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Human Sleep Patterns in Antarctica

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Summary: Eight volunteers wintering in a French coastal station in Antarctica underwent 156 polysomnographic night recordings. The subjects, selected for their usual good sleeping habits, were recorded on 17–21 nights throughout the wintering in sessions of 2 to 3 consecutive nights. A two-way analysis of variance showed that most of the subjects' sleep characteristics were not similar, leading the authors to study the individual time course of sleep variables. As the subjects slept in their own comfortable quarters, there was no "polar insomnia," no first night effect, nor any relationship between sleep pattern variations and climatic changes. In all subjects, delta sleep tended to increase throughout the wintering, whereas stages 1 and 2 decreased. No significant variation was seen in paradoxical sleep (PS), neither between subjects nor with time. PS latency was also within normal range, but it was bimodally distributed in subjects S1, S2, and S8. Some other sleep variables also varied in certain subjects. Such was the case for sleeping time, which decreased throughout the wintering period in subject S8, the least adapted individual. However, due to the limited number of subjects, no statistical attempt could be made to link individual differences in sleep patterns and adaptation to life in Antarctica.
Key Words: Antarctica—Isolated small groups—Paradoxical sleep latency—Psychological adaptation—Sleep.

Sleep disturbances are common in unusual environments (1). In early antarctic expeditions, "polar insomnia" was a frequent complaint. The "Big Eye" was qualified as epidemic by Taylor (2), who linked it to the polar night and homesickness. It is classically accompanied by headaches and light depression, with irritability and increased sensitivity to social or physical stimuli (3). In Antarctica, sleep studies were first conducted with questionnaires (4–7). Insomnia was found to be rare, but night sleep was light and frequently interrupted. Sleep latency was long, and people complained of daytime sleepiness. These alterations prevailed during winter and were attributed to the rigorous climate, polar night, or emotional and psychological reactions elicited by isolation (8).

Polysomnographic studies are more recent. Joern et al. (9) examined sleep in two subjects upon arrival at the South Pole (altitude 2,804 m). They lost delta sleep (stages 3 and 4), and the oldest (aged 50) even suffered from paradoxical sleep (PS) diminution with apneic episodes. Also at South Pole Station, four subjects (aged 23–32) were

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tested for long-term changes in their sleep patterns (10). The subjects were recorded before and after the antarctic sojourn, and four times in the field with three recording sessions during winter. Each session lasted 3 nights. Delta sleep disappeared in Antarctica, PS decreased, especially in winter, and sleep latency increased. In both studies, hypoxia due to altitude was held responsible for the observed sleep disturbances. Paterson (11) also found a decrease in delta sleep in 10 subjects wintering at the British antarctic coastal station of Halley Bay, but the author used pooled data from a total of 38 night recordings. Contrarily, Soviet studies failed to find sleep alterations in coastal stations, leading Bogolovskii (8) to state that polar insomnia is no longer found in the modern comfortable antarctic stations.

Our study deals with data obtained from 156 polysomnographic recordings in 8 subjects who wintered at the French antarctic coastal station of Dumont d'Urville (140°01′ east, 66°40′ south) during the 21st French Polar Expedition in Adélie Land. The results are examined in a descriptive manner.

METHODS

Of the 28 expedition members, 8 volunteers (mean age 29.6 ± 2.6 years) (Table 1) were chosen for their usual good sleeping habits. Their psychological adaptability to living in an isolated small group had been tested following their application for the expedition. The applicants were ranked in four classes (A, very good adaptability; B, good; C, mediocre; D, bad, not to be hired). In the field, individual adaptation was scrutinized constantly and ranked from A to D as above by the medical officer and the expedition chief (Table 1). As found by Crocq et al. (12,13), the results obtained in the field differed from what could have been expected from the selection prior to departure. Due to the inconsistency between predictions and the actual adaptation to field conditions, the subjects were numbered according to their adaptation to life in Antarctica: S1 was very well adapted; S8, poorly adapted.

TABLE 1. *Psychological adaptation of the 8 subjects (S1 to S8) over the wintering year*

	S1	S2	S3	S4	S5	S6	S7[a]	S8
Age (years)	35	25	28	31	45	25	25	23
Average adaptation level[b]	24.90 (A)	24.95 (A)	25.00 (A)	25.10 (A)	26.16 (B)	26.38 (B)	28.76 (C)	30.57 (D)
Monthly medical examination[b]	A	A	A	A	A	A	B	C
Number of medical consultations[b]	6 (B)	12 (C)	2 (A)	16 (C)	5 (B)	3 (A)	2 (A)	6 (B)
Incidents[b]	A	A	A	A	A	A	C	D
Medical officer's overall conclusion[b]	A	A	A	A	A	A–B	A	C
Expedition chief's overall conclusion[c]	—	A	A	B	A	A–B	B	C
General conclusion[d]	A	A	A	B	B	B	B–C	C

[a] S7 had adaptation problems until July.
[b] Twice a month the medical officer surveyed the behavior of each subject and his place in the group (a mark of 24 is for a very good adaptation, 30 is for a very bad adaptation), interviewed each subject each month during the systematic medical check up, noted the number of total medical consultations, noted the incidents involving discussion or quarrel with other expedition members, and estimated the overall adaptation of each subject.
[c] The expedition chief made an adaptation report on each individual at the end of the wintering.
[d] Overall conclusion after returning to France.

A total of 17–21 night recordings was performed on each subject. Due to logistical reasons, the subjects were registered only in Antarctica from April 8 to December 1. To minimize experimental strain (1), recording sessions lasted 2–3 consecutive nights. Each subject slept ad lib in his bed and bedroom. The ALVAR Minihuit polygraph was placed in the corridor of the sleeping quarters. On the average, lights were turned off at 11:35 p.m. ±6 min, and waking time was at 7:25 a.m. ±15 min. Polysomnographic recordings consisted of electroencephalogram, electrooculogram, and electromyogram, as previously described (14). The night watch was kept by the field observer, who also scored the sleep traces in Adélie Land and after returning to France, following Rechtschaffen and Kales' recommendations (15). The traces were scored blind and afterwards attributed to the correct subject. Three groups of calculations were made. The general sleep characteristics concerned recording time (from lights out until the subject's preferred time of arising), sleep period time (SPT; from falling asleep to morning wakening), awakenings occurring during SPT (A), total sleep time (TST; SPT minus A), and sleep latency (time elapsed between lights out and the first minute of the first 10 min of stage 2 interrupted by less than 2 min of wakefulness) (16). The internal sleep organization was examined by calculating the percentage of each stage of sleep versus TST and studying the temporal distribution of delta sleep within each sleep cycle (17). Finally, the distribution of paradoxical sleep (PS) and PS latency were calculated. Two PS phases were considered to be different when separated by more than 15 min (18). PS latency was considered to be the time elapsed from the first stage 2 to the first minute of PS (16). PS latency minus awakenings occurring before the first PS episode (16) was also calculated.

Hypnograms were drawn to analyze the temporal distribution of sleep stages and awakenings during each night in all subjects. The complete set of graphs has been given by Buguet (19).

The subjects slept at ambient temperatures of around 20°C and used sheets and blankets at will to obtain thermoneutral comfort. During the day, they were often exposed to the outside climate, mainly in winter when the frozen sea allowed prolonged walks away from the station island. During the experimental period, outside temperatures averaged from −10 to −20°C, with winds blowing at 10.38 m/s. The cooling power was that of a polar atmosphere (mean windchill index 1,606.5 $W \cdot m^{-2}$). Atmospheric pressure averaged 984.45 mb, relative humidity 65.3%, and insolation 5.08 h/day with a maximum in January and a minimum in June.

RESULTS

Table 2 presents the monthly average of sleep characteristics in all subjects, except for S3 and S8 during the November sessions, as data were missing. Calculations were made on only 146 nights, with partially incomplete data being discarded.

A two-way analysis of variance revealed significant differences between subjects (subject effect) for recording time ($p < 0.001$), SPT ($p < 0.01$), TST ($p < 0.01$), stages 1 and 2 ($p < 0.001$), and stages 3 and 4 ($p < 0.001$). Such an effect was not observed for PS. Due to the subject effect, a group study with pooled data was ruled out, and the subjects were examined separately.

The time course of general sleep characteristics is shown in Fig. 1, and individual mean values are given in Table 3. SPT stayed close to recording time, and TST averaged 96.1 ± 0.6% of SPT. A two-way analysis of variance did not reveal any variation

TABLE 2. *Sleep characteristics averaged for the eight subjects throughout the wintering months from April to November (±SEM)*

	April	May	June	July	Aug	Sept	Oct	Nov	Mean
Number of nights	23	16	10	14	24	28	17	14	18.2
Recording time (min)	467.5 ± 6.5	471.6 ± 7.4	456.1 ± 11.7	479.1 ± 9.6	475.6 ± 8.3	469.0 ± 7.6	452.7 ± 15.7	472.0 ± 8.7	468.5 ± 3.4
Sleep period time (min)	457.5 ± 4.8	464.9 ± 7.4	444.5 ± 11.1	471.7 ± 9.4	467.4 ± 8.5	460.4 ± 7.7	442.2 ± 14.5	463.6 ± 8.9	460.2 ± 3.4
Awake time (min)	16.3 ± 2.1	16.4 ± 3.3	10.5 ± 1.9	14.3 ± 2.8	18.4 ± 3.8	23.5 ± 4.3	16.8 ± 2.8	20.6 ± 3.7	17.9 ± 1.3
Total sleep time (min)	443.8 ± 7.4	448.5 ± 5.6	433.9 ± 10.2	457.4 ± 8.3	449.0 ± 9.0	436.4 ± 7.4	425.4 ± 15.0	443.0 ± 10.3	442.2 ± 3.4
Stages 1 + 2 (min)	278.7 ± 9.0	279.8 ± 9.9	260.3 ± 12.9	273.7 ± 12.8	248.1 ± 10.2	251.1 ± 7.3	222.4 ± 11.6	237.4 ± 10.1	256.2 ± 3.9
Stages 3 + 4 (min)	53.3 ± 4.4	63.5 ± 7.2	70.0 ± 8.5	85.9 ± 11.3	87.2 ± 7.6	66.4 ± 4.9	95.9 ± 5.7	91.8 ± 5.9	75.4 ± 2.7
PS (min)	112.3 ± 4.7	105.1 ± 4.7	103.6 ± 7.2	97.8 ± 5.1	114.3 ± 5.5	119.3 ± 4.4	107.0 ± 5.8	113.8 ± 3.6	110.7 ± 1.9
Number of PS phases	4.6 ± 0.2	4.3 ± 0.2	3.9 ± 0.3	4.2 ± 0.2	4.5 ± 0.1	4.3 ± 0.1	4.4 ± 0.2	4.4 ± 0.2	4.4 ± 0.1
Mean sleep cycle (min)	99.0 ± 2.4	107.3 ± 3.6	109.9 ± 6.8	105.8 ± 3.5	101.3 ± 3.1	104.3 ± 2.8	96.4 ± 2.8	104.9 ± 4.5	103.0 ± 1.2
Sleep latency (min)	7.8 ± 1.2	6.1 ± 1.2	5.4 ± 1.7	5.9 ± 1.4	6.6 ± 1.6	8.6 ± 1.2	6.5 ± 1.1	5.1 ± 1.2	6.8 ± 0.6
PS latency minus awake (min)	77.1 ± 6.0	87.4 ± 6.7	75.4 ± 7.1	82.9 ± 6.0	81.4 ± 4.7	72.3 ± 3.8	68.5 ± 3.7	77.6 ± 6.6	77.0 ± 2.0

of sleep efficiency with time (month effect). S5 and S6 exhibited long midnight awakenings at the end of winter. However, TST remained above 450 min without any sleep disruption, and these subjects did not complain of lack of sleep. Only S8 experienced a constant decrease in recording time, SPT, and TST throughout the wintering period. However, the ratio TST/SPT remained at a high of 95%. Furthermore, S8 did not complain of insomnia, and the number of changes in sleep stages did not vary. Incidentally, S7, who had adaptation problems until July, also showed a downward sleep time trend until this date. Sleep latency was short in all subjects.

The time course of sleep stages throughout the wintering is shown in Fig. 2. Individual mean values are given in Table 4. In all subjects, delta sleep was generally low during the first recording sessions, even disappearing in S1 in May and June. Delta sleep then increased ($p < 0.05$, with a two-way analysis of variance) and stages 1 and 2 decreased ($p < 0.01$). A winter increase seemed to occur in subjects S3 through S7, but statistical analysis failed to reveal a significant trend. Sleep stages in S8 were irregular from one night to another.

The number and mean duration of the 659 sleep cycles studied (Table 5) showed little variation, except for S8, who experienced the lowest (2 cycles) as well as the highest (7 cycles) values observed. In all subjects, the distribution of delta sleep and PS during the night did not vary throughout the wintering period. The first PS phase [early PS% of Vogel et al. (20)] represented 14.3 ± 7% of total PS duration, the major part of PS occurring during the following phases (late PS%).

Mean PS latency is given for each subject in Table 5. PS latency minus awake averaged at least 95% of PS latency, due to few awakenings before the occurrence of the first PS phase. High values were observed in S1, S2, S7, and S8, with higher variability

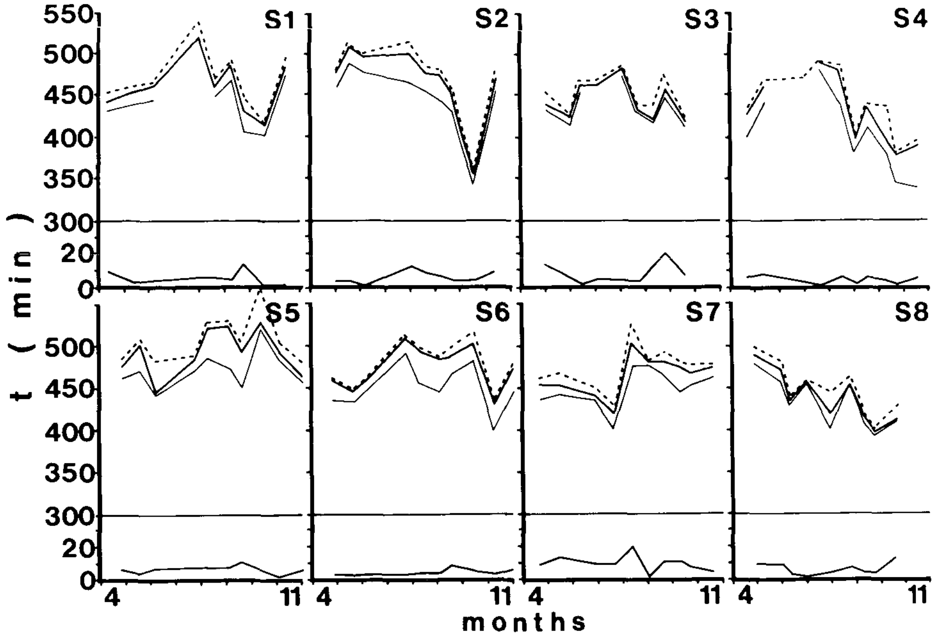

FIG. 1. Time course of the general sleep characteristics (expressed in minutes) averaged for each recording session in each subject (S1 through S8) from April (4) to November (11). Recording time (dashed line), sleep period time (thick line), and total sleep time (thin line) are given in the upper graph. Sleep latency is represented in the lower graph. Interruptions are due to missing or incomplete data.

(judged by standard deviation) in S1, S2, and S8. In the latter subjects, PS latency distribution was bimodal (Fig. 3). Median values for PS latency minus awake were 80.5, 74.5, and 64 min, respectively, for S1, S2, and S8, with the values ranging between 49 and 138, 58 and 149, and 40 and 131 min. The shortest PS latency was seen in S5 in April (28 min), the longest in S7, also in April (158 min). A correlation test did not reveal any relationship between the time of falling asleep and PS latency duration.

No first night effect (1) was observed when examining the first versus the second night of each recording session in each subject (paired t-test). Neither was there any

TABLE 3. *Mean values of general sleep characteristics in each subject (S1 through S8) during wintering, expressed in minutes ±SEM*

	S1	S2	S3	S4	S5	S6	S7	S8
Recording	474.2	479.2	457.1	437.7	507.5	477.5	473.6	451.2
time	± 9.2	± 10.3	± 6.6	± 10.4	± 7.8	± 7.0	± 6.4	± 9.8
Sleep period	466.8	473.2	439.9	430.6	492.5	473.6	463.6	443.4
time	± 9.4	± 10.2	± 6.4	± 10.7	± 9.0	± 6.8	± 6.4	± 10.1
Awake	18.1	23.1	4.8	26.1	23.0	23.9	16.0	8.7
time	± 2.2	± 2.1	± 1.0	± 4.1	± 7.0	± 2.7	± 2.3	± 2.1
Total sleep	441.3	450.1	435.2	397.8	469.5	449.8	449.2	433.1
time	± 7.5	± 9.2	± 6.0	± 11.4	± 11.2	± 7.2	± 6.8	± 10.5
Sleep	6.2	6.1	8.8	4.4	6.8	3.4	10.0	6.1
latency	± 1.2	± 1.2	± 2.1	± 0.9	± 1.0	± 0.5	± 2.0	± 1.4
TST/SPT (%)[a]	96.0	95.2	99.0	93.7	95.3	94.9	96.6	98.0
	± 0.5	± 0.4	± 0.3	± 1.0	± 1.4	± 0.6	± 0.5	± 0.5

[a] The ratio TST/SPT, i.e., total sleep time/sleep period time, is expressed as a percentage.

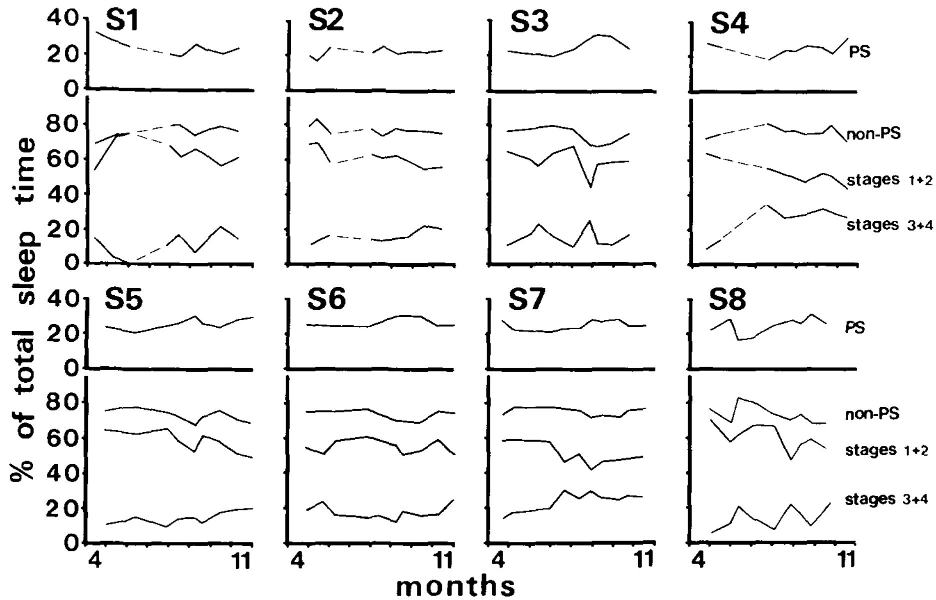

FIG. 2. Time course of sleep stages (PS, paradoxical sleep; non-PS sleep, nonparadoxical sleep, stages 1 + 2, stages 3 + 4) averaged for each recording session in each subject (S1 through S8) from April (4) to November (11). The values are expressed as a percentage of total sleep time.

relationship between sleep pattern variations and meteorological changes (multiple correlation test).

DISCUSSION

This polysomnographic study of 156 recordings performed in 8 volunteers over an 8-month period on the coast of Adélie Land is the largest sleep survey on people wintering on a station in Antarctica.

According to the criteria of Monroe (21), the subjects were "good" sleepers. Despite variations in sleeping time throughout wintering, they did not suffer from lack of sleep. The so-called "polar insomnia" has, in fact, deserted the comfortable modern-day scientific antarctic stations (8). The only strain consists in the geographical isolation from the "civilized" world and in the imposed comradeship proper to small human groups. There was no first night effect, certainly because of the experimental setting. The subjects slept in their own bed and bedroom under the observation of one of their com-

TABLE 4. *Mean values of sleep stages of the eight subjects (S1 through S8) over the wintering, expressed as a percentage of total sleep time ± SEM*

	S1	S2	S3	S4	S5	S6	S7	S8
Paradoxical sleep	25.1 ± 1.2	21.7 ± 0.7	25.7 ± 1.3	25.0 ± 1.3	25.6 ± 0.9	26.3 ± 0.8	25.3 ± 0.9	25.3 ± 1.3
Stages 1 + 2	63.4 ± 2.1	62.9 ± 1.4	59.4 ± 2.0	50.8 ± 1.8	60.0 ± 1.4	55.7 ± 1.0	51.0 ± 1.7	61.1 ± 1.9
Stages 3 + 4	11.7 ± 2.9	15.5 ± 1.1	15.1 ± 1.6	24.2 ± 2.0	14.3 ± 0.2	18.0 ± 0.9	23.9 ± 1.4	13.6 ± 1.6

TABLE 5. *Sleep cycles and internal organization of paradoxical sleep in the eight subjects (S1 through S8) (± SEM)*

	S1	S2	S3	S4	S5	S6	S7	S8
Mean sleep cycle duration (min)	98.2 ± 3.0	102.4 ± 2.6	105.6 ± 3.6	85.9 ± 2.2	108.7 ± 3.8	103.4 ± 2.9	116.2 ± 3.1	90.9 ± 3.6
Number of PS sleep phases	4.6 ± 0.2	4.3 ± 0.1	4.0 ± 0.1	4.7 ± 0.2	4.4 ± 0.2	4.4 ± 0.1	3.8 ± 0.1	4.7 ± 0.2
Mean duration of PS sleep phases (min)	24.0 ± 1.0	26.6 ± 0.3	28.0 ± 1.6	21.4 ± 1.3	28.0 ± 1.3	27.3 ± 1.1	29.9 ± 2.1	23.4 ± 1.1
Early PS%	15.2 ± 2.8	14.8 ± 1.8	17.9 ± 1.8	17.1 ± 1.6	10.6 ± 0.9	10.9 ± 0.8	12.1 ± 1.3	16.8 ± 3.2
Early PS% (% of total sleep time)	3.7 ± 0.01	3.2 ± 0.01	4.7 ± 0.01	4.9 ± 0.01	2.7 ± 0.01	2.9 ± 0.01	3.0 ± 0.01	3.7 ± 0.01
PS latency[a] (min)	91.6 ± 32.4	89.1 ± 28.7	74.4 ± 18.2	69.3 ± 25.2	74.4 ± 20.3	70.3 ± 10.3	86.6 ± 21.6	79.5 ± 33.2
PS latency[a] minus awake (min)	88.1 ± 30.0	84.7 ± 27.3	74.2 ± 18.1	62.2 ± 18.7	73.8 ± 20.1	69.3 ± 9.9	85.2 ± 20.8	78.2 ± 33.0

[a] Plus or minus standard deviation.

panions, producing a friendly and relaxed environment in which Coble et al. (22) and Browman and Cartwright (23) have not observed the first night effect. Also, due to the comfortable living conditions at Dumont d'Urville Station, sleep patterns were not influenced by climatic changes.

All sleep variables were within normal range (17). Statistical analysis failed to prove

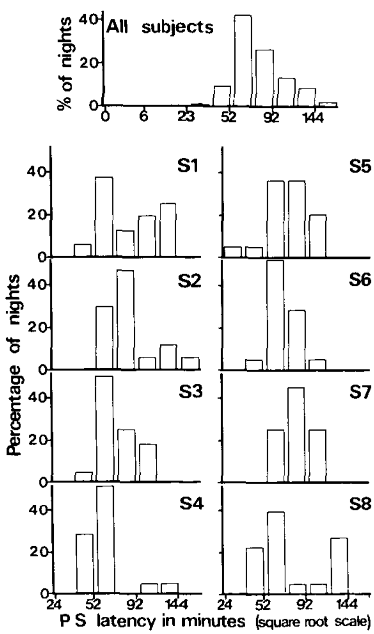

FIG. 3. Frequency distribution of PS latency minus awake for the eight subjects (S1 through S8) and for pooled data across all subjects, using a square-root scale, as in Kupfer et al. (24).

any relationship with the individual ability to adapt to life in isolation. This may be due to the small number of subjects, the fact that the subjects were not recorded together, and most certainly to the quality of the psychological selection prior to the expedition departure. Nevertheless, S8, who was the least adapted member of the polar team, differed from the other subjects by a constant decrease in sleeping time and erratic changes in sleep structure from one recording to another.

Delta sleep disappeared temporarily in S1 only. This differs from the delta sleep suppression found at South Pole Station (9,10) and at Halley Bay (11), certainly because the American and British subjects were submitted to stress due to altitude or discomfort, whereas such conditions were not met at Dumont d'Urville, where delta sleep increased. Improved physical fitness may have been involved, as more exercise was performed in winter time (14), due to numerous walks on the sea-ice and to the Emperor penguins' rookery. Also, cold-acclimatization, which probably occurred (19), may have played a role.

There was no change in PS throughout the wintering. However, due to a limited paper supply, the paper speed used on the polygraph (5 mm/s) did not allow an accurate account of eye movements during PS. However, early PS%, which has been shown to increase in depressives (20,24), remained within the normal range, as did the distribution of PS latency, which corresponded to that of the younger normal control group of Kupfer et al. (24).

In conclusion, insomnia or major sleep disturbances are no longer a common feature in polar expedition members living in modern and comfortable antarctic stations and who have been submitted to a rigorous medical and psychological screening. Sleep pattern variations may be linked to numerous environmental and personal factors (8), with special reference to psychological adaptation to life in small isolated human groups and to the extreme light–dark alternation (2,7,11). The results of the present study cannot be used to affirm the relationship between a definitive sleep-adaptation and stressful environments, as our subjects could not be recorded before or after the expedition.

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