Analysis and Interpretation of Polygraphic Sleep Recordings and Overnight Sleep and Fatigue Indices During a Three-Night Simulation of Noise Conditions Aboard the International Space Station

by:
Valérie Gil
5232 Earnscliffe Ave,
Montréal, Québec,
H3X 2P5.

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On behalf of
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as represented by
Defence R&D Canada - Toronto
1133 Sheppard Avenue West
Toronto, Ontario, Canada
M3M 3B9

DRDC Scientific Authority
Joseph Baranski
(416) 635-2145

Defence R&D Canada - Toronto

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Author

Dr Valérie Gil

Approved by

Dr Joseph Baranski

Head, Judgement and Decision Making Group

Approved for release by

K. M. Sutton

Chair, Document Review and Library Committee

Abstract

Fifteen healthy volunteers, were grouped in teams of five. Two teams were exposed to noise during the day only (day noise group; 5 males and 5 females), 2 teams were exposed day and night (all noise groups; 5 males and 5 females), and 1 team was not exposed to any noise (control group of 2 males and 3 females). Participants were equipped for continuous ambulatory recording of EEG, EOG and EMG and completed 9 x 1-hour experimental blocks during the experiment. The overnight sleep periods were scheduled between 22h00 and 06h00. Electroencephalogram (EEG) data was recorded continuously from Day 1 to Day 4. All groups spent more time in lighter sleep stages and had very little SWS (less than 8%). Since sleep composition was affected in all three groups we can hypothesize that they were affected by the cloistered environment. The most probable cause of this SWS reduction is exposure to a cloistered environment. Noise exposure, did not show an impact on SWS since no significant difference were found between the groups. In contrast, an effect of the degree of exposure to noise was found on the percentage of REM sleep. The all noise group showed less percentage of REM sleep than the day noise group, which in turn showed less percentage of REM sleep than the control group. Objective measurement of sleepiness through the 4 min eyes closed task showed that subjects exposed to noise continuously tended to have more difficulty resisting sleep than control or day noise groups. Even though it did not reach the level of significance, subjects also showed the influence of time of day by having more stage 1 sleep at 08h00 than in the afternoon or evening trials. Self-evaluation of their sleepiness showed similar patterns. In conclusion, sleep was negatively affected by the cloistered environment and to a certain extent by the exposure to noise. The present findings showed reduction of REM sleep in proportion to the degree of exposure to noise and a limited impact of noise on objective sleepiness.

Résumé

Quinze volontaires en bonne santé ont été répartis en équipes de cinq personnes. Deux équipes ont été exposées au bruit le jour seulement (groupe de bruit diurne : cinq hommes et cinq femmes), deux équipes ont été exposées au bruit jour et nuit (groupe de bruit constant : cinq hommes et cinq femmes) et une équipe n'a été exposée à aucun bruit (groupe témoin : deux hommes et trois femmes). Les participants étaient munis d'un enregistreur ambulatoire en continu des données de l'électroencéphalogramme (EEG), de l'électrooculogramme (EOG) et de l'électromyogramme (EMG). De plus, ils ont été soumis à neuf séries de tests d'une heure chacune durant l'expérience. Les périodes de sommeil nocturnes étaient prévues entre 22 h et 6 h. Les données de l'EEG ont été enregistrées de façon continue du jour 1 au jour 4. Chez tous les groupes, les stades de sommeil léger ont été plus longs et la durée du sommeil lent a été très courte (moins de 8 %). Comme la durée des stades du sommeil était modifiée dans les trois groupes, nous pouvons avancer l'hypothèse que l'environnement cloîtré avait des effets sur le sommeil et qu'il représentait la cause la plus probable de la réduction du sommeil lent. L'exposition au bruit n'avait aucune répercussion sur le sommeil lent, car aucune différence significative n'a été relevée entre les groupes. En revanche, nous avons observé une corrélation entre le degré d'exposition au bruit et le pourcentage de sommeil paradoxal. Chez le groupe de bruit constant, le pourcentage de sommeil paradoxal était plus faible que chez le groupe de bruit diurne, et chez ce dernier groupe, le pourcentage de sommeil paradoxal était plus bas que chez le groupe témoin. La mesure objective du sommeil durant une période de quatre minutes où nous demandions aux sujets de fermer les yeux a révélé que le groupe de bruit constant avait plus de difficulté à résister au sommeil que le groupe témoin et que le groupe de bruit diurne. Même si les résultats n'étaient pas significatifs, nous avons observé que le moment de la journée avait une influence sur le sommeil : à 8 h, le premier stade du sommeil était plus long qu'il ne l'était l'après-midi ou le soir. L'auto-évaluation du sommeil révélait des tendances similaires. En conclusion, l'environnement cloîtré et, dans une certaine mesure, l'exposition au bruit avaient des effets négatifs sur le sommeil. Les résultats montrent une réduction du sommeil paradoxal proportionnelle au degré d'exposition au bruit et un faible impact du bruit sur les paramètres objectifs du sommeil.

Executive summary

Twenty-five healthy volunteers were grouped into teams of five and were cloistered for three days in the DRDC Toronto diving chamber in order to simulate living conditions aboard the International Space Station (ISS). In an attempt to simulate ambient noise conditions aboard the ISS, 2 teams were exposed to continuous noise (72 dBA) during the day and night (all noise groups: 5 males and 5 females), two teams were exposed to the same noise during the day only (day noise groups: 5 males and 5 females), and 1 team was not exposed to noise (control group: 2 males and 3 females). Participants were equipped for continuous ambulatory recording of EEG, EOG and EMG and completed 9 x 1-hour cognitive test battery during the 3-day experiment.

The results indicate that sleep was negatively affected by the cloistered environment and to a certain extent by the exposure to noise. All groups spent more time in lighter sleep stages and had very little slow wave sleep (SWS: less than 8%). Subject's sleeping in an unfamiliar environment often experience poor sleep which is presumed to be due to central nervous system arousal in response to stress (Roehrs et al., 1989). REM sleep, on the other hand, was reduced proportionally to noise exposure. These findings are consistent with results in the literature (Kawada and Suzuki, 1999; Terzano et al., 1990) showing a decreased in percentage of REM sleep, SWS, and an increase of stage changes and wake time with increasing noise exposure. Time of day had as much of an effect on objective sleepiness as noise exposure. Subjects exposed to noise had more difficulty resisting sleep, particularly in the early morning (i.e., 08h00). Subjective sleepiness showed a similar impact of time of day but no effect of noise.

In conclusion, the current study indicates that both noise and a cloistered environment had a negative impact on sleep parameters for individuals exposed to continuous 72 dBA noise for a three-day period. Although subjects spent 8 hours per night in bed, their sleep infrastructure was restricted by the environmental conditions to lighter sleep stages. Three days of sleep impairment due to noise and a cloistered environment could result in cognitive performance degradation as shown in a recent sleep reduction study by Belenky and colleagues (2003). Future investigations should examine a longer period of adaptation to a cloistered environment in order to better distinguish between the effects of cloistering and noise.

Gil, V., 2003. Analysis and Interpretation of Polygraphic Sleep Recordings and Overnight Sleep and Fatigue Indices During a Three-Night Simulation of Noise Conditions Aboard the International Space Station. CR 2003-085 Defence Research and Development Canada – Toronto.

Sommaire

Quinze volontaires en bonne santé ont été répartis en équipes de cinq personnes. Deux équipes ont été exposées au bruit le jour seulement (groupe de bruit diurne : cinq hommes et cinq femmes), deux équipes ont été exposées au bruit jour et nuit (groupe de bruit constant : cinq hommes et cinq femmes) et une équipe n'a été exposée à aucun bruit (groupe témoin : deux hommes et trois femmes). Les participants étaient munis d'un enregistreur ambulatoire en continu des données de l'électroencéphalogramme (EEG), de l'électrooculogramme (EOG) et de l'électromyogramme (EMG). De plus, ils ont été soumis à neuf séries de tests cognitifs d'une heure chacune durant l'expérience.

Les résultats indiquent que l'environnement cloîtré et, dans une certaine mesure, l'exposition au bruit avaient eu des effets négatifs sur le sommeil. Chez tous les groupes, les stades de sommeil léger ont été plus longs et la durée du sommeil lent a été très courte (moins de 8 %). Les sujets qui dorment dans un environnement non familier ont souvent des problèmes de sommeil qu'on croit attribuables à une stimulation du système nerveux central en réponse au stress (Roehrs et coll., 1989). En revanche, le sommeil paradoxal était réduit de façon proportionnelle à l'exposition au bruit. Ces résultats concordent avec ceux décrits dans la littérature (Kawada et Suzuki, 1999 et Terzano et coll., 1990), qui font état d'une diminution du pourcentage de sommeil paradoxal et de sommeil lent et d'une augmentation du nombre de changements de stade et du temps d'éveil. Le moment de la journée avait autant d'effet sur les paramètres objectifs du sommeil que l'exposition au bruit. Les sujets exposés au bruit avaient plus de mal à résister au sommeil, difficulté encore plus marquée à 8 h le matin. Le moment de la journée avait aussi un effet sur les paramètres subjectifs du sommeil, contrairement au bruit, qui n'en avait aucun.

En conclusion, l'étude a révélé que le bruit et l'environnement cloîtré avaient tous deux un effet négatif sur les paramètres du sommeil chez les personnes exposées pendant trois jours. Les sujets passaient huit heures au lit, mais en raison de l'environnement, leur sommeil était limité aux stades de sommeil les plus légers. Trois jours de troubles du sommeil occasionnés par le bruit et un environnement cloîtré pourraient entraîner une dégradation de la performance cognitive semblable à celle observée dans l'étude récente de Belenky et coll. (2003) sur la réduction du sommeil. Dans l'avenir, les études devraient comporter une période d'adaptation plus longue à l'environnement cloîtré de façon qu'il soit plus facile de distinguer les effets de l'environnement de ceux du bruit.

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Introduction

A recent collaborative project involving NASA, the Canadian Space Agency, and DRDC-Toronto, explored a number of human performance issues related to prolonged exposure to the noise environment aboard the International Space Station (ISS) complex (see Able et al., 2003). Specifically, the study examined the effects of continuous noise (72 dBA) exposure over a 3-day time period in a cloistered environment that modeled living and acoustic conditions on the ISS. Performance measures included hearing, speech communication, voice parameters, vestibular function, cognitive function, reaction time, physiological well-being, and quality of sleep. This report investigates whether the exposure to continuous noise during the day only or during the day and night affects sleep and objective and subjective sleepiness parameters.

To date, the literature studying the effects of noise exposure during sleep has focused on intermittent noise exposure from road or airplane traffic. Both home and controlled laboratory studies indicate that noise results in greater difficulty in falling asleep, more frequent awakenings during the night, and reports of poorer sleep quality (e.g., Jurriens et al., 1983; Thiessen, 1978). Since sleep deprivation has well-known negative consequences on performance it is possible that poor quality sleep in a noisy environment could disrupt performance. To our knowledge there have been few studies evaluating the effects of continuous, low intensity noise exposure on sleep (Kawada and Suzuki, 1999; Terzano et al., 1990) and none have examined the effects of continuous noise exposure on sleep in cloistered environments such as those aboard the ISS.

Method

Subjects

Twenty-five subjects participated in the study, 13 females and 12 males. Participants were required to be healthy, have good hearing, no history of sleep disturbances, and have normal or corrected to normal vision. Subjects were asked to refrain from alcohol consumption 36 hours prior to commencing the study. Finally, subjects were notified that caffeine and nicotine substances would not be permitted during the study.

Apparatus

Electrophysiological data was collected with ambulatory recorders (Embla from Flaga hf) for the entire duration of the experiment. Somnologica software (Flaga hf) was used on a PC computer to analyze electrophysiological signals. The experiment was conducted in the largest of the diving chambers housed in the Experimental Diving Unit of DRDC-Toronto. The chambers are comprised of tree connecting pods. One pod provided living quarters for five subjects, where lounges were converted to bunks for sleeping. The second pod housed sink, toilet and shower facilities. The third pod was used to house the experimental equipment for cognitive testing. Custom computer software was used to administer the cognitive test battery on Pentium PC computers with color monitors during the experiment[1]. For all tasks, team and individual cognitive performance, responses were given by pressing buttons on a PC mouse. Noise modeling background noise on the International Space Station (ISS) was presented throughout the chamber under the noise condition exposures. Subjects were continuously monitored by video surveillance camera to ensure appropriate intervention if and when required.

Procedure

Subjects were grouped in teams of 5. Two teams were subjected to noise during the day only (5 males and 5 females), 2 teams during day and night (5 males and 5 females), and 1 team (control) was not subjected to any noise (2 males and 3 females). Each group of 5 subjects participated over the course of one week. Subjects arrived in the lab around 09h00 on Day 1. Following a general introduction to the facilities, subjects signed informed consent forms for their participation. Subjects were also asked to complete a battery of questionnaires and tests to determine their health. Day 1 was spent practicing the battery of cognitive tasks to be performed during the cloistering portion of the experiment starting Day 1 at 17h00 and ending Day 4 at 17h00 (i.e., 72 hrs). All meals and snacks were provided. Task practice concluded at 19h00 on Day 1.

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[1] Custom computer software developed by NTT Inc.

At approximately 13h00 of Day 1, subjects were equipped with 9 surface electrodes for continuous ambulatory recording of electroencephalogram (EEG), left and right electroocculograms (EOG), and submental electromyogram (EMG). The EEG was obtained from the C4-A1, C3-A2, Oz-A1 derivations. The overnight sleep was scheduled between 22h00 and 06h00. Electroencephalogram (EEG) data was recorded continuously from Day 1 to Day 4. Subjects' electrodes were remove at 16h00 on Day 4. They were then debriefed and paid for their participation.

Materials and Methods

Electroencephalogram (EEG) data was recorded from Monday evening to Thursday afternoon using Embla ambulatory recorders and surface electrodes. Sleep recordings included three electroencephalograms (C3-A2, C4-A1, Oz-A1), two electrocculograms (EOG-R-C1, EOG-L-C1) and one electromyogram (under the chin). Sleep stages were scored in 30-sec epochs according to standardized procedures (Rechtschaffen and Kales 1968). Time in bed (from lights out to lights on), sleep period time (from falling asleep to lights on), awakenings occurring during sleep (greater than 2 min), total sleep time (sleep period time minus wakefulness), and sleep latency (from lights out to the first stage of sleep), were calculated for each sleep period. Wakefulness and sleep stages (REM sleep, stages 1, 2, 3 and 4) were analyzed by measuring total duration and proportion to TST. Latency to slow-wave sleep (SWS) and REM sleep (from sleep onset to the beginning of SWS or REM sleep) were also measured for each sleep episode. Two SWS or REM sleep phases differed when separated by more than 10 min. The number of phases and mean phases duration was calculated for SWS and REM sleep.

Dependent sleep variables were analyzed using a series of ANOVAs in which Condition (All noise, Day noise or Control) and Gender (Male, Female), were between-subjects factors and Night (first, second or third overnight), was a repeated measures within-subjects factor. The level of significance was fixed at 5%. Following ANOVAs, post hoc comparisons were conducted when appropriate. No significant differences were found between gender for any of the sleep variables.

Results

Overnight sleep period

Data from one overnight sleep period of a day noise subject (1 female) and 2 overnight sleep periods from a day and night noise subject (1 female) were lost due to technical problems. The composition of the overnight sleep period for all conditions (control, day noise, all noise) differed from the sleep composition documented in young healthy adults (20 to 30 years old). The normal sleep variables for young adults expressed as a percentage of total sleep time consist of 2 to 3 % wakefulness, 45 to 60 % stage 1+2, 15 to 30 % SWS, and 20 to 35 % of REM sleep (Carskadon and Dement, 1989).

Subjects in all conditions had slightly more wakefulness (greater than 5 %), spent greater time in lighter stages 1+2 (between 65% and 75%), and less than 8% of the time was spent in slow wave sleep. However, the control and day noise groups managed to spend the normal percentage of time in REM sleep (between 20 and 25%). The all noise group spent between 16 and 20% of their sleep time in REM sleep.

There was a significant condition by night effect for sleep period time ($F=2.84$, $p < 0.03$) and total sleep time ($F=3.84$, $p< 0.009$). The group exposed only to day noise spent less time asleep than the other two groups and more so on the second and third night. Sleep latency showed a similar significant interaction between condition and night ($F=3.41$, $p < 0.017$). Day noise subjects took significantly more time to fall asleep on the second day than the control or all noise subjects, and they took almost twice as long to fall asleep on the third night than the control subjects (55 and 23 minutes respectively). Subsequently, sleep efficiency was affected (i.e., the condition by night effect almost reached significance, $p < 0.06$). Again the day noise group had lower sleep efficiencies than the control or all noise group for the last 2 nights.

As a result of the significant difference found in time spent in bed between groups, only the relative value of sleep stage variables were taken into consideration. The percentage of sleep time spent in Stage 2 was significant reduced ($F=4,72$, $p < 0.014$) between the first night (65.9%) and the second (62.7%) and third night (62.3%) in all groups. On the other hand, the percentage of time spent in REM sleep was significantly different ($F=6.34$, $p< 0.006$) between conditions. The all noise group spent 19% of its time in REM sleep compared to 23% for the day noise group and 26.5% for the control group. A similar effect was found in the number of REM phases showing a significant difference ($F=10.7$, $p < 0.0001$) between the day noise group (4,5) in comparison to the all noise group (3.5) and the control group (3.9).

Table 1. Overnight sleep characteristics of Control (n = 5), Day noise (n= 10) and All noise (n = 10) subjects. All mean values are given with one standard deviation (s.d.). (* indicates a significant time by condition, ° indicates a significant condition effect, and † indicates a significant time effect).

		Control						**Day Noise**						**All Noise**						**P-value**
Nights		first		second		third		first		second		third		first		second		third		
			s.d.		s.d.		s.d.		s.d.		s.d.		s.d.		s.d.		s.d.		s.d.	
	Time in bed (TIB)	440,5	106,3	494,4	1,6	475,9	0,2	482,6	2,6	483,4	3,5	480,1	9,8	485,9	3,8	488,9	8,5	484,4	2,6	ns
	Sleep period time (SPT)	430,9	103,0	469,0	12,6	450,9	7,0	458,5	10,8	428,2	33,0	424,4	16,3	471,3	8,4	470,9	15,9	436,4	22,4	0,03*
	Total sleep time (TST)	389,9	90,1	440,4	17,7	420,5	15,5	422,1	28,8	397,1	28,0	380,7	16,0	437,1	22,2	446,3	17,5	413,0	25,3	0,009*
	Sleep efficiency (TST/SPT)	88,9	4,3	89,0	3,6	88,4	3,2	87,5	5,9	82,1	5,6	79,3	3,4	89,9	4,7	91,3	2,9	85,3	5,3	0,06*
	Sleep latency	9,6	10,7	25,4	12,8	25,0	7,1	24,0	10,3	55,2	32,2	55,6	9,2	14,6	8,6	17,9	9,0	48,1	22,7	0,017*
In minutes	Wakefulness	41,0	26,3	28,6	19,0	30,4	14,1	36,5	23,7	31,1	28,3	43,7	22,4	34,2	17,4	24,6	14,9	23,4	24,8	ns
In minutes	Stage 1	24,9	16,7	27,7	16,2	33,7	21,2	35,2	16,0	30,4	18,2	33,7	11,2	32,7	13,4	34,4	8,3	33,8	17,2	ns
In minutes	Stage 2	235,8	51,5	268,4	29,6	251,2	17,1	278,5	26,5	246,4	28,1	229,7	24,0	298,5	32,1	288,9	34,9	271,7	33,3	0,012
In minutes	Stage 3	17,0	21,4	18,8	18,7	20,4	20,2	17,7	15,7	22,7	14,8	17,9	16,4	27,6	11,5	27,4	16,0	21,9	10,7	ns
In minutes	Stage 4	6,1	8,8	8,3	18,0	5,7	11,4	2,7	4,3	3,9	7,1	3,3	7,5	4,1	4,8	4,5	6,7	1,7	2,5	ns
In minutes	Slow-wave sleep (SWS)	23,1	30,1	27,1	33,1	26,1	30,3	20,4	19,3	26,7	19,7	21,2	22,7	31,8	13,8	32,0	21,3	23,7	13,0	ns
In minutes	REM sleep	106,1	27,3	117,2	16,9	109,5	23,4	87,9	31,2	93,6	14,4	96,1	16,4	74,1	29,2	90,9	12,3	83,6	22,5	0,030
In minutes	Movement time (MT)	0,5	0,5	0,6	0,6	0,6	0,8	0,4	0,5	0,1	0,3	0,2	0,3	0,5	0,5	0,3	0,3	0,3	0,3	ns
In minutes	SWS latency	44,6	30,8	24,5	5,1	49,4	45,1	42,7	35,1	29,2	20,4	36,5	22,6	34,1	34,7	25,4	6,6	44,1	51,6	ns
In minutes	REM latency	94,7	63,7	77,8	16,8	89,6	24,9	80,6	41,5	83,5	29,5	61,9	23,9	121,8	56,7	99,6	36,9	86,4	23,0	ns
In minutes	Mean REM sleep phases duration (min)	90,6	18,7	97,7	18,3	86,8	9,7	87,3	9,9	76,1	16,4	75,7	21,5	122,9	35,2	109,6	32,3	103,4	22,1	ns
In minutes	Mean SWS phases duration (min)	42,3	9,0	66,4	6,7	93,5	5,1	99,6	6,4	106,1	8,1	49,1	24,1	124,8	4,5	148,5	5,7	107,1	6,5	ns
Relative	Wake (%SPT)	9,1	4,8	6,0	3,9	6,7	3,1	7,9	5,2	7,0	6,0	10,1	4,8	7,2	3,7	5,1	3,0	5,2	5,3	ns
Relative	Stage 1 (%TST)	6,1	3,4	6,4	4,0	8,1	5,5	8,6	4,5	8,0	5,6	8,9	3,1	7,6	3,4	7,7	1,9	8,3	4,7	ns
Relative	Stage 2 (%TST)	61,1	6,5	60,8	5,9	59,8	3,9	66,0	5,3	62,0	5,5	60,3	5,6	68,3	5,7	64,6	6,7	65,7	6,4	0,014†
Relative	Stage 3 (%TST)	4,2	5,2	4,2	4,2	4,8	4,9	4,1	3,6	5,5	3,3	4,7	4,2	6,4	2,8	6,1	3,5	5,2	2,4	ns
Relative	Stage 4 (%TST)	1,5	2,2	1,8	3,9	1,4	2,7	0,6	1,0	0,9	1,6	0,9	1,9	0,9	1,1	1,0	1,5	0,4	0,6	ns
Relative	SWS (%TST)	5,7	7,4	6,0	7,2	6,2	7,3	5,6	4,4	4,7	4,4	6,5	5,9	7,3	3,3	7,1	4,7	5,6	2,9	ns
Relative	REM (%TST)	27,1	1,4	26,6	4,0	25,9	4,7	20,6	6,7	23,6	3,6	25,2	4,2	16,8	6,1	20,4	3,1	20,2	5,1	0,006°
Relative	MT (%TST)	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,0	0,1	0,0	0,1	0,1	0,1	0,0	0,1	0,1	0,1	ns
Absolute	REM phases	3,4	0,5	4,2	0,4	4,0	0,0	4,5	0,6	4,5	0,7	4,6	0,9	3,2	0,8	3,6	0,7	3,7	0,7	0°
Absolute	SWS phases	1,6	0,9	2,0	1,0	2,8	1,3	2,2	1,0	2,2	0,8	1,8	0,9	2,9	1,6	2,3	0,7	2,7	0,8	ns
Absolute	Awakenings (>2 min)	9,6	5,7	7,8	4,5	9,0	5,3	10,9	7,4	10,1	8,8	11,2	5,8	10,0	5,5	7,6	5,9	7,0	7,7	ns
Absolute	Arousals (>3 sec)	94,6	27,1	99,8	32,3	98,0	38,9	92,8	27,2	92,4	43,6	87,7	27,2	107,0	45,9	105,7	30,4	101,1	39,0	ns
Absolute	Stage changes	124,4	45,5	135,2	16,3	142,0	21,1	151,5	23,5	142,3	34,9	135,8	12,6	153,1	27,6	150,1	22,4	143,7	28,9	ns

Four minutes eyes closed test

Four minutes eyes closed trials occurred approximately every 6 hours starting on Day 1 at 20h00. A total of 9 trials were delivered before the end of the experimental procedure on Day 4. Wakefulness and sleep stages were scored for the entire duration of each trial in 30-sec epochs according to standardized procedures (Rechtschaffen & Kales, 1968). In order to compare the results from the subjects' self-assessment of fatigue and their EEG evaluation, the total number of minutes of sleep (all stages) was also calculated for each subject and trial (figure 1). From the 15 subjects who participated in the study EEG data from the eyes closed trials of 1 subject were lost due to technical problems. Data of the last 5 trials from another subject was also lost due to poor EEG tracing.

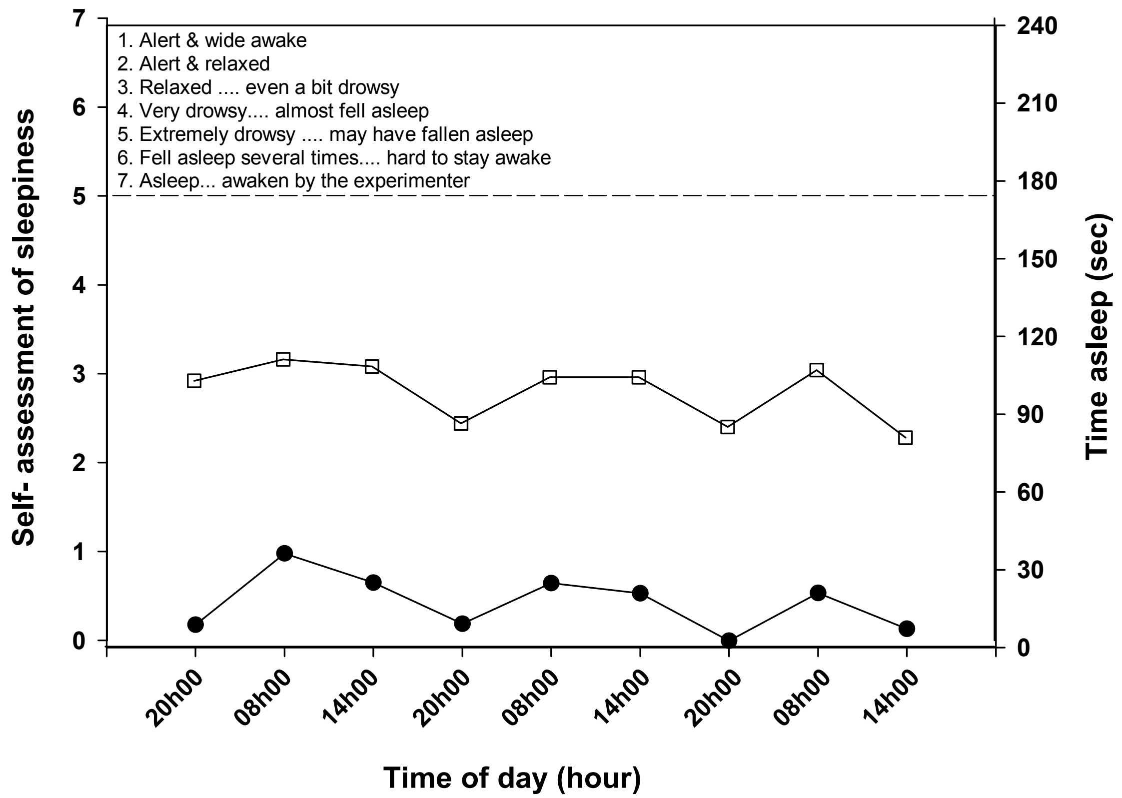

Figure 1. Mean values of total time spent asleep (close circle) for each four minutes eyes closed trials and self-assessment of sleepiness (open square) given immediately after each trial as a function of time of day. (N=14)

Total sleep and self-assessments of sleepiness dependent variables were analyzed using a series of ANOVAs in which conditions (All noise, day noise, or control), was a between-subject factor and Trials (9 trials at 08h00, 14h00 or 20h00) was a repeated factor. The level of significance was set at 0,05. Following ANOVAs, post hoc comparisons were conducted when appropriate. It was hypothesized that mean levels for the dependent variables would show a significant increase in the total amount of sleep and self-assessment of sleepiness as the exposure to noise increased.

Subjects who fell asleep during trials showed only stage 1 sleep. No significant interaction effect was found for stage 1 sleep. However, a condition effect on time spent in stage 1 almost reach significance ($p<0,06$) showing the control group spending only 5.7 sec asleep compared to the all noise group (24.5 sec). The day noise group fell in between with 16,9 sec of stage 1 sleep. A similar trend was seen for a time of day effect (0,07) where subjects slept more on trials done early in the morning (27,7 sec) than in the afternoon (18,1 sec), or evening (6,8 sec) trials. A significant time of day effect ($F=2,08$, $p<0,04$) was also found in self-assessment. Subject's self-assessment showed a similar pattern as stage 1 sleep (figure 1). Subjects felt subjectively more awake at 20h00 (0,9 on a scale of 7) than at 08h00 and 14h00 (3.04).

Sleep composition

Subject's exposure to the new environment and recording conditions can affect negatively their overnight sleep composition which in fact differed from the normal ranges reported in the literature for their age group (Carskadon & Dement, 1989). The normal sleep variables for young adults expressed as a percentage of total sleep time consist of 2 to 3 % wakefulness, 45 to 60 % stage 1+2, 15 to 30 % SWS, and 20 to 35 % of REM sleep (Carskadon & Dement, 1989). All groups spent more time in lighter sleep stages and had very little SWS (less than 8%). The percentage of Stage 2 sleep was also greater on the first night than on the second and third night showing a "first-night" effect (Agnew et al., 1966). Since sleep composition was affected in all three groups we can hypothesized that they were affected by the cloistered environment. Subject's sleeping in an unfamiliar environment often experience poor sleep. Sleep alterations due to unfamiliar sleep environment usually disappear after two nights (Roehrs et al., 1989). Smaller percentage of SWS is not typical of young adults sleep composition. Again, the most probable cause of this SWS reduction is exposure to a cloistered environment. Such sleep alterations are presumed to be due to an arousal of the central nervous system provoked by any environmental or psychological factor that produces a brainstem reticular activation system (RAS) arousal (Roehrs et al., 1989). It is a normal response to stress.

Noise exposure, did not show an impact on SWS since no significant difference were found between the groups. Contrary to the present findings, these studies SWS and more specifically Stage 4 showed a gradual decrease with increasing intensities of noise exposure (Terzano et al., 1990). However, the reduction of SWS by the impact of a cloistered environment was so great that it could have masked a possible reduction of SWS by noise. In contrast, an effect of the degree of exposure to noise was found on the percentage of REM sleep. The all noise group showed less percentage of REM sleep than the day noise group, which in turn showed less percentage of REM sleep than the control group. These results are consistent with the findings of Kawada and Suzuki (1999) and Terzano and colleagues (1990) showing a decrease in percentage of REM sleep and an increase of Stage 2 under continuous exposure to noise from 45dBA to 75dBA. Terzano and colleagues (1990) also showed an increase of stage changes and wake time and a reduction of total sleep time. The absence of significant effect of noise on variables such as stage changes or the number of arousals could be explained by the additional effect of sleeping in a cloistered environment for all groups including the control group even though the present values for these variables fell into what is considered normal (10 to 15 arousals per hour, 130 to 140 stage changes) for this age group (Magalang et al., 1996; Riemann et al., 1997).

Objective measures of sleepiness

Objective measurement of sleepiness through the 4 min eyes closed task showed that subjects exposed to noise continuously tended to have more difficulty resisting sleep than control or day noise groups. Even though it did not reach the level of significance, subjects also showed the influence of time of day by having more stage 1 sleep at 08h00 than in the afternoon or evening trials. Self-evaluation of their sleepiness showed similar patterns with higher values after 08h00 in the morning and smaller ones at 20h00. At best subjects assessed their sleepiness as "very drowsy …. almost fell asleep" but never as "extremely drowsy … may have fallen asleep". Either the subjects couldn't evaluate if they were asleep for a few seconds or they did not want to admit it. For the most part subjects probably did not know they fell asleep. It has been shown that healthy individuals almost always report being awake when awaken from stage 1, and about half of the time when awaken from the sleep onset of stage 2 (Agnew & Webb; 1976, Coates et al., 1983). Time spent asleep was only spent in stage 1 sleep. On the other hand, as it can be observed (in figure 1) subject self-assessments were also affected by time of day and displayed similar fluctuations as the objective evaluation of sleepiness.

Conclusions

The results indicate that sleep was negatively affected by the cloistered environment and to a certain extent by the exposure to noise. The very small percentage of time spent in SWS are indicative of an arousal of the central nervous system generally attributed to stress. The present findings showed reduction of REM sleep in proportion to the degree of exposure to noise and a limited impact of noise on objective sleepiness. Greater impact on objective sleepiness may have been masked by the fact that all groups showed a reduction in SWS. On the other hand, REM reduction observed in the noise group may be linked to their tendency to show stronger time of day variations in objective sleepiness. Subjects exposed to noise tended to fall asleep more often in the morning time of day at witch REM pressure is the strongest. Interestingly, subjects' self-assessments reflected the same time of day fluctuations than objective sleepiness. A larger number of individual in the control group could have emphasized some of the tendencies seen in the data such as greater sleep disturbances caused by noise exposure. Also, screening for snoring individuals would be advisable when subjects need to sleep in a cloistered environment. Within a control group of 5 subjects, 2 subjects were reported as snorers (snoring was confirmed in tracing) and one also had occasional episode of bruxism.

Thus, the current study indicates that in situations requiring individuals to live for several days in a cloistered and noisy environment, a negative effect on their sleep composition has to be considered. Reduction in REM sleep due to noise over several days could result in cognitive performance degradation as shown in a recent study by Belenky and colleagues (2003). Their results suggest that the brain adapts to chronic sleep restriction by stabilizing performance at a reduce level. Another study showed similar reduction in REM sleep apparently resulting in an increasing number of lapses during a vigilance task and an decreasing cognitive accuracy over successive days of sleep reductions (Van Dongen et al., 2003). The present study needs to be replicated in order to be able to distinguish better between the specific impact of a cloistered environment and noise exposure on sleep, and subjective and objective sleepiness.

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14. ABSTRACT

(U) Fifteen healthy volunteers, were grouped in teams of five. Two teams were exposed to noise during the day only (day noise group; 5 males and 5 females), 2 teams were exposed day and night (all noise groups; 5 males and 5 females), and 1 team was not exposed to any noise (control group of 2 males and 3 females). Participants were equipped for continuous ambulatory recording of EEG, EOG and EMG and completed 9 x 1-hour experimental blocks during the experiment. The overnight sleep periods were scheduled between 22h00 and 06h00. Electroencephalogram (EEG) data was recorded continuously from Day 1 to Day 4. All groups spent more time in lighter sleep stages and had very little SWS (less than 8%). Since sleep composition was affected in all three groups we can hypothesized that they were affected by the cloistered environment. The most probable cause of this SWS reduction is exposure to a cloistered environment. Noise exposure, did not show an impact on SWS since no significant difference were found between the groups. In contrast, an effect of the degree of exposure to noise was found on the percentage of REM sleep. The all noise group showed less percentage of REM sleep than the day noise group, which in turn showed less percentage of REM sleep than the control group. Objective measurement of sleepiness through the 4 min eyes closed task showed that subjects exposed to noise continuously tended to have more difficulty resisting sleep than control or day noise groups. Even though it did not reach the level of significance, subjects also showed the influence of time of day by having more stage 1 sleep at 08h00 than in the afternoon or evening trials. Self-evaluation of their sleepiness showed similar patterns. In conclusion, sleep was negatively affected by the cloistered environment and to a certain extent by the exposure to noise. The present findings showed reduction of REM sleep in proportion to the degree of exposure to noise and a limited impact of noise on objective sleepiness.

(U) Quinze volontaires en bonne santé ont été répartis en équipes de cinq personnes. Deux équipes ont été exposées au bruit le jour seulement (groupe de bruit diurne : cinq hommes et cinq femmes), deux équipes ont été exposées au bruit jour et nuit (groupe de bruit constant : cinq hommes et cinq femmes) et une équipe n’a été exposée à aucun bruit (groupe témoin : deux hommes et trois femmes). Les participants étaient munis d’un enregistreur ambulatoire en continu des données de l’électroencéphalogramme (EEG), de l’électrooculogramme (EOG) et de l’électromyogramme (EMG). De plus, ils ont été soumis à neuf séries de tests d’une heure chacune durant l’expérience. Les périodes de sommeil nocturnes étaient prévues entre 22 h et 6 h. Les données de l’EEG ont été enregistrées de façon continue du jour 1 au jour 4. Chez tous les groupes, les stades de sommeil léger ont été plus longs et la durée du sommeil lent a été très courte (moins de 8 %). Comme la durée des stades du sommeil était modifiée dans les trois groupes, nous pouvons avancer l’hypothèse que l’environnement cloîtré avait des effets sur le sommeil et qu’il représentait la cause la plus probable de la réduction du sommeil lent. L’exposition au bruit n’avait aucune répercussion sur le sommeil lent, car aucune différence significative n’a été relevée entre les groupes. En revanche, nous avons observé une corrélation entre le degré d’exposition au bruit et le pourcentage de sommeil paradoxal. Chez le groupe de bruit constant, le pourcentage de sommeil paradoxal était plus faible que chez le groupe de bruit diurne, et chez ce dernier groupe, le pourcentage de sommeil paradoxal était plus bas que chez le groupe témoin. La mesure objective du sommeil durant une période de quatre minutes où nous demandions aux sujets de fermer les yeux a révélé que le groupe de bruit constant avait plus de difficulté à résister au sommeil que le groupe témoin et que le groupe de bruit diurne. Même si les résultats n’étaient pas significatifs, nous avons observé que le moment de la journ 6. Keywords, descriptors or identifiersEnter words or phrases separated by semi-colons. 7. Contributing agenciée avait une influence sur le sommeil : à 8 h, le premier stade du sommeil était plus long qu’il ne l’était l’après-midi ou le soir. L’auto?évaluation du sommeil révélait des tendances similaires. En conclusion, l’environnement cloîtré et, dans une certaine mesure, l’exposition au bruit avaient des effets négatifs sur le sommeil. Les résultats montrent une réduction du sommeil paradoxal proportionnelle au degré d’exposition au bruit et un faible impact du bruit sur les paramètres objectifs du sommeil.

15. KEYWORDS, DESCRIPTORS or IDENTIFIERS

(U) noise, sleep composition, EEG, cloistered environment