Proceedings of the Institute of Acoustics

STRATEGIC PLAN FOR RESEARCH ON EFFECTS OF AIRCRAFT NOISE ON HUMAN HEALTH

Major R. C. Kull, Jr and L. S. Finegold

Noise and Sonic Boom Impact Technology Advanced Development Program Office
OL-AC HSD/YAH
Wright-Patterson Air Force Base, Ohio, USA 45433

1. INTRODUCTION

The United States Air Force, in order to be responsive to extant public health laws and public concerns, has developed a research plan to study the effects of military aircraft noise on human health. This paper presents a brief background of this type of research, some of the rationale for the approach presented, and a summary of the steps to be taken to determine the feasibility of the research.

Military strategy requires that Air Force pilots be prepared to fly high speed, low-altitude missions in a wartime environment. In order to be proficient at flying these missions, pilots must train using similar operational tactics. There exists throughout the United States Military Training Routes (MTRs) specifically designed for pilots to perform low-level training missions. The National Environmental Protection Act requires that the US Air Force assess the environmental impacts of newly proposed MTRs prior to their operation. The Noise and Sonic Boom Impact Technology (NSBIT) Advanced Development Program Office is tasked with the research and development of environmental noise impact assessment technology. The NSBIT mission includes research on the effects of aircraft noise on humans, animals, and structures.

Residential aircraft noise exposure has been alleged to be associated with adverse health effects ranging from blood pressure changes to mental hospital admissions, increased drug use, birth defects, and even death (Cohen et. al., 1980; Jenkins et. al., 1979; Knipschild and Oudshorn, 1977; Jones and Tauscher, 1978; Meecham and Shaw, 1979). Many such allegations are based on meager scientific evidence and are highly speculative. Although a large body of research treating the effects of noise on physical and psychological health has accumulated over the last few decades, even the best of this work fails to provide clear evidence of adverse health effects. Much of the research has concentrated on health effects of high level, long duration, continuous noise exposure in the workplace, rather than on intermittent residential exposure to transportation noise. No one would argue that noise can affect people physiologically in varying degrees, producing responses ranging from transient elevations of pulse rate and blood pressure to long term hearing damage. Physiological responses of this sort are not, however, specific to aircraft noise exposure, and are generally considered as signs of unremarkable homeostatic processes. Yet, there are still many unknowns, including: dosage-effect relationships, demonstrations of causality, indications of clinical significance, and documentation of the effectiveness of noise-related interventions in reducing health hazards.

Determination of potential health consequences of military aircraft overflight noise has proven to be especially difficult for a number of reasons. The technical literature contains numerous controversial reports suggesting that noise exposure (not necessarily that produced by aircraft overflights) can have adverse effects on human health, including hearing effects. The fact that most of these reports deal with levels and circumstances of noise exposure very different from residential exposure to aircraft noise from low altitude overflights does not necessarily lessen the controversy.

There are two major reasons why the existing epidemiologic literature does not provide adequate or suitable answers to the issues being addressed in the current study. The first is that previous research has predominately studied occupational noise exposure, with some studies being done around airports, rather than residential exposure to military aircraft overflight noise. Occupational studies normally involve an 8-hour day of continuous noise exposure, with the Day-Night Average Sound Level (DNL) often being above 75 dBA. Thus, the vast majority of previous studies have not addressed noise exposure characteristic of that experienced under low-altitude military training conditions. The one major exception is the series of laboratory and field studies sponsored by the Federal Republic of Germany (FRG) Environmental Agency (inter alia, Curio, Ising, et. al., 1986; Spreng, Leupold, et. al., 1988; and Ising and Spreng, 1988).

For airport studies, although the noise is not continuous, such as it is in a factory setting, there may be hundreds of flights per day and a DNL usually above 65 dBA. In low-altitude military training areas, the flights are sporadic and unpredictable. In some areas, there may only be a few overflights per week. The noise characteristics also differ considerably between an airport or occupational setting and the military training environment. In the latter case, the noise usually has very fast onset rates, short durations, very high peak levels and unpredictable scheduling. Because of this and other reasons, there are serious questions about applying the results of studies from occupational settings and around airports to the very different case of exposure to military low-altitude aircraft overflight noise.

The second reason why previous research does not provide the type of information being sought concerns methodological considerations relevant to this type of research. The majority of previous epidemiologic studies of noise exposure effects have used cross-sectional or ecologic designs, rather than more robust etiologic research designs (such as a prospective cohort study). The latter methodological approach (i.e., the use of etiologic research designs) is necessary in order to be able to adequately be able to infer that a cause and effect relationship exists between the noise exposure and any observed health effect outcomes, if any are discovered. As discussed at length in Thompson et. al. (1989), a great deal of thoughtful consideration has been given to the methodological (research design options) and pragmatic (such as availability of a sufficiently large sample size) issues involved in planning the current study, leading to the requirement that the epidemiologic study being contemplated be designed using a prospective, etiologic type of methodology.

Although there are few published epidemiologic studies of residential exposure to noise, both the Caerphilly and Speedwell Collaborative Heart Disease Studies and the Bonn Traffic Noise Study (which were presented at the 5th International Congress on Noise as a Public Health Problem in Stockholm in 1988) used prospective research designs. Some quite interesting data is resulting from these well-designed, large-scale field research efforts. However, major differences in noise exposure characteristics between residential traffic noise exposure and exposure to low-altitude military aircraft overflight noise make generalization of the results from the former type of source noise to the latter highly questionable.

Despite a considerable amount of research on the effects of noise on health, the scientific literature on this subject provides no conclusive proof as to the presence or absence of noise-induced extra-auditory health effects and only rough guidelines for even the planning of this type of research. As stated in the NATO CCMS final report for the Pilot Study on Aircraft Noise in a Modern Society (NATO, 1989), "Humans produce a number of physiological responses to noise but as yet there is no clear evidence that repeated elicitation of these responses leads to irreversible changes and permanent health effects." (p. II-11).

Other reasons include the lack of definitive empirical data to support or refute the existence of a causal relationship between noise exposure and human health, and the absence of a quantitative dose-response predictive model. Not withstanding the lack of credible information, the Air Force must often respond to claims of consequential health effects of noise exposure produced by its flight operations. Since there is a lack of conclusive evidence to support the view that military flight operations does not pose a meaningful hazard to health, the Air Force must respond to allegations by documenting the logical, procedural, and statistical flaws of published studies. The need to find more persuasive responses has grown as the recent trend toward increased training of aircrews in low altitude flight operations has created greater residential noise exposure.

2. NATURE OF NOISE EFFECTS ON HEALTH

The weight of evidence (inter alia, Hattis, et. al. 1980; Thompson 1981;

Thompson, et. al. 1989) suggests that if residential aircraft noise exposure does have long term adverse health consequences, the cardiovascular system is the most likely physiological system in which such consequences might be detected. On the other hand, if these effects do exist, they are undoubtedly very subtle, long term, and indirect. Any linkage between residential aircraft noise exposure and cardiovascular damage is almost certainly mediated by psychosocial and other nonacoustic factors. The most plausible means for production of disease from residential aircraft noise exposure is through annoyance or startle effects, which could arguably cause an unknown degree of physiological stress that might be capable, by incompletely understood means, of adversely affecting cardiovascular functioning.

Previous research on extra-auditory effects includes studies of both industrial and residential noise exposure; the latter focusing on transportation noise (both street traffic noise and a few studies around airports). Several reviews of this extensive literature have been published (Welch, 1979; Hattis, et. al. 1980; Taylor, et. al. 1980; Thompson, 1981; Rehm, 1983; Dejoy, 1984; Kryter, 1985; and Thompson, et. al. 1989), although no definitive conclusions can yet be drawn from the published study results.

Research on hearing loss includes both temporary threshold shift (TTS) and noise-induced permanent threshold shift (NIPTS) as noise exposure effects. A considerable amount of research has been conducted on hearing loss, although it focuses primarily on occupational noise exposure, and a variety of models exist for predicting these effects (see Kryter, 1985, for a discussion of relevant research and available prediction schemes). After many years of research and international discussions, ISO 1999 (1988) is now the internationally accepted document used for predicting hearing loss as a function of noise exposure parameters, age, and sex. However, for United States MTR overflights, the duration, absolute level, and frequency of occurrence of indoor aircraft noise intrusions are insufficient to damage hearing, noise-induced hearing loss is not a plausible consequence of residential exposure to low-altitude aircraft noise.

3. FACTORS COMPLICATING THE STUDY OF HEALTH EFFECTS

Many factors complicate the design of studies of health effects of residential aircraft noise exposure. These include 1) an incomplete understanding of biological mechanisms and the clinical significance of potential effects of noise exposure 2) difficulties in measuring and estimating long term, source-dependent personal exposure to aircraft noise 3) the long latency period and small magnitude of the more plausible effects (i.e. cardiovascular disease) 4) the difficulty of controlling or otherwise accounting for the effects of numerous covariables 5) the lack of sites at which adequate populations of exposed and non-exposed persons can be distinguished and studied, and 6) the ethical and pragmatic impossibility of conducting controlled experimental investigations and/or controlled interventions in the populations and exposure circumstances of greatest relevance. The practical consequences of these obstacles imply considerable risk of misclassification bias, ecologic fallacy, and low statistical power. This also implies that any credible study requires costly, long term, and technically difficult studies.

4. RESEARCH METHODS FOR STUDYING HEALTH EFFECTS

Three basic approaches to the study of health effects of aircraft noise exposure can be identified: 1) an epidemiologic approach, in which evidence is sought in community-based etiologic studies of differences in specified health conditions between exposed and nonexposed populations; 2) a clinical approach, in which closely controlled, short term observations are made of relatively small numbers of people exposed to aircraft noise; and 3) a physiological approach, in which experiments may be performed on infrahuman species to elucidate potential biological mechanisms and demonstrate the effectiveness of interventions. Each of these approaches has both advantages and disadvantages, but NSBIT chose to pursue epidemiologic studies because they are more directly relevant for predicting environmental impacts and refuting alleged adverse health effects in exposed residential populations. An epidemiologic approach has the advantages of the results applying directly to human populations in residential settings, providing a credible basis for estimating disease prevalence rates, and permitting direct refutation of many alleged health consequences of noise exposure. Unfortunately, there are drawbacks to this approach. Epidemiologic research methodology is not optimal for the study of weak effects lacking biological markers, multiply-caused diseases with long latency periods, effects with incompletely understood causal mechanisms, and effects subject to multiple covariables.

To adequately and accurately predict human health effects in response to military aircraft overflight noise, an inferential cause-effect relationship between the two must be shown to exist and a quantitative dosage-effect relationship must be developed relating the independent and dependent variables. In order to establish a causal inference, should one exist, the study approach is to use a cohort-type design as opposed to a cross-sectional or ecologic study. This etiologic design will be a community-based, prospective study in order that actual noise exposures and health end-points can be measured.

Before implementing a study to obtain the required data, however, it is important to have a general process model of a plausible mechanism by which aircraft noise could potentially affect human health. The model presented in Figure 1 addresses, at a conceptual level, independent variables, covariables, and dependent variables (health consequences) that could conceivably be involved in a causal chain between aircraft noise exposure and potential human health impacts. This figure provides a model of a potential chain of events linking noise exposure and human health impacts and was originally presented in Thompson et al. (1989). The full details and a discussion of this model may be found in that document. The primary concept underlying development of the general process model is that noise acts as any other physiological or psychological stressor to the human system. Thus, what is generally known about human responses to environmental stressors could potentially be applied to the present study. There are several implications for a study design developed from this general process model. The first, and most important, is the complexity and poorly understood nature of the covariables. Many of these have high correlations with either the independent or dependent variables, making them difficult to control for in an experimental design.

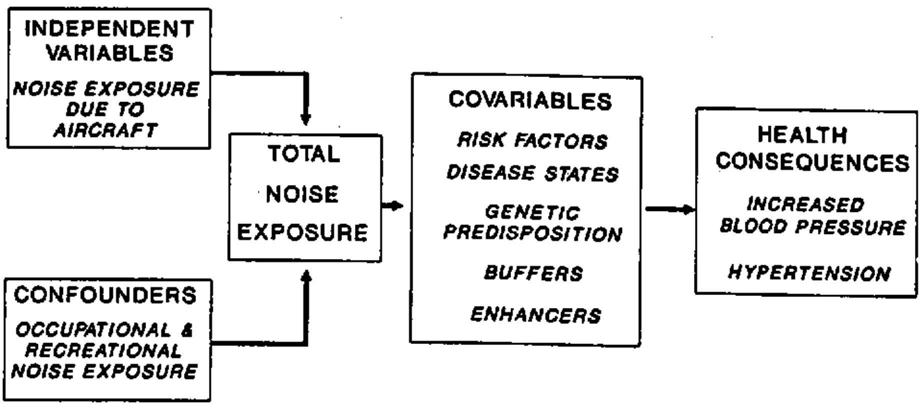

FIGURE 1: A general process model for CVD

As is the case with the majority of previous related studies, the extra-auditory dependent variables in the present effort will consist of cardiovascular-related health consequences (see Table 1 for a listing of potential variables). The proposed causal pathway, however, is not a direct physiological link between exposure and effect. With the exception of possible hearing damage from very loud noise, the general process model being adopted assumes a significant involvement of cognitive psychological processes (and, to some unknown extent, emotions) as part of the general process model. It may not be the physical properties of the noise that are important to the individual's health, but rather the person's interpretation and evaluation of the noise which are posited to determine the health effects. Such a conclusion implies that noise is not inherently harmful, but only potentially harmful, unless it is found to be annoying or stressful.

TABLE 1. VARIABLES IN CAUSAL CHAIN

Exposure Variables	Potential Covariates	Hypothesized Health Consequences
Total noise exposure	Genetic predisposition (race, family history)	* Hypertension
Number of aircraft noise intrusions	Behavior type (Type A, B behavior)	* Increased Blood Pressure
Onset rate of aircraft noise intrusions	Disease states (diabetes, etc.)	* Hearing Loss
Noise exposure above threshold	Occupational & recreational noise exposure	Arrhythmia
Distribution-sensitive measures (peak, centiles)	Conventional cardiovascular risk factors (cigarette smoking, cholesterol, LDL, HDL, alcohol, sedentariness, diet, obesity, sodium intake, age, sex)	Myocardial Infarction
	Other physiological enhancers (excessive autonomic system activation)	Mental Illness
	Psychological enhancers (other psychological stress, annoyance, low perceived control over stressor, anticipated threat, neuroticism)	Depression (acute, chronic)
	Buffers (social support, low background noise, Type B behavior, high control over stressor, healthy diet, young age, good physical condition)	Reproductive outcomes (low birth weight, teratism)
	Annoyance	Sudden cardiac death

* Potential health outcomes will be addressed in the current study.

There are also differences between reversible, short term and more persistent, long term responses to noise. The long term responses are of primary interest for the current study, since these would probably be more prone to progress to a variety of pathological states. The occurrence of both short and long term responses depends, among other things, on the combinations and/or levels of situationally-specific mediating variables. Only defined disease states are considered for inclusion as dependent variables for several reasons. First, measurable disease states are more amenable to study using epidemiologic research strategies in large populations than are reversible short term reactions. Ultimately, disease end points are of interest to the general public for intervention or mediation efforts. Secondly, even though it is now possible to simultaneously measure biochemical and hormonal responses, patterns of responses to specific stressor events are poorly understood. It is not yet possible to establish a threshold separating those changes which have significance for health from those which do not, since it is not known at what point irreversible physiological changes begin to make a significant contribution to an eventual disease process.

5. PRESENT STRATEGY

The present strategy involves several steps. First, a study will be performed to determine the feasibility of prospective epidemiologic research on the effects of low altitude aircraft overflight noise on human health. This feasibility study will investigate the presence of populations within appropriate noise exposures, determine the accessability of health records of the same population, determine the appropriate control populations, and estimate the probability that the noise exposure will exist for approximately five to ten years.

Once the feasibility study is complete, the results will be examined against previously established criteria required for an epidemiologic research project. The results of this examination will be evaluated independently by a committee of the National Academy of Science. The results of the feasibility study and the independent evaluation will determine if a prospective epidemiologic study is feasible. Should the study be infeasible, the Air Force will evaluate the possibility of epidemiologic studies of aircraft noise near civilian airports or military airbases.

6. REFERENCES

Cohen, S., , Evans, G.W., Krantz, D.S., and Stokols, D. (1980). Physiological, Motivational, and Cognitive Effects of Aircraft Noise on Children. American Psychologist 35(3): 231-243.

Curio, I. and Ising, H. (1986). Health Effects of Noise from Military Low-level Flights- Pilot Study. Environmental Research Plan of the Federal Minister of Environment, Nature Conservation, and Nuclear Safety. Report No. 86-10501112.

DeJoy, D.M. (1984). A Report of the Status of Research on the Cardiovascular Effects of Noise. Noise Control Engineering Journal 23: 32-39.

Hattis, D. Richardson, B., and Ashford, N.A. (1980). Noise, General Stress Responses, and Cardiovascular Disease Processes: Review and Reassessment of Hypothesized Relationships. EPA Report No 550/9-80-101.

Ising, H. and Spreng, M. (1988). Effects of Noise from Military Low-level Flights on Humans. Proceedings of the 5th International Congress on Noise as a Public Health Problem. (p. 84) Swedish Council for Building Research, Stockholm, Sweden.

ISO 1999. (1988). Acoustics- Determination of Occupational Noise Exposure and Estimation of Noise-Induced Hearing Impairment. International Organization for Standardization. (2nd ed.).

Jenkins, L.M., Tarnopolsky, A., Hand, D.J., and Barker, S.M. (1979). Comparison of Three Studies of Aircraft Noise and Psychiatric Hospital Admissions Conducted in the Same Area. Psychological Medicine 9: 681-693.

Jones, F.N. and Tauscher, J. (1978). Residence Under an Airport Landing Pattern as a Factor in Teratism. Archives of Environmental Health 33(1): 10-12.

Knipschild, P. and Oudshoorn, N. (1977). Medical Effects of Aircraft Noise: Drug Survey. International Archives of Occupational and Environmental Health 40: 197-200.

Kryter, K.D. (1985). Nonauditory System Response to Noise and Effects on Health. The Effects of Noise on Man (2nd ed.) (pp. 389-524). New York, N.Y.: Academic Press, Inc.

Meecham, W.C. and Shaw, N. (1979). Effects of Jet Noise on Mortality Rates. British Journal of Audiology 13: 77-80.

NATO (1989). Aircraft Noise in a Modern Society, Final Report of the Pilot Study. Report No. 185.

Rehm, S. (1983). Research on Extraaural Effects of Noise Since 1978. In G. Rossi (Ed.), Noise as a Public Health Problem: Proceedings of the Fourth International Congress, Vol 1, (pp. 527-547). Milano, Italy: Centro Richerche E. Studi Amplifon.

Spreng, M., Leupold, S., and Emmert, B. (1988). Possible Hearing Damage Caused by Low-Altitude Flight Noise. Environmental Research Plan of the Federal Minister of Environments, Nature Conservation, and Nuclear Safety. Report No. 10501213/04.

Taylor, S.M., Young, P.J., Bernie, S.E., and Hall, F.L. (1980). Health Effects of Noise: A Review of Existing Evidence. Report to Motor Vehicle Manufacturers Association of the United States, Inc. Contract No. MU 8018-C1101. McMaster University, Hamilton, Ontario, Canada.

Thompson, S.J. (1981). Epidemiology Feasibility Study: Effects of Noise on the Cardiovascular System. Report No. EPA 550/9-81-103.

Thompson, S., Fidell, S., and Tabachnick, B.G. (1989). Feasibility of Epidemiologic Research on Nonauditory Health Effects of Residential Aircraft Noise Exposure: Summary of Literature on Cardiovascular Effects on Noise Exposure. Volume III. HSD-TR-89-007, Brooks Air Force Base, Texas.

Welch, B.L. (1979). Extra-auditory Health Effects of Industrial Noise: Survey of Foreign Literature. AMRL TR 79-41. Wright-Patterson Air Force Base, Ohio.