Journal of Sound and Vibration (1997) **205**(4), 405–409

DAILY SLEEP CHANGES IN A NOISY ENVIRONMENT ASSESSED BY SUBJECTIVE AND POLYGRAPHIC SLEEP PARAMETERS

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(*Received* 3 *March* 1997)

Habituation of sleep to a noisy environment was investigated by self-rated sleep scores, polygraphic sleep parameters, and a performance test on the following morning. The self-rated sleep questionnaire, OSA, includes five factors of subjective sleep quality: sleepiness, sleep maintenance, worry, integrated sleep feeling and sleep initiation. The polygraphic sleep parameters were six sleep stages in minutes, sleep latency, REM latency, REM cycle, REM duration, frequency and duration in minutes of awakening during sleep, total sleep time, number of sleep stage shifts, sleep efficiency, number of sleep spindles and density. The differences between reaction times before sleep that night and the following morning were also examined. The subjects were twelve students aged 19 to 21 who were tested a total of 96 nights. Each subject slept in an experimental room and was exposed to recorded passing truck noise with peak levels of 45, 50, 55 and 60 dB(A) at intervals of 15 min. Significant changes were recognized in Stage 1, MT, frequency of awakening and number of sleep stage shifts. The authors speculate that the decrease in the shallow stage as noisy nights were repeated reflects habituation of night sleep to repeated passing truck noise, whose interval, duration and nature was constant.

1. INTRODUCTION

Habituation to noise during sleep can be assessed by measuring improved quality of sleep with time. Although it has been claimed that there is no development of habituation to any type of noise [1], Griefahn reported detecting habituation to noise based on the fact that REM latency, subjective assessment of falling asleep and reaction time as psychomotor performance became significantly shorter [2].

Griefahn and Gross defined habituation as the return of a measured parameter to its baseline in each subject [3]. Fidel and Jones analyzed polygraphy-based sleep measurements and reactions of inhabitants living near an airport before and after the cessation of frequent nocturnal air traffic [4]. No differences in these parameters were observed in noisy and quiet environements, a finding consistent with those of Griefahn and Gross.

Öhrström and Björkman reported the effects of the road traffic noise of heavy vehicles on consecutive nights [5]. There were no indications of habituation in subjective sleep quality, mood or performance. Greater tiredness and decreased performance during the noisy period were seen, although the differences were not significant.

Changes in sleep-associated parameters in a noisy environment were evaluated.

0022–460X/97/340405 + 05 $25.00/0/sv971005

2. METHODOLOGY

The subjects were twelve male students aged 19 to 21 years. They all had normal hearing according to the results of hearing acuity tests. Alcoholic beverages and daytime naps were prohibited before the experiment. Each subject went to bed in the experimental room at 23:00 and awakened no later than 07:00, at which time an alarm clock was activated. Total sleep recording time averaged eight hours. Each subject was paid $100 US per night.

Polygraphic sleep parameters were determined from an electoencephalogram (EEG), electrooculogram (EOG) and electromyogram (EMG). EEG electrodes were positioned according to the international 10–20 method (C_3–A_2 and C_4–A_1). C_3–A_2 recording was mainly used in the analysis. EEG, EOG and EMG were recorded by using a telemetry system (Nihon Kohden Co., Ltd., Tokyo). The sleep polygraphic parameters in this study were sleep stages (S1, S2, S3 + S4, SR, MT) in minutes, sleep latency (SL), REM latency (RL), total sleep time (TST), awakening during sleep in minutes (TW) and frequency (FW), sleep efficiency in percentages (EFFIC), number of stage shifts per night, REM duration (RD), REM cycle (RC), total number of sleep spindles per night (SP1) and density in minutes (SP2) according to the sleep EEG atlas by Rechtschaffen and Kales [6]. SL was defined as time in minutes from lights out until the start of stage 2. Sleep spindles were detected with the help of an original computer system [7]. Simple reaction time was measured by the DATICO "Terry 84" reaction time device, chosen for the WHO neurobehavioral core test battery. The subject's task was to give rapid motor responses to repetitive visual stimuli presented at random intervals of 1·0 to 10·0 seconds. The subjects were presented with 64 stimuli to which they must respond, and the mean reaction time of the 64 responses was calculated. Differences in simple reaction time within 15 minutes before going to bed and within 15 minutes after waking in the morning (RT) were used in the analysis.

Self-rating sleep was reported by the subject the following morning. Particular questionnaires exist for self-rating sleep [8–11]. In Japan, the OSA questionnaire is frequently used [12]. Five OSA scores, sleepiness (F1), sleep maintenance (F2), worry (F3), integrated sleep feeling (F4) and sleep initiation (F5), were used. The more the quality of sleep improved, the higher the scores became.

The experiment was conducted from May to July and October to December in 1992, 1993 and 1994. Each subject slept in an experimental room and was exposed to truck noise. Twelve non-consecutive nights for each subject were recorded. If the complete series of measurements had been made, 144 sets of data (12 subjects × 12 nights each) would have been obtained. However, owing to 48 polygraphic measurement failures, only 96 sets of data could be used for the analysis. Background noise in the experimental room was L_{eq} 30 dB(A).

The noise used was recorded passing truck noise having a duration of 20 s (see Figure 1). Four peak levels were prepared from the master tape by turning down the volume to 45, 50, 55 and 60 dB(A), and the subject was exposed to 20 s noise recordings every 15 min at "random" peak volumes by using an integrated amplifier (Model AU-D707X, Sansui Co, Ltd., Tokyo) (see Figure 2). The same "random" volume sequence was repeated across all subjects. Speakers were positioned 1·5 m from the subjects.

Simple regression analysis was conducted as a statistical procedure by NAP [13].

3. RESULTS

Pearson's moment correlation coefficients (CC), the gradient and intercept of a simple regression analysis of each sleep parameter for each night, are listed in Table 1. There were

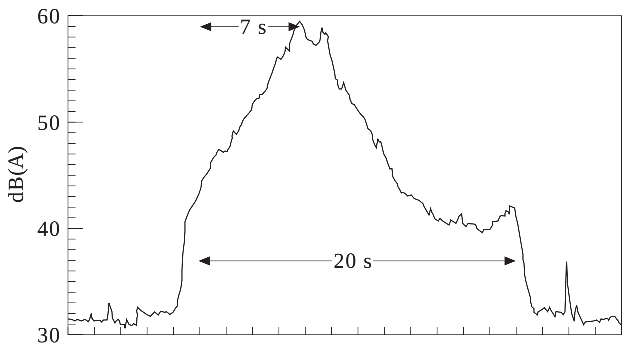

Figure 1. Time record of sound levels of passing truck noise with a duration of 20 s. Peak sound levels were turned down to 45, 50, 55 and 60 dB(A).

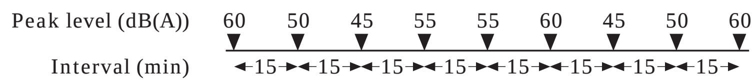

Figure 2. Time schedule of noise exposure. Exposure was repeated at 15 min intervals throughout the night.

significant reductions in sleep stage 1 ($p < 0{\cdot}01$), MT ($p < 0{\cdot}05$), frequency of awakening ($p < 0{\cdot}01$) and number of stage shifts per night ($p < 0{\cdot}01$). There were no significant changes in other sleep parameters, including F1, F2, F3, F4, F5, RT, SP1, SP2, sleep stages (S) 2, S3 + S4, SR, SL, RL, TST, TW, EFFIC, RD, RC.

The CC of SHIFT was the highest ($-0{\cdot}469$) of the four significant parameters, and the regression equation was SHIFT $= -4{\cdot}8536 \times$ Night $+ 206{\cdot}8$ (Figure 3).

4. DISCUSSION

Habituation means becoming less sensitive to noise. Only Stage 1, MT, frequency of awakening and number of stage shifts among the 22 sleep parameters showed significant decreases in the later days of exposure. The decreases in S1 and frequency of awakening

TABLE 1

Pearson's moment correlation coefficient (CC) *between each sleep parameter and the number of nights*; *gradient and intercept were described when* CC *is significant*

F1	F2	F3	F4	F5	RT	SP1	SP2	S1	S2	S3 + S4
−0·102	0·105	−0·004	−0·023	0·002	−0·126	−0·072	−0·078	−0·273‡	−0·004	−0·176

SR	MT	SL	RL	TST	TW	FW	EFFIC	SHIFT	RD	RC
0·073	−0·227†	0·197	−0·158	−0·166	0·049	−0·299‡	−0·181	−0·469‡	0·103	0·053

S1 $= -1{\cdot}0532 \times$ Night $+ 36{\cdot}335$, MT $= -0{\cdot}2841 \times$ Night $+ 13{\cdot}815$, FW $= -0{\cdot}1511 \times$ Night $+ 2{\cdot}053$, SHIFT $= -4{\cdot}8536 \times$ Night $+ 206{\cdot}8$.

Note. F1 to F5 are five factors of OSA, sleepiness, sleep maintenance, worry, integrated sleep feeling and sleep initiation; RT, the value calculated by the formula: reaction time before sleep minus reaction time the next morning; SP1, total number of sleep spindles; SP2, spindle density per minute; S1-4, stages 1–4 in minutes; SR, stage REM in minutes; MT, movement time in minutes; SL, sleep latency; RL, REM latency; TST, total sleep time; TW, Awakenings in minutes; FW, Frequency of awakening; EFFIC, sleep efficiency (%); SHIFT, number of stage shifts per night; RD, REM duration in minutes; RC, REM cycles in minutes.

† $p < 0{\cdot}05$; ‡ $p < 0{\cdot}01$.

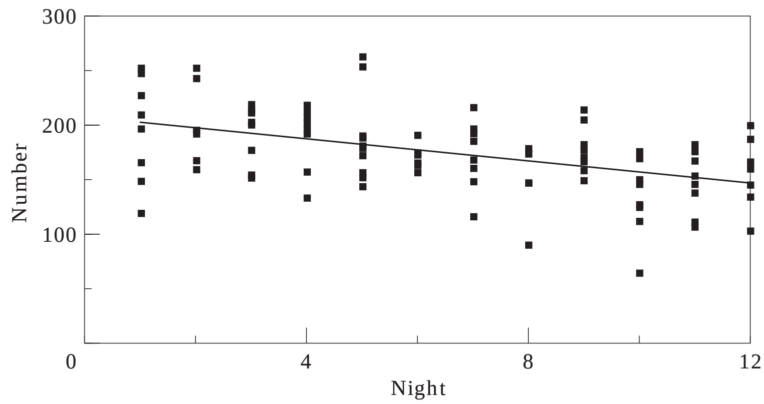

Figure 3. Changes in stage shifts per night based on repeated measurements. $y = -4{\cdot}8536x + 206{\cdot}8$; $R^2 = 0{\cdot}2202$.

indicate evidence of relative increases in deep sleep, which may be indirectly related to the decrease in MT or stage shift.

Thiessen reported habituation in awakenings in the case of transient noise exposure, but no habituation of stage shifts [14–16]. His study was conducted to detect the percentage of reaction immediately after noise exposure. He defined that percentage stage shift as the percentage of a sleep stage that became shallower. Percentage of time awake and percentage stage shift linearly decreased, but the gradient of percentage of time awake was steeper than the percentage stage shift. The authors previously analyzed percentage of Stage 2 epochs that became shallower, and no significant habituation to noise was found [17]. Öhrström and Björkman reported adverse effects, though not significant, based on repeated measurement of tiredness and a performance test (reaction time) [5].

Twenty minutes uninterrupted by disturbance is required for good quality sleep [18]. In this study, the subjects were exposed to peak noise every 15 minutes, an interval that was probably inadequate for restoration of sleep. The regularity of the interval and duration of noise exposure, and the constant nature of the noise, i.e., passing truck noise, may have contributed to the habituation of sleep to noise.

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