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# Effects of pre-sleep simulated on-call instructions on subsequent sleep

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ABSTRACT

Nightly interventions, prevalent to on-call situations, can have negative consequences for those involved. We investigated if intervention-free-on-call-nights would also mean disturbance-free-sleep for people on-call. 16 healthy sleepers spent three nights in the laboratory: after a habituation night, reference and on-call night were counterbalanced. Subjects were instructed to react to a sound, presented at unpredictable moments during the night. Participants were unaware of the fact that the sound would never be presented. These vigilance instructions resulted in more subjective wake after sleep onset (WASO), lower subjective sleep efficiency and significantly lower experienced sleep quality. Objectively, a longer sleep onset, an increased amount of WASO and significantly lower sleep efficiency were observed. During deep sleep, significantly more beta activity was recorded. Apart from real nightly interventions increased vigilance during the night causes sleep to be less efficient and less qualitative as shown by an increase in wake-activity and a distorted sleep perception.



## 1. Introduction

Being on-call during the night, defined as being available while sleeping during the night when summoned for service or use (Cayne and Lechner, 1992), is known to be a common practice among care givers and medical staff (Jamner et al., 1991), firemen (Finnerty, 1977) and military personnel (Spielman and Glovinsky, 1991), but this also counts for engineers (Torsvall and Åkerstedt, 1988), nuclear power plant controllers, space shuttle controllers (Patterson and Woods, 2001) or parents of young children (Keener et al., 1988; Spielman and Glovinsky, 1991; Weinger and Ancoli-Israel, 2002).

The frequent interventions during the night can have several negative consequences for those who are involved, either for the on-call person or for those depending on them. Apart from the immediate sleep inertia, effects such as grogginess, disorientation and cognitive impairment (Bonkalo, 1974; Howard, 2005; Patterson and Woods, 2001; Wertz et al., 2006), nightly interventions might lead to partial sleep deprivation in the sense that sleep is fragmented and possibly also reduced (Bonnet and Arand, 1995; Weinger and Ancoli-Israel, 2002). The above "on-call" definition even covers Boonstra et al.'s (2007) definition of sleep fragmentation: "The case in which an organism is permitted to sleep but wakes up and falls asleep again at certain intervals."

Several studies (both field and laboratory) among medical personnel confirm the observation that clinical performance is negatively affected by the sleep disturbing effects of an on-call night (Grantcharov et al., 2001; Howard, 2005; Taffinder et al., 1998; Weinger and Ancoli-Israel, 2002; Wesnes et al., 1997). Wesnes et al. (1997) studied the effects of a weekend on-call in a surgical unit. The doctors worked in total about 35 h and slept around a mean of 4 h both Saturday and Sunday night. Cognitive function testing on Monday morning resulted in significant impaired results compared to after a weekend off duty. In an experimental set-up, Taffinder et al. (1998) investigated the effects of both a night of total sleep deprivation and a sham night on-call (meaning that participants were disturbed at 0000 am, 0300 am and 0600 am). The following morning the six participating surgeons performed a laparoscopy in a simulator. Compared to a full night's sleep, the number of errors and the time needed to complete the surgery increased significantly in a linear way with most errors and time needed after the sleep deprivation night. Both studies point out the potential danger of medical errors due to on-call induced sleep deprivation.

The expectation to be ready to awaken from nighttime sleep for potential interventions also manifests itself in private life and can exert an important influence there too. A study by Keener et al.

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(1988) on nighttime parental interventions demonstrated that the perception of the temperament of one's baby by parents is related to objective variables regarding the sleep continuity of one's baby. Babies who need frequent nighttime interventions are considered more temperamentally difficult and arrhythmic than babies who have longer sleep periods and who needed shorter nighttime interventions. Keener et al. (1988) also pointed out that this negatively shapes the parental perception of one's infant, which might possibly influence the parent-infant relationship.

In addition to third party persons, the health of the on-call persons is at stake as well. They might injure themselves, and experience more negative moods, whereas positive moods decrease (Howard, 2005). Wesnes et al. (1997) observed in their study among doctors that they felt less energetic, less confident and more confused following a weekend on-call. The impairment in attentional speed and the decrease in vigilance sensitivity that they observed were in magnitude close to the impairments produced by an alcohol intoxication close to or above the safe limit for driving (Wesnes et al., 1997), a result supported by Dawson and Reid (1997) who found an equal performance impairment after 24 h of sleep deprivation and at a blood alcohol concentration of 0.1%. Also, regarding sleep, partial sleep deprivation due to an on-call situation might result in an acute state of situational insomnia (Lavie et al., 1991). In the long run when the partial sleep deprivation becomes regular, this acute state of insomnia might become more chronic (Dinges et al., 1997; Weinger and Ancoli-Israel, 2002).

There are, at least, two specific characteristics of an on-call situation determining its effect. First of all, being on-call as defined above implies that the number of interventions might vary from one night upon the other, with the possibility that not a single alert occurs (Finnerty, 1977; Torsvall et al., 1987). However, intervention-free-on-call-nights do not necessarily imply disturbance-free-sleep in those people who are on-call. A study by Richardson et al. (1996) among medical house staff revealed that uncovered interns' sleep was more fragmented and contained less slow wave sleep per hour of sleep than the sleep of interns whose sleep period was covered by a night-float physician. This difference in sleep quality was even observed when no pages occurred during the sleep period. In a sleep diary study among engineer officers Torsvall et al. (1987) have shown that also on nights without interventions, sleep quality is reduced and uneasiness was reported. In an EEG-study among ship engineers, Torsvall and Åkerstedt (1988) observed a shortened sleep length, less slow wave sleep and REM-sleep and decreased delta activity. Also, the heart rate was elevated. Many of these effects were already present in the 3 h of sleep before the first intervention. In the two latter studies (Torsvall and Åkerstedt, 1988; Torsvall et al., 1987) these pre-intervention disturbances were attributed to the apprehension to a sleep disturbing intervention. This brings us to the second determining characteristic, being the fact that many on-call situations have a certain affective load, for example, paramedics on duty in a 911 emergency station can face dangerous conflict situations or tragic accidents (Jamner et al., 1991), astronauts might be called to duty for unusual situations in a high risk environment (Patterson and Woods, 2001) or during war both soldiers and civilians might experience the stress of on-call situations. A study by Lavie et al. (1991) among the Israeli people during the Persian Gulf War, focused on the sleep problems experienced by the frequent nightly chemical missile attacks. People were afraid of not being awakened by the alarms or, if they were awakened, of not having enough time to bring themselves into safety. It is clear that these nightly interventions implicate a certain level of stress.

In earlier studies regarding the sleep disturbing effect of on-call situations it is nevertheless difficult to clearly differentiate between the effects of either the apprehension to the call or the actual call. Therefore the present study tried to break the on-call situation down to its basics. We presented to healthy sleeping subjects an on-call situation with only the possibility of a nightly intervention but without a real intervention. In addition the stimulus and the requested action were kept as neutral as possible. In this way, we had the opportunity to investigate the specific effect of the expectancy to be awoken from sleep and the need to respond adequately, as a factor that is part of all on-call situations. We hypothesized that this neutral, simulated on-call situation within healthy sleeping subjects would negatively influence the sleep macro- and microstructure. Specifically, an increase in awakenings and Stage N1 sleep together with a decrease in deep sleep were expected as also an increase in high frequency EEG-activity during deep sleep. In addition to these objective influences, we also hypothesized lower subjective sleep quality and more frequent and longer awakenings as indicated in the sleep diaries, in response to the simulated on-call situation.

**Table 1**
Overview of the experimental procedure of one night.

| Time (h) | Activity |
|---|---|
| 0700 pm | Arrival at the laboratory completion of CS, ES and KSS[a] |
| | Application of the electrodes |
| 1035 pm | Experimental On-Call condition: on-call instruction[b] |
| 1045 pm | Completion of CS, ES, KSS, POMS and AD-ACL[a] |
| 1100 pm | Bedtime |
| | Start of PSG[a] recording |
| 0700 am | Awakening |
| | Electrodes removed |
| 0715 am | Completion of CS, ES, KSS, POMS, AD-ACL[a] and sleep diary |
| 0730 am | Shower and breakfast |
| 0800–0900 am | Start normal daytime activities |

[a] CS = cognitive scale; ES = emotion scale; KSS = Karolinska sleepiness scale; POMS = profile of mood state; AD-ACL = activation/deactivation adjective checklist; PSG = polysomnography.
[b] See Section 2.2.2 for detailed on-call instructions.

## 2. Materials and methods

### 2.1. Participants

Eighteen volunteers (eight men and ten women), between the ages of 18 and 29 years (23.9 years ±0.8) participated in the study. They were recruited through advertisements at the university website and random university mailing lists, not including psychology students whose prior knowledge of deception experiments could bias the study. To be included they had to be in general good health, non-regular smokers and non-abusers of alcohol or other substances that influence the central nervous system. Adherence to the healthy sleep standards was ensured based on the Pittsburgh Sleep Quality Index (PSQI) (Buysse et al., 1989), the Insomnia Interview Schedule (Morin, 1993) and a general intake interview. Only volunteers with PSQI scores equal or lower than five were included in the study. Selected participants who during the reference night had a sleep onset latency of 30 min or more (Morin, 1993) were excluded. All participants signed informed consent forms. Complete participation to the study was rewarded with €150 independent of any results or performance.

### 2.2. Design and procedure

Two weeks prior to the experiment and during the experimental week, participants had to fill out sleep diaries to control for any abnormalities in their sleep–wake rhythm. Participants spent three nights in the laboratory: a habituation night followed by two test conditions [on-call (On-Call) and reference (REF) night] in counterbalanced order and with one night wash out at home in between. Table 1 shows an overview of the experimental procedure of one night. The Institutional Review Board approved the study protocol.

#### 2.2.1. Questionnaires

The evening of the habituation night subjects completed the Arousal Predisposition Scale (APS) (Coren, 1988). This 12-item scale has a five-point response format (from 1 being "never" to 5 being "always"). High scores for this scale are indicative of a higher intensity of the construct.

Sleep diaries inform us about time awake in bed and drug intake or alcohol or caffeine use in the late evening. In the morning, subjects evaluated sleep quality and how refreshed they felt on an eleven-point visual analog scale (VAS) (from 0 being "extremely bad" to 10 being "extremely good").

The Cognitive VAS-Scale (CS) assesses two cognitive complaints - problems concentrating and memory deficits – on a four point VAS-scale (from 1 being "absolutely not" to 4 being "seriously"), giving a total score of minimum 2 and maximum 8. The higher the score on the CS, the more problems were experienced.

The Emotional VAS-Scale (ES) assesses four emotional states – "feeling of being tense", "feeling of being gloomy", "feeling of being active" and "feeling of being relaxed" – on a four point VAS-scale (from 1 being "absolutely not" to 4 being "seriously"), giving a total score of minimum 4 and maximum 16. The higher the score on the ES, the more negative the affect experienced.

The Karolinska Sleepiness Scale (KSS) (Åkerstedt and Gillberg, 1990) runs from 1 ("extremely alert") to 9 ("very sleepy, having trouble staying awake") and assesses subjective sleepiness level.

The 32-item version of the Profile of Mood States (POMS) [Dutch translation by Cluydts (1979)] is a four-point adjective scale (from 1 being "totally disagree" to 4 being "totally agree") that results in five subscales including: tension (6–24), depression (8–32), anger (7–28), fatigue (6–24) and vigor (5–20). Higher scores are indicative of a higher intensity of the construct experienced.

The 27-item Activation/Deactivation Adjective Checklist (AD-ACL) (Mackay et al., 1978) is a four-point adjective checklist (from 1 being "totally disagree" to 4 being "totally agree") that results in two subscales: Stress and Arousal. Higher scores indicate higher levels of stress and arousal experienced.

#### 2.2.2. On-call instruction

Approximately 25 min before going to bed participants went to their room where the written on-call instructions were given. These instructions implied that during the night, one or more times a sound could be presented. If during the night this particular sound would be heard, subjects were asked to press a button at hand as quickly as possible (within 30 s). After correctly pressing the button three times to a presented sound, no sound would be presented for the remainder of the night. Participants were also told that the presentation of the sound was completely, automatically controlled. So, the program would choose randomly the amount of sounds presented and the time point at which to present these sounds. They were also told that the sound protocol would only start as soon as they were asleep. Furthermore, it was mentioned that pressing the button without a preceding sound would not have any effect.

After reading the instructions a sample sound (5 s of white noise) was presented through speakers in the bedroom. Because the effect of the presented noise on sleep was not the focus of this study, the sound was never presented during the night. However, beforehand, participants were unaware of this deception.

Prior to the core study, a two case pilot study was executed to check the credibility of the simulation. In this pilot study, a brief one-page questionnaire consisting of a few questions concerning the credibility of the instructions, the experiment and the simulation was given to the subjects to fill out in the morning; and, the results confirmed the credibility of the induction.

### 2.3. Polysomnography (PSG) and fast Fourier transform (FFT) analyses

According to the 10–20 system, electro-encephalogram (EEG) electrodes were placed at positions F3, C3, O1, F4, C4 and O2 with A1 and A2 contralaterally as reference, together with electro-oculogram, submental electromyogram and electrocardiogram electrodes. All channels were measured at 200 Hz by the Medatec DREAM system (Medatec nv., Brussels, Belgium). Afterwards the PSG-recordings were blinded and scored by trained technicians, according to the criteria of the American Academy of Sleep Medicine (Iber et al., 2007). To analyze the fluctuation in sleep stage distribution over the night, next to overall all-night sleep stage distribution, for each hour separately the sleep stage distribution was analyzed and this for the first 6 h after sleep onset.

Fast Fourier transform (FFT) analyses were based on the computation of the following frequency bands for all consecutive 30-s epochs: delta (0.5–4 Hz), theta (5–8 Hz), alpha (8–12 Hz), sigma (12–16 Hz), low beta (16–20 Hz) (beta-lo) and high beta (20–24 Hz) (beta-hi). Hereby we focused ourselves on C3-A2 and C4-A1 during Stage N3. The 30-s sleep scores were used to group the power spectrum analyses results and epochs with artifacts were excluded by visual examination (Jenni and Carskadon, 2004) [mean percentage + SE (standard error) artifact-free 30-s epochs of Stage N3 (REF: 91.5 ± 1.9; On-Call: 94.6 ± 1.0; Wilcoxon paired *t*-test = 43.0; n.s.; *n* = 16)].

Sleep onset latency (SOL) was individually defined as the time between lights out and the first three consecutive epochs of Stage N1. Good morning time (GMT) was the final wake episode before getting out of bed.

### 2.4. Statistical analysis

Due to lack of normal distribution of the data and small sample size, non-parametric methods of analysis were used. All questionnaire data were rescaled (if necessary) so that each scale's minimum score would be zero. The questionnaire data of the CS, ES and KSS were analyzed using non-parametric Friedman ANOVA. The condition (REF or On-Call) and time (upon arrival, in the evening and in the morning) were extracted as within – subject variables. Where appropriate Wilcoxon paired *t*-tests were used for post hoc analyses. Bonferroni correction was applied to adjust the $\alpha$ of 0.05 to correct for multiple comparisons. Considering the within subject design Wilcoxon paired *t*-tests were used to analyze the POMS, AD-ACL, sleep diaries and EEG data. All statistical analyses were executed using STATISTICA 10 (StatSoft, Inc., 1984–2011). Data were expressed as mean ± SE (standard error).

**Table 2**
Evening and morning scores of the stress and arousal subscales of the AD-ACL both for the reference (REF) and On-Call conditions (mean ± SE).

| AD-ACL | Evening | Morning | *T*-score |
|---|---|---|---|
| REF-Stress | 12.07 ± 1.71 | 10.27 ± 1.76 | 37.00 |
| On-Call-Stress | 12.33 ± 2.23 | 11.20 ± 1.28 | 40.00 |
| *T*-score | 51.00 | 41.50 | |
| REF-Arousal | 15.00 ± 1.88 | 20.80 ± 1.72 | 15.00* |
| On-Call-Arousal | 18.53 ± 1.43 | 19.20 ± 1.18 | 38.00 |
| *T*-score | 12.00* | 45.50 | |

* $p < 0.05$.

## 3. Results

Two female subjects had to be excluded according to the exclusion criteria (see Section 2.1). All objective variables have a sample size of 16. Except from the "sleep quality" and the "feeling refreshed" scores, all subjective variables have a sample size of 15 instead of 16. The morning sleep diary and questionnaire data of one subject were missing.

### 3.1. Questionnaires

On the APS scale one subject had a score below the 'low arousal' category. Five subjects had a score within the 'low arousal' category, 10 subjects in the 'average arousal' category and none in the 'high arousal' category. When analyzing the data from the CS-scale, no significant main effects over time (including arrival, evening and morning) were found (REF: $\chi^2_{df=2} = 0.78$; n.s.; On-Call: $\chi^2_{df=2} = 1.23$; n.s.; $n = 15$). Between conditions a trend towards more reported cognitive problems in the On-Call condition was observed ($\chi^2_{df=1} = 3.20$; $p < 0.10$). For the ES-scale no significant differences were observed between conditions ($\chi^2_{df=1}$; n.s.) or over time (including arrival, evening and morning) (REF: $\chi^2_{df=2} = 3.64$; n.s.; On-Call: $\chi^2_{df=2} = 0.17$; n.s.; $n = 15$). A significant main effect for time (including arrival, evening and morning) was found for the KSS score (REF: $\chi^2_{df=2} = 12.49$; $p < 0.01$; On-Call: $\chi^2_{df=2} = 17.09$; $p < 0.001$; $n = 15$). Post hoc analyses (Bonferroni correction: $\alpha/3$) showed that both in the REF ($T = 10.00$; $p < 0.017$; $n = 15$) and the On-Call ($T = 0.00$; $p < 0.003$; $n = 15$) conditions subjects evaluated themselves significantly sleepier in the evening than upon arrival. In the morning of the REF condition this sleepiness was significantly less than in the evening ($T = 11.00$; $p < 0.017$; $n = 15$) and at an equal level as upon arrival ($T = 30.00$; n.s.; $n = 15$). In the morning after the On-Call night subjects felt themselves almost as sleepy as in the evening ($T = 15.00$; n.s.: $n = 15$) and tended to feel sleepier than upon arrival ($T = 12.00$; $p < 0.03$; $n = 16$). For the subscale Stress of the AD-ACL no significant effects were found over time (including evening and morning) or between conditions. On the Arousal subscale of the AD-ACL, subjects felt significantly less aroused in the evening of the REF condition than in the evening of the On-Call condition. They also felt significantly more aroused in the morning of the REF condition compared to the evening. Within the On-Call condition no significant change in Arousal from the evening to the morning was observed (see Table 2 for an overview of the AD-ACL results).

On the subscale Tension of the POMS, subjects expressed to be significantly more tensed in the evening of the On-Call condition compared to the morning. The tension in the evening of the On-Call condition tended to be higher than in the evening of the REF condition. For the Depression scale of the POMS, a trend was observed.

**Table 3**
Evening and morning scores of the subscales tension (T), depression (D), anger (A), fatigue (F) and vigor (V) of the POMS both for reference (REF) and On-Call conditions (mean ± SE).

| POMS | Evening | Morning | *T*-score |
|---|---|---|---|
| REF-T | 1.47 ± 0.54 | 1.67 ± 0.66 | 7.50 |
| On-Call-T | 2.27 ± 0.71 | 1.07 ± 0.44 | 12.00* |
| *T*-score | 13.00[a] | 9.00 | |
| REF-D | 2.27 ± 0.90 | 1.40 ± 0.65 | 6.50[a] |
| On-Call-D | 2.27 ± 1.17 | 1.87 ± 0.59 | 12.00 |
| *T*-score | 22.00 | 12.00 | |
| REF-A | 1.53 ± 0.68 | 1.80 ± 0.64 | 13.00 |
| On-Call-A | 1.93 ± 0.85 | 1.67 ± 0.60 | 14.00 |
| *T*-score | 2.50[a] | 29.00 | |
| REF-F | 5.60 ± 1.22 | 1.73 ± 0.57 | 0.00** |
| On-Call-F | 3.33 ± 0.86 | 2.53 ± 0.68 | 15.00 |
| *T*-score | 10.50* | 21.00 | |
| REF-V | 5.93 ± 0.84 | 7.67 ± 1.01 | 20.50 |
| On-Call-V | 7.40 ± 0.70 | 7.87 ± 0.65 | 30.50 |
| *T*-score | 11.50[a] | 59.00 | |

[a] $p < 0.10$.
* $p < 0.05$.
** $p < 0.01$.

The Depression score was lower in the morning after the REF night compared to the evening. Subjects tended to have more feelings of anger in the evening of the On-Call night than in the evening of the REF night. Subjects felt significantly less fatigue in the evening of the On-Call condition and they felt significantly less fatigue in the morning of the REF condition compared to the evening. Subjects tended to feel less vigor in the evening of the REF condition compared to the evening of the On-Call condition (see Table 3 for an overview of the POMS results).

### 3.2. Sleep diaries

The analysis of the sleep diary data did not result in significant differences between the REF and the On-Call condition regarding the SOL ($T = 16.00$; n.s.; $n = 15$) and the GMT ($T = 8.50$; n.s.; $n = 15$). Trends were observed for Total Sleep Time (TST) ($T = 17.00$; $p < 0.10$; $n = 15$), subjective sleep efficiency ($T = 18.00$; $p < 0.10$; $n = 15$; see Fig. 1.) and for the percentage of Wake After Sleep Onset (WASO) ($T = 16.00$; $p < 0.10$; $n = 15$). Subjects tended to indicate that they had slept on average 27 min less and had been on average 5 min more awake during the On-Call night than during the REF night (see Fig. 1.). The mean duration of the WASO was significantly longer ($T = 0.00$; $p < 0.05$; $n = 15$) during the On-Call night compared to the REF night (see Table 4 for an overview of the sleep diary results).

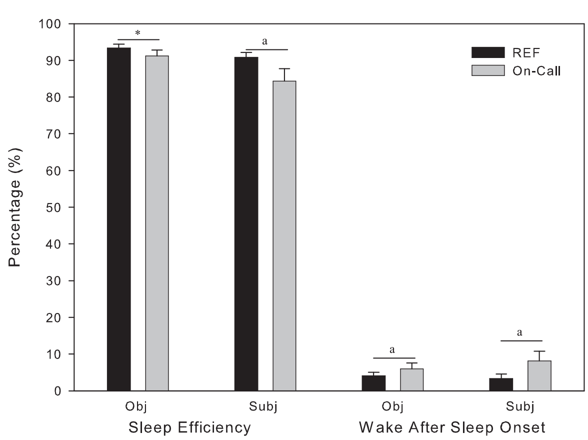


**Fig. 1.** Percentage of sleep efficiency and wake after sleep onset both objective (PSG-data) and subjective (sleep diary-data) in REF and On-Call condition, $^{*}p < 0.05$; $^{a}p < 0.10$.

**Table 4**
Sleep Diary variables: both for the reference (REF) and On-Call conditions (mean ± SE).

| | REF | On-Call | *p* |
|---|---|---|---|
| SOL[a] (min) | 17.00 ± 3.23 | 24.00 ± 6.68 | n.s. |
| GMT[a] (min) | 11.00 ± 3.09 | 15.00 ± 5.07 | n.s. |
| TST[a] (min) | 427.00 ± 10.13 | 400.00 ± 17.67 | <0.10 |
| % WASO[a] | 3.61 ± 1.27 | 8.61 ± 3.85 | <0.10 |
| Length of WASO periods | 8.00 ± 2.48 | 17.20 ± 3.60 | <0.05 |
| % Sleep efficiency | 90.65 ± 1.30 | 84.19 ± 3.56 | <0.10 |

[a] SOL (min) = sleep onset latency in minutes; GMT (min) = good morning time in minutes; TST (min) = total sleep time in minutes; % WASO = percentage wake after sleep onset.

There was no significant difference in subjects' evaluation of feeling refreshed in the morning between the REF and the On-Call condition ($T = 17.00$; n.s.; $n = 16$). Subjects evaluated the sleep quality of their On-Call night (mean = 6.19; SE = 0.38) significantly lower ($T = 16.00$; $p < 0.05$; $n = 16$) than the quality of their REF night (mean = 7.25; SE = 0.45).

### 3.3. Polysomnography (PSG)

No significant differences between the REF and the On-Call condition were found with regard to the sleep stage distribution, the latency to Stage N3 sleep, the GMT (51.00; n.s.; $n = 16$) and the TST ($T = 48.00$; n.s.; $n = 16$). A trend was observed regarding the SOL ($T = 34.50$; $p < 0.10$; $n = 16$) and the amount of WASO ($T = 35.00$; $p < 0.10$; $n = 16$). During the On-Call night there was a trend to more WASO compared to the REF night (see Fig. 1.). Between conditions there was a significant difference in sleep efficiency (see Fig. 1.) with less sleep efficiency in the on-call condition ($T = 30.00$; $p < 0.05$; $n = 16$) (see Table 5 for an overview of the PSG-results).

The fluctuation in sleep stage distribution for the first 6 h after sleep onset was analyzed. Next to significant fluctuations over time, also significant differences in the amount of Stage N3 ($\chi^2_{df=11} = 77.47$; $p < 0.001$; $n = 16$) were found between the two conditions. Post hoc analyses (Bonferroni correction: $\alpha/6$) showed that during the third hour after SO there was significantly less Stage N3 sleep ($T = 16.00$; $p < 0.0083$; $n = 16$) in the On-Call night (see Fig. 2 for an overview).

### 3.4. FFT

A significantly higher amount of low beta activity was found in the Stage N3 of the On-Call condition at position C3 ($T = 27.00$; $p < 0.05$; $n = 16$) and C4 ($T = 26.00$; $p < 0.05$; $n = 16$). For high beta activity a trend was observed at position C3 ($T = 34.00$; $p < 0.10$; $n = 16$) and a significant difference at position C4 ($T = 27.00$; $p < 0.05$; $n = 16$) in Stage N3, with more beta-hi activity in Stage N3

**Table 5**
PSG variables: both for the reference (REF) and On-Call conditions (mean ± SE).

| | REF | On-Call | *p* |
|---|---|---|---|
| SOL[a] (min) | 9.72 ± 1.35 | 12.78 ± 1.79 | <0.10 |
| GMT[a] (min) | 3.03 ± 0.99 | 2.41 ± 0.83 | n.s. |
| TST[a] (min) | 434.50 ± 7.14 | 422.31 ± 10.19 | n.s. |
| % Stage N1[a] | 9.55 ± 1.30 | 11.47 ± 1.94 | n.s. |
| % Stage N2 | 43.99 ± 2.44 | 42.35 ± 1.55 | n.s. |
| % Stage N3 | 29.38 ± 2.07 | 29.31 ± 1.83 | n.s. |
| % REM | 17.09 ± 2.12 | 16.87 ± 1.68 | n.s. |
| % Awake | 4.10 ± 1.02 | 5.98 ± 1.60 | <0.10 |
| Stage N3-L[a] | 13.38 ± 1.68 | 13.80 ± 1.83 | n.s. |
| Sleep efficiency | 93.58 ± 1.07 | 91.29 ± 1.71 | <0.05 |

[a] SOL (min) = leep onset latency in minutes; GMT (min) = good morning time in minutes; TST (min) = total sleep time in minutes; % Stage N1/N2/N3 = percentage Stage N1/N2/N3; Stage N3-L = latency to Stage N3 presented in minutes.

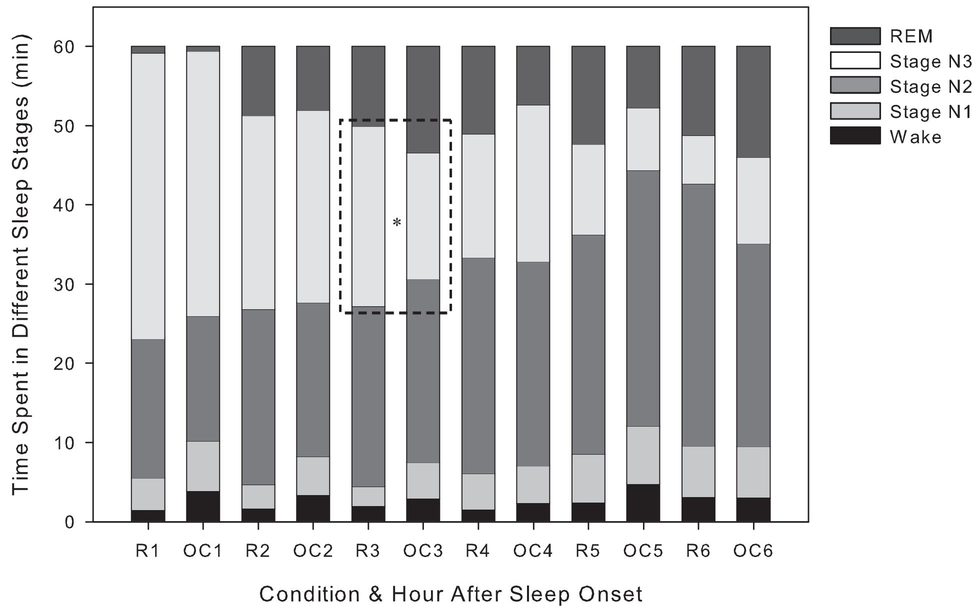


**Fig. 2.** Sleep Stage Distribution for the 1st 6 h after sleep onset. R1–R6: first-sixth hour of sleep in REF condition; OC1-OC6: first-sixth hour of sleep in On-Call condition. Dotted rectangle frames the significant difference in Stage N3 between REF and On-Call condition, *$p < 0.0083$ (Bonferroni correction).

of the On-Call condition. For the lower frequencies no significant differences or trends were observed (see Table 6 for an overview of the FFT results).

## 4. Discussion

In accordance with the aim of our study we succeeded in simulating an on-call situation with only the expectation of a nightly intervention but without a real intervention: participants were convinced of the genuineness of the instructions as we could register that one third of them pressed the button at least once during the on-call night, although no sound was presented. They also felt more tensed after reading the instructions. All participants had average or below average arousability scores on the Arousal Predisposition Scale suggesting them to be less vulnerable to stress inducing factors. Nevertheless, as hypothesized both objective sleep data and subjective sleep evaluations were negatively influenced in response to the simulated On-Call situation compared to the reference condition.

A small change in the amount of deep sleep in the On-Call condition was observed which is in line with the findings of Richardson et al. (1996) among medical house staff and of Torsvall and Åkerstedt (1988) among engineer officers. Furthermore our subjects also declared to have slept on average 27 min less during the on-call night and in line with Torsvall et al.'s (1987) sleep diary study, our subjects reported a significantly lower sleep quality after the On-Call night. With a mean difference of 9 min, the subjects had also the impression that they were lying awake significantly longer during the on-call night. Polysomnographic results showed a trend towards longer sleep onset and more wake after sleep onset, causing the on-call night to be significantly less efficient, but with greater mean differences in subjective than objective measures (sleep onset, total sleep time and sleep efficiency) subjects tended to over estimate the disturbance of the on-call instruction.

The reason for this increased wakefulness is speculative. In both studies Torsvall, Åkerstedt et al. (Torsvall and Åkerstedt, 1988; Torsvall et al., 1987) put apprehension forward as a possible culprit. Earlier studies have shown that apprehension stress for the upcoming working day decreases slow wave sleep and negatively influences sleep quality (Kecklund and Åkerstedt, 2004). The apprehension for an unpleasant awakening advances wake-up time (Kecklund et al., 1997) and anticipation to be awakened elicits an anticipatory adrenocorticotropine release (Born et al., 1999), adrenocorticotropine in its' turn can promote awakenings (Follenius et al., 1985). Studies among animals also showed that under stress conditions (like the risk of predation) animals (like birds and rats) tend to spend more time in lighter sleep states (Lima et al., 2005) in order to be more alert for upcoming danger. Consequently, in our study, apprehension to the presentation of a noise fragment is possible to increase the amount of light sleep and hence decrease the amount of deep sleep. This was suggested by the significantly increased amount of beta low and beta high activity.

We can conclude that our results point out that apart from real nightly interventions and apart from a stressful environment, a sleep with increased vigilance is less efficient and likely to be less qualitative as shown by an increase in wake activity and light sleep and a decrease in restorative deep sleep.

Present findings also contribute to the empirical evaluation of theoretical models on the development and persistence of insomnia complaints. Many models of insomnia (Espie et al., 2006; Harvey, 2002; Lundh and Broman, 2000; Morin, 1993; Riemann et al., 2010) have put apprehension or negative expectations about sleep forward as an important perpetuating factor. A vicious circle is assumed in which safety behaviors and the occurrence of disturbed nights (or the distorted sleep quality perception) enhance

**Table 6**
FFT frequencies at location C3 and C4 for Stage N3 in the reference (REF) and On-Call conditions (mean % ± SE).

| SWS | REF | | On-Call | |
|---|---|---|---|---|
| | C3 | C4 | C3 | C4 |
| Delta | 84.26 ± 0.80 | 85.27 ± 0.80 | 83.89 ± 0.75 | 84,34 ± 0.77 |
| Theta | 9.08 ± 0.50 | 8.50 ± 0.50 | 9.10 ± 0.49 | 8,88 ± 0.51 |
| Alpha | 3.08 ± 0.20 | 2.92 ± 0.22 | 3.16 ± 0.17 | 3,09 ± 0.19 |
| Sigma | 2.33 ± 0.21 | 2.28 ± 0.21 | 2.33 ± 0.18 | 2,41 ± 0.17 |
| Beta-lo | 0.56 ± 0.05* | 0.48 ± 0.05* | 0.64 ± 0.06* | 0,58 ± 0.06* |
| Beta-hi | 0.34 ± 0.03[a] | 0.27 ± 0.03* | 0.39 ± 0.04[a] | 0,34 ± 0.04* |

[a] $p < 0.10$ between the REF and On-Call conditions.
* $p < 0.05$.

the negative expectations about sleep. In turn, these expectations result in negatively toned cognitive activity when trying to sleep on the one hand and on the other hand safety behaviors are further stimulated by these cognitions. Although, little is known about the start of the vicious circle, the results from our experiment on young healthy sleepers are sleep phenomena that have been observed in insomnia patients as well, suggesting a potential precipitating role, in addition to a perpetuating one, for negative expectations in the insomnia pathology.

However, both stimulus (the five seconds of white noise) and the action requested (pressing a button at hand) were neutral and meaningless. Our subjects also commented in the morning that during the night the stimulus was hard to distinguish from other sounds, both because of the shortness and the neutrality of the noise.

To relieve the suboptimal conditions of an on-call night, future research might investigate the effect of other stimuli (less neutral, more clear and louder) under the same simulated on-call conditions to find out if an optimal (maybe even personalized) waking method would put the person on-call his mind at rest and would optimize the small amount of sleep that might be left in advance or in between the possible interventions. Future research should also investigate the extent to which the sleep disturbing effects of an intervention free on-call night would compromise next day performance.

## Conflict of interest statement

This was not an industry supported study. The authors have indicated no financial conflicts of interest.

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