Overview of research into sleep disturbance due to noise in the last three years

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INTRODUCTION

It is well established that noise can disturb sleep and if this disturbance is severe and frequent enough it can lead to significant fragmentation and sleep deprivation which seriously affects our physical and mental health. In the early days of modern sleep research there was a considerable emphasis on understanding the importance of the type and structure of sleep in terms of its electro-physiologically defined sleep stages and the nature of recovery sleep following sleep deprivation (Dement & Greenberg 1966). However, it is unclear how the well documented deleterious effects of these early sleep deprivation studies can be applied to environmental noise disturbed sleep (Zaharna & Guilleminault 2010) as the typical level of environmental noise is usually not severe enough to produce the same degree of sleep deprivation and/or fragmentation as the early experimental studies were designed to provoke significant outcomes.

Nonetheless, it has been clearly established that we can have autonomic responses to noise at low levels that do not produce wakefulness (Muzet 2007), as well as responses that could be described as minor fragmentation which includes shifts to lighter sleep stages, movement and/or brief wakefulness which are frequently associated with limb and body movement (Ollerhead et al. 1992). In addition, there is clear evidence that night-time noise has been associated with cardiovascular disease (Jarup et al. 2008) and stroke in the elderly (Sorensen et al. 2011. What is lacking is evidence of a clear pathway that directly links noise (at ecological levels) and disturbed sleep with cardiovascular disease.

One factor that makes it difficult to determine clear dose response relationships for these autonomic and minor sleep fragmentation responses to noise is that they also occur naturally in the absence of noise and any other obvious external agent. The dilemma has been how to establish an acceptable point at which the additional reactions to noise results in clear negative health endpoints (Brink et al. 2009). Adding to the dilemma is the large number of uncontrolled non-auditory factors e.g. annoyance, work and psychosocial stress, and personal characteristics e.g. noise sensitivity, that are known to affect our sleep and reaction to noise.

TRANSPORTATION NOISE

The last 3 years has seen continued interest in the effect of transportation noise on sleep. This has been driven mainly by the continued and planned expansion of aviation and high speed trains, which is considered to develop faster than noise suppressing technology. The future predictions for air-travel volumes indicate considerable growth and increased noise which outweighs the reductions due to quieter jet aircraft and other noise mitigation measures (Girvin 2009). The main focus of research into noise disturbed sleep over the last couple of decades has been in Europe. This has in part been a consequence of the realization of the European Noise Directive (END) which required governments to provide detailed noise maps of urban

conglomerations in member states and then to produce Action Plans on the basis of these Maps, which should outline how citizens living in the particularly noisy areas in the Maps are going to gain relief. This implies the need for quantification of the effectiveness of practical intervention measures that may be applied.

Over the last three years the FAA (US) have set about developing a 'Research Roadmap' for future work into 'Advancing Aircraft Noise Impacts Research' with a main emphasis on sleep disturbance and annoyance caused by aircraft noise (Girvin 2009). The essential aim of such research is to provide the best evidence for the formulation of legislation to regulate noise that has the potential to harm citizens. The research development process for the Noise Research Roadmap started with the formation of two small groups of experts and stakeholders in sleep disturbance and annoyance generation. This focus was broadened in 2009 at Euronoise in Edinburgh and Internoise in Ottawa where an International Forum on Aircraft Noise Impacts was held and further developed with Annual Research Roadmap Meetings in Washington in 2010 & 2011.

The differences in noise-induced sleep disturbance due to different transportation mode (air, road and rail singularly and in combinations) has received considerable debate and conjecture in the literature. A recent laboratory based study (Basner et al. 2011) has shed considerable light on the topic. They studied 72 subjects (32 male) for 11 consecutive nights with 0, 40, 80 and 120 noise events employed in a balanced design, in terms of number of noise events, maximum sound pressure level and equivalent noise load. The results showed that road traffic caused the most obvious changes in sleep structure and continuity whereas air and rail was considered more disturbing subjectively. This was attributed to road traffic noise events being too short to be consciously perceived by the subjects that had awoken in response to the event. The results also showed that while subjective annoyance was greater for aircraft noise, cortical and cardiac responses during sleep were lower for air compared to road and rail traffic. A fascinating result was that most (>90 %) of the noise induced awakenings merely replaced awakenings that would have occurred spontaneously, which helped to preserve sleep continuity and structure despite the noise. This suggests that within limits there is some homeostatic mechanism for internal monitoring and control of waking arousals (or maintaining sleep) that are allowed during each night's sleep.

THE WHO – EUROPE

The WHO – Europe have continued to be instrumental in driving the environmental health agenda in Europe and published the Night Noise Guidelines (NNG 2009) which summarize the deliberations of many experts and provide a clear and simple guide for planners and regulators. The NNG summarize the relationship between night noise and health effects into four ranges of continuous outside sound level at night (Ln):

<30 dB – no substantial biological effects should normally be expected;
30-40 dB – primary effects on sleep start to emerge and adverse effects in vulnerable groups;
40-55 dB – sharp increase in adverse health effects while vulnerable groups become severely affected;
>55 dB – adverse health effects occur frequently with high percentage of the population annoyed.

to be more pragmatic. Elucidation of the mechanism by which noise-disturbed sleep leads to significant reduction in health is a primary goal to resolve this issue.

There have been a number of reviews of the literature in the last 3 years on the effect of noise on sleep. The BEL Report (2009) set out to estimate dose-response relationships between noise exposure and health impacts in the UK which focused on the 'key' outcomes of cardiovascular effects, hypertension and sleep disturbance. However, they found that despite sleep disturbance being a well developed area with robust data, no consensus on any single dose-response relationship between noise level and sleep disturbance could be used to inform a cost-benefit analysis. Also, they concluded that no quantitative link could be established between sleep disturbance due to noise and any long term adverse health effects. But it was possible to find a robust link between noise exposure and hypertension. The authors considered that further research was needed to investigate the links between noise and air pollution and links between transient sleep disturbance and long term health effects.

Another review (Jones 2009) of aircraft noise and sleep disturbance in 2009 was carried out for the CAA (UK) and found results inconclusive and often contradictory with considerable practical design difficulties. The author suggested the need for large-scale long-term epidemiological field studies that include cardiovascular and hormonal measures at various exposure sites. The study should include actigraphy and some polysomnography for calibration and validation, to resolve the links between environmental noise, sleep disturbance and health.

A further review (Partner Project 2010) funded by the Partnership Program in the US and Canada concluded that aircraft noise can cause sleep fragmentation which can involve increases in the number and length of awakenings, reduced SWS and REM and increased heart rate and blood pressure, reduced subjective sleep quality, increased sleepiness and annoyance but only a small effect on performance next day.

OUTSTANDING ISSUES

There are a number of outstanding issues which need to be considered and addressed in any further research work. It is very difficult to attribute long term health effects directly to sleep disturbance as it takes several years for these illnesses to become apparent (Babisch 2006) and many potential risk factors have been identified in the genesis of cardiovascular disease.

There are various methods employed in sleep recording (van de Water et al. 2011) and each has its own advantages and definition of disturbed sleep so some appropriate combination of methods would seem the most acceptable way forward to reduce the cost and 'method bias'.

Site and subject selection in any future field study is important as it seems to the current author that a good proportion of residents near to airports or busy roads etc may represent 'noise survivors' who did not avoid buying a property near to a major noise producer and individuals who have not moved away because they are able to cope with the noise.

Age and socioeconomic status are major co-factors in considerations of noise and health and its end-points e.g. sleep disturbance, where healthy young adults tend to be generally good sleepers while the middle-aged and elderly tend to have poorer sleep with increased susceptibility to disturbance and fragmentation as a result of noise. Higher socioeconomic status allows individuals to chose homes in more desir-

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