COMMENTARY

Noise Pollution: A Ubiquitous Unrecognized Disruptor of Sleep?

Commentary on Basner et al. Single and combined effects of air, road and rail traffic noise on sleep and recuperation. SLEEP 2011;34:11-23 and on Test et al. The influence of hearing impairment on sleep quality among workers exposed to harmful noise. SLEEP 2011;34:25-30.

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IN THIS ISSUE OF *SLEEP* APPEAR REPORTS BY BASNER AND COLLEAGUES[1] AND BY TEST AND COLLEAGUES[2] THAT CONTRIBUTE IMPORTANT INFORMATION concerned with the impact of noise on sleep from two different perspectives. Basner et al. studied the direct effect of noise from different transport modes (air, rail, and road; singularly and in combinations) on sleep in a laboratory facility. Test et al. investigated the effect on worker's sleep of long-term noise in the workplace in a field study. These are contentious fields of sleep research that are of growing importance relative to the somewhat forgotten role of environmental exposure in sleep health. However, research on noise and sleep does not always produce results that are clear and unequivocal. Regulatory bodies in many countries are seeking to bring in new legislation to control, regulate and limit the noise produced by industries, such as air transport, based on clear-cut evidence about the potential harmful effects of noise on health-related outcomes such as sleep.

For inexplicable reasons, noise related sleep disturbance does not seem to have been an issue that attracted much scientific enquiry before 1963, as evidence by the fact that Nathaniel Kleitman[3] in his seminal tome *Sleep and Wakefulness* does not mention this subject despite basing his book on 4,337 references—which even includes one on William Shakespeare's favoured sleeping position! The public health impacts of noise began to emerge as an issue in the 1960s, however.

Noise Producer Gain versus Noise Receiver Loss

The studies by Basner et al. and Test et al. confront the difficult issue of noise as by-product of activities that are generally welcomed for economic prosperity by the worker and industrialist in the noisy industry, and by the traveller in the aircraft, train, or automobile, but not by the resident in receipt of the noise disturbance. The Basner et al. study is topical and timely, as transport noise at night has become a major problem in many large conurbations subjected to around-the-clock service provision that includes transportation activity. This work[1] compares these three main sources of transportation noise and details their individual and combined effects on sleep and annoyance, which adds to and extends earlier reports.[4-6] This disturbance is at odds with the expectation that comes with a general increase in affluence and lifestyle in developed and developing countries, which is frequently associated with reduced tolerance for negative environmental factors such as night-time noise. Many citizens consider access to an undisturbed night's sleep as a basic human entitlement essential for maintaining their health and well-being.

Laboratory versus Field

Basner et al. report on a laboratory study that allows for a large degree of experimental control not possible in a field setting, but which brings significant habituation issues across the period of study.[1] The field setting gives realism with high levels of ecological validity but with little control of confounding factors. There can be dilemmas on how to treat field data, for example with the effects of aircraft noise on the sleep of local residents where noise from a passing aircraft could wake a child or the family dog, who then wakes the entire household. There are no easy answers to these issues other than to conduct both laboratory and field studies in the best possible scientific manner and develop a composite picture that best fits the laboratory and field data.

Is Health Affected by Noise-Induced Sleep Disturbance?

There is a recent controversy whether physiological responses to noise during sleep have meaningful health consequences that are amenable and valid for the construction of dose-response (noise level-physiological) curves.[7-9] However, it has been established that long-term traffic exposure, especially at night, increases the risk of cardiovascular disease.[10] It has also been demonstrated that noise-induced cardiac arousals do not habituate across nights of study,[5,11] which underlines their potential relevance in the long-term cardiovascular consequences of noise-induced sleep disturbance. The crux of the issue that is yet to be resolved is this—what is the mechanism by which noise-disturbed sleep could lead to significant reduction in health?

This debate underlines the need for a consensus on methodological approaches, measurement techniques and end-points of outcome variables to enhance the comparability and value of future studies. Another realization is the major interpretive difference between the European view of health, which can include mental and physical well-being, not just an absence of disease, and the North American position, which is more pragmatic. Some authors even doubt the ability of experts to define future limit values for "health" which could be used in political considerations for regulation and control.[9]

How Does Noise at the Same Sound Level from Air, Rail, and Road Traffic Cause Different Responses during Sleep?

A major contribution of the study by Basner and colleagues is the balanced design (in terms of number of noise events, maximum sound pressure level, equivalent noise load/energy) that provides a clear comparison of the impact on sleep of the

Submitted for publication November, 2010
Accepted for publication November, 2010
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three traffic modes, and that manages to shed light on the fundamental acoustic issues that give rise to the differences in their potential for disturbance.

The acoustic explanation for the difference in cortical and cardiac arousal responses to traffic mode was shown to be due to rise-time in the sound pressure level (SPL) and the energy level, particularly in the high frequency range (>3 kHz). This has parallels with auditory evoked potential research in which the "ramp" characteristics of the sound envelope are highly related to the cortical response recorded. This provides important insights for the optimization of mitigation measures (e.g., SPL rise-times could be lowered by nocturnal speed control while energy reductions could be gained either by sound insulation of bedrooms or improved sound engineering of vehicles). Some research has already been completed in this area.[11]

Subjective versus Objective Evaluations of Traffic Noise

A particularly interesting finding reported by Basner et al. was a clear difference between the objective and subjective evaluations during the night.[1] Road traffic caused the most obvious changes in sleep structure and continuity, while air and rail traffic noise exposure were considered more disturbing subjectively. This was attributed to road traffic noise being too short to be consciously perceived by the subjects that were awakened by this noise, which supports earlier suggestions that consciously perceived noise events are needed for subjective assessment of sleep quality.[12] The results showed that while daytime annoyance was greatest for air traffic, cortical and cardiac responses at night were lower for air compared to road and rail traffic noise.[1]

A fascinating result of Basner et al. was that most of the noise induced awakenings (>90%) merely replaced awakenings that would have otherwise have occurred spontaneously, which helped to preserve sleep continuity and structure despite the noise. This would suggest that within limits there is some homeostatic mechanism for internal monitoring and control of major arousals that can be allowed during each night's sleep. There is a need for large-scale epidemiological field studies to resolve many of the issues raised by Basner et al., and for studies that include cardiovascular and hormonal measures, to fully understand the effects of noise during sleep on health and well being. There is also a need to understand how noise exposure in the daytime may affect nocturnal sleep, which was the focus of the study by Test and colleagues.[2]

Noisy Work Environments Can Lead to Tinnitus and Hearing Impairment, which Are Associated with Reductions in Sleep Quality and Insomnia

There has been little clear agreement on how long term working in noisy environments impacts on the quality of sleep. Test et al. investigated the relationship between sleep quality and hearing impairment as a result of prolonged exposure to industrial noise. There is a long history of such studies but the methodologies have not always been of high quality, and they have frequently been tainted by uncontrolled confounding variables (e.g., age, smoking, coffee and alcohol intake, air pollution, personal exposure levels, attitude and sensitivity to noise, stress, work shifts).

Test et al. compared 99 hearing impaired (25dBA down in the 1 kHz-4 kHz range) workers with 199 with no hearing impairment and found tinnitus was the most prevalent sleep disturbing factor, with 75% higher score among those affected (P = 0.001). They also concluded that hearing impairment was independently associated with sleep disturbance, especially insomnia, regardless of age and years of exposure. These sleep findings are at odds with a much smaller Brazilian study,[13] where despite hearing loss due to noise exposure, the quality and quantity of sleep was no different for workers in noise exposed and unexposed conditions.

Test and colleagues consider the particular strengths of their study were the homogeneity of the study population with regards exposure to the same harmful workplace noise, allowing them to compare sleep quality between similar groups who differed only in hearing status. In addition, they had relatively large sample sizes, all attended the same Occupational Clinic, were tested by the same method and the hearing was assessed by the same audiometric equipment.[2] They also indicated some weaknesses: the reliance on self reported sleep quality despite using a validated tool (Mini Sleep Questionnaire), and hearing assessment was restricted to one test that required the cooperation of the subject and the timing varied across the work shift. Most of these shortcomings could be relatively easily rectified in future work. One issue with this area of research stems from tinnitus being a subjective experience with no current objective correlate, which raises the possibility of individual manipulation for perceived benefit. However, this was a well-designed study with clear results that need to be replicated in other noisy working environments to fully gauge the general applicability of its findings.

These two studies clearly highlight that need for sleep research to focus on the role of environmental variables—especially noise—on sleep health in a world in which noise from many sources is a 24-hour phenomenon of increasing public health concern.

DISCLOSURE STATEMENT

Dr. Hume has indicated no financial conflicts of interest.

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