PSYCHOPHYSIOLOGICAL EFFECTS OF EXPOSURE TO AIRCRAFT OR ROAD TRAFFIC NOISE

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Introduction

Sleep has always been a source of questions to mankind and it is an activity on which he lays great importance. The effects of noise on sleep are dreaded by the population exposed to traffic noise. All enquiries made on noise take this aspect into account.

The wish for a peaceful period during the night is strongly expressed (1). Specific enquiries have been carried out on night noise disturbance (2)(3), because a definite difference was noted between day and night disturbance (4). On the practical aspect, one of the main questions is to know whether one should propose a specific index or else an extension of the validity of the day period (example of the 06.00-24.00h British L_{10} calculated) or else a ponderation of the night period (example of the American LDN).

The psychophysiological researches on sleep must help to enlighten the necessity for a specific index.

The documentary analyses of the works on sleep perturbed by noise show common features :

i - the studies take place in the laboratory during short exposure periods
ii - the samples are often young and healthy people
iii - the datas analysed concern the immediate effects of noise : the authors examine the effects of noise on the physiological signals (EEG, ECG, body breathing movements). Sometimes the sleep structure of the disturbed night is compared to that of a reference night (studies of C.G. RICE, P. MORGAN, J. LUKAS, A. MUZET) (5) (6) (7) (8). A few studies concern the secondary effects (subjective evaluation of the night spent : performance tests : R. WILKINSON (9).

Well controlled laboratory studies help to establish the role of acoustical parameters such as :
- the noise peak level
- the duration
- the emergence (and the role of the background noise)
- the number of noises and the interval between them
- the significance of the noise.

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Experimental plan and instrumental methods

The leading idea of new steps in research on sleep takes three important points into account :

- the exposure of the subjects studied must be of long duration
- the conditions must be realistic : on the material and psychological level as well as on the acoustical level which leads to in situ recordings
- the samples will be more varied than in a laboratory.

This leads to the adoption of light instrumental methods with miniaturised equipment as well as the use of a remote reading system. One naturally records signals identical to those of experiences in laboratories : EEG, eye movements, muscular activity and heart rythm. The noise is registered continuously during the night, inside the subject's bedroom. The subjects are accustomed to wearing electrodes for 3 days, before recording.

Results

Experiment on road traffic noise 1973-1975

This experiment recorded the sleep of twelve men from 25 to 50 years of age, living alongside a motorway, before and after its construction, according to Figure 1.

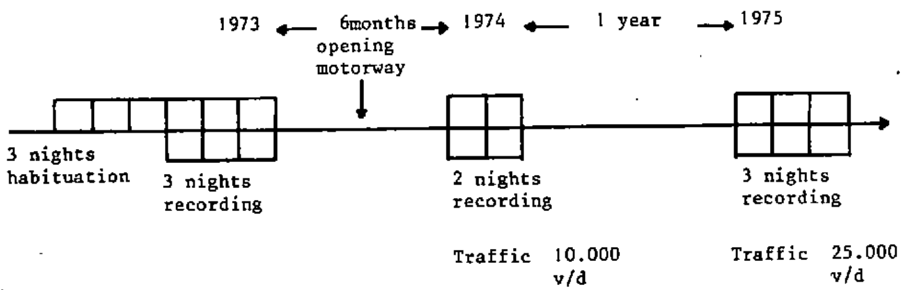

Figure 1. Temporal scheme of the experience

The appearance of traffic noise increases the time to fall asleep and somewhat reduces the duration of the first part of the night as compared to noiseless sleeping nights, although the total sleep duration is hardly modified. The Leq level inside the bedrooms is 40 ± 3 dB(A), the park levels being 55 ± 5 dB(A).

The second point refers to the important reduction (16 min of deep sleep (stages 3 + 4) following the construction of the motorway, as compared to pre-construction silent nights. On the physiological level, it follows that this specific reduction generates in a sample averaging 35 years of age sleep comparable to that of a group of normal men between 50 and 60 years old.

The periods of deep sleep are the most important to prevent or reduce physical tiredness and ensure the production of anabolisant hormones. Eventual long term effects on health are foreseen.

Experiment on aircraft noise

An experiment, also made in situ, concerned the riverains of an airport recently put into operation. 40 men have been recorded during a total of 160 nights after a year exposure to noise. Night traffic, i.e. during the subject's sleep is moderate : average of 11 flights, ranging from 5 to 35 flights per night. The average Leq is 40 $\pm$ 5 dB(A) and the peaks L_1 = 60 $\pm$ 10 dB(A) inside the residences. The immediate results of the analysis of the effects of a plane flight show a definite habituation to the highest noises levels, but there exist reactions against lower noises levels, see Figure 2. One considers reactions to noise as a linear function of peak noise : $y = 0{,}2\ x + 1{,}4$ ($r = .49$)

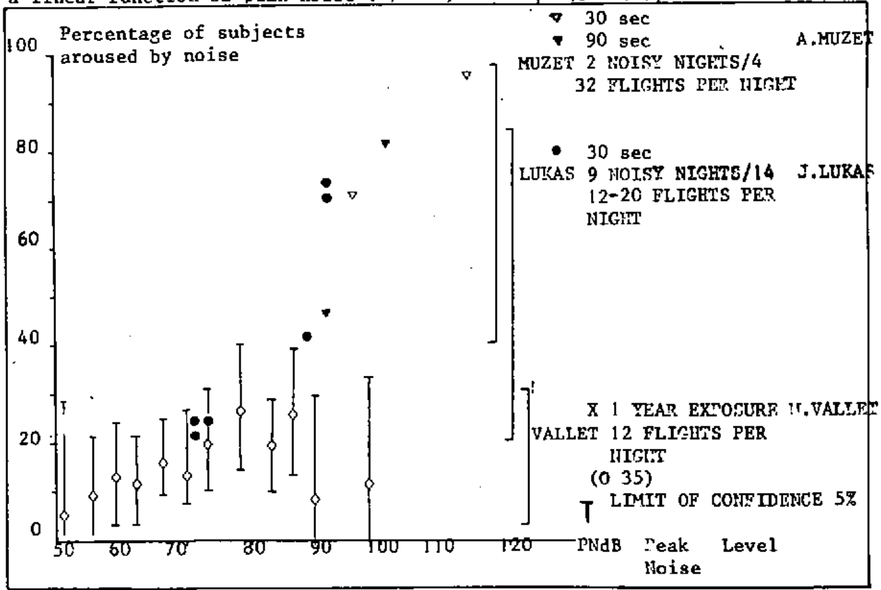

Figure 2 - Comparison laboratory field studies.Percentage of subjects aroused by noise.

A minimum of reactions to noise is observed when the following conditions are gathered : night Leq 35 dB(A) and number of flights between 10 and 15. Above these thresholds the percentage of awakenings and stage changings increases significantly.

Long exposure to road traffic noise

In a current study , financed by the Common Market and associating British,

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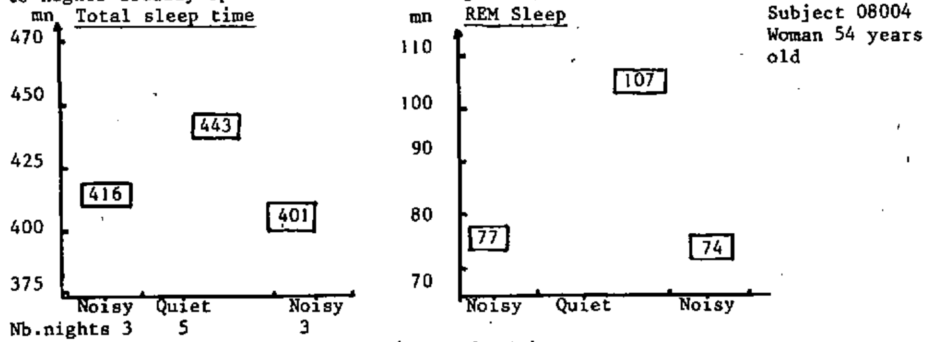
German, Dutch and French laboratories, studies the sleep of subjects exposed in the past 5 years to motorway traffic noise on the same site as the first §. The subjects are placed in quiet conditions, always in their flat, either reinforcing the insulation of the windows or, as it is our case, by changing the bedroom on the quiet side of the building. On records, in this acoustic situation improved by 10 dB(A) Leq on average, that the total sleep duration increases as compared to nights usually spent with noise (see Figure 3)



Figures 3and 4

Besides, the length of the paradoxal sleep(or dream)shows a regular shortage under noise. See Figure 4. This shows that, after 5 years exposure to traffic, adaptation is not achieved.

Conclusions

Sleep disturbance by noise has several aspects which, in spite of the mechanisms of adaptation supplied by the body, have a durable regular aspect. It appears that this disturbance generates sooner or later a significant increase of the use of medicines or of the nervous fatigue of a fraction of the population exposed. Besides, it must be known that the amount of sleep does not only depend on night noise. It was recently shown (MOURET)(10) that the dose of noise received during the day had an influence on the noise structure. An acoustical index to express sleep disturbance should take this into account.

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CONSIDERATIONS ON THE APPLICATION OF L_{EQ}-TYPE NOISE IMMISSION MEASURES.

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In recent years immission measures based on the concept of the equivalent continuous noise level have rapidly gained importance, and proved to be very useful tools. It may be good, however, to look back and see why this change may have come about.

Measures of noise immission

The purpose of noise immission measurements and criteria is to protect human beings from sound sources that are beyond their control. In this context, the sound would usually come from somewhere outside the building that contains, or houses the people we want to protect.

A variety of noise sources can contribute to this same problem. In most cases, traffic noise sources will dominate. They are characterized by fluctuating sound levels. Since irregular level fluctuations can be evaluated elegantly by means of statistical considerations, this method has received much attention. In England, the 10 per cent level L10 was introduced, and in Switzerland we interpreted the term 'frequent noise peaks' as L1, and the mean noise level as L50. These measures served their purpose quite well, at least for typical situations in the vicinity of rather busy roads.

In order to have universally applicable criteria, these must be useable also for situations with little traffic, and for other noise sources. Statistical levels may not be adequate in this case. For example, a L10 - criterion of 70 dB(A) would allow the use of a siren producing a level of 110 dB(A) or more for five minutes of every hour (= 8.3% of the time), and L1 has the same problem for periods of less than 36 seconds per hour. Since it is usual to make evaluations for periods of the order of 8 hours, the total permissible time with high noise levels can be quite considerable. There are important noise sources with high sound levels and short durations, such as aircraft and railway passings. Heavy goods vehicles on roads with a moderate traffic volume also cause noise peaks that are hard to limit by means of statistical noise limit specifications.

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A second disadvantage of statistical levels is the difficulty of predicting the result for superimposed noise sources. There is no simple way of adding statistical noise levels, unless you know the complete time history of each noise component.

The experience of these difficulties has promoted the use of a noise immission measure that easily allows superpositions, and that theoretically includes any type of acoustical event, and therefore also very short ones. The equivalent continuous noise level Leq fits the requirements. It only leaves one question open: the length of the averaging time period.

The averaging time period affects the importance of short acoustic events in the overall evaluation. The overall Leq will always have a component of background noise. If this noise level is much exceeded, even for only a short time, then the corresponding peak sound level will become important for the subjective reaction of the listener. As an example, we can perhaps assume that a single event of one second duration may be ignored, but a high-level signal of 10 seconds duration will not easily go unnoticed. Such a peak will have different effects on the Leq - level, depending on the length of the evaluation period. In a one-hour period, the peak with 10 seconds duration will correspond to a continuous level that is 26 dB lower. The level difference becomes 35 dB for a 8-hour evaluation period, and 40 dB for 24 hours. If we consider a situation, where a legal limit of Leq is set at 60 dB(A), then the 24-hour definition will only offer some protection against peak levels approaching 100 dB(A). This makes the limit less effective than it was probably intended to be.

The temptation is great to try and make the Leq-value include all known effects of noise at the same time. An important example is the fact, that we are more sensitive to noise at night. The traditional approach was based on road traffic measurements at a time, when these levels did drop by about 10 dB(A) at night, compared to the day-time conditions. We then hoped to keep up this difference by means of noise regulations. In fact, not all noise sources behave in this way. And recent social surveys have shown the number of highly annoyed people to be about the same as in the daytime, if the noise levels are 5 dB(A) lower at night. But even that level difference cannot be promoted or protected, if it is not explicitly stated. The combined noise measures would then only serve to state existing conditions, and not to keep the night-time noise levels down.

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Limits of noise immission

In any given situation, we deal either with measured noise immission levels, or with levels obtained by suitable prediction methods. In both cases the results need to be compared with a standard, in order to find useful conclusions. Here we meet with the difficulty, that not all people can be treated alike. Apart from the traditional difference between human beings and passengers within any type of vehicle, we also make differnces between places of work, and between different dwellings and homes. This again can only be justified by the need to keep up as good a standard as possible in each case. We know that technology has already caused examples of exceedingly severe noise pollution, where a remedy can hardly be found. It is not easy, even if the required funding can be provided, to balance the efforts for best overall results. The legal scale of limit values must serve as a criterion for this kind of decision, and therefore needs to be carefully chosen.

Practical aspects

For any given type of noise immission measure, industry is capable of producing suitable measuring devices. Even with the best instruments, the user will have to know when and where to take measurements. If we consider the difference between the side of a house facing the road, and the backside, or the difference between the outdoor sound levels and the inside levels that depend on a variety of building construction parameters, this problem is rather important. Many homes have an internal layout of rooms based on geographical or topographical considerations, and may not lend themselves easily to noise protection for he occupants. The Swiss approach for the measurements has been to place a microphone in the plane of an open window. In this way, the location of measurement is well defined, and no hard reflecting surface is close to the microphone. The microphones are usually also sufficiently protected against wind and rain.

Development of new legislation for noise immission protection

The Swiss government is developing new legislation along the lines mentioned above. A survey on night-time noise annoyance has recently been completed. The current state of preparation, and the set of limit criteria will be described at the meeting.