

Changes in EEG Power Density During Sleep Laboratory Adaptation

*Michel Toussaint, *Rémy Luthringer, *Nicolas Schaltenbrand, *Alain Nicolas, *Anne Jacqmin,
*Gabriella Carelli, †Julien Gresser, ‡Alain Muzet and *Jean-Paul Macher

**Foundation for Applied Neuroscience Research in Psychiatry, Centre Hospitalier, Rouffach, France;*
†*Laboratoire TROP, Université de Haute-Alsace, Mulhouse, France; and*
‡*Laboratoire de Physiologie et de Psychologie Environnementales, CNRS, Strasbourg, France*

Summary: First- and second-night effects on the electroencephalogram (EEG) were investigated by means of polygraphic sleep recordings and all-night spectral analysis. Eighteen normal subjects were studied for three consecutive nights in a hospital sleep laboratory. Visual sleep scoring showed that there was a first-night effect in normal subjects similar to that reported previously [increased wakefulness; decreased total sleep time, sleep efficiency, and rapid eye movement (REM) sleep].

Spectral analysis of the sleep EEG revealed important changes, most of which occurred in REM sleep. Increased delta, theta, and beta1 power densities accompanied by decreased mean frequency were seen in REM sleep in the second night. On the basis of REM sleep deprivation results previously published, our data suggest that the second night could be affected by partial REM sleep deprivation that occurred in the first night. Delta and theta power density values decreased in the first non-rapid eye movement episode of nights 1 and 2; this could result from increased REM sleep pressure. The overall consistency of spectral data in the first and second night with REM sleep findings derived from visual scoring in the first night lends further support to this hypothesis.

The sleep disturbance experienced during the first night in a sleep laboratory may be a useful and valid model of transient insomnia. Therefore, we conclude that data from all nights recorded should be included in assessing a subject's sleep. **Key Words:** First-night effect—Sleep—Polysomnography—EEG—Spectral analysis.

The first-night effect is a well-known phenomenon in sleep recordings, especially those carried out in sleep laboratories. That is why it has become a common practice to make several consecutive recordings and to exclude the first night of sleep from the analysis. So far, most of the studies have been performed in normal subjects (1-8), and results were based on classical sleep variables calculated from visual sleep stage scoring.

The first-night effect in normal subjects is mainly characterized by a lower sleep efficiency, increased wakefulness, and longer rapid eye movement (REM) sleep latency, plus a reduction of the amount of REM sleep (1-8). The major factors thought to account for this effect are the unfamiliar surroundings of a sleep laboratory (9,10) and the ability of the subjects to adapt to the instrumentation, namely the electrodes (11). Therefore, some authors hypothesized that the

second and perhaps also the third nights reflect a sleep pattern resulting from partial sleep deprivation caused by the first-night recording (3,8).

While visual sleep scoring is useful for characterization of sleep architecture and continuity, it is insufficient for more refined, quantitative analysis of sleep electroencephalogram (EEG) (12). All-night spectral analysis of the sleep EEG provides quantitative information on the continuously fluctuating patterns of the EEG during sleep (13-15). Many studies in sleep research now use spectral analysis, but to our knowledge none has evaluated the first-night effect. For these reasons, we have evaluated the first-night effect on sleep EEG spectral data in normal subjects.

METHODS

Subjects

Eighteen healthy volunteers (13 males, 5 females) ranging from 20 to 36 years of age (mean \pm SD, 25.8 \pm 5.2 years) coming to the sleep laboratory for the very first time were included in this study. The data

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Address correspondence and reprint requests to Michel Toussaint, Ph.D., Foundation for Applied Neuroscience Research in Psychiatry (FORENAP), Centre Hospitalier—Secteur 8, 68250 Rouffach, France.

used were taken from different pharmacological sleep studies performed in the laboratory in baseline condition.

All volunteers underwent laboratory tests, drug screening for psychoactive substances, and a psychological examination before final inclusion in the study. None admitted to abnormal sleep patterns. They were requested not to take any medication during the month prior to the study and were not allowed to take any drug or to drink alcohol during the entire duration of the study. They were also asked to refrain from excessive caffeine consumption throughout the study. Written informed consent was obtained, and the study was performed in accordance with French law and with guidelines for the conduct of clinical trials drawn up by the World Medical Assembly (Helsinki, Tokyo, Venice, and Hong Kong).

Polysomnograms were recorded on the first three consecutive nights. Each subject reported to the laboratory about 1 hour before bedtime and slept in an individual sound-attenuated and comfortably furnished bedroom. Lights-out was at 10 p.m. To prevent daytime sleep and to have an homogeneous diurnal activity for all subjects, participants were requested to remain in the hospital during the entire duration of the study and were placed under the supervision of the nursing staff.

Signal recordings and digitization

Two EEG derivations (C3-A2 or C4-A1 and Cz-O1 or CZ-O2), one chin electromyographic (EMG) derivation, and one electrooculographic (EOG) derivation (left vs. right outer eye canthus) were recorded during sleep. Analogue amplifiers situated in the subject room were used for signal amplification and filtering (Bessel type, order 2) with the following cut-off frequencies: 0.5–30 Hz for the EEG, 0.5–15 Hz for the EOG, and 5–70 Hz for the EMG. A 50-Hz notch filter (–30 dB) was used to attenuate electrical noise. Amplified and filtered analogue signals (EEG, EOG, and EMG) were transmitted via cables to a central analysis area, digitized at 128 Hz (12-bit resolution), and stored on a Unix-based workstation.

This computerized sleep recording system has been described in a previous publication (16). It is designed around a classical Unix workstation (68040 processor—32 Mbyte RAM, TELMAT, Soutz, France) with high graphic capabilities (19-inch color XWindow terminal with $1,248 \times 1,024$ resolution, NCD, Mountain View, CA), 1.3 Gbyte hard disk, 5 Gbyte DAT backup, and local network connection. It incorporates a high performance analog-to-digital (AD) and digital signal processing (DSP) card based on a transputer in order to record and process simultaneously in real time up

to 32 electrophysiological signals. EEG spectral results can be obtained continuously during acquisition or immediately after the recording. During the recording, the signals are displayed continuously on the monitor just like on a polygraph.

Sleep scoring and sleep variable definition

Sleep stages were scored visually in 30-second epochs from the recording, according to Rechtschaffen and Kales criteria (17), directly from the monitor (16). Movement time epochs were not scored separately but were included in the wake stage. Interexpert agreement (two scorers), estimated in the laboratory on an epoch-by-epoch basis, averaged 87.5% (18).

All-night summary variables were derived from the visual scoring of recordings using standard criteria and were divided into two groups: sleep continuity indices and sleep architecture indices. Sleep continuity indices included total sleep time, sleep efficiency in percent (total sleep time/total recording period \times 100), sleep onset latency (SL) (time from lights-out to the first occurrence of a stage 2 epoch), and REM sleep latency (REM SL) (time from sleep onset to the first epoch of stage REM). Sleep architecture indices included duration and percentage of time spent asleep in the different stages of sleep (i.e. REM, stage 1, stage 2, and slow-wave sleep, i.e. the sum of sleep stages 3 and 4). Non-rapid eye movement (NREM) sleep (i.e. the sum of sleep stages 2, 3, and 4) was also calculated.

Power spectral analysis

For each subject, one EEG derivation (Cz-O1 or Cz-O2) was selected to determine the power spectra. The spectral analysis was performed by the fast Fourier transform (FFT) algorithm. The epoch length was 2 seconds (256 points), and truncating error was reduced by applying a Hanning window. In addition, the values for 15 adjacent 2-second epochs were averaged to yield power density values for 30-second periods. Thus, sleep visual scores of each 30-second epoch were synchronized with power density values. The values of adjacent 0.5-Hz frequency bins were collapsed into delta (0.5–3.5 Hz), theta (4–7.5 Hz), alpha (8–12.5 Hz), beta1 (13–21.5 Hz), and beta2 (22–30 Hz) frequency bands. Spectral data standardization and synchronization over individual nights were completed according to the method described by Borbély and colleagues (13–15,19). To standardize the values of different individuals, power density data from 30-second epochs were expressed in each frequency band (i.e. delta, theta, alpha, beta1, or beta2) as the percentage of the mean value of all NREM epochs (i.e. stages 2

TABLE 1. Sleep parameters (mean and standard deviation) obtained for three consecutive nights in a group of 18 healthy volunteers

Sleep parameters	Controls (n = 18)						Night 1 vs. night 2	Night 2 vs. night 3
	Night 1		Night 2		Night 3			
	Mean	SD	Mean	SD	Mean	SD	p ^a	p
Total sleep time (min)	415.0	43.4	430.7	36.5	431.4	39.0	ns ^d	ns
Sleep efficiency (%)	85.8	6.9	90.5	4.5	89.8	5.2	<0.01	ns
Sleep onset latency (min)	25.9	21.9	21.5	18.1	21.4	17.8	ns	ns
REM sleep latency (min)	85.9	43.3	79.4	33.8	73.3	25.8	ns	ns
Wake (min)	66.5	32.3	44.4	20.9	47.4	25.3	<0.01	ns
Wake after sleep onset (min)	43.2	22.6	26.3	10.7	29.2	18.6	<0.01	ns
Stage 1 (min)	15.1	12.4	19.3	8.6	15.3	12.4	ns	ns
Stage 2 (min)	225.5	34.7	226.6	42.3	211.0	34.5	ns	ns
SWS ^b (min)	92.8	27.5	89.8	21.9	106.2	30.5	ns	ns
NREM ^c (min)	318.2	38.1	316.4	38.4	317.2	37.0	ns	ns
REM (min)	81.6	27.1	95.0	20.2	98.9	20.0	ns	ns
Wake (%)	16.9	9.4	10.6	5.7	11.4	6.9	<0.01	ns
Stage 1 (%)	3.8	3.3	4.5	2.1	3.6	2.8	ns	ns
Stage 2 (%)	54.6	8.4	52.4	7.2	48.9	7.0	ns	ns
SWS (%)	22.2	5.6	21.0	5.4	24.6	6.5	ns	ns
NREM (%)	76.8	5.8	73.4	5.2	73.5	4.7	<0.01	ns
REM (%)	19.5	5.9	22.1	4.5	23.0	4.2	ns	ns

SD, standard deviation; REM, rapid eye movement; SWS, slow-wave sleep; NREM, non-rapid eye movement.

^a p refers to two-tailed paired student *t* test after applying Holm's post hoc correction.

^b SWS = stages 3 + 4.

^c NREM = stages 2 + 3 + 4.

^d ns = not significant (> 0.05).

+ 3 + 4) within that frequency band, yielding relative values. Epochs of wakefulness or movement time were excluded from the analysis, as well as epochs in which the limit of the AD converter was reached (usually owing to movement artifacts). All 2-second epochs with artifacts were visually identified and excluded from further computations.

Finally, power density parameters were calculated within a specific period of time (e.g. NREM and REM sleep in the whole night or in NREM-REM sleep cycles). NREM-REM sleep cycles were defined according to established criteria (20) by the succession of an NREM sleep episode of at least 15 minutes' duration and an REM sleep episode of at least 5 minutes' duration.

Statistical analyses

Sleep stage parameters (Table 1) were compared according to the following two-step statistical analysis. First, to assess possible differences between the three nights across all subjects, we used a one-way analysis of variance (ANOVA) for repeated measures with each sleep parameter alternatively as factor, and time of sleep studies (night 1 vs. night 2 vs. night 3) as the repeated measure. Second, to evaluate the presence of a first-night effect, we used two-tailed paired student *t* tests to assess the significance of differences in polygraphic sleep parameters between night 1 and night 2 and between night 2 and night 3. Statistical signifi-

cance levels were adjusted (21) to account for multiple comparisons.

Relative power values were normalized by log transform, before statistical analysis using the same strategy as for the sleep parameters was applied. For the graphical display of the spectral data, geometric means and standard deviations of the relative values were plotted.

RESULTS

Sleep stage parameters

Table 1 lists the data and significant differences observed between nights 1 and 2 and between nights 2 and 3 on the various sleep parameters derived from visual scoring. All parameters showing significant differences ($p < 0.05$ after correction for multiple testing) between consecutive nights are included. On the first night, as compared to the second night, sleep efficiency was lower (85.8% vs. 90.5%; $p < 0.01$), wakefulness was increased (66.5 vs. 44.4 minutes at $p < 0.01$ and 16.9% of the total sleep time vs. 10.6% at $p < 0.01$), and so was wakefulness after sleep onset (43.2 vs. 26.3 minutes at $p < 0.01$). Total sleep time was decreased on the first night (415 minutes) as compared to the second (430.7 minutes) and third night (431.4 minutes), but these differences were not statistically significant.

NREM sleep percentage was increased on the first night compared to the second night (76.8 % vs.

73.4%; $p < 0.01$). However, this increase resulted from the total sleep time increase since NREM in minutes did not change over the three nights. REM SL was delayed on the first and second nights, but these changes were not significant because of the large standard deviation of the samples. REM sleep duration and percentage were lower during the first night (81.6 minutes; 19.5%) compared to both the second (95 minutes; 22.1%) and third night (98.9 minutes; 23%), but these differences were not significant. However, omitting the correction for multiple testing (21) on the basis of a descriptive data analysis procedure as proposed by Abt (22), a difference below the 0.05 significance level would be obtained for these latter REM measures.

No significant differences were found when comparing night 2 with night 3.

Averaged EEG spectral power of the first four NREM-REM cycles of the night

Mean spectral parameters of NREM and REM sleep for each of the first four NREM-REM cycles, calculated on nights 1, 2, and 3, are plotted relative to the corresponding all-night NREM mean value in Fig. 1. Alpha, beta1, and beta2 frequency bands are not shown in NREM sleep, nor is beta2 in REM sleep since no statistical differences were observed.

During NREM sleep, no statistical differences were found between nights 1 and 2. Power densities in the delta and theta bands were significantly lower in nights 1 and 2 compared to night 3. However, these differences were confined to the first cycle of the nights. In both delta and theta frequency bands, power density exhibited a clear decreasing trend from cycle 1 to 4 in the three nights.

During REM sleep, many more modifications were noticed, especially in the delta, theta, and beta1 bands. A similar pattern was observed in the three frequency bands, but did not always reach significance in each of the four cycles of the night. These changes were characterized by a decrease of the delta, theta, and beta1 power densities in night 1 as compared to night 2 in the first and second cycles. No significant modifications were observed between nights 2 and 3 in these two cycles. In the third and fourth cycles, delta power density value exhibited a significant increase in night 2 compared to both nights 1 and 3, whereas fewer consistent changes were observed in the theta and beta1 frequency bands, showing this pattern in the third cycle only. No significant changes in the latter frequency bands could be found between the three nights in the fourth cycle. In fact, significant modifications were present in the delta frequencies in all

REM cycles, and in the theta and beta1 frequencies for the second and third REM cycles.

To better assess these REM modifications, we calculated the average mean frequency of the 0.5–30-Hz spectrum over the entire REM period as well as in each of the four REM episodes of the three nights. While the mean frequency in REM sleep was comparable on nights 1 (4.81 ± 0.6 Hz) and 3 (4.77 ± 0.5 Hz), a significant decrease ($p < 0.01$; two-tailed paired student t tests) was present in the second night (4.1 ± 0.5 Hz) compared to both nights 1 and 3. The same results were obtained in the four REM episodes analysis. These data demonstrated a general slowing of the EEG activity in REM sleep of the second night.

Dynamics of EEG power density

To analyze the mean time course of the power density in each frequency band, each NREM episode was subdivided into 20 equal intervals (i.e. percentiles), and each REM episode was subdivided into five percentiles (15,19). For each percentile, the individual standardized mean power density was calculated and then averaged over subjects.

For statistical analysis of the changes in NREM episodes, three-factor repeated measures ANOVAs (23) using Greenhouse-Geisser (24) corrections for non-symmetry of compound, with factors "night" (N1, N2, N3), "NREM episode" (1 to 3) and "percentile" (1 to 20), were calculated on log-transformed values for each frequency band (delta, theta, alpha, and beta1). No significant effects of "night" were found in any frequency band (factor "night" NS, interaction "night" \times "NREM episode" NS, and "night" \times "percentile" NS), thus showing no first-night effect on NREM sleep EEG dynamics.

We analyzed REM episodes using the same method, but we replaced the second factor by "REM episode" (1–3) and the third factor by "percentile" (1–5). In contrast to NREM results, a "night" effect was obtained in all frequency bands (delta: $F(2,32) = 10$, $p = 0.0012$ and theta: $F(2,32) = 10.1$, $p = 0.0009$ for "night" and no interactions; alpha: $F(2,32) = 3.8$, $p = 0.04$ for "night" and $F(4,64) = 4.97$, $p = 0.008$ for "percentile" and no interactions; beta1: $F(2,32) = 5.43$, $p = 0.01$ for "night" and $F(2,32) = 5.17$, $p = 0.016$ for "REM episode" and no interactions). No significant effect on the intraepisodic dynamics of any activity was found (interaction "night" \times "percentile" NS). Modification of the time course between REM episodes was not present either (interaction "REM episode" \times "percentile" NS).

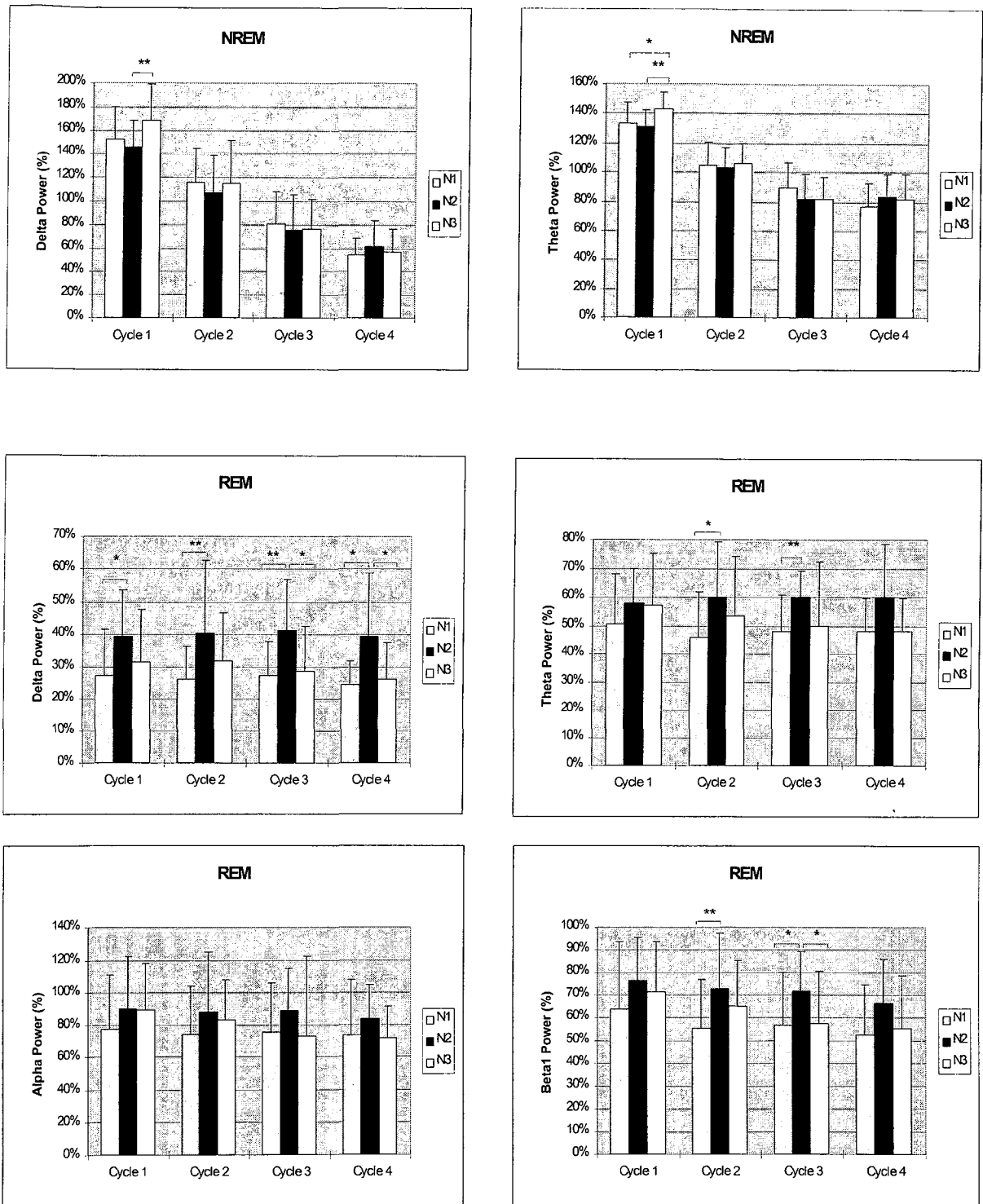


FIG. 1. Mean EEG power density of delta and theta in NREM (upper two panels) and delta, theta, alpha, and beta1 in REM sleep (lower four panels) plotted for the first four NREM-REM sleep cycles. The data represent geometric means ($n = 18$) and standard deviation. Before averaging over subjects, the value of each frequency band was expressed relative to the corresponding all-night NREM mean value. The frequency bands in which the values differed significantly between nights after applying Holm's post hoc correction are indicated over the values by one ($p < 0.05$) or two stars ($p < 0.01$; two-tailed paired student t test).

DISCUSSION

Our findings are consistent with previously published normative data (1,3,5,8) and confirm the presence of a first-night effect in laboratory recording of sleep, but they extend the adaptation effect beyond the first night for several sleep EEG spectral parameters. Based on parameters derived from visual scoring (Table 1), this effect was mostly characterized by increased wakefulness and decreased total sleep time and efficiency. Moreover, a clear trend toward REM sleep reduction in the first night was observed. Unlike previous studies, including a recent one from our group (1,3,5,8), REM SL increase did not reach statistical significance, but it seems likely that it would do so with a larger number of subjects. Therefore, these results support the conclusion reached in earlier studies (1-3,5,6,8) that an increased state of vigilance or arousal accounts for the first laboratory night effect. They also demonstrate REM sleep modifications that could be interpreted as a frequent tendency to miss the first REM period on the first night (1-3,5,8).

Whereas visual scoring of sleep failed to detect significant modifications in REM and NREM sleep in the second night, spectral analysis revealed a number of changes (Fig. 1). In REM sleep, EEG power densities in the delta, theta, and beta1 frequencies were significantly higher in night 2 than those in nights 1 and 3, while at the same time, the EEG mean frequency was significantly lower. These findings support the hypothesis that the depth of sleep is increased in the second night.

It is known that, after sleep deprivation, power densities during REM sleep are enhanced in the delta and theta frequency bands, as well as in the 12-15-Hz frequency range (14) in the first three cycles of the recovery night. Furthermore, it has been demonstrated (25) that the largest differences obtained in REM sleep are not found in the first REM episode but in subsequent cycles. The REM spectral pattern we observed in the second night showed these characteristics, assuming power density in the beta1 band to be close to the one in the 12-15-Hz frequency range. Therefore, the present results indicate that the increase of power density in REM sleep observed in night 2 is related to partial REM sleep deprivation in the first night. The REM sleep duration decrease observed in the first night further supports this hypothesis. It is also supported by previous studies on sleep stages (1-3,5,6,8), demonstrating that adaptation is completed for REM sleep by night 3 in normal subjects.

In NREM sleep, delta and theta power density values exhibited a significant decrease in the first NREM episode of nights 1 and 2 compared to night 3 (Fig. 1). This decrease might be caused by the effects of REM sleep pressure in the first and second nights.

These results concur with REM sleep deprivation findings (26,27) that demonstrated that the NREM power spectrum during an REM deprivation period was significantly lower than baseline for frequencies between 0.25 and 7 Hz (i.e. delta and theta frequencies). Therefore, the overall consistency of both REM and NREM spectral data with spectral results from REM sleep deprivation lends further support to our hypothesis.

To further investigate the dynamic of sleep, we evaluated the temporal variation, namely the time course of EEG power density parameters (i.e. delta, theta, alpha, and beta1) during sleep. Dynamics of each power density parameter across and within NREM episodes was similar in the three consecutive nights. Conversely, modifications were obtained in REM sleep, but these modifications could not be linked to a typical REM time course since no specific REM dynamics across and within REM episodes could be found. From this analysis, it can be concluded that the processes underlying the homeostatic aspect of sleep regulation are not modified by laboratory adaptation.

Finally, our findings validate the usual procedure of eliminating the first night of recording when studying subjects' basic sleep structures. In addition, the present study demonstrates that care should be taken when assessing the second night, which should be eliminated when investigating REM and NREM sleep by means of all-night spectral analysis. However, it should be mentioned that spectral data in REM sleep from first night could be used since no modifications were observed. Our results, in combination with other studies, concur with the conclusion of Coble et al. (4) and Browman and Cartwright (6) that sleep environment is a critical factor in the process of adaptation in normal subjects. A familiar setting (comfortable hotel-type laboratory and cordial staff) as already reported (4,6) is sufficient to reduce but not fully eliminate the first-night effect on sleep in normal adults. The sleep disturbance experienced during night adaptation in a sleep laboratory may be a useful and valid model of transient insomnia associated with an unfamiliar sleep environment (28). From this point of view, we agree with Wauquier et al. (10) that the first night effect is more than a mere laboratory artifact, and rather represents "the constitutional age-related functional adaptability of the CNS" (p. 10). It seems therefore reasonable that first-night data should not be discarded simply because of current practice, but could be used in subsequent analyses.

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REFERENCES

1. Agnew HW, Webb WB, Williams RL. The first night effect: an EEG study of sleep. *Psychophysiology* 1966;2:263-6.
2. Mendels J, Hawkins DR. Sleep laboratory adaptation in normal subjects and depressed patients ("first night effects"). *Electroencephalogr Clin Neurophysiol* 1967;22:556-8.
3. Schmidt HS, Kaelbling R. The differential laboratory adaptation of sleep parameters. *Biol Psychiatry* 1971;3:33-45.
4. Coble P, McPartland RJ, Silva WJ, Kupfer DJ. Is there a first night effect? (A revisit). *Biol Psychiatry* 1974;9:215-9.
5. Webb WB, Campbell SS. The first night effect revisited with age as a variable. *Waking Sleeping* 1979;3:319-24.
6. Browman CP, Cartwright RD. The first-night effect on sleep and dreams. *Biol Psychiatry* 1980;15:809-12.
7. Hoch CC, Reynolds CF III, Kupfer DJ, Berman SR. Stability of EEG sleep and sleep quality in healthy seniors. *Sleep* 1988; 11:521-7.
8. Toussaint M, Luthringer R, Schaltenbrand N, et al. First-night effect in normal subjects and psychiatric inpatients. *Sleep* 1995; 18:463-9.
9. Sharpley AL, Solomon RA, Cowen PJ. Evaluation of first night effect using ambulatory monitoring and automatic sleep stage analysis. *Sleep* 1988;11:273-6.
10. Wauquier A, Van Sweden B, Kerkhof GA, Kamphuisen HAC. Ambulatory first night sleep effect recording in the elderly. *Behav Brain Res* 1991;42:7-11.
11. Hilten JJ van, Braat EAM, Van der Velde EA, Middelkoop HAM, Kerkhof GA, Kamphuisen HAC. Ambulatory activity monitoring during sleep: an evaluation of internight and intra-subject variability in healthy persons aged 50-98 years. *Sleep* 1993;16:146-50.
12. Borbély AA. New techniques for the analysis of the human sleep-wake cycle. *Brain Dev* 1986;8:482-8.
13. Borbély AA, Baumann F, Brandeis D, Strauch I, Lehmann D. Sleep deprivation: effect on sleep stages and EEG power density in man. *Electroencephalogr Clin Neurophysiol* 1981;51:483-93.
14. Dijk DJ, Brunner DP, Borbély AA. Time course of EEG power density during long sleep in humans. *Am J Physiol* 1990;258: 650-61.
15. Aeschbach D, Borbély AA. All-night dynamics of the human sleep EEG. *J Sleep Res* 1993;2:70-81.
16. Toussaint M, Schaltenbrand N, Paiva T, et al. An architecture for EEG signal processing and interpretation during sleep (ES-PIS). *Comput Methods Programs Biomed* 1994;45:55-60.
17. Rechtschaffen A, Kales A. *A manual of standardized terminology, techniques and scoring system for sleep stages of human subjects*. Washington, DC: U.S. Government Printing Office, 1968.
18. Schaltenbrand N, Lengelle R, Toussaint M, et al. Sleep stage scoring: comparison between visual and automatic analysis in normal subjects and patients. *Sleep* 1996;19:26-35.
19. Achermann P, Dijk DJ, Brunner DP, Borbély AA. A model of human sleep homeostasis based on EEG slow-wave activity: quantitative comparison of data and simulations. *Brain Res Bull* 1993;31:97-113.
20. Feinberg I, Floyd TC. Systematic trends across the night in human sleep cycles. *Psychophysiology* 1979;16:283-91.
21. Holm S. A simple sequentially rejective multiple test procedure. *Scan J Statist* 1979;6:65-70.
22. Abt K. Descriptive data analysis: a concept between confirmatory and exploratory data analysis. *Methods Inf Med* 1987;26: 77-88.
23. SAS Institute, Inc. *SAS/STAT users guide*. version 6, 4th edition, vol. 1-2. Cary, NC: Statistical Analysis Systems Institute, Inc., 1989.
24. Greenhouse SW, Geisser S. On methods in the analysis of profile data. *Psychometrika* 1959;24:95-112.
25. Dijk DJ, Brunner DP, Borbély AA. EEG power density during recovery sleep in the morning. *Electroencephalogr Clin Neurophysiol* 1991;78:203-14.
26. Beersma DGM, Dijk DJ, Blok CGH, Everhardus I. REM sleep deprivation during 5 hours leads to an immediate REM sleep rebound and to non-REM sleep intensity. *Electroencephalogr Clin Neurophysiol* 1990;76:122-44.
27. Feinberg I, Baker T, Leder R, March JD. Response of delta (0-3 Hz) EEG and eye movement density to a night with 100 minutes of sleep. *Sleep* 1988;11:473-87.
28. Roehrs T, Vogel G, Sterling W, Roth T. Dose effects of temazepam in transient insomnia. *Arzneimittelforschung* 1990;40: 859-62.