Overview of the World Health Organization Workshop on Aircraft Noise and Health

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INTRODUCTION

A workshop was convened by the WHO Centre for Environment and Health to examine the evidence for the effects of aircraft noise exposure on physical and mental health in Bonn on October 11-12th 2007. A working group of experts on noise and health was asked to prepare draft chapters which were rigorously reviewed and discussed at the meeting. The health topics, based on previous WHO projects, included annoyance, sleep, cardiovascular health, physiological (stress hormone) effects, effects on cognition and mental health. Papers on exposure assessment and risk management were also prepared. The workshop included experts from Europe, North America, Australia and Japan as well as representatives from the International Civil Aviation Organization (ICAO). The objective was to produce a WHO document 'Evidence Review on Aircraft Noise and Health' based on a systematic review of the scientific literature.

METHODS

The working group was expected to apply the method of 'health hazard identification' to the issue of aircraft noise. Authors used systematic review techniques to assess the peer reviewed published literature on noise and health. Peer reviewed literature was supplemented by reports from significant studies and conference proceedings. When the published literature is limited, authors adopted narrative review of the available evidence. Each chapter was expected to follow a standard format, describing the review protocol, search strategy and identification of relevant studies. Systematic assessment of study validity included evidence for causal associations, characteristics of exposure-response associations, and discussion of whether the results could be explained by chance or bias such as confounding. For health topics where sufficient evidence was available, meta-analyses were carried out. Conclusions were drawn up taking account of high quality studies with the key results expressed in tables.

RESULTS

The results from each chapter were summarized as follows.

Annoyance

Annoyance has been described as a feeling of displeasure associated with any agent or condition, known or believed by an individual or group to adversely affect them. This chapter focussed on meta-analyses by Miedema & Vos (1998), Finegold & Finegold (2002), Fidell & Silvati (2004), and van Kempen & van Kamp (2005), who provide comparable exposure-response relationships for aircraft noise. The relationship shows a non-linear increase of the percentage of highly annoyed people with increased noise levels. However, they differ with respect to the degree of scatter, and with respect to the location of the maximum scatter.

Today there are many more aircraft movements at civil airports, individual aircraft have become less noisy at the same engine power, although the mean engine power has increased. Although the trade-off between the levels of overflights in energy equivalent noise metrics like DNL proved to be approximately correct for the prediction of noise annoyance in a study around Amsterdam/Schiphol airport, it is plausible that several acoustic features that are not reflected in DNL level influence annoyance. There is evidence for an increasing trend of average annoyance responses over time (van Kempen & van Kamp 2005). That is, more recently, residents living near modern airports show more aircraft noise annoyance than in former times. One explanation for this trend may be that residents near modern airports are often subjected to large changes in noise exposure.

The reviews do not distinguish between “low-rate changing” and “high-rate changing” airports, and there is evidence that noise situations changing at a high rate, especially the mere expectation of an increase of aircraft movements in the near future, increases the degree of residential noise annoyance. Increased ambient road traffic near airports, population characteristics, changes in study design or response rate may also contribute to increased annoyance. Residents living near airports tend to say that “aircraft noise is getting louder” even when the LAeq or DNL goes down (Fidell et al. 1998). This may be because: (a) residents react to the increased number of aircraft movements, (b) residents react to the increase of the background noise levels due to the increased number of aircraft cruising in the vicinity of the airport at the same time. Several authors conclude that the energy-approach to the aircraft noise description puts too little weight to the increased number of movements (MVA Consultancy 2007). MVA Consultancy (2007) suggests in the final ANASE report that giving the number of aircraft movements a weighting more akin to NNI (i.e. 15) rather than 10 might be more appropriate for predicting annoyance from aircraft noise.

The combination of expectancy effect and increased annoyance for a certain time period after the change is called “overshoot reaction”, because residents in high-rate change situations are considerably more annoyed than in low-rate change situations at comparable noise levels. After several years, the elevated annoyance tends to return to levels expected from low-rate change situations (Breugelmans et al. 2007). The recent Schiphol longitudinal studies demonstrate that at all noise levels, the percentages of highly annoyed residents is considerably higher than expected from established dose-response relationships, in anticipation of and even two years after the abrupt change.

Sleep

This chapter focused on aspects of aircraft noise and sleep disturbance less extensively covered in the WHO European Night Noise Guidelines. There are many methodological issues in the measurement of sleep disturbance: polysomnography, remains the gold standard for measuring sleep. This method however is cumbersome and resource intensive and many studies have to rely on less reliable methods. EEG awakenings are probably the clearest indication of sleep disturbance.

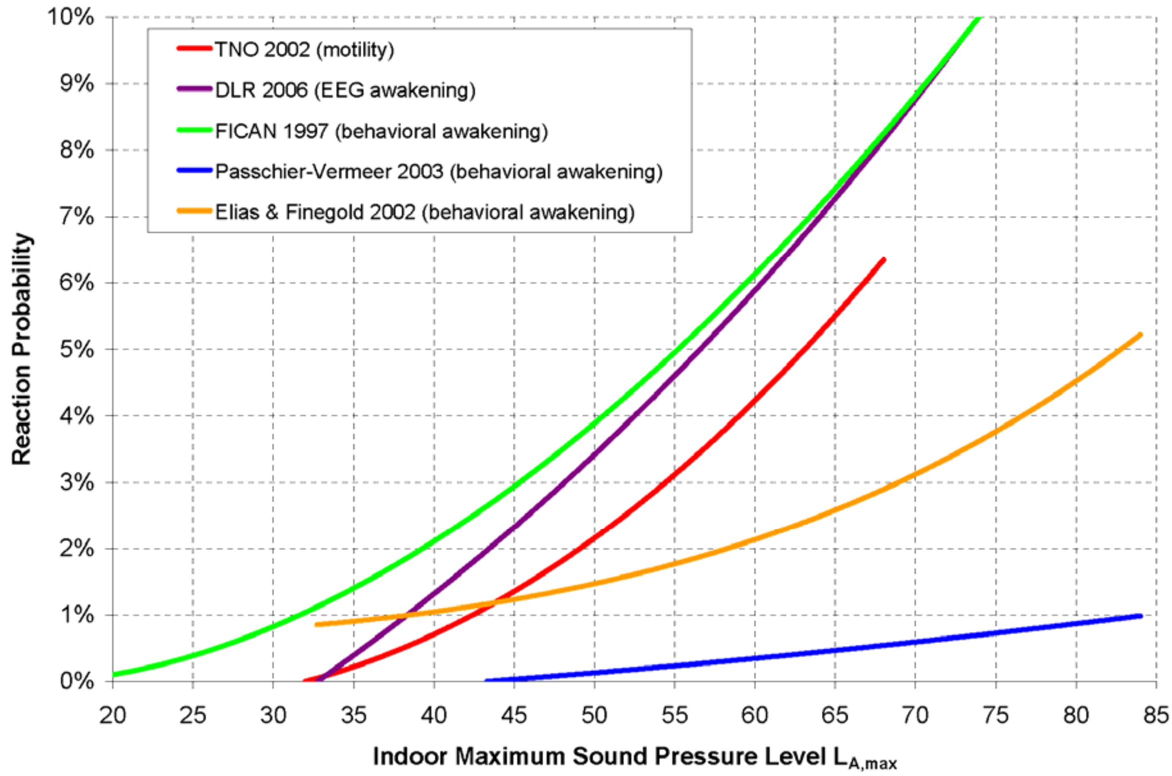

Figure 1: Dose-response relationships between indoor maximum sound pressure level $L_{A,max}$ and the reaction of the sleeper. For "FICAN 1997", "Finegold & Elias 2002" and "Passchier-Vermeer 2003", SEL was converted to $L_{A,max}$ by subtracting 16.4 from the respective indoor SEL value and then dividing by 0.877.

All five dose-response curves show monotonously increasing reaction probabilities with simultaneously increasing $L_{A,max}$. The dose-response curve for behavioral additional awakening derived by Passchier-Vermeer predicts considerably fewer behavioral awakenings at the same $L_{A,max}$ compared to the FICAN and Finegold & Elias curves, most likely for two reasons. First, the FICAN curve predicts the maximum, not the average, percent of the exposed population expected to be behaviorally awakened. Second, the FICAN and the Finegold & Elias curves seem to include spontaneous behavioral awakenings, whereas the Passchier-Vermeer curve concerns behavioral awakenings additional to spontaneous awakenings.

Dose-response curves are usually based on the average response in the investigated population. If protection concepts are based on this average response, the protection will necessarily be too high for some and too low for other parts of the population. In order to ensure that all relevant parts of the population are well enough protected, preventive measures can be taken, such as artificially elevating the dose-response curve or setting lower limit values than necessary (based on the average reaction in the population).

Cardiovascular effects

Epidemiological studies or surveys directly related to associations between aircraft noise and cardiovascular disease (CVD) outcomes were reported distinguishing between adults and children. Clinical manifestations of cardiovascular diseases are not very likely in young people. Therefore blood pressure is the major outcome that has been studied in children and adolescents. In adults, however, manifestations of high blood pressure (hypertension) and ischemic heart disease (myocardial infarction, angina pectoris, ischemic signs in the ECG, heart failure) are major outcomes of interest.

61 epidemiological studies addressed the association between transportation noise and cardiovascular endpoints; 20 on commercial aircraft noise, 8 military aircraft noise. Repeated studies carried out around Schiphol airport revealed higher relative risks of cardiovascular medication ranging between 1.2 and 1.4 for a noise level difference of approximately 10 dB(A). In the most recent phase of the Schiphol environment and health monitoring program a higher risk of approximately 1.8 was found for the same noise level difference. A recent cross-sectional study carried out around Cologne airport in Germany demonstrated higher individual prescriptions of antihypertensive and cardiac drugs in subjects exposed to high levels of aircraft noise, particularly, during the night and the early morning hours (3-5 hrs). Preliminary results from a Swedish follow-up study carried out around Stockholm's airport suggest more use of antihypertensive medication in subjects exposed to noise levels ('FBN') of more than 55 dB(A) compared to less exposed (relative risk 1.6).

In the later studies, no noise effects were found with respect to hospital admissions for cardiovascular disease. However, a statistically significant effect of L_{den} was found on self-reported hypertension. When the noise level increased by 3 dB(A) the odds ratio was 1.2, which corresponds with a relative risk of approximately 1.8 for a 10 dB(A) difference in noise level, confirming earlier studies. In a new multi-centre study carried out around six European airports a significant increase in the risk of hypertension of 1.1 (95 % CI = 1.0-1.3) for a 10 dB(A) difference of aircraft noise during the night (L_{night}) was found (Järup et al, 2007). Around Stockholm’s Arlanda airport an exposure-response association between aircraft noise and high blood pressure was found with relative risks ranging between 1.1 and 2.1 for noise levels between approximately 'FBN' = 53 to 63 dB(A) (Rosenlund et al. 2001). In the single prospective study around this airport subjects exposed to weighted energy-averaged levels ('FBN') above 50 dB(A) had a significant relative risk of 1.2 for the development of hypertension over the 10-year follow-up period compared with less exposed (Eriksson et al. 2007). The increase in risk per 10 dB(A) was 1.2 (95 % CI = 1.0-1.2). Meta-analysis of the HYENA, Stockholm, Okinawa and Amsterdam studies showed a pooled fixed effect estimate of 1.13 (95 %CI 1.06-1.20). Studies in children from Los Angeles and Munich found elevated systolic blood pressure in relation to aircraft noise, although these have not consistently confirmed by the recent RANCH Study (van Kempen et al. 2006). Overall, recently published powerful epidemiological studies indicate that aircraft noise exposure around airports increases the risk of elevated blood pressure.

Stress hormone effects

This chapter reviewed the evidence on aircraft noise exposure and hormonal responses including adrenaline, noradrenaline and cortisol. A search on aircraft noise and various hormonal outcomes yielded 14 citations in Pubmed and 2 in PSYCinfo; these were supplemented by conference papers and reports. Among the five studies in children levels of adrenaline and noradrenaline were raised in both the cross sectional and longitudinal reports from the Munich Study in relation to aircraft noise exposure and increases in aircraft noise exposure around the newly opened Munich airport (Evans et al. 1998). By contrast urinary catecholamines were not raised in the larger noise exposed sample from the West London Schools Study (Haines et al. 2001). All the studies consistently showed no relationship between aircraft noise exposure and urinary cortisol. In eight adult studies four showed increased levels of cortisol and two studies showed increased levels of catecholamines. Three experimental studies showed no increase in catecholamines and another field study showed no increase in relation to cortisol. A report from the German Aerospace Center (Maass & Basner 2003) found no effects of aircraft noise intensity or frequency on either free cortisol or catecholamines in parallel laboratory and field studies.

Mental health

PSYCinfo yielded 4 studies on aircraft noise and mental disorders and Pubmed 57 articles on aircraft noise and mental disorders. Early studies of psychiatric hospital admissions around Heathrow airport show no convincing associations between aircraft noise exposure and admission to hospital. Community studies of aircraft noise suggest some association between aircraft noise exposure and acute symptoms of waking in the night, irritability, depression, difficulty getting to sleep, swollen ankles, burns, cuts, minor accidents and skin troubles. Aircraft noise exposure is associated with higher scores on a screening questionnaire for anxiety and depression in highly educated and professional groups but not in the general population. Franssen's study around Schiphol Airport suggests an association between noise and non-prescribed sleep medication but no association with prescribed antidepressants and sedatives (Franssen et al. 2004). Japanese studies find that high levels of military aircraft noise are associated with depressive and anxiety symptoms but there are issues with the length of interval between assessment of noise exposure and depressive and anxiety symptoms. Using a standardised structured psychiatric interview Hardoy et al.'s (2005) study in Sardinia found an association between aircraft noise exposure and anxiety disorders. In contrast, van Kamp et al in a methodologically superior longitudinal panel study reported at Internoise 2007 found no relationship between change in aircraft noise exposure and mental health measured by screening questionnaire. The Munich Study (Evans et al. 1998) has shown that aircraft noise exposure is associated with decreased quality of life both cross-sectionally and longitudinally. However, more formal measures of anxiety and depression and parent assessed emotional and conduct disorders were not found to be related to aircraft noise in further studies (Haines et al. 2001; Stansfeld et al. 2005). Overall, there is reasonable evidence that noise impairs quality of life in children but does not cause more serious mental health problems.

Cognitive effects in children

Aircraft noise exposure has been related to the fraction of students reading below grade level in schools around New York and in two elementary schools chronic aircraft noise exposure (65 dB LAeq) was associated with impairment of reading and speech perception. Around Heathrow Airport chronic aircraft noise exposure was associated with poorer reading comprehension measured by standardized scales with adjustments for age, deprivation and main language spoken (Haines et al. 2001). In a further study of 451 children noise exposure was associated with impaired reading on difficult items, after adjustment for age, main language spoken and household deprivation. High levels of noise exposure were not associated with impairments in mean reading score, memory and attention or stress responses. In the Munich airport study (Hygge et al. 2002) long–term memory and reading were impaired in the noise group at the new airport and improved in the formerly noise–exposed group at the old airport. Short–term memory also improved in the latter group after the old airport was closed. At the new airport, speech perception was impaired in the newly noise–exposed group. Mediational analyses suggest that poorer reading was not mediated by speech perception, and that impaired recall was in part mediated by reading. In the cross-national RANCH Study there was a linear exposure-effect associations between exposure to chronic aircraft noise and impairment of reading comprehension (p=0·0097) and recognition memory (p=0·0141) maintained after adjustment for mother's education, socioeconomic status, longstanding illness, and extent of classroom insulation against noise (Stansfeld et al. 2005).

CONCLUSIONS

Overall, despite a limited number of studies in some areas there is good evidence for exposure–response associations between aircraft noise and annoyance, sleep disturbance, high blood pressure, and children's cognitive impairment. Evidence for the association with mental health and hormonal responses is limited. An important issue is the need for an accurate and reliable exposure assessment of aircraft noise relevant to the respective health outcomes. Conclusions on each topic are summarised below.

Annoyance: Exposure-response relationships have been established predicting the percentages of people expressing annoyance given a certain level of noise exposure. Results of more recent studies show annoyance reactions to aircraft noise that are much higher than expected from the earlier established exposure-response curves. Research into the possible causes for the observed increase in annoyance is still continuing, but part of it may be due to the fact that many recent noise annoyance studies took place in airport situations with an increased rate of change, especially with respect to the number of aircraft movements. Thus, established exposure-response curves to predict annoyance reactions should be used with caution in changing noise situations.

Sleep: Five dose-response curves show monotonously increasing reaction probabilities with simultaneously increasing aircraft $L_{A,max}$ in which behavioural awakenings, EEG measures and motility were the sleep outcomes. Laboratory studies consistently show stronger effects of noise exposure than field studies but field studies have greater ecological validity. L_{night} is probably the most practical index for night time noise regulation as it is espoused by the European Noise Directive although energy-averaged measures do not take full account of impact of individual noise events on sleep disturbance.

Cardiovascular Disease: There is sufficient evidence for a positive relationship between aircraft noise and high blood pressure and the use of cardiovascular medication. However, no single common exposure-response relationship or possible effect thresholds could be established for the association between aircraft noise and cardiovascular risk due to methodological differences between studies and the lack of continuous or semi-continuous (multi-categorical) noise data. There is some indication of a stronger association between night time noise level and hypertension.

Stress hormone responses: There is some consistent evidence that aircraft noise exposure in children is associated with raised levels of catecholamines but not cortisol although there is a need for more studies to replicate these results. The associations between aircraft noise levels and hormone responses in adults are unclear.

Mental health: There is some evidence that aircraft noise is related to symptoms of common mental disorder such as depression or anxiety rather than more serious mental disorder but in general the results of these studies are inconsistent. Overall, there is reasonable evidence that noise impairs quality of life in children but does not cause more serious mental health problems.

Cognitive impairment: Aircraft noise has detrimental effects on learning, memory and reading in children. This conclusion is further strengthened by noting that more than twenty studies have shown detrimental effects of noise on children's reading and memory, and there is no study to the contrary. But even though a significant cause-effect relationship is established, it is still unclear how much impairment and at which noise level the impairing effects begin. Experimental noise studies demonstrate that acute (aircraft) noise exposure is a sufficient and efficient short term cause of impaired memory.

Noise management: Successful noise management should be based on the fundamental principles of precaution, the polluter pays and prevention. An integrated noise policy should include several control procedures: measures to limit the noise at the source, noise control within the sound transmission path, protection at the receiver's site, land-use planning, education and raising of public awareness. With careful planning, exposure to noise can be avoided or reduced. A sufficient distance between residential areas and an airport will make noise exposure minimal. Additional insulation of houses can help to reduce noise exposure from airports. For new buildings, standards or building codes should describe the position of houses and the ground plan of houses with respect to over-flight paths and also the required sound insulation of the façades. Unless legal constraints in a country proscribe a particular option, the evaluation of control options must take into account technical, financial, social, health and environmental factors, as well as the speed with which they can be implemented, and their enforceability. Environmental Noise Impact Assessment (ENIA) process is one of the major tools available for managing the risks associated with exposure to aircraft noise, in affected communities. The aim of this process is to provide environmental protection for a planned project by foreseeing and preventing environmental noise problems.

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