

## Amsterdam University of Applied Sciences

### Effect of nocturnal sound reduction on the incidence of delirium in intensive care unit patients

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*Published in:*  
Intensive & critical care nursing

*DOI:*  
[10.1016/j.iccn.2017.01.008](https://doi.org/10.1016/j.iccn.2017.01.008)

[Link to publication](#)

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*Citation for published version (APA):*  
van de Pol, I., van Iterson, M., & Maaskant, J. (2017). Effect of nocturnal sound reduction on the incidence of delirium in intensive care unit patients: an interrupted time series analysis. *Intensive & critical care nursing*, 41(August), 18-25. <https://doi.org/10.1016/j.iccn.2017.01.008>

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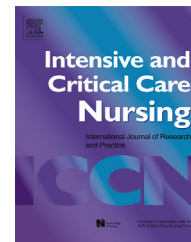
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# Lighting, sleep and circadian rhythm: An intervention study in the intensive care unit



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Accepted 4 July 2015

## KEYWORDS

Circadian rhythm;  
Critical care;  
Content analysis;  
Cycled light;  
Intensive care unit;  
Interview;  
Mann–Whitney-test;  
Lighting;  
Nursing;  
Sleep

**Summary** Patients in an intensive care unit (ICU) may risk disruption of their circadian rhythm. In an intervention research project a cycled lighting system was set up in an ICU room to support patients' circadian rhythm. Part I aimed to compare experiences of the lighting environment in two rooms with different lighting environments by lighting experiences questionnaire. The results indicated differences in advantage for the patients in the intervention room ( $n=48$ ), in perception of daytime brightness ( $p=0.004$ ). In nighttime, greater lighting variation ( $p=0.005$ ) was found in the ordinary room ( $n=52$ ). Part II aimed to describe experiences of lighting in the room equipped with the cycled lighting environment. Patients ( $n=19$ ) were interviewed and the results were presented in categories: "A dynamic lighting environment", "Impact of lighting on patients' sleep", "The impact of lighting/lights on circadian rhythm" and "The lighting calms". Most had experiences from sleep disorders and half had nightmares/sights and circadian rhythm disruption. Nearly all were pleased with the cycled lighting environment, which together with daylight supported their circadian rhythm. In night's actual lighting levels helped patients and staff to connect which engendered feelings of calm.

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<http://dx.doi.org/10.1016/j.iccn.2015.07.001>

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### Implications for Clinical Practice

- Most patients are aware of the lighting environment, indicating the importance of adapting lighting to patients' preferences.
- Light and lighting which follow a natural rhythm support patients' circadian rhythm.
- Lighting experiences are highly individual. Light at night can be both disturbing and provide a feeling of security.

## Background

This study focuses on patients' experiences and reports of being cared for in an intensive care unit (ICU) patient room, provided with a cycled lighting intervention that aims to support the patients' circadian rhythm and health. The circadian rhythm is constituted of regular day and night over approximately 24 hours and light and darkness is important for the human health in supporting the body's circadian rhythm (Gaggioni et al., 2014; LeGates et al., 2014). As early as 1912 Nightingale described light and the rhythm of night and day as two important factors in supporting and restoring patient health. Sleep and wakefulness is the most obvious circadian rhythm in humans (Germain and Kupfer, 2008) and both states have been described as basic human needs by Henderson (1966). The circadian rhythms are driven by the circadian pacemaker in the anterior hypothalamus which functions as the person's inner clock (Saper et al., 2004). Exogenous stimuli such as light are able to set the circadian rhythm in motion (Veitch et al., 2004). Furthermore, light stimulates the immune system by regulating the pineal neurohormone melatonin (Maestroni, 2001), it initiates the absorption of Vitamin D (Mason et al., 2011) and has been reported to reduce the number of days in hospital for patients with bipolar depression (Benedetti et al., 2001).

It is also important to emphasise that light, circadian rhythm and sleep are interrelated and interdependent (Dijk and Archer, 2009). The presence of nighttime light suppresses the melatonin level, which is normally highest at night (Duffy and Wright, 2005). The level of melatonin is widely accepted as an indicator for the circadian rhythm (Benloucif et al., 2005). There are indications that the constant variations in circadian rhythms, due to the changing hormone levels, experienced by night workers have increased the risk of cancer, as well as infectious and autoimmune diseases (Lockley et al., 2003).

### Critically illness, light and circadian rhythm

As the most critically ill and vulnerable patients are cared for in the ICU it is most important for their survival and health that the environment supports patient restorative processes. Unfortunately the ordinary indoor light environment in ICUs does not always support patients' circadian rhythms. Lighting is sometimes used at high levels at night, during treatments, examinations and nursing activities and this may risk disrupting the circadian rhythm (Dunn et al., 2010). Mean illumination levels measured in four different ICUs ranged at night from 2.4 to 145 lx and in the day from 55.3 to 165 lx (Dennis et al., 2010; Frisk et al., 2004; Meriläinen et al., 2010; Verceles et al., 2012). These

measurements highlight two main problems, a pattern of low illumination levels by day and high levels by night.

The ICU patients' nighttime sleep is described as abnormal and fragmented with reduced periods of REM sleep (Elliott et al., 2013). Light in the night is one known factor for sleep disruption when it impairs melatonin secretion (Kamdar et al., 2012). Circadian rhythms are temporally disturbed in most ICU patients; some develop temporal disorganisation and the circadian pacemaker may become effectively free-running (Frisk et al., 2004; Gehlbach et al., 2012; Perras et al., 2007). Furthermore, sleep deprivation is one important risk factor for ICU delirium (Girard et al., 2008). Patients' vulnerability increases with lack of sleep and are characterised by increased sensitivity to light, noise and activity (McKinley et al., 2002). The health, wellbeing and recovery of patients are dependent upon their ability to get a normal sleep and circadian rhythm. Most research into light environments affecting the circadian rhythm in an ICU context has been done with infants (Engwall et al., 2014; Morag and Ohlsson, 2011). Based on the knowledge concerning light and its importance to the circadian rhythm it would seem important to measure and then evaluate and report patients' experiences.

### Aims

This study consisted of two parts: in Part I, the aim was to evaluate and compare patients' experiences of lighting environments in two ICU rooms with different lighting environments; in Part II, the aim was to describe patients' experiences of an ICU room equipped with a cycled lighting environment.

### Method

This study was a part of a larger study concerning patient experiences of the ICU environment with regard to sleep, rest and circadian rhythms (Engwall et al., 2014; Johansson et al., 2012). Part I was a comparative, descriptive study which included data from a questionnaire used to compare two patient groups, one exposed to a cycled lighting system and the other to an ordinary lighting system. Part II had an explorative and descriptive design based on data derived from nineteen interviews, subjected to qualitative and quantitative content analysis (Krippendorff, 2004).

### Setting

The study was conducted in an eight-bed general ICU in a regional hospital in Sweden in which a new cycled lighting intervention designed to promote circadian rhythm and

**Table 1** Schedule concerning 14 different light scenes in periods and illumination levels in the intervention room. Illumination level in lux measured in January 2012.

Light scenes in the intervention room	Time	Illumination levels in lux in horizontal plane at the patients head in January 2012, intervention room
1	7–8 am	58
2	8–10 am	615
3	10–10.30 am	450
4	10.30 am–1pm	330
5	1–3 pm	210
6	3–5 pm	450
7	5–6 pm	330
8	6–7 pm	210
9	7–8 pm	81
10	8–8.45 pm	58
11	8.45–9 pm	30
12	9–9.15 pm	12
13	9.15–9.30 pm	8
14	9.30–7 am	2

health was installed and used in a modified two-bed patient room (intervention room). An identical two-bed patient room was left untouched for comparison (ordinary room).

In the intervention room, a cycled lighting system was developed in cooperation with an expert in environmental psychology and lighting engineers. The lighting system aimed to simulate natural light regarding localisation, brightness and colours of light, worked in 14 different light scenes that were all controlled automatically by software round the clock. The light sources were located at floor level and on walls and a light fitment providing indirect light hung down 45 cm from the ceiling, shining upward in order not to blind the patient. The colour of light varied in two different tubes (2700 K and 6500 K) shining from the light fitment. The day lighting lasted from 07.00 to 19.00 hours. In the morning, a warm, low-level light started the day and with a continued brighter morning period that aimed to wake and alert the patients. At noon the levels became lower and daylight shone through the windows. In the afternoon the lighting levels were higher again and in the evening the same warm colour and low-level lighting as in the morning was repeated. By night, light levels were even lower and

**Table 2** Light settings in illumination levels in the ordinary room. Illumination level in lux measured in January 2012.

Different light sources in comparison room	Illumination levels in lux in horizontal plane at the patients head in January 2012, comparison room
Lightings at wall	147
Lightings in ceiling and walls	810
Night lamps	0.7

only the light sources near the floor were used. The staff then used localised lighting for work when necessary. In the two-bed ordinary room which was used as a control the light sources had been installed in 1992 and the staff switched the light on and off manually according to their own and the patients' preferences. Both rooms featured north-facing windows which let in daylight and provided a view of a grassy slope as well as a small glimpse of the sky. Light levels were measured at each light setting in the intervention room and at each light source in the ordinary room (Tables 1 and 2, Engwall et al., 2014).

## Participants and procedure

Patients, who were admitted to the ICU, were assigned to one of the two rooms according to patient flow. If beds in both rooms were available, patients were assigned randomly. In some cases, the patient's health condition and special needs as well as the number of staff determined which room the patient was allocated to (Fig. 1).

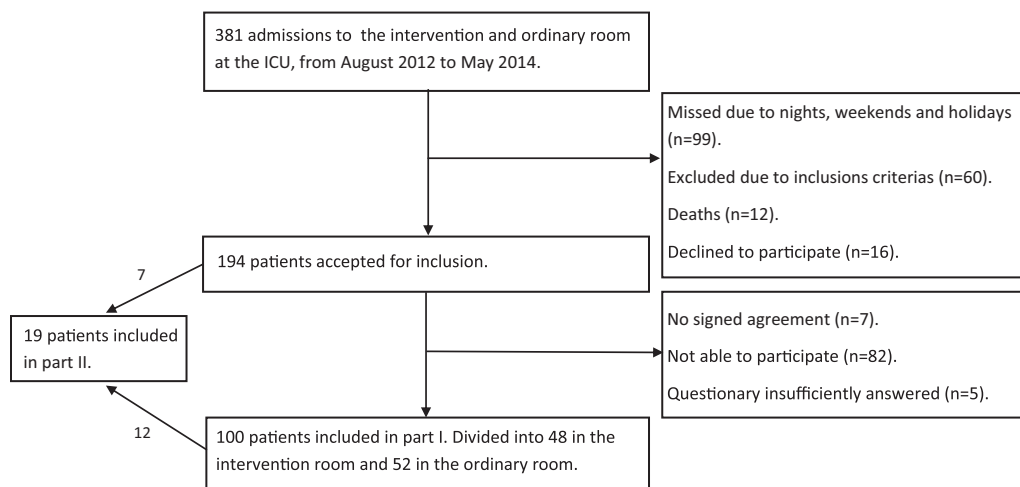
Inclusion criteria for completing the questionnaire (Part I) were competence in the Swedish language and a stable health condition. Exclusion criteria were the presence of psychosis, dementia, blindness, heavy brain injuries or testing positive on Confusion Assessment Method for the ICU (CAM-ICU). Demographic data is presented in Table 3.

Inclusion criteria for participating in the interview study (Part II) were placement in the intervention room for at least two nights, competence in the Swedish language, ability to remember the previous nights and being healthy enough to cope with an interview. Exclusion criteria were the same as described above. The first author visited the patients in the ICU or shortly after discharge in the general ward. Patients healthy enough to cope with an interview were asked to participate. A total of 19 patients took part; two declined participation (Table 4). Twelve of the 19 patients both participated in the interviews and answered the questionnaire. Seven of the 19 patients were only able to participate in the interviews, conducted after discharge from the ICU. Their poor health situation prevented them from completing the questionnaire (Fig. 1).

During the period of data collection a protocol was completed, including all patients admitted to one of the two-bed rooms. Excluded and included patients, demographics, type of data collection, place and period of care, deaths, consent and discharge were all noted. There were significant differences (Table 5) between patients included in the study and those who were excluded in relation to Simplified Acute Physiology Score (SAPS) and numbers of mechanically ventilated patients.

## Data collection

Part I comprises data collected by means of a written questionnaire, developed by environmental psychology researchers (Küller and Laike, 1998; Küller and Wetterberg, 1993). It consists of 17 dichotomous, semantic, seven-grade scales and when using different adjectives it focuses on experiences of lighting environments. An example of an item from the questionnaire is showed in Fig. 2.



**Figure 1** Flowchart of patient selection, Parts I and II.

**Table 3** Demographic data (numbers of patients, age, sex, SAPS and mechanically ventilation) and comparisons between patients in the intervention and the ordinary room, in the day and night, Part I.

	Patients in the intervention group, day	Patients in the ordinary group, day	<i>p</i> -Value, day, <i>t</i> -test. Significant value, <0.05	Patients in the intervention group, night	Patients in the ordinary group, night	<i>p</i> -Value, night, <i>t</i> -test. Significant value, <0.05
<i>n</i>	45	50		17	13	
Age in year, mean	60	62	0.491	63	64	0.844
Gender ratio, men ( <i>n</i> )	24	25	0.838	12	10	1.000
SAPS score, mean	51.07	47.74	0.345	52.47	53.46	0.819
Mechanically ventilated ( <i>n</i> ) <sup>a</sup>	25	23	0.413	10	6	0.713

<sup>a</sup> Number of patients using invasive or noninvasive ventilation.

The questionnaire was used to compare patients' experience of the light environment in the intervention with that in the ordinary room. Reliability was tested and revealed four orthogonal components named; hedonic tone, brightness, variation and flicker. The questionnaire has previously been used in research with healthy people (Küller and Laike, 1998).

The assessment of the light environment was performed in the patient's room at the end of their stay in the ICU or when they were able to participate. The questionnaire was administered by nursing or research staff and completed by

the patients. Sometimes the patients were helped with the writing. The questionnaire took about five to ten minutes to complete. The data were collected from August 2012 until May 2014.

In Part II, semi-structured interviews supported by an interview guide were used to gain a deeper understanding of the patients' experience of the light environment and circadian rhythm (Fig. 3). Interviews were conducted immediately prior to or after patients' discharge from the ICU to the general ward and varied in length from five to forty minutes depending on the patients' experiences and health. The interviews were recorded and transcribed. Only patients from the intervention room were included in the analysis as the researchers' were interested in patient experiences of the cycled lighting environment. These interviews were conducted in January 2013 and from September 2013 until April 2014. The patients were drawn from the dataset ( $n = 194$ ) and ( $n = 100$ ) based on inclusion criteria (Fig. 1).

## Analysis

Part I shows scores and mean values for every factor which were statistically analysed (IBM software® SPSS 21) using

**Table 4** Demographic data (number of patients, sex and age, mechanically ventilated), Part II.

	Patients in the intervention room
<i>n</i>	19
Age in year, mean	65
Gender ratio, men ( <i>n</i> )	13
Mechanically ventilated ( <i>n</i> ) <sup>a</sup>	16

<sup>a</sup> Number of patients using invasive or noninvasive ventilation.

**Table 5** Demographic data (numbers of patients, age, sex, Simplified Acute Physiology Score (SAPS) and mechanical ventilation) comparisons between included and excluded patients, Part I.

	Patients in the inclusion group	Patients in the excluded group	<i>p</i> -Value, <i>t</i> -test. Significant value, <0.05
<i>n</i>	100	281	
Age in year, mean	61	60	0.431
Gender ratio, men ( <i>n</i> )	52	168	0.195
SAPS score, mean	49.40	55.19	0.011
Mechanically ventilated ( <i>n</i> ) <sup>a</sup>	50	193	0.001

<sup>a</sup> Number of patients using invasive or noninvasive ventilation.

How do you experience the light in this room?

Select by ticking the following scale:

Dark        Light

**Figure 2** An example of an item from the questionnaire, Part I.

the Mann–Whitney test to compare patients' lighting experiences between the two rooms, both by day and at night.

The interview data in Part II, were subjected to both quantitative (Krippendorff, 2004) and qualitative conventional (Hsieh and Shannon, 2005) content analysis, focusing on the text's subjective content.

The transcripts were read several times; wholeness was sought and meaningful concepts noted. Codes were created which described small parts of the content of the interviews. The codes were then assembled in one document and by identifying and comparing similarities in the codes they were put into different clusters linked to each other by content. These clusters formed subcategories which described similar content and were then organised into categories. This process was created inductively and kept close to the transcripts to ensure credibility. There was a quantifying part

in the analysis process as five questions in the interview guide could be answered with yes or no. These results are presented separately.

## Ethical considerations

Ethical approval was given by the Regional University Ethics Research Committee (no 695-10). The Helsinki declaration of Ethical Principles for Medical Research involving human subjects guided the study (World Medical Association, 2013). Patients received both verbal and written information and were informed of their rights as voluntary participants prior to providing written consent to participation in the study. Patients were asked to participate when their health situation was stable: at the beginning, middle or end of their stay. Researchers evaluated the patients' ability to participate regarding their health situation in collaboration with the ICU head and the allocated nurse. Patients were treated sensitively and the data collection was ended if patients were unable to complete questionnaires or interviews. Every day in the period of data collection one of the researchers was responsible for the process at the ICU. Patients were admitted to the ICU around the clock and were asked to participate as soon as it was possible.

1. How have you been sleeping in this room during the nights here in the ICU?
2. How has it been for you to fall asleep?
3. Have you been afraid to go to sleep?
4. Have you woken up during the night?
5. What or who woke you up?
6. Do you remember anything that happened during the nights here in the ICU?
7. What feeling do you get when you think of the nights here in the ICU?
8. Have you had any dreams or visions?.
9. What help did you get to sleep?
10. Did you sleep here in the room during the day?
11. What was sleep during the day like?
12. Did you feel rested during the day?
13. How do you sleep at home?
14. How have you kept track of the time during the day?
15. How have you been able to keep track of the morning, afternoon, evening and night?
16. How have you distinguished between day/night?
17. What time of day is it now?
18. What do/did you think about the lighting in the room?
19. Did the light vary during the day? If yes, describe how.
20. What did you think of the brightness at night? Did the light disturb your sleep?
21. Was it light enough for you to feel safe during the night?

**Figure 3** Semi-structured interview guide used in Part II.

**Table 6** Patients' assessment of the light environment, Part I.

Factor	Intervention room, day Mean	Ordinary room, day Mean	Mann–Whitney-test <i>p</i> -Values significant <i>p</i> -value, <0.05	Intervention room, night Mean	Ordinary room, night Mean	Mann–Whitney-test <i>p</i> -Values significant <i>p</i> -value, <0.05
Hedonic tone	5.18	4.94	0.280	5.28	5.01	0.166
Brightness	4.75	4.07	0.004	3.84	3.73	0.619
Variation	3.95	4.00	0.564	3.50	4.58	0.005
Colour	3.65	3.22	0.325	3.40	3.64	0.753
Flicker	2.26	1.94	0.415	2.15	2.55	0.128

**Table 7** Patients' experiences of sleep, nightmares/visions, circadian rhythm and pleased with the cycled lighting environment, Part II.

Participants	Slept badly in the ICU	Slept badly at home	Experiences of nightmares or/and illusions	Experiences of disturbed circadian rhythm	Pleased with the cycled lighting environment
<i>N</i> = 19	11/18 <sup>a</sup>	4/17 <sup>b</sup>	9/19	9/19	16/17 <sup>b</sup>

<sup>a</sup> One patient missing.

<sup>b</sup> Two patients missing.

## Results

The results from the questionnaire (Part I) are presented in text and in [Table 6](#).

### Lighting experiences, Part I

The questionnaire involved 100 patients ([Fig. 1](#)) cared for in one of the two rooms who completed a total of 95 assessments in the daytime and 30 at night; i.e. 25 patients completed assessments for both day and night. A significant difference was found between lighting environments in the two rooms' for brightness ( $p=0.004$ ) in the day time, favouring the intervention room. There was a significant difference ( $p=0.005$ ) for variation between the two rooms at night, indicating greater lighting variation in the ordinary room ([Table 4](#)).

### Lighting experiences, Part II

When analysing the interviews, five questions from the interview guide could be answered with yes or no. The result indicated that nearly all the patients were pleased with the lighting environment in the intervention room. They slept worse in the ICU than at home. Nearly all those who experienced disrupted circadian rhythm also had nightmares ([Table 7](#)).

The analysis of the interviews is presented in text in the following main categories (headings) and subcategories (underlined) ([Table 8](#)).

#### A dynamic lighting environment

This category describes experiences such as pleasantness, levels of lightings and variation. Most, but not all, of the patients could talk about their memories and experiences of

**Table 8** Patients' experiences of lighting/light in the intervention room presented in categories and subcategories, Part II.

A dynamic lighting environment	Impact of lighting on patients' sleep	The impact of lighting/lights impact on the circadian rhythm	The lighting calms
Pleasant and healthy lightings	Both poor and good night time sleep	Diverse perceptions of the regularity of day and night	Anxiety and searching for security
Acceptable lighting levels at nights	Levels affecting sleep	Disturbing impact	Severe anxiety replaced by calm
Variations in the lighting round the clock		Supporting impact	The lighting clarity created security

the lighting and the daylight, both in the day and at night; others had only sporadic memories.

Patients who recalled the light environment generally talked about a pleasant and healthy lighting environment, as one patient said:

“It was nice, it was not sharp and it was a pleasant light”  
No 23.

The lighting affected their wellbeing and health positively. The clear morning light was important as it increased alertness and affected their mood in a good way. Lighting was sometimes taken for granted and the patients had not always reflected on it during their stay in the ICU but they were able to compare it with another lighting environments e.g. often the lighting environment at home but also that on other hospital wards, including the one where the interview was performed. One patient said:

“It you think back, it is much more uplifting to be in that light (at the ICU) than this (on a general ward).” No 8.

Several patients recalled that there were acceptable lighting levels at night. It was not completely dark but more like twilight. Most did not experience the light levels at night as disturbing although they were aware that the light was brighter than at home. One patient said:

“It is obvious that it was quite a bright light but we do not have complete darkness where we sleep either...it does not hurt me to sleep in half-bright light, so to speak”.  
No 14.

Lighting levels were assessed as acceptable. There were patients who wanted brighter surroundings. Some assessed the lighting levels as almost too high but they understood that the levels were a compromise. The room in the ICU was not only a place for patients; it was also a place of work for staff and the patients’ demands concerning lighting levels that were not the only important issue. As one patient expressed it:

“It could have been darker, but the staff must be able to work there too”. No 9b.

Experiences of variations in the lighting round the clock were also described. There were different opinions about whether the lighting varied between day and night and during the day. Some of the patients experienced clear differences in the lighting between day and night. They also noticed that the light was dimmed during the evening and became darker at night. The variations in lighting during the day were harder to detect. A few reported a vague feeling about changes in lighting levels and colour during the day. The transitions between the different light scenes were soft and un-disturbing. Most did not notice the transitions but instead thought that the lighting followed the daylight outside the windows. One said:

“Yes it has varied dependent on how it was outside, I have noticed that at 7 (pm) when it started to get dark outside, at the same time it got darker inside too, it was probably some kind of combination”. No 23.

### Impact of lighting on patients’ sleep

This category describes’ experiences of sleep and how light is related to sleep. Patients emphasised the importance of sleep, for recovering and regaining health.

Both poor and good night time sleep was experienced. Patients who reported poor sleep quality mentioned difficulties getting to sleep, nights with no sleep at all or nights with frequent awakenings and with fragmented sleep.

“Bad, I have only slept for periods of 30 to 45 minutes, then I was woken up. It has not been an even sleep, one of the longest nights for ages”. No 26.

Others felt they slept well:

“Yes relatively well, I have to say. No 27.

Lighting levels affected their sleep but the patients had different opinions about the lighting levels in relation to sleep. Some of them wanted it darker while a few wanted it brighter. Most felt that the lighting levels were appropriate. It was not so bright that it was disturbing but bright enough to orientate themselves in the room. One said:

“...it was good that you could see a lot, and you were not inside a dark sack, so to say”. No 22.

Some patients current the present lighting levels to the ability to sleep. The lighting could be one reason their sleep was disturbed. One patient sad about sleep:

“Abysmal, thanks to it being so bright.” No 19.

Other patients thought that the lighting levels were moderate for sleeping in. The fact that the patients were able to talk about their experiences and saw a positive connection between sleep and darkness was clarified in their reflections concerning sleep and rest during the day. Most of them had slept on and off during the day despite the daylight and the lighting and were surprised about this. As one expressed it:

“You have taken it easy, even if the light was switched on, you were so tired that you could just close your eyes for a while, then you fell asleep”. No 23.

### The impact of lighting/lights on the circadian rhythm

This category describes patients’ experiences concerning circadian rhythm and its relationship to light.

The patients had diverse perceptions of the regularity of day and night. For some it was hard to keep a normal rhythm which in turn led to being confused about time and the loss of the ability to distinguish between day and night, which was perceived as very difficult. Another interviewee also mentioned this saying:

“No I have not been able to do that, for example in the night when they told me that the time was 2 am...it cannot be true, it is in the middle of the day”. No 6.

Others were completely oriented as to time and it was completely natural and easy for them to separate day and night. One related the ability to separate day and night to his health situation, saying:

“I have been ill, but not that ill”. No 2.



Lighting's disturbing impact on the circadian rhythm when it was switched on by the staff during the night, was reported and expressed as follows:

"When the light was switched on, I did not know (if it was day or night) because it was basically the same light". No 13.

The lighting levels were considered low but at the same time brighter than at home. This was perceived by a few as disturbing the maintaining of the circadian rhythm and one said:

"It was a good lighting environment, without dazzle. Then the lighting was reduced at 10 pm, I think, but it did not help me (to orientate about day and night)".

In answer to the question about what helped to maintain a normal circadian rhythm the lighting inside and the daylight supporting impact of the windows were mentioned. Both light and darkness were important for the circadian rhythm. Answering a question about how it had been possible to distinguish between day and night one patient said:

"It is the light and everything, the sun is shining outside... Yes and when the lights were turned up and down I was able to follow (the day and night), oh yes...". No 9

### The lighting calms

This category describes experiences of anxiety or security. The following descriptions show how the lighting clarified the environment and how anxiety was alleviated by light.

Patients often experienced anxiety and searched for security in their surroundings. They pondered more over their health situation and prognosis at night and their thoughts could sometimes result in feelings of anxiety and fear of losing control over their situation. One patient said:

"Yes, it was a night, the second or the third, when you thought that. Then I had a lot of pain and slept badly, what has happening? Is this the way everything will end? No 14.

Others felt secure in spite of the unfamiliar environment and their vulnerable situation. The patients connected to their inner security, which they felt was independent of the surrounding environment. The lighting environment also affected their possibility of feeling secure and the light allowed severe anxiety replaced by calm. Some patients had been totally terrified during the nights but there were also those who felt trust and had been calm. An older patient remembered how his mother got the children to sleep in the evening, by leaving the lights switched on. Severe anxiety was alleviated by light during the night.

During the most worrying period, a bedside lamp could be used. This contributed to feelings of calmness, as one patient said:

"... It got better when the light was switched on. It felt more secure in a way". No 13.

Most of the patients considered the lighting levels high enough for them to feel secure.

Despite the room being well-lit some patients fell easily asleep and slept well during the day. Some described that they slept, on and off; the light was not disturbing; staff were around them and they felt secure.

The lighting clarity created security by lighting up the surroundings. Light was a prerequisite for perceiving the surrounding objects in the room in a realistic way. Fear and anxiety could occur when the patients were unable to orientate themselves in the room. The lighting levels enabled them to see and identify the staff. The staff played an important role in creating calm in the patients and being able to see them and have a face to focus on was comforting. It confirmed that they existed and that someone was there and able to help them. One patient expressed this:

"...security were more about seeing the staff...". No 19.

## Discussion

### Reflections on the findings

This study does not show clearly that the current light intervention affected such factors as maintenance of circadian rhythm with subsequent benefit to the patient's recovery. However, developing knowledge about patient experiences of light environments and their relation to circadian rhythm and health is an important starting point. The present study shows that patients could think about and assess light environments despite severe illness and complex treatments. This is an important result. Our findings indicate a cycled light system in advantageous and that people continuously interact with their surrounding environment (Olausson et al., 2013; Rashid, 2006). Light is one important factor in this and our findings are meaningful, but more research needs to be done.

The results from the questionnaire showed significant differences in favour of the intervention room regarding factor for brightness in daytime. This factor comprised the adjectives light, weak, drab and brilliant. According to previous knowledge, it is important to get bright light in the morning and in the daytime to start up and support the circadian rhythm. Bright light in the morning increases human alertness and mood, by suppressing the hormone melatonin (highest in the night) and increasing cortisol, the hormone of alertness (Chan et al., 2012; Figueiro and Rea, 2010). These changes in hormone activity due to light levels are one important part of the circadian rhythm which in turn supports health. Results from previous measurements of light in the intervention room reported lux values as 615 between 8 and 10 am (Table 1, Engwall et al., 2014). Together with the present study's results it indicate that the cycled lighting environment better support patients' circadian rhythm than the lighting environment in the ordinary room. In this room only the lighting at wall normally were switched on in daytime and here the lux values were only 147. Lightings in ceiling and walls reported values at 810 lx (Table 2). These high values of light were normally only a fact when special examinations were performed.

The patients in the ordinary room were also able to detect differences in variations of the lighting distributions

at nighttime (8–8.45 pm) and assessed the lighting environment as more varying. The factor for variation comprised the adjectives concentrated, evenly distributed and focused. The patients may be identified a couple of different light sources that spread the light in a shifting way. In contrast to the intervention room where the indirect light spread the light more uniformly, as here shone upwards in the ceiling and on the wall. A smooth, well distributed lighting environment without parts of dark shadows and glare is recommended and is more comfortable for individuals (Canadian Centre for Occupational Health and Safety, 2014).

The intervention room is not only a place where the patient can rest and restore. It is also a place where the staff should be able to work and the light levels should promote writing and allow assessment of patients' conditions and be able to read and watch over the technological equipment. Patients were aware of this situation when they assessed the light levels at night as a compromise. In spite of impaired health condition they interacted with the physical environment and the staff and were able to prioritise others' needs before their own. One way to overcome competing lighting demands is to include patients, staff and relatives in the design procedure (Perkins, 2013).

Most patients reported that their sleep was worse in the ICU than at home. This corresponds with previous research (Little et al., 2012) where light was one of five most frequently cited reasons for sleep deprivation. These researchers proposed nocturnal modification such as dim light that can be compared with our cycled lighting intervention.

Nine interviewees reported disrupted circadian rhythm. This is also well-known from previous research (Verceles et al., 2012). Eight of these nine patients also reported nightmares or visions and seven slept badly and were mechanically ventilated. Sleep disorders, nightmares and disrupted circadian rhythm are present in patients with ICU delirium and previous research shows that 60–80% of mechanically ventilated patients and 20–55% of non-ventilated ICU patients with experiences from delirium (Pisani et al., 2009; Thomason et al., 2005).

Patients' inner clocks were perceived as being inconsistent with clock time, a known effect of light exposure between midnight and dawn in mammals (Hut et al., 1999), as it turns the inner clock backwards. Earlier research shows that brighter light affects the inner clock more than dim light (Duffy et al., 1996). Some patients in the present study reported very disturbed inner circadian rhythms as well as light exposure at various points through the night. The lighting levels also, however had a comforting effect on the patients in the night as they could see and relate to staff. This finding is in agreement with studies in an emergency ward where patients said that seeing the nurse entering the room increased their sense of safety and security (Shattell et al., 2005).

The cycled lighting environment based on scientific research concerning light, circadian rhythm and health was reported as pleasant by 16/17 interviewed. From a caring perspective it is important to reflect on patients' individual experiences. It is important with a balance between supporting the circadian rhythm by lighting and making patients feel safe and comfortable. The most positive way of designing a lighting environment might be to allow patients

to decide individually about in the lighting environment to meet their requirements (Thompson et al., 2012). The patient is in many ways the caring expert and it is very important that their preferences should guide the caring process (Coulter et al., 2008). It is also possible that different diseases and health conditions may require differing light environments. In the future, the ability to individualise an environmental lighting protocol to meet the needs of each patient would be ideal in creating a more healing environment in the ICU.

Knowledge about patients' perceptions and experiences of light environments, together with physical measurements of lighting and daylight's role in establishing the circadian rhythm are considered useful for future research.

## Critical reflections

Two different methodological approaches were used. The questionnaire has been used in previous studies but is not designed specifically for ICU environments. The 17 questions were relatively easy to complete but patient fatigue and reduced ability to concentrate could be a weakness. However, many patients completed the questionnaire by themselves or asked the researcher for supplementary information. Most of the patients were tired and exhausted which precluded open-ended interviews. An interview guide with short and simple questions (Kvale and Brinkmann, 2009) was used as more suited to the patients' condition and ability to narrate their experiences. One patient was able to narrate spontaneously without support from the interview guide. In other cases the questionnaire worked well in relation for its purpose. Content analysis was found useful for analysing relatively short transcriptions.

Some patients used the interviews as a chance to voice their ICU experiences in general. Interviews may have a supporting function in providing the patients with the opportunity to have somebody listen who is familiar with ICU care and thus able to understand (Nordentoft and Kappel, 2011). The interviewer (ME) is experienced in prehospital and critical care and the other researchers, apart from being experienced in intensive care, are also familiar with ICU research. Interviews allow follow-up questions to be asked, giving a deeper and clearer understanding. Today's sedation practices have moved from a deeper towards a lighter sedation regimen. This is something to consider as patients are more awake and thus sensitive to the surrounding space (Egerod et al., 2013).

Allocation of patients to the two rooms was sometimes determined by their special needs in the ICU. However, no significant differences between the two groups were found in relation to sex, age, use of respirator and SAPS. This made it possible to compare the two patient groups' experiences of light.

The participants represented various ages, had severe different diseases or traumas and had undergone individual treatments involving the use of potent drugs. Extra protection was given, in terms of a sensitive approach and collaboration with staff and next of kin, when planning and collecting the data because of the patients' vulnerability and the increased risk of personal harm (Liamputtong, 2007). The most critically ill patients could not be included

in the study as they were unable to cooperate. They were included in the exclusion group and had significantly higher SAPS values and mechanical ventilator use (Table 3). Unfortunately this group's experiences were missed. The research group had joint discussions concerning the analysis. The quotations in the result section are an expression of the authenticity of the participants' statements and the context (Elo and Kyngäs, 2008).

## Conclusions

Many of the patients in the ICU had experiences of sleep disorders and disrupted circadian rhythms. A cycled lighting system that copied the natural light was considered important and was assessed as pleasant and together with daylight, supported for the circadian rhythm. Most patients were aware of and able to assess light environments even if they had experiences from critical illness and treatments. Appropriate lighting levels in the environment helped patients and staff to connect to each other, which engendered feelings of calm and security.

## Acknowledgements

Thanks to Fagerhults Lighting AB for constructing and installing the cycled lighted system, Annelie Ryberg, Anna-Karin Windell and Ewa Lagerström for excellent help with the data collection, Göran Jutengren for important guidance regarding statistics and Pat Shrimpton for the language review.

### Funding

The authors have no sources of funding to declare.

### Conflict of interest statement

The authors have no conflict of interest to declare.

### Ethical statement

None.

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