ERGONOMICS, 1978, VOL. 21, NO. 5, 325–330

Sleep at Home and in the Sleep Laboratory: Disturbance by Recording Procedures

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Nineteen healthy men, aged 20 to 55 yr, who did not suffer from insomnia had their sleep recorded by EEG and EOG in the laboratory for 3 to 12 nights each over periods of 1 to 4 weeks. They also gave subjective reports each day which proved to be valid although not always very accurate assessments of their sleep latency, the number of mid-night awakenings and the times of sleeping in the laboratory. There was some ' adaptation ' to the laboratory over the first 2 nights, but awakenings during the night continued for up to 12 nights to be reported more than twice as frequently in the laboratory than at home. They were apparently often caused by intermittent traction of electrodes on the face and scalp as the subjects turned over in bed From the point of view of mid-night awakenings, EEG/EOG recordings are unlikely to give an accurate assessment of the subject's usual sleep, even after several ' adaptation ' nights.

1. Introduction

In recent years, all-night electroencephalographic (EEG) studies have contributed greatly to our knowledge of sleep and wakefulness. Although it is widely recognized that sleep is often disturbed on the first night in the laboratory (Agnew *et al.* 1966), and sometimes also on the second night (*e.g.* Březinová and Oswald 1972), it is commonly believed that on subsequent nights most subjects will have ' adapted ' to the laboratory and will sleep as well as they usually do at home. Kales *et al.* (1973) compared sleep recorded objectively at home with that recorded from the same subjects in the laboratory and concluded that the laboratory did not continually disturb sleep. However, the implicit assumption has been made in previous investigations that, after the first few nights, the attachment of electrodes to the subjects does not affect their sleep in any situation. Were such disturbance to occur often it would be a distinct disadvantage with the recording procedures which are now widely used.

The present investigation was concerned with recording sleep by EEG for 3 to 12 nights in normal subjects as they ' adapted ' to the sleep laboratory, and also testing the validity and accuracy of their subjective reports about sleep in the laboratory. In the final phase of the investigation, comparisons were made between these subjective reports and those made at other times by the same subjects at home. We sought evidence, therefore, on whether or not sleep was often disturbed by the recording procedures, even after several nights in the laboratory.

2. Method

The experimental subjects were 19 healthy male volunteers aged 20 to 55 yr, who did not suffer from insomnia and who were not taking any medication. They were told that they were involved in experiments to define normal variations in sleep habits and their physiological correlates. The responses of all subjects to the Cornell Medical Index health questionnaire were within normal limits.

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Fifteen of the subjects, aged 20–22 yr, slept for three consecutive nights in the sleep laboratory. The remaining four subjects (aged 24, 43, 52 and 55 yr) slept for 12 nights each over periods of three or four weeks; that is, for three or four week-nights in the laboratory each week. The subjects each slept without purposeful disturbance, in separate bedrooms which were warm and sound-attenuating. All-night recordings were made of the EEG (C_4-A_1 electrode positions), electrooculogram (EOG) recorded from electrodes at the outer canthus of each eye and either the ECG (two chest leads) or the electrical resistance of palmar skin using electrodes on the tips of the index and middle fingers of one hand (Johns 1971). Standard EEG electrodes (chloride-coated silver, 9 mm diameter) were attached to the scalp by collodion, and to the other sites by adhesive tape. There was a bundle of flexible wires approximately 1 m long between the subject's head and a multipin-connector at the head of the bed. The times of beginning and ending the recordings were varied to suit each subject's daily routine which was interferred with as little as possible. Sleep latency was measured in minutes from lights-out to the first appearance of spindles in the EEG of stage 2 sleep.

Each morning in the laboratory after the subjects dressed, and without knowledge of any of the recorded results, they answered in writing a brief questionnaire about their night's sleep: how long it took them to fall asleep initially, at what time they had fallen asleep and had finally woken, how often they had awoken during the night, and what caused each awakening. They rated the overall quality of sleep on a 5-point scale (' very poor ' = 1, to ' very good ' = 5).

Subjects in the group of 15 were asked several weeks later to answer the same questionnaire on five consecutive weekdays when sleeping at home. The four subjects who were studied for longer periods each gave 8 to 11 of such daily reports about their sleep at home during the week before first sleeping in the laboratory and during the ensuing month.

The results were analysed by *two-way analysis of variance* (differences between nights, allowing for differences between subjects) by *Wilcoxon's matched-pairs signed-ranks test* (with the correction for ties), *Spearman's rank correlation* and *chi-squared tests*. Geometric means were calculated for sleep latencies, which had been log-transformed, instead of the arithmetic mean used for the other variables.

3. Results

3.1. *Sleep in the Laboratory*

There were objective differences between the sleep on successive nights in the laboratory which suggested that some adaptation to the novelty of the recording situation did occur (Table 1). The objective sleep latency decreased significantly from the first to the second night ($p < 0{\cdot}01$), and was shorter again on the third night ($p < 0{\cdot}05$). It did not change significantly after the third night in the four subjects studied for 12 nights each. As with the objective latencies, those reported subjectively also decreased significantly up until the third night ($p < 0{\cdot}01$), but not thereafter.

The times of falling asleep initially and of finally waking did not differ significantly on successive nights, although the latest times for each subject tended to be on the first night. The subjective quality of sleep improved over the first three nights ($p < 0{\cdot}05$), but subsequently did not improve further.

Awakenings recorded objectively during the night were more frequent, although not significantly so, on the first night than on either the second or third nights. Thereafter they occurred with about the same frequency each night until the end of

Table 1. The objective and subjective characteristics of sleep in the laboratory (*a*) for three nights each in 19 subjects, and (*b*) for longer periods in four of the subjects, with the corresponding subjective reports about sleep at home.

	(*a*) 19 subjects				(*b*) 4 subjects		
	Nights in laboratory			Nights at home	Nights in laboratory		Nights at home
	1st	2nd	3rd		4–7th	8–12th	
Sleep latency (min)—objective	16·7	15·5	12·5	—	10·0	13·9	—
—subjective	23·6	16·2	11·3	10·6	11·4	11·7	7·8
Time of falling asleep initially							
—objective	0020	0006	0005	—	2348	2343	—
—subjective	0023	0006	0001	0018	2348	2344	2354
Time of finally waking—objective	0739	0739	0740	—	0658	0702	—
—subjective	0733	0735	0732	0742	0658	0654	0656
Quality of sleep (5 = very good: 1 = very poor)	3·3	3·8	4·0	3·9	3·6	3·8	4·1
No. of awakenings per night							
—objective	5·6	4·1	4·8	—	6·1	6·9	—
—subjective	1·8	1·5	1·2	0·5	1·4	1·5	0·6
No. of subject-nights without reported awakenings	2	5	7	67	3	2	20
No. of subject-nights with 1 reported awakenings	9	5	6	32	6	9	13
No. of subject-nights with 2+ reported awakenings	8	9	6	12	7	9	3

the experiment. There were similar trends in the number of awakenings reported subjectively, although fewer awakenings were reported each night than were recorded objectively (see below). With each of the variables there was considerable variation within subjects which did not follow the general trends.

3.2. *Validity of Subjective Reports*

Comparisons between the corresponding subjective and objective variables for sleep in the laboratory are summarized in Table 2. The objective and subjective sleep latencies (both measured on a log scale) were highly correlated and differed only by an insignificant amount from one another: similarly with the times of falling asleep at night. The reported times of finally waking were, on average, about 6 min earlier than those measured objectively, although the two variables were highly correlated.

The number of awakenings reported subjectively each night was significantly correlated with, although less than, the total number recorded objectively (Table 2). Fewer awakenings were remembered than were recorded, of at least 2 min duration, although more were reported than were recorded of 8 min or longer. The closest

Table 2. Comparisons between the objectively measured and subjectively reported characteristics of sleep in the laboratory on 91 nights for 19 subjects.

	Measured objectively	Reported subjectively	Correlation ρ	p*	Mean difference ± S.D. of differences	p*
Sleep latency (min)	13·5	14·1	0·66	<0·001	1·0 ± 1·9	>0·8
Time of falling asleep initially	2401	2400	0·88	<0·001	0·0 ± 15 (min)	>0·8
Time of finally waking	0724	0718	0·88	<0·001	5·8 ± 18 (min)	<0·05
Total no. of awakenings/nights	5·5	1·5	0·30	<0·005	4·0 ± 3·7	<0·001
No. of awakenings of 2+ min	2·8	(1·5)	0·30	<0·005	1·3 ± 2·3	<0·001
No. of awakenings of 4+ min	1·7	(1·5)	0·22	<0·05	0·3 ± 1·9	>0·2
No. of awakenings of 8+ min	0·8	(1·5)	0·33	<0·005	0·7 ± 1·4	<0·001

* degrees of freedom = 89. *Spearman's Rank Correlation or Wilcoxon's match-pairs signed-ranks test.*

relationship was between reported awakenings and those recorded of at least 4 min duration.

With the proviso that awakenings during the night which lasted less than 4 min each were unlikely to be remembered next day, the results suggest that the various subjective reports were valid, although not always very accurate assessments of sleep for the subjects of this experiment.

3.3. *Sleep at Home and in the Laboratory Compared*

Comparisons could be made only on the basis of the subjects' reports (Table 1) which we assumed were as accurate at home as they had proved to be in the laboratory.

The subjective sleep latency was significantly prolonged for the first two nights in the laboratory and thereafter was the same as the mean latency at home. The mean times of falling asleep and of finally waking were similar in the two situations. In the laboratory, the subjective quality of sleep was poorer on the first night than at home ($p < 0{\cdot}05$), and subsequently it approached but did not always reach the subjects' usual quality of sleep.

It was in the frequency of reported awakenings that sleep in the laboratory differed most from that at home. After apparently adapting to the laboratory over the first two nights, seven of the 19 subjects (37%) did not remember waking on the third night, while six subjects (32%) reported waking at least twice. However, 60% of their nights at home were without awakenings and only 9% involved two or more awakenings (χ^2 test, $p < 0{\cdot}05$). Even after three weeks in the laboratory, sleep was more fragmented subjectively than it usually was at home ($p < 0{\cdot}01$), a difference which was present in each subject. The mean duration of reported awakenings at home was the same as that in the laboratory (9 min), but the causes for the awakenings were different (Table 3).

Table 3. The frequency of awakenings during the night attributed to different causes, per 100 nights' sleep at home and in the laboratory for 19 subjects.

	No. of awakenings:	
Cause of awakening	At home	In laboratory
Recording wires	—	13
Unidentified influences	14	70
To void urine	15	39
Noise	12	10
Feeling too cold	6	3
Generally uncomfortable	2	7
Dreams	4	7
Light shining on face	1	0

The presence of the recording electrodes and wires was reported by eight of the 19 subjects to be a cause of their waking during the night. Other awakenings which occurred for ' unknown ' reasons were more common, absolutely and in relation to other disturbing influences, in the laboratory than at home. The reverse was true of awakenings due to noise and the environmental temperature.

4. Discussion

The results suggest that many normal subjects adapt only partially to the EEG/EOG recording procedures which are commonly used in the study of sleep and wakefulness. Most, but not all of the present subjects showed the so-called ' first-night effect ' (Agnew *et al.* 1966): they took longer to fall asleep and awoke more frequently on the first night than on the second. However, this effect was also present to some extent on the second night, as other investigators have found. Psychiatric patients have been reported to take longer than healthy subjects to ' adapt ' to the sleep laboratory (Mendels and Hawkins 1967), although psychiatric illness among the subjects cannot be invoked to explain the present results.

The evidence that the subjects' sleep in the laboratory continued to be disturbed to some extent after the second night and for up to 12 nights, in relation to their usual sleep at home, depends on the validity of their subjective reports. Such reports about the times of sleeping, the sleep latency and the number of awakenings during the night were all shown to be valid for the present subjects' sleep in the laboratory, although their accuracy was not the same for all questions and was higher for sleep latency than for the frequency of awakenings. The validity, reliability and accuracy of subjective reports of sleep latency have previously been discussed in more detail for a larger group of normal subjects of which the present subjects formed a part (Johns 1976). The finding that awakenings of less than 4 min duration are usually not remembered next day is in accord with the results reported by Baekeland and Hoy (1971).

After two ' adaptation ' nights in the laboratory, the present subjects continued to report more than twice as many awakenings as they did at home, and this difference continued for up to four weeks. If the subjects exaggerated the number of awakenings in the laboratory for some reason, then they did not also exaggerate their sleep latency which, by the third night, was the same as that at home. There was no evidence from the reported duration of awakenings that those in the laboratory were simply more prolonged and therefore remembered more frequently. The subjects' reports about what caused the awakenings could not be checked and if, after waking spontaneously, a subject felt a wire near his face, he might mistakenly claim later that it had woken him. Nevertheless, this would not explain the increased total number of awakenings. Nor could the difference be explained by the times of sleeping which were similar at home and in the laboratory. Noise and the environmental temperature were less of a disturbance to sleep in the laboratory than at home and there were no complaints about the beds being uncomfortable.

The results suggest that the attachment of electrodes and wires was a continuing disturbance of sleep in the laboratory and, therefore, that the recordings did not provide an accurate assessment of the subjects' usual sleep. Despite some adaptation to the laboratory and to being investigated, subjects probably do not readily adapt to intermittent traction by electrodes on their face and scalp as they move in bed during the night. Simply to record their sleep at home, whether by telemetry or otherwise, would presumably not overcome this problem. Other laboratories often use more electrodes than we did and, hence, might expect at least as much disturbance to sleep.

The validity and accuracy of EEG/EOG recordings of sleep has not been challenged previously, although their relatively low reliability in terms of the relationship between measurements on successive nights in the same subject has been pointed out (Clausen *et al.* 1974) and the usual interpretation of objectively measured sleep latencies has been questioned in some cases (Johns 1976). The frequency of awakenings is an important characteristic of a night's sleep (Johnson 1973, Johns 1975). That this frequency should be increased by the recording procedures, even after several nights in the laboratory, would sometimes be a serious disadvantage with such methods, although not necessarily interfering with comparisons between ' treatment ' nights, as in hypnotic drug trials.

The present results serve to emphasise that, despite their relative inaccuracy, subject reports are valid, at least for normal subjects, and have an important part to play in the investigation of sleep and wakefulness. They should supplement EEG/EOG recordings in the laboratory and can be used for surveys of sleep habits among groups of subjects in the community (Johns *et al.* 1971).

Dix-neuf sujets de sexe masculin, âgés entre 20 et 55 ans et ne présentant pas de troubles insomniaques ont dormi au laboratoire pendant 3 à 12 nuits étalées chacune sur des périodes de 1 à 4 semaines. Leurs EEG et EOG de sommeil ont été enregistrés. Ces sujets fournissaient également, chaque jour, leurs appréciations subjectives concernant leur latence d'endormissement, leur nombre d'éveils et leur durée de sommeil en laboratoire. Ces appréciations se sont avérées valides, quoique pas toujours très précises. Pendant les deux premières nuits, il y a eu une ' adaptation ' aux conditions de laboratoire, mais pendant une période allant jusqu'à 12 nuits, les sujets faisaient état d'éveils spontanés durant la nuit allant jusqu'à une fréquence double de celle qu'ils auraient eu à la maison. Apparemment ces réveils étaient dus aux tractions intermittentes des électrodes sur la face et sur le scalp lorsque les sujets se retournaient dans leur lit.

En égard aux réveils nocturnes, les enregistrements EEG et EOG ne semblent pas pouvoir fournir une évaluation précise du sommeil habituel des sujets, même après plusieurs nuits d'adaptation.

Neunzehn gesunde Männer im Alter zwischen 20 und 44 Jahren, die nicht unter Schlaflosigkeit litten, wurden für die Dauer von 3 bis 12 Nächten über eine Zeitspanne von 1 bis 4 Wochen bezüglich ihres EEG- und EOG-Verhaltens im Schlaf untersucht. Gleichzeitig machten die Versuchspersonen subjektive Angaben zu ihrer Schlaftiefe, der Anzahl nächtlicher Aufwachereignisse und der Zeitdauer des Schlafs im Laboratorium. In den ersten beiden Nächten zeigten sich Adaptationserscheinungen an den Laboratoriumsschlaf, jedoch war die Anzahl der Aufwachereignisse in den nachfolgenden bis zu 12 Nächten mehrs als doppelt so häufig im Laboratoriumsschlaf als im Schlaf zu Hause. Sie wurden öfter dadurch verursacht, daß infolge von Körperbewegungen im Bett die Elektroden im Gesicht und auf der Kopfhaut auseinandergezogen wurden. Bezogen auf die nächtlichen Aufwachereignisse sind EEG- und EOG-Ableitungen nicht gleichwertig, um eine genaue Einschätzung des gewöhnlichen Schlafs der Versuchspersonen zu geben, selbst nach einigen Adaptationsnächten.

References

AGNEW, H. W. Jr., WEBB, W. B., and WILLIAMS, R. L., 1966, The first night effect: an EEG study of sleep. *Psychophysiology*, **2**, 263–266.

BAEKELAND, F., and HOY, P., 1971, Reported vs. recorded sleep characteristics. *Archives of General Psychiatry*, **24**, 548–551.

BŘEZINOVÁ, V., and OSWALD, I., 1972, Sleep after a bedtime beverage. *British Medical Journal*, **2**, 431–433.

CLAUSEN, J., SERSEN, E., and LIDSKY, A., 1974, Variability of sleep measures in normal subjects. *Psychophysiology*, **11**, 509–516.

KALES, A., BIXLER, E. O., and SCHARF, M. B., 1973, A comparison of home telemetry and sleep laboratory recordings with insomniac patients. *Sleep Research*, **2**, 178.

JOHNS, M. W., 1971, Methods for assessing human sleep. *Archives of Internal Medicine*, **127**, 484–492.

JOHNS, M. W., 1975, Factor analysis of objective and subjective characteristics of a night's sleep. *Psychological Medicine*, **5**, 413–418.

JOHNS, M. W., 1976, Validity of subjective reports of sleep latency in normal subjects. *Ergonomics* (In press).

JOHNS, M. W., GAY, T. J. A., GOODYEAR, M. D. E., and MASTERTON, J. P., 1971, Sleep habits of healthy young adults: use of a sleep questionnaire. *British Journal of Preventive and Social Medicine*, **25**, 236–241.

JOHNSON, L. C., 1973, Are stages of sleep related to waking behaviour? *American Scientist*, **61**, 326–338.

MENDELS, J., and HAWKINS, D. R., 1967, Sleep laboratory adaptation in normal subjects and depressed patients (' First night effect '). *Electroencephalography and Clinical Neurophysiology*, **22**, 556–558.

Manuscript received 29 September 1976.