the hedonic price, contingent evaluation and direct cost methods. It is the hedonic price method which concerns us in this paper and we shall now proceed to explain its fundamentals.

2. THE HEDONIC PRICE METHOD

The method has its origins in utility theory and is based upon the assumption that the price of a heterogeneous good is a function of its attributes. This price (P) can be expressed by the relationship:

$$P = a_0 + a_1x_1 + a_2x_2 + \ldots\ldots + a_nx_n$$

where a_0 is a constant and a_i is the marginal implicit price (dP/dx_i) of attribute x_i.

In this linear equation, linear forms of the coefficients are commonly selected. However, non-linear forms involving logarithms and exponential functions have been used, and it is quite common for the logarithm of the price (P) to be employed. The task is to evaluate the coefficients a_i by use of multiple linear regression.

There is no physical market in which the price of a good (more correctly, a 'bad') such as noise or air pollution can be evaluated. The housing market, however, can be used as an implicit or proxy market to enable this evaluation to be carried out. When considering a house for purchase, a potential buyer is assumed to take into account its attributes and the relative prices of those attributes. For example, other things being equal, one would expect a potential buyer to be prepared to pay a higher price for a house in a relatively quiet area than for a similar house near a heavily trafficked (and hence noisier) road.

Care must be exercised in the selection of attributes. They must be relevant contributors to house price and not significantly correlated with other variables whose presence could impair the accuracy of the determination. Attributes which have been employed in hedonic price calculations can be separated into three categories: house related, locational and environmental [3][4]. House related attributes depend upon the house design and the allotment. They include: house age and construction, number of rooms, bathrooms and garages, the existence of a swimming pool and air conditioning, and allotment area. Locational attributes are associated with the situation of the site in the neighbourhood, and include the distances to shopping centres, schools, parks and potential work sites. Environmental variables of interest are transportation noise levels, traffic accident rates and air pollution concentrations.

3. APPLICATIONS OF THE HEDONIC PRICE METHOD

In Australia, the hedonic price method has been employed for a range of purposes, such as: examining the impact of a freeway on residential housing values [5], studying the demand for local amenity [6], analysing housing characteristics [7] and determining the effect of traffic noise on house prices [4][8]. The method has been employed widely in OECD countries, particularly France and the United States, to determine the pollution depreciation index, which is the percentage fall in the price of a residence for a percentage or unit increase in the value of some form of pollution. For example, sulphation, oxidants and suspended solids (particulates) have been selected as environmental attributes. Values of the pollution depreciation index have been found to range from 0.01 for oxidants to 0.50 for particulates and sulphation [3]. In addition, estimates have been made of the noise depreciation index (NDI), the percentage depreciation in house price per decibel increase in noise level, for road and aircraft traffic [3].

Berglund and Lindvall [1] point out that NDI values for environmental noise in the 1970s ranged from 0.3 to 0.8 per cent/dB, while during the 1980s they had risen to around 1 per cent/dB. An NDI value of 0.5 per cent/dB(A), which is in the mid-range of reported findings, is commonly used in OECD countries for cost estimations for new and modified roadways. In Australia, values of 0.5 and 1.0 per cent/dB(A) have been employed by the Environment Protection Authority (Victoria) [9] for transport costing. The New South Wales Roads and Traffic Authority [10] has adopted a value of 0.9 per cent/dB(A).

A summary of evaluations of NDI carried out in Australia is shown in Table 1. It is an updated version of information previously reported [4].

Table 1 Noise Depreciation Index Values

Year	Author	Location	NDI	Descriptor
1977	Abelson	Sydney	0.5 *	L_{A10}
1983	Bradley and Holsman	Sydney	0.69; 1.8 * 0.53; 2.3 *	$L_{Aeq, 5 h}$ $L_{A10, 5 h}$
1995	Environment Protection Authority (Victoria)	Victoria	0.44 - 0.80	L_{Aeq}
1996	Renew	Brisbane	1.0 1.0 1.1	$L_{Aeq, 24 h}$ L_{Adn} $L_{A10, 18 h}$
1998	Renew (see 4. Discussion)	Brisbane	1.1 1.2 1.1	$L_{Aeq, 24 h}$ L_{Adn} $L_{A10, 18 h}$

* calculated by Modra [8]

4. DISCUSSION

The 1996 Brisbane study [4] has been extended to include a further eight independent variables, making a total of eighteen, some of which were employed by McLeod [6]. When linear coefficients were used as in the previous study, there was a slight increase in the value of the explained variance. This implies that the additional variables provided a better fit to the price equation. As seen in Table 1, there was a small increase in the value of NDI, with values in the range 1.1 to 1.2 per cent/dB(A). The variables showing the highest significance (p= 0.001) were: number of bathrooms, allotment area and distance to the city centre. Traffic noise level was significant at the 95 per cent level, along with installation of an air conditioner and appearance of the house.

The hedonic price method has been used to estimate the social cost of traffic noise in France by determination of the depreciation in the value of existing housing [11]. In Australia, a similar determination has been made for arterial roads in Melbourne [9].

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