Journal of Sound and Vibration (1997) **205**(4), 411–415

TRANSIENT EFFECT OF THE NOISE OF PASSING TRUCKS ON SLEEP EEG

S. Suzuki, T. Kawada, Y. Kiryu, Y. Sasazawa and Y. Tamura†

Department of Public Health, Gunma University School of Medicine, Maebashi, Japan

(*Received* 3 *March* 1997)

Twelve subjects were each exposed to the noise of passing trucks at peak levels of 45, 50, 55 and 60 dB(A) for 15 min intervals throughout the night each for seven to 12 nights. Effects of the noise were observed by sleep electroencephalograpy (EEG). Three EEG parameters were affected by the noise event during stage 2. The number of spindles per epoch was depressed on average from 1·78 to 1·02 spindles per epoch or to 57% by the noise event of 60 dB(A), which lasted for only one minute. The threshold level for inducing the decrease was 32 dB(A), as assessed by a regression equation. Time % delta wave was depressed for six minutes, with a threshold level of 41 dB(A). The integral EMG increased in response to the noise event for one minute, and the threshold level for the integral EMG was 34 dB(A).

1. INTRODUCTION

Several papers have reported the effect of noise on sleep electroencephalograms (EEGs) [1–4]. The effects of actual road traffic noise at L_{eq} 46·7 dB(A) on sleep EEG was observed for a total of 72 nights in an apartment room facing a busy road used by about 30 000 cars a day. The only significant effect on 22 parameters of the sleep EEG in five subjects was a decrease in total REM sleep time. The result of that study suggested that the minimum effective level of traffic noise on all-night sleep EEG was L_{eq} 45 dB(A) [5].

An assessment of the instantaneous effect of a passing-truck noise on sleep was then attempted by examining the subjects' EEG and the most sensitive change observed in response to noise was reported as being in stage 2, and the least sensitive change in stage REM [6]. Peak truck noise of 45 dB(A) changed 12·9% of stage 2 sleep to shallower stages, and 60 dB(A) truck noise changed 23·6%. The rate of change in the control was 4·3%. The change to shallower stages lasted only one minute just after exposure to the noise of four passing trucks. The change was the result of a decreased number of spindles in each epoch caused by exposure to three levels of passing-truck noise: 55, 60 and 65 dB(A) [7]. The number of spindles increased in the other epochs unexposed to noise, leading to an increase in the total number of spindles during the nights the subjects were exposed to noise. This may be a compensatory mechanism to maintain sleep of the brain on noisy nights [6, 7].

Changes in sleep EEG caused by the four peak levels of passing-truck noise of 45, 50, 55 and 60 dB(A), will not be reported as changes in stages [6] but as changes in three bio-electric parameters: number of spindles, % delta wave, and the electromyogram (EMG).

† Present address: Tokyo University of Mercantile Marine, Etchujima 2, Koto-ku, Tokyo 135, Japan

0022–460X/97/340411 + 05 $25.00/0/sv971006

2. SUBJECTS AND METHODS

Twelve men aged 19 to 21 years were allowed to fall asleep in a bedroom and then exposed to noise while asleep. Their EEGs were recorded. One subject was exposed per night for seven to 12 non-consecutive nights. The subjects had normal hearing, and had been told neither to nap during the day nor drink alcoholic beverages.

EEG electrodes were placed according to the international 10–20 method. An EEG and an EMG were recorded by using the telemetry system of Nihon Kohden Company, Ltd. Sleep stages and parameters, including spindles, delta waves, and EMGs, were analyzed with our computerized EEG analysis system [8] according to Rechtschafffen and Kales [9]. Road traffic noise was recorded in a room of an apartment with the window open. A representative passing truck noise with a peak level of 65 dB(A) and a duration of 20 s was chosen. The peak sound level by octave band analysis was 54 dB at 2 Hz. The volume was reduced to four peak levels of passing-truck noise: 60, 55, 50 and 45 dB(A). The four levels were edited in the order of 50, 45, 55, 55, 60, 45, and 50 dB(A), with intervals of 15 min, so that one cycle lasted two hours [6]. If a subject slept eight hours, he was exposed to 32 noise events. Exposure was continued throughout the night. Background noise level in the bed room was L_{eq} 30 dB(A). No air conditioner was used during the months of the experiment, conducted in the spring and autumn for three years to obtain sufficient data for the analysis. Noise events that occurred during stage 2 accounted for about two thirds of the total epochs of about 1300 a night. Only the EEG recorded when noise occurred during stage 2 was analyzed in this study. Thus, each level of peak noise occurring during stage 2 was picked up from the EEG of 12 subjects for each seven to 12 nights, which amounted in total to 500 events or more for each level of truck-passing noise.

3. RESULTS

The average number of spindles per epoch in stage 2 decreased in response to the four levels of passing-truck noise, 45, 50, 55 and 60 dB(A), from 1·85 to 1·32, 1·85 to 1·35, 1·78 to 1·12, and 1·78 to 1·02, respectively. There was an average of 534 to 570 noise events, and the percentage decreases were 26%, 27%, 37% and 43%, respectively. It took one minute to recover to the pre-exposure number of spindles per epoch (see Figure 1).

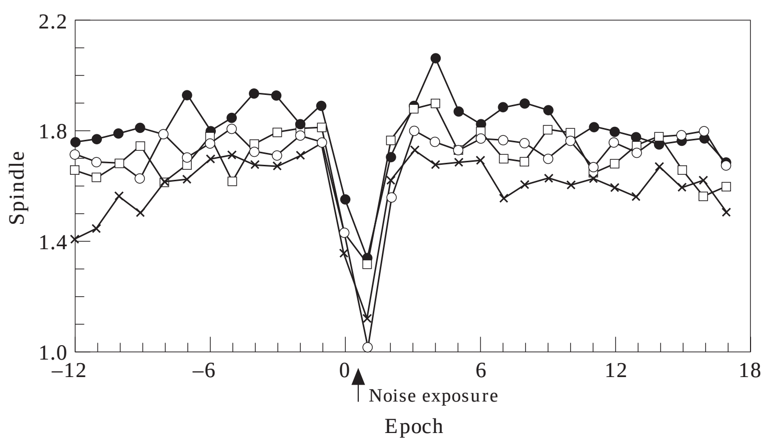

Figure 1. Average number of spindles/epoch in sleep EEG, before, during and after a passing-truck noise exposure of four peak levels: 45, 50, 55 and 60 dB(A). One epoch is 20 s. Noise events occurring during stage 2 are presented. –□–. 45 dB(A), 534; –●–, 50 dB(A), 558; – × –, 55 dB(A), 570; –○–, 60 dB(A), 563.

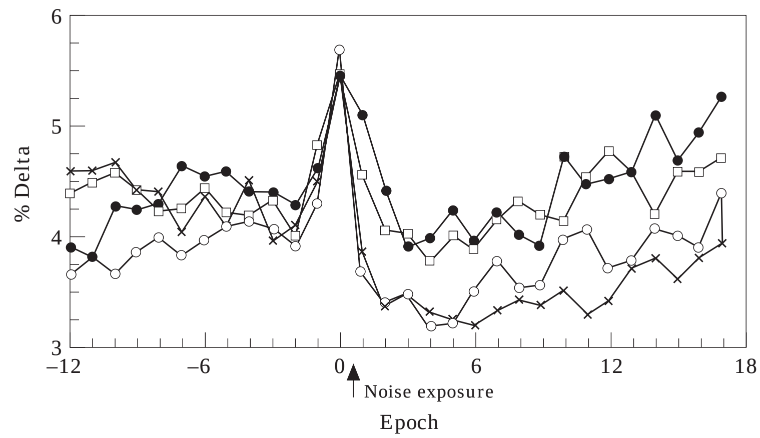

Figure 2. Average time % delta wave/epoch in sleep EEG, before, during and after a passing-truck noise exposure of four peak levels: 45, 50, 55 and 60 dB(A). One epoch is 20 s. Noise events occurring during stage 2 are presented. Key as Figure 1.

The decrements of number of spindles per epoch (Y) were plotted against the four peak levels of passing-truck noise (X), yielding the regression line $\mathrm{Y} = 0{\cdot}0272X - 0{\cdot}858$ ($r^2 = 0{\cdot}951$). A minimum effective peak sound level or threshold level of 32 dB(A) was calculated by the regression equation.

% Delta wave per epoch first increased sharply (K-complex by noise), and then decreased at the peak truck noise levels of 55 and 60 dB(A) for 6 min, thereafter recovering almost to the pre-exposure level (see Figure 2). The decrease in % delta wave per epoch at 45 and 50 dB(A) was about one-third of those of 55 and 60 dB(A) and lasted only three minutes. Decrements of % delta wave (Y) were plotted against the four peak levels of passing-truck noise (X), yielding the regression line $Y = 0{\cdot}056X - 2{\cdot}29$ ($r^2 = 0{\cdot}894$). The minimum effective peak noise level for % delta wave decrease was calculated to be 41 dB(A) by the regression equation.

Passing-truck noise gave an effect on the EMG. This is shown as the integral voltage of the EMG in Figure 3, which shows the changes before, during, and after a passing

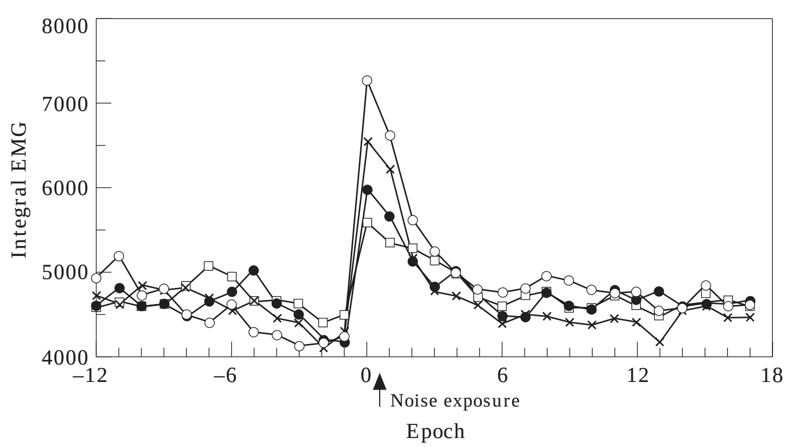

Figure 3. Average integral EMG/epoch in sleep EEG, before, during and after a passing-truck noise exposure of four peak levels: 45, 50, 55 and 60 dB(A). One epoch is 20 s. Noise events occurring during stage 2 are presented. Key as Figure 1.

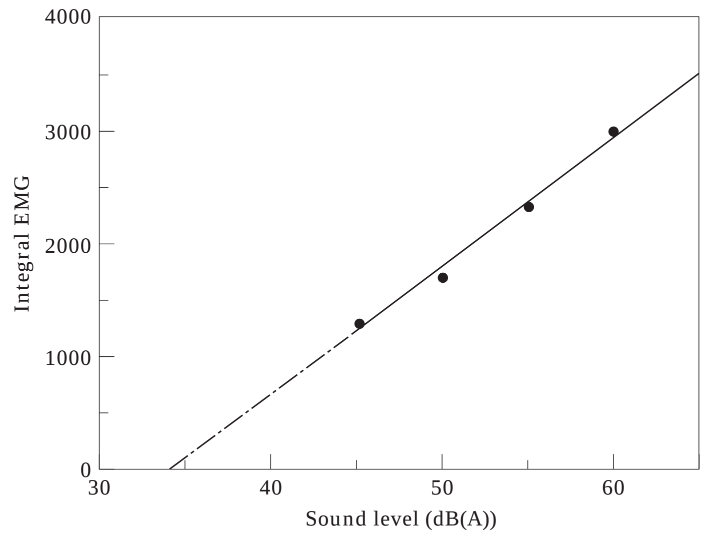

Figure 4. Average increment of integral EMG (Y)/epoch plotted against the four peak sound levels (X) of passing-truck noise. The regression equation is given in the text. The threshold of the increment is 34 dB(A).

truck-noise event at the four peak levels. The louder the passing-truck noise, the larger the integral EMG. The change lasted only one min (see Figure 3). The increments of the integral EMG from stage 2 (Y) were plotted against the four peak levels of passing-truck noise (X) (see Figure 4). The regression line $Y = 107X - 3580$ ($r^2 = 0.994$), indicates that the minimum effective peak level of a passing-truck noise is 34 dB(A).

4. DISCUSSION

In the previous experiment [7] on excessive exposure to noise from passing trucks, the spindle decrements were 43% and 62% at 60 and 65 dB(A), respectively, which indicates a reasonable and continuous decrease in spindles in the present experiment. The minimum level causing a spindle decrease, the threshold, was estimated by extrapolation from the regression equation to be 32 dB(A). This level almost coincides with the extrapolated stage shift and waking values on the EEG in the passing-truck noise exposure experiment by Thiessen *et al*. [10–12].

Transient increases in the delta wave have been reported in response to peak noise exposure [13], even though its total decreases in all-night sleep [14]. Peak truck noise depressed the delta wave for six or more minutes in the present experiment, which could lead to depressed delta wave or slow-wave sleep in all-night sleep. The threshold for the transient effect of truck peak noise on delta wave was 41 dB(A), lasting for several minutes. Kawada [12] concluded that the threshold value for the effect of noise on all-night sleep is 40 dB(A) based from five reports on the subject.

The integral EMG had the closest dose–effect relationship with the peak level of passing-truck noise exposure. The origin of the EMG is not exactly known. It may be that a physiological reaction to a sound stimulus shows a close dose–effect relationship. Part of this muscle reaction is attributable to facial muscle contraction, movement of the digits, or to gross body movement. Body movements in response to intermittent noise events have been investigated by Öhrstrom and Rylander [15, 16]. The muscle contraction resulting in the body movements may be one of the most sensitive parameters of a noise event. In the present study, the minimum effective peak truck sound level for the integral EMG was 34 dB(A). This threshold is based on the data of sleep parameters recorded when the event occurred during sleep stage 2. The threshold was 41 dB(A) when the noise event occurred in stage 3 or 4. It could be concluded from this that the observed EMG reaction to noise events is less sensitive in sleep stage 3 or 4 than in stage 2.

More integrated studies are needed to evaluate the effect of noise on sleep, including the elemental parameters of the EEG, sleep stage, performance after sleep, and subjective sleep ratings, including the compensatory mechanisms in the brain for exposure to noise and habituation to noise.

REFERENCES

1. R. T. Wilkinson and K. B. Campbell 1984 *Journal of Sound and Vibration* **75**, 468–475. Effect of traffic noise on quality of sleep: assessment by EEG, subjective report or performance the next day.
2. B. Griefahn and E. Gross 1986 *Journal of Sound and Vibration* **105**, 375–385. Noise and sleep at home: a field study on primary and after effects.
3. B. Griefahn 1986 *American Journal of Industrial Medicine* **9**, 261–269. A critical load for nocturnal high-density road traffic noise.
4. J. L. Eberhardt and K. R. Axelsson 1987 *Journal of Sound and Vibration* **114**, 417–434. The disturbance by road traffic noise of the sleep of young male adults as recorded in the home.
5. T. Sato, M. Ogawa, and S. Aoki 1991 *Nippon Koshu Eisei Zasshi* (*Japanese Journal of Public Health*) **38**, 200–210. Effect of road traffic noise on sleep, a paired comparison between sleep polygraphic parameters recorded in a noisy apartment along a road with traffic and those recorded in a quiet suburban house. (In Japanese)
6. T. Kawada and S. Suzuki 1995 *Perceptual and Motor Skills* **80**, 1031–40. Instantaneous change in sleep stage with noise of a passing truck.
7. T. Kawada and S. Suzuki 1994 *Japanese Journal of Psychiatry and Neurology* **48**, 87–103. Transient and all-night effects of passing truck noise on the number of sleep spindles.
8. S. Aoki, T. Kawada, K. Takeuchi, M. Ogawa and S. Suzuki 1989 *Japanese Journal of Hygiene* **43**, 1092–1101. Effects of noise on sleep, Part 1: Development of an automatic analysing system for all-night sleep polygraphy by microcomputer (In Japanese).
9. A. Rechtschaffen and A. Kales 1968 A *Manual of Standardized Terminology. Techniques and Scoring System for Sleep Stages of Human Subjects*. Washington, DC: Public Health Service, U.S. Government Printing Office.
10. G. J. Thiessen and A. C. Lapointe 1978 *Journal of The Acoustical Society of America* **64**, 216–222. Disturbance of sleep by noise.
11. G. J. Thiessen 1983 in *Proceedings of the* 4*th International Congress on Noise as a Public Health Problem* **2** (G. Rossi, editor), 995–1005: Milano: Centro Ricerche e Studio Amplifon. Effect of intermittent and continuous noise traffic noise on various sleep characteristics and their adaptation.
12. T. Kawada 1995 *Japanese Journal of Hygiene* **50**, 932–938. Effects of traffic noise on sleep: a review.
13. R. T. Wilkinson and S. Allison 1983 *in Proceedings of the* 4*th International Congress on Noise as a Public Health Problem* **2** (G. Rossi, editor), Milano: Centro Ricerche e Studio Amplifon. Effects of peak traffic noise during sleep on ECG and EEG.
14. A. A. Jurriens 1980 *Proceedings of the* 3*rd International Congress on Noise as a Public Health Problem*, *ASHA Reports* 10 (J. Tobias, G. Jansen and W. D. Ward, editors. Maryland: American Speech-language Hearing Association. Sleeping twenty nights with traffic noise: Results of laboratory experiments.
15. E. Öhrström, R. Rylander and M. Björkman 1988 J*ournal of Sound and Vibration* **127**, 441–448. Effects of night time road traffic noise: an overview of laboratory and field studies on noise dose and subjective noise sensitivity.
16. E. Öhrström and R. Rylander 1990 *Journal of Sound and Vibration* **143**, 93–101. Sleep disturbance by road traffic noise—a laboratory study on the number of noise events.