# USER RESPONSES TO LIGHTING DESIGN WITH RESPECT TO LEVEL OF ALERTNESS

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**Abstract**

Artificial light gives, compared to daylight, an altered input to the transduction through melanopsin and ipRGC to the human brain in spectral profile, timing, duration as well as differs in the way that the light is distributed in the space. To stay in artificial light affects the subjects hormonal release and by that physiologically the experience of being alert. The highest level of alertness in the group of subjects can be seen when a subject is having a level of cortisol of 672 nmol/L as well as 165 nmol/L and when staying in a combination of 20 Lux horizontal illuminance (HI, middle of the floor) and 65 Lux (HI, middle of working table) as well as when staying in a combination of 349 Lux HI (middle of floor) and 1340 Lux HI (middle of the working table). Results show that the level of cortisol in the bloodstream does not decline for all subjects; instead, increases can be seen during the day. Level of alertness does not follow level of cortisol for all subjects; instead, a high level of alertness can be seen when a subject has a low level of cortisol. Subjects self-evaluated on the highest level of alertness can be seen when staying in a low level of light.

**Keywords:** Cortisol; individual level of alertness.

## 1. INTRODUCTION

Artificial light is needed as a complement for daylight to be able to be efficient and safe in work and for quality of life as well. Since we stay in an increasing amount of time in the indoor environment it is important to know if differences can be seen in level of alertness and in hormonal release when the subjects stay in daylight or in artificial light in the indoor environment. The motif for focusing on hormonal levels and level of alertness is to see if subjects respond in another way physiologically to artificial light during the day compared to daylight.

### 1.1 Problem area and relevant research

Level of alertness is an important part of being vital, effective and at comfort when staying in the indoor environment. If differences can be seen in level of alertness when staying in daylight

compared to when staying in artificial light, this need to be corrected. If the pattern of changes in hormones is altered when staying indoor compared to outdoor the reason for this should be investigated to be able to correct this towards what is seen outdoors. It is a rather new phenomenon that researchers in lighting design include aspects of physiology [Perry et al. 1987]. After the findings of melanopsin and the intrinsic photosensitive retinal ganglioncell (ipRGC), user responses to lighting design are investigated from many perspectives and in an increasing multidisciplinary way. User responses are investigated at hospitals by Koga and Iwata [2010] as well as studied in retail stores [Martau et.al 2010]. Van Bommel described early the physiological response to the lighting application in the working environment [2006]. Environmental lighting and diseases are investigated by Stevens et al. [2007]. The user´s responses to full-spectrum light at workplaces are the research question of Martel [2005]. From different aspects are the topic man and light investigated with a focus not only on the visual part but on the physiological part as well. It is difficult to find information about individual subjects and their responses and preferences for light. Lucia Ronchi shows the variability of the visual sight. The variability in the sleep and wake up habits among 55,000 subjects is investigated by Roenneberg et al. in the EU-clock project [Ronchi 2009, 2010; Roenneberg et al. 2007]. Rutger Wever is another researcher that worked with mappings of the human diurnal rhythm on a large scale [Wever 1979, 1992]. S.M. Pauley [2004] and Pechaceck, Andersen & Lockley [2008] show the urgent need of focusing on the physiological problems related to the use of artificial light.

### 1.2 Aims

To investigate if patterns can be seen in level of alertness when staying in daylight and artificial light in the indoor environment?

To investigate if differences can be seen in level of alertness when the subjects stay in daylight or in artificial light in the indoor environment?

To investigate if differences can be seen, in levels of cortisol, adrenaline and noradrenaline when the subjects stay in daylight and in artificial light?

To investigate if differences seen in hormonal levels among subjects can be related to PS in the room and light settings in the study?

### 1.3 Problem formulation

Humans stay in an increasing amount of time in the indoor environment. Can differences be seen in level of alertness when staying in daylight compared to when staying in artificial light, indoors? Is it possible to find pattern of changes in level of cortisol, adrenaline and noradrenaline that is different when the subjects stay in daylight or in artificial light indoors?

### 1.4 Research questions

Can patterns be seen in level of alertness when staying in daylight and artificial light in the indoor environment?

Can differences be seen in level of alertness when the subjects stay in daylight or in artificial light in the indoor environment?

Can differences be seen, in the levels of cortisol, adrenaline and noradrenaline when the subjects stay in daylight and in artificial light?

Can differences seen in hormonal levels among subjects be related to photonstreams (PS) in the room and light settings in the study?

## 2. METHODS USED IN THE STUDY

### 2.1 Study design

This study is performed in three room and light settings similar in architectural and interior design but different in light settings. The subjects stayed for one day in each room. Data about the subjects' experiences, responses and performances in the three rooms was collected with questionnaires about emotional experience and cognitive performance. Blood samples were collected at 8:00-8:15, 12:00-12:15 and 16:00-16:15. The subjects remained in the same electromagnetic radiation (EMR) during the day with an exception of 15 min. when the blood samples were taken. All blood samples were due to practical reasons taken in solely daylight.

### 2.2 Participants

The study was conducted at Jonkoping University. The test subjects were recruited by group mail sent to all students enrolled in the lighting design program at Jonkoping University. 20 people applied to participate in the study (m=24.6 years) and were chosen by convenience. The group consisted of 12 women and 8 men. Each participant received books worth 2,000 SEK for their participation in the study. The subjects were divided into subgroups based on sex, Burells test (BT) and the visual comfort test (VCT).

**Table 1.** Subgroups in the study**.**

| **Groups subgroups** | | **Groups subgroups** | |
|---|---|---|---|
| Subj. 1-20 | | OVCT | Mean and over mean for VCT |
| Male | | UVCT | Under mean for VCT |
| Female | | OVCT- male | Mean and over mean for VCT- male |
| OBT | Mean and over mean for Burell's test | OVCT- female | Mean and over mean for VCT- female |
| UBT | Under mean for Burell's test | UVCT-male | Under mean for VCT- male |
| OBT- male | Mean and over mean BT- male | UVCT-female | Under mean for VCT |
| OBT- female | Mean and over mean BT- female | OBT-OOVCT | Mean and over mean for BT<br>Mean and over mean for VCT |
| UBT- male | Under mean BT- male | OBT-UUVCT | Mean and over mean for BT<br>Under mean for VCT |
| UBT- female | Under BT-female | UBT-OOVCT | Under mean for BT<br>Mean and over mean for VCT |
| | | UBT-UUVCT | Under mean for BT<br>Under mean for VCT |

**2.3 Instruments used in the study**

*Burells test: The* subjects' self-evaluated disposition to experience of stress was measured by using *Gunilla Burrell's personality test* (BT). The subjects assign by 20 questions in a range of 1-4 points **(**20p=min, 80p=max) their disposition to experience stress in everyday life (http://www.hjart-lungfonden.se /HLF/ Aktuellt/Ar-du –stressad).

2. The subject´s experiences were measured with the test called *I feel at the moment*. The test measures the users experiences with a semantic scale from 1-4+. The test is based on contradictory feelings graded in very, rather and very (sleepy-alert goes from very sleepy, rather sleepy, rather alert, and very alert), (Environmental psychology, Lund University).

*VCT:* The subject´s preferences for level of light were measured with the visual comfort test (VCT). The test was developed by Dr. Bo Persson at KTH in Sweden. It was used to measure the preferred level of light at the working table. Bo Persson did the test with a white paper on a white table and repeated the procedure for three times. Then, he did the same procedure with a white paper on a black table. The test was completed in 2006, by M. Säter to be used for measurement of both the level of light at the working table and for the preferred complementary level of ambient light. A white paper on a black table was used in the study.

*Positive room descriptive words:* The subjects were asked when they left the study to describe the room they just left as carefully as possible. The positive room descriptive words were counted and were given 1 point each. No limit was set for the number of words that were counted. The test was developed by Monica Säter at the Department of Lighting Design at Jonkoping University in 2006.

*Bloodsamples:* Test of the physiological response to light was investigated via tests for the hormones cortisol, adrenaline, noradrenaline, melatonin and oxytocin. A visual analysis was also applied. In order to gather data surrounding the physiological responses to the three lighting environments, saliva and blood specimens were collected from the test subjects. The bloodsamples were used to measure the levels of cortisol, melatonin, adrenaline, noradrenaline and oxytocin in the participants. The specimens were collected by a biomedical analyst from the Ryhov County Hospital (*Länssjukhuset Ryhov*). The analyses were carried out by Ingegerd Thudén and Carina Tengham as described below.

S-Cortisol: The tests were conducted in 4 ml test tubes. The specimens were marked in accordance with normal routines. The tubes were allowed to stand for 30-60 minutes and then put in a centrifuge. Half of the serum was pipetted into a polypropylene test tube and marked with a barcode label. The specimens were then re-labelled and frozen. The primary test tube was refrigerated.

P-cathecholamines: The test was conducted in three chilled 6 ml heparin test tubes. These were either placed in an ice bath or immediately in a cold centrifuge. The plasma was separated into two polypropylene test tubes, at least 1.8 ml in each tube. These were labelled with the name of the test subject and the time. One tube was labelled with "Cathecholamines back up". The label was flagged and the tube placed in a freezer. P-oxytocin: The test was conducted in a 10 ml K3-EDTA test tube. It was then placed in an ice bath or directly in a centrifuge. The plasma was

divided between two propylene tubes and labelled with the test being carried out and the time. One tube was labelled “Oxytocin, back up”. The labels were flagged and the tubes frozen.

**Test conduction**

Handling the tubes. The test tubes were transported daily to the Clinical Chemistry Department in carrying cases equipped with freezer clamps. Ice cubes and freezer clamps were available each day. Left-over material, centrifuge and waste were transported away at the end of the study. In the oxytocin test, the test tubes were frozen at -70 ºC. In the test for catecholamines, the tubes were frozen at -70 ºC. Cortisol tests were treated as routine tests and the backup test tubes were frozen at -20 ºC.

**2.4 Procedure**

The subject stayed outside the test rooms before the experiment started and entered then in a balanced order of presentation. Instructions to the test subjects were transmitted via MP3 players. The test had the following schedule that was repeated three times during one day in the three test rooms. *7:15–8:15* Gathering at the school, anaesthetic cream, Emla was rubbed in to prevent pain from needles, specimen collection, and breakfast. Task 1, Completed before entering the room. 8:15– 8:30 Entering the room. 8:30–8:50 Task 2, SMB, 4 min. Task 3, Check list: 2 min 30 s. Task 4, Lighting experience: 4 min. Task 5, *I feel at the moment* : 2 min, 30 s. Task 6, Pattern corrections: 5 min, 30 s., Total 19 min. 8:50–12:00 Study for examination. 11:00 Reminder to take Emla and that there is one hour to go before the next round of specimen collection. No intake of food between 11:00-12:00. 12:00-12:15 Specimen collection: blood and saliva.

12:15- Lunch.13:00- Task 7, Lighting experience: 4 min. 13:15 Task 8, Checklist: 2 min. 30 s. Task 9, *I feel at the moment*: 2 min, 30 s. Task 10, Letter correction: 5 min. 30 s. 13:15-16:00 Study for the examination: 2 h, 45 min. 15:00 Reminder to take Emla and that there is one hour to go before the next round of specimen collection. No food between 15:00-16:00. 16:00-16:30 Specimen collection: blood and saliva. 16:30 Task 11, Lighting experience: 4 min. Task 12, *I feel at the moment*: 2 min. 30 s. Task 13, Character correction: 5 min. 30 s. Task 14, Checklist: 2 min. 30 s. Task 15, SMB: 4 min., Total 18 min. 16:50-17:25 Study for examination: 35 min. Task 16, *I feel at the moment*: 2 min. 30 s. 17:30 End of test. The subjects went home and returned to the school to participate in days 2 and 3 of the test.

**2.5 Analysis of data**

Data was analysed with the analytic software SPSS.

**2.6 Design of the room and light settings**

The three room and light settings, almost identical in architecture and interior design, differed in the lighting equipment (Figures 1-12, Tables 2-15). In order to neutralise temporary differences in level of daylight that only lasted, for a short while, a mean daylight day was constructed. The mean daylight day was based on the measurements of 4 and 10 March 2006. Horizontal illumination was measured in the middle of the floor. The levels of light in Room 2 were

designed close to the measured values of horizontal illumination seen in the mean daylight day. The position of luminaries, light distribution and level of light differed in the three rooms. One room, Room 1, used only daylight as task and ambient light and was completed with two candles if needed during the day. Two of the rooms, Rooms 2 and 3 were darkened and were equipped only with artificial light. The light in Room 2 was designed mimicking daylight*. The light in Room 3 was designed to deviate from daylight*. *= in some extent, see methods (Figures 1-12, Tables 2-15). The doors in Rooms 1, 2 and 3 were painted in a blue-reddish colour with NCS code 4060R70B. The walls in Rooms 1, 2 and 3 were painted with a neutral white latex paint with NCS code 0502Y. The floors in the three rooms were covered with a carpet of linoleum in beige with NCS code 6500. The ceilings in the three rooms were equipped with acoustic boards painted in white with NCS code 0502Y. The work space had a work table of birch with black metal legs, 1400mm x 600mm and 720 mm. All three rooms were equipped with a reading place with an armchair in a wine red cloth with wooden legs, Ø450mm, height 540mm at the reading place. The corridor outside of the three test rooms was screened off from daylight with black cloth and was equipped with two separate lighting systems. The first was equipped with incandescent light bulbs; the other had low energy light bulbs and was used as a complementary lighting system to enable the subjects to go to the restroom in the same light in which they stayed in the test rooms (Figures 1-12, Tables 2-15).

### 2.6.1 Lighting conditions Rooms 1, 2 and 3.

Data about the lighting applications in the three rooms can be found in tables 2-15 and in figure 1- 12.

### 2.6.2 Measurement points

**Table 2.** Measurement points Room 1.

| Room 1 | Measurement point |
|---|---|
| Ambient light HI | Middle of the floor |

**Table 3.** Measurement points Rooms 2 and 3

| Rooms 2 , 3 | Size cm | | | M. points | | | |
|---|---|---|---|---|---|---|---|
| | Length | Width | Height | Length | Width | Height | |
| Work table | 140 | 60 | 72 | 70 | 30 | 0 | Edge of table, 66 cm fr. wall 2 |
| Floor | 340 | 285 | 267 | 170 | 142 | 0 | |
| Reading place | | | | 57 | 62 | 76 | |
| | | | | From wall 3 | From wall2 | | |
| Wall at the table | | | | 136 cm from wall | | 107 cm over the floor | |
| Wall at the door | | | | 80 cm from wall 1 | | 110 | 80 cm from wall 1 |
| Wall at the reading place | | | | 105 cm from wall 2 | | | |

## **2.6.3** Level of horizontal and vertical illumination

**Table 4.** Level of HI Room 1, 8.00, 10.00, 12.00.

| **Mean day Lux** | **8.00** | **10.00** | **12.00** |
|---|---|---|---|
| Floor HI | 62 | 230 | 367 |
| Window frame HI | 749 | 1761 | 3290 |

MF= middle floor MLF= middle lower window frame

**Table 5**. Level of HI Room 1 14.00, 16.00, 17.00

| **Mean day Lux** | **14.00** | **16.00** | **17.00** |
|---|---|---|---|
| Floor HI | 184 | 114 | 50 |
| **Window frame HI** | **2647** | **1303** | **531** |

MF= middle floor MLF= middle lower window frame HI= horizontal illumination *Measurement point in the middle of the floor

**Table 6**. Illuminance Room 2, 8.00, 10.00 and 12.00

| 08.00 Illuminance | | | | | 10.00 Illuminance | | | | 12.00 Illuminance | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lux | Lux | | | Lux | Lux | | | Lux | Lux | | |
| Place | 1* | 2* | | | 1* | 2* | | | 1* | 2* | | |
| Work table HI | 170 | 171 | | | 1500 | 1490 | | | 1780 | 1780 | | |
| Floor HI | 40 | 41 | | | 330 | 330 | | | 340 | 348 | | |
| Reading place HI | 145 | 146 | | | 445 | 448 | | | 617 | 615 | | |
| Wall at table VI | 44 | 44 | | | 326 | 325 | | | 480 | 470 | | |
| Wall at the door VI | 55 | 53 | | | 414 | 410 | | | 433 | 435 | | |
| Wall at the reading place VI | 120 | 128 | | | 255 | 260 | | | 340 | 330 | | |

HI=horizontal illumination, VI=vertical illumination, 1*=first measurement, 2*=second measurement

**Table 7.** Illuminance Room 2, 14.00, 16.00 and 17.30

| 14.00 Illuminance | | | | | 16.00 Illuminance | | | | 17.30 Illuminance | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lx | Lx | | | Lx | Lx | | | Lx | Lx | | |
| Place | 1 * | 2* | | | 1* | 2* | | | 1* | 2* | | |
| Work table HI | 1180 | 1180 | | | 290 | 290 | | | 211 | 215 | | |
| Floor HI | 237 | 239 | | | 70 | 74 | | | 38 | 38 | | |
| R place HI | 364 | 364 | | | 185 | 188 | | | 148 | 149 | | |
| Wall w- table VI | 327 | 330 | | | 95 | 98 | | | 67 | 68 | | |
| Wall door VI | 350 | 347 | | | 168 | 163 | | | 69 | 68 | | |
| Wall r place VI | 221 | 220 | | | 147 | 149 | | | 120 | 120 | | |

HI=horizontal illumination, VI=vertical illumination, 1*=first measurement, 2*=second measurement

**Table 8.** Illuminance Room 3, 8.00, 10.00, and 12.00

| 08. 00<br>Illuminance | | | | | 10. 00<br>Illuminance | | | | 12. 00<br>Illuminance | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lux | Lux | | | Lux | Lux | | | Lux | Lux | | |
| Place | 1* | 2* | | | 1* | 2* | | | 1* | 2* | | |
| Work table HI | 65 | 65 | | | 67 | 66 | | | 216 | 217 | | |
| Floor HI | 20 | 19 | | | 18 | 17 | | | 56 | 55 | | |
| Reading<br>Place HI | 27 | 27 | | | 19 | 20 | | | 27 | 30 | | |
| Wall at table VI | 22 | 21 | | | 21 | 21 | | | 82 | 81 | | |
| Wall at the door VI | 8 | 8 | | | 8 | 8 | | | 27 | 26 | | |
| Wall at the reading place VI | 10 | 10 | | | 8 | 8 | | | 20 | 20 | | |

HI=horizontal illumination, VI=vertical illumination, 1*=first measurement, 2*=second measurement

**Table 9.** Illuminance Room 3, 14.00, 16.00 and 17.30

| 14. 00<br>Illuminance | | | | | 16. 00<br>Illuminance | | | | 17. 30<br>Illuminance | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lux | Lux | | | Lux | Lux | | | Lux | Lux | | |
| Place | 1* | 2* | | | 1* | 2* | | | 1* | 2* | | |
| Work table HI | 240 | 244 | | | 1340 | 1340 | | | 3500 | 3510 | | |
| Floor HI | 43 | 42 | | | 349 | 347 | | | 1060 | 1090 | | |
| Reading Place HI | 31 | 32 | | | 178 | 180 | | | 430 | 440 | | |
| Wall at table VI | 58 | 58 | | | 533 | 534 | | | 1710 | 1730 | | |
| Wall at the door VI | 17 | 17 | | | 148 | 147 | | | 470 | 470 | | |
| | 16 | 16 | | | 120 | 119 | | | 360 | 360 | | |

HI=horizontal illumination, VI=vertical illumination, 1*=first measurement, 2*=second measurement

### 2.6.4 Design of the lighting application in Room 1.

In Room 1, only daylight was used for task lighting and ambient light. The daylight fluctuated in level of light in a way that is normal for the season (February-March) and as a result of the type of window opening in the room, as well as the cardinal direction at the location. No shielding of the window was used. Based on the measurements of two test days, a mean day of daylight was created (Table 10, 11). The use of a mean day was done with a measure point placed in the middle of the floor collecting data of daylight based on the fourth and the tenth of March to get an overall, rough, reference to ambient daylight (see discussion of methods). The light started low, increased, increased, decreased, decreased and decreased drastically. The subject received two optional candles as complementary lighting if needed. In order to enable visiting the restroom in the same lighting as in the present test room, two candlelight's was placed in the

restroom. The collection of blood samples for all subjects was done during 15 minutes in daylight (Figures 1-12, Tables 2-15).

**Fig. 1.** R 1

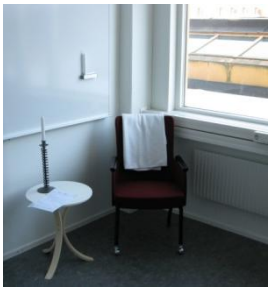

**Fig. 2.** R 1

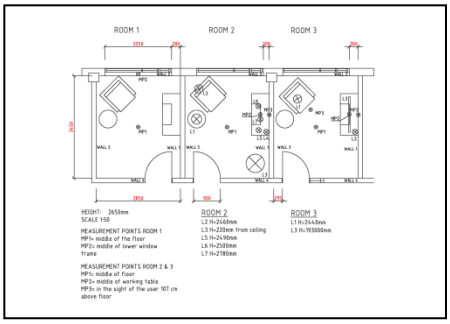


**Fig. 3.** Floor plan Room 1.

**Table 10.** Horizontal illumination, daylight. 8.00-17.00

| | 8.00 | 9.00 | 10.00 | 11.00 | 12.00 | 13.00 | 14.00 | 15.00 | 16.00 | 17.00 |
|---|---|---|---|---|---|---|---|---|---|---|
| 4 March | 65 | 158 | 353 | 282 | 390 | 378 | 246 | 169 | 98 | 40 |
| 10 March | 59 | 207 | 106 | 182 | 343 | 320 | 219 | 198 | 130 | 59 |
| Mean day | 62 | 183 | 230 | 232 | 367 | 349 | 233 | 184 | 114 | 50 |

**Table 11.** Horizontal illumination, daylight 8.00-17.00, middle of lower part of the window 8.00-17.00

| | 8.00 | 9.00 | 10.00 | 11.00 | 12.00 | 13.00 | 14.00 | 15.00 | 16.00 | 17.00 |
|---|---|---|---|---|---|---|---|---|---|---|
| 4 March | 748 | 1688 | 2330 | 1595 | 3500 | 2970 | 2616 | 1891 | 1113 | 452 |
| 10 March | 750 | 2320 | 1191 | 1873 | 3080 | 2990 | 2678 | 2250 | 1493 | 609 |
| Mean day | 749 | 2004 | 1761 | 1734 | 3290 | 2980 | 2647 | 2071 | 1303 | 531 |

### 2.6.5 The design of the lighting application in Room 2

The light in Room 2 was designed to mimic daylight*. The windows were covered and daylight shaded out. The light in the room consisted of only artificial light. The subjects had no possibility to dim the light. The level of light varied linearly during the day and from a low level increased, increased, decreased, decreased and decreased by the use of a lighting control system. In order to enable visiting the toilet in the same lighting conditions as in the present test room two incandescent light sources were placed in the restroom. The collection of blood samples for all subjects was done during 15 minutes in daylight (Figures 1-12, Tables 2-15).

**Fig. 4.** R 2

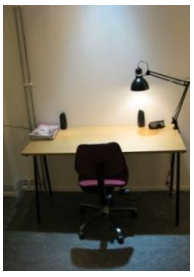

**Fig. 5.** R 2

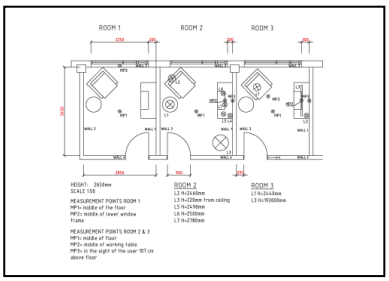


**Fig. 6.** Floor plan Room 2.

**Table 12**. Horizontal and vertical illumination Room 2

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| R 2. Amb.HI Lux | Middle of the floor | 40 | 330 | 340 | 237 | 70 | 38 |
| R 2. W-table Lux | Middle of table | 170 | 1500 | 1780 | 1180 | 290 | 211 |

M.P= measuring point, HI=horizontal illumination, VI= vertical illumination

**Table13**. Lighting equipment Room 2

| | | | | |
|---|---|---|---|---|
| L1 | Luminaire | Incandescent 40W E14 small globe | Floor standing table lamp at reading space | Reading area |
| L2 | Luminary Par 20 | Halo par 20 50W 10° | Light aperture 246 cm above floor<br>47 cm from wall 3, 44 cm from wall 2<br>6° from wall 3, 0° from wall 2 | Reading area<br>Centre measurement<br>Centre measurement |
| L3 | Cloth shaded luminary 222 cm high | Incandescent 4x60W E27 big bulb | 47 cm from wall 1, 50 cm from wall 4<br>22 cm from ceiling, cloth shaded lamp Ø 31 cm<br>Attached to upper right hand corner of desk | 2nd and 4th lamp<br>1st and 3rd lamp |
| L4 | Luminary | Incandescent 60W Halopar | against wall 1 | Work space |
| L5 | Par 20 | 20 50W 10° | Light aperture 249 cm above floor<br>36 cm from wall 1, 162 cm from wall 4<br>slanted 20° from wall 4 | Centre measurement<br>Centre measurement |
| L6 | Par 20 | Halopar 20 50W 10° | Light aperture 250 cm above floor<br>37 cm from wall 1, 243 cm from wall 4<br>slanted 5° from wall 3, slanted 6° from wall 2 | Centre measurement<br>Centre measurement |
| L7 | Spotlight | Colour CDMT 70W 942 | 202 cm from wall 4, 30 cm from wall 1<br>278 cm from floor | Centre measurement<br>Lamp mounted on roller |
| | Fan regulator Off/On Metal halogen lamp | | | Above inside ceiling<br>Driver HID-PVC 070/G CDM 2 dimmers, Botex MPX 405 |

## 2.6.6 The design of the lighting application in Room 3

The light in Room 3 was designed to deviate from daylight*; the windows were covered with all daylight shaded out, and the light in the room consisted only of artificial light. The subjects had no possibility to dim the light. The level of light varied linearly during the day starting low, decreased, increased, decreased, increased and increased drastically by the use of a lighting control system. In order to enable visiting the restroom in the same lighting conditions as in the present test room, three compact fluorescents were placed in the restroom. The collection of blood samples for all subjects was done during 15 minutes in daylight (Figures 1-12, Tables 1-14).

**Fig 9** R 3

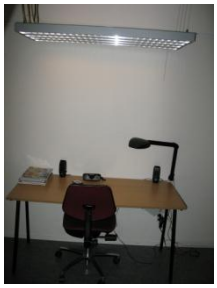

**Fig 10** R 3

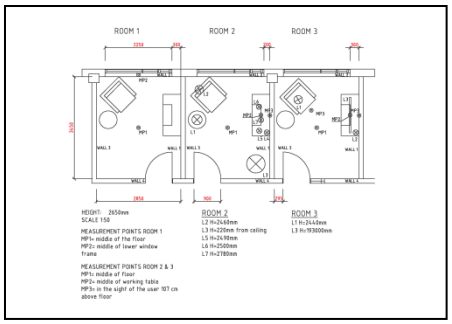


**Fig. 11**. Floor plan Rom 3.

**Table 14.** Level of illumination, Room 3.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| R 3. Artificial light Amb. light HI | Middle of the floor | 20 | 18 | 56 | 43 | 349 | 1060 |
| R 3. Artificial light W-table | In the eyesight | 65 | 67 | 216 | 240 | 1340 | 3500 |

M.P. = measurements point, HI= horizontal illumination, VI= vertical illumination

**Table 15.** Study 2. Room 3. Lighting application, equipment

| | | | |
|---|---|---|---|
| Table mounted work task luminary | PL-C 13W, 840, 4p | Attached to upper right corner of desk | Work space |
| Fluorescent luminary | | | |
| Closest to the wall, warm | TL5 HO 54W 830 | 193 cm from floor | Work space |
| 3rd from the wall, warm | TL5 HO 54W 830 | 193 cm from floor | Work space |
| 2nd from the wall, cold | TL5 HO 54W 965 | 193 cm from floor | Work space |
| 4th from the wall, cold | TL5 HO 54W 965 | 193 cm from floor | Work space |

Regulation via light board over DMX to addressed luminaries over a regulation system

## 3. RESULTS

*Level of alertness seen in the group:* In table 16 is revealed that mean for self-evaluated level of alertness when the subjects stayed in the three rooms (*n* =20) showed only minor differences (R1 M=2, 9, R2 M=2, 6, R3 M=3, Table 16). But when looking at mean for alertness and time of the day, differences can be found. The highest mean for level of alertness in Room 1 and 2 was seen at 13.00 and the lowest mean at 17.30 in Room 1 and 16.00 in Room 2 (*n* =1-20, 12.00 R1M=3, R2 M=2,8. 16.00 R1M=2,9, R2 M=2,5, Table 16).

The mean for level of alertness in Room 3 was converted and the highest was seen at 16.00 and the lowest at 12.00 (*n* =1-20, 12.00 R3 M=2, 8, 16.00 R3=3, 2, Table 16).

*Level of alertness seen in the subgroup:* When the subjects were divided into subgroups the means for level of alertness do not differ much; *Room 1*) 12.00, R1 M= UBT-male 3 (*n*=5), OBT-male 3, 4(*n*=3), UBT-female 3(*n*=8), OBT-female 2, 5(*n*=4). 16.00 R1 M= UBT-male 3,2 (*n*=5), OBT-male 3(*n*=3), UBT-female 2,8(*n*=8), OBT-female 2,8(*n*=4); *Room 2*) 12.00, R2 M= UBT-male 2,6(*n*=5), OBT-male 2,8(*n*=3),UBT-female 2,9(*n*=8), OBT-female 2,5(*n*=4). 16.00

R2 M= UBT male 1, 8(*n*=5), 2, OBT-male 3, 4(*n*=3), UBT-female 2, 6(*n*=8), OBT-female 2, 3(*n*=4); *Room 3)*12.00, R3 M= UBT-male 2,8(*n*=5), OBT-male 3(*n*=3), UBT-female 2,9(*n*=8), OBT-female 2,3(*n*=4), 16.00 R3 M= UBT-male 3,2(*n*=5), OBT-male 3,1(*n*=3), UBT-female 3,3(*n*=8), OBT-female 3,3(*n*=4) (Table 17).

Male subjects that were self-evaluated as high in being stressed (OBT male subject) had at 5/9 occasions a minor higher self-evaluated level of alertness compared to the mean, for male subjects participating in the study; R1) 12.00, OBT-male 3,4(*n*=5), Male 3,1(*n*=3). R1, 16.00. OBT-male 3(*n*=3), Male 3(*n*=8), 1. R1 17.30, OBT-male 2, 7(*n*=3). Male 2, 9(*n*=8). R2 12.00. OBT-male 3. Male 2, 8(*n*=8). R2, 16.00 OBT-male 3, 4(*n*=3), male 2, 4(*n*=8). R2 17.30, OBT-male 2, 7(*n*=3). Male 2, 3(*n*=8). R3, 12.00, OBT-male 3(*n*=5). Male 2, 9(*n*=8). R3, 16.00 OBT-male 3(*n*=3). Male 3, 1(*n*=8). R3 17.30 OBT-male 2, 7(*n*=3). Male 2, 9(*n*=8), (*Table 17*).

The part of the female subjects that evaluated themselves as high in being stressed (OBT-female) had at 1/9 occasions a minor higher level of alertness compared to the group of female subjects participating in the study; *Room 1*), 12.00, OBT-female 2.5(*n*=4), Female 2, 8(*n*=12). R1, 16.00 OBT-female 2, 8(*n*=4), Female 2, 8(*n*=12). R1 17.30 OBT-female 2, 5(*n*=4), Female 2, 7(*n*=12); *Room 2*) 12.00, OBT-female 2, 8(*n*=4), Female 2, 8(*n*=12). R2, 16.00 OBT-female 2, 3(*n*=4), Female 2, 4(*n*=12). R2 17.30, OBT-female 2, 8(*n*=4), Female 2, 5(*n*=12). R3, 12.00, OBT-female 2, 3(*n*=4), Female 2, 6(*n*=12); *Room 3*) 16.00 OBT-female 3, 3(*n*=4), Female 3, 3(*n*=12). R3 17.30 OBT-male 2, 8(*n*=4). Female 2, 9(*n*=12), (*Table 18*).
Both UBT- male (*n*=5) and female (*n*=12) subjects and OBT- male (*n*=3) and female (*n*=4) subjects have by mean the highest level of alertness at 16.00 in Room 3 (*Table 17*).

*Span of level of alertness:* When the span for individual values for level of alertness is revealed, the widest span for level of alertness within the group of subjects (*n* =1-20) can be seen in Room 1, 12.00, (2,5-3,4= 0,9 ); the most narrow span can be seen in Room 3, 16.00, 3-3,3= 0,3 (*Table 18*). The span is narrower in Room 1 between 12.00-16.00, increase in Room 2 and decrease in Room 3 at the same time (*Table 19*). In decreasing level of light is the span of level of alertness decreasing in Room 1, daylight but increase in Room 2. In increasing level of light in Room 3 is the span narrower.

*Level of cortisol related to level of alertness*: The highest mean for the day in cortisol among the subjects (*n* =1-20) is seen in Room 2 at the same time the lowest mean for level of alertness was seen. The lowest mean for cortisol was seen in Room 3 where the highest mean for level of alertness for the day was seen (*Room 1*M=243nmol, *Room 2* M=246 nmol, *Room 3* M=233 nmol. (*Table 16, 20*).
When the individual levels of cortisol in Rooms 1, 2 and 3 at 8.00, 12.00 and 16.00 for the subjects (*n* =1-20) are compared to individual levels of alertness in the same room and at the same time, they are not congruent (*Tables 10, 11, 12, 14, 21, 22, 23, 24, 25*).
The subjects´ (*n* =1-20) highest individual values for cortisol in Rooms 1, 2 and 3 at 8.00, 12.00 and 16.00 are not congruent with the highest levels of light in the study in the same room and at the same time (*Tables 10, 11, 12, 14, 21, 22, 23, 24, 25*).The subjects´ (*n* =1-20) highest

individual values for cortisol in Rooms 1, 2 and 3 at 8.00, 12.00 and 16.00 are not congruent with the highest level of the room evaluated as comfortable by the individual (*Tables 21, 22, 23, 24, 25*). The subjects´ (*n* =1-20) highest individual level of alertness is in the study seen in both low and high levels of light (*Table 26*).

**Table 16**.Mean for self-evaluated level of alertness (*n*=1-20) in Rooms 1- 3, 13.00, 16.00, and 17.30

| **Level of alertness (N=1-20)** | **Room 1** | **Room 2** | **Room 3** |
|---|---|---|---|
| 13.00 | 3 | 2,8 | 2,8 |
| 16.00 | 2,9 | 2,5 | 3,2 |
| 17.30 | 2,8 | 2,4 | 2,9 |
| M= | 2,9 | 2,6 | 3 |

Scale 1-4

**Table 17 A**. Self-evaluated level of alertness (*n*=5) UBT-male, scale 1-4.

| **Subj BT UBT-Male 5** | **R1 12.00** | **R 1 16.00** | **R 1 17.30** | **R2 12.00** | **R 2 16.00** | **R2 17.30** | **R 3 12.00** | **R3 16.00** | **R3 17.30** |
|---|---|---|---|---|---|---|---|---|---|
| 1=38 | 4 | 4 | 4 | 2 | 1 | 2 | 3 | 3 | 3 |
| 7=30 | 4 | 4 | 4 | 3 | 2 | 2 | 3 | 3 | 3 |
| 16=30 | 3 | 3 | 3 | 2 | 2 | 2 | 3 | 4 | 3 |
| 19=38 | 2 | 2 | 2 | 3 | 2 | 2 | 2 | 2 | 2 |
| 20=40 | 2 | 3 | 2 | 3 | 2 | 2 | 3 | 4 | 4 |
| Tot. | 15 | 16 | 15 | 13 | 9 | 10 | 14 | 16 | 15 |
| **M** | **3** | **3,2** | **3** | **2,6** | **1,8** | **2** | **2,8** | **3,2** | **3** |

Scale 1-4+ wt= work task, number see methods. OBT= mean and over mean for BT, UBT= under mean for BT.

**Table 17 B**. Self-evaluated level of alertness (*n*=3) OBT-male, scale 1-4.

| **Subj. BT OBT Male** | **R1 12.00** | **R 1 16.00** | **R 1 17.30** | **R2 12.00** | **R 2 16.00** | **R2 17.30** | **R 3 12.00** | **R3 16.00** | **R3 17.30** |
|---|---|---|---|---|---|---|---|---|---|
| 4=53 | 3 | 2 | 2 | 3 | 3 | 2 | 3 | 3 | 3 |
| 14=45 | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 2 |
| 18=61 | 3 | 4 | 3 | 3 | 4 | 3 | 3 | 4 | 3 |
| Tot. | 10 | 9 | 8 | 9 | 10 | 8 | 9 | 9 | 8 |
| M | 3,4 | 3 | 2,7 | 3 | 3,4 | 2,7 | 3 | 3 | 2,7 |
| All male | 25 | 25 | 23 | 22 | 19 | 18 | 23 | 25 | 23 |
| M | 3,1 | 3,1 | 2,9 | 2,8 | 2,4 | 2,3 | 2,9 | 3,1 | 2,9 |

Scale 1-4+ wt= work task, number see methods. OBT= over mean for BT, UBT= under mean for BT

**Table 17 C**. Self-evaluated level of alertness (*n*=8) UBT-female, scale 1-4

| **Subj. BT UBT Female** | **R1 12.00** | **R 1 16.00** | **R 1 17.30** | **R2 12.00** | **R 2 16.00** | **R2 17.30** | **R 3 12.00** | **R3 16.00** | **R3 17.30** |
|---|---|---|---|---|---|---|---|---|---|
| 3=37 | 2 | 1 | 2 | 2 | 2 | 2 | 3 | 4 | 3 |
| 5=39 | 3 | 3 | 3 | 3 | 3 | 3 | 4 | 3 | 3 |
| 6=39 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 4 |
| 9=37 | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 3 | 2 |
| 10=41 | 3 | 2 | 3 | 2 | 2 | 1 | 1 | 3 | 3 |
| 12=29 | 4 | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 13=37 | 3 | 3 | 3 | 3 | 2 | 1 | 3 | 4 | 3 |
| 17=37 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| Tot. | 24 | 22 | 23 | 22 | 21 | 18 | 23 | 26 | 24 |
| **M** | **3** | **2,8** | **2,9** | **2,8** | **2,6** | **2,2** | **2,9** | **3,3** | **3** |

Scale 1-4+ wt= work task, number see methods. OBT= over mean for BT, UBT= under mean for BT.

**Table 17 D**. Self-evaluated level of alertness (*n*=4) OBT-female, scale 1-4

| **Subj. BT OBT Female** | **R1 12.00** | **R 1 16.00** | **R 1 17.30** | **R2 12.00** | **R 2 16.00** | **R2 17.30** | **R 3 12.00** | **R3 16.00** | **R3 17.30** |
|---|---|---|---|---|---|---|---|---|---|
| 2=58 | 2 | 3 | 3 | 4 | 3 | 3 | 2 | 3 | 3 |
| 8=42 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 3 |
| 11=49 | 3 | 4 | 3 | 2 | 1 | 2 | 3 | 4 | 3 |
| 15=44 | 3 | 2 | 2 | 2 | 2 | 3 | 1 | 3 | 2 |
| Tot. | 10 | 11 | 10 | 11 | 9 | 11 | 9 | 13 | 11 |
| M | 2,5 | 2,8 | 2,5 | 2,8 | 2,3 | 2,8 | 2,3 | 3,3 | 2,8 |
| **All female** | **2,8** | **2,8** | **2,7** | **2,8** | **2,4** | **2,5** | **2,6** | **3,3** | **2,9** |

Scale 1-4+ wt= work task, number see methods. OBT= over mean for BT, UBT= under mean for BT.

**Table 18.** Mean for self-evaluated alertness (*n*= 1-20). Scale 1-4+. Rooms 1, 2 and 3, 8.00, 12.00, 16.00

| **8.00 Room1 Level of alertness** | **12.00 Room1 Level of alertness** | **16.00 Room1 Level of alertness** | **8.00 Room 2 Level of alertness** | **12.00 Room 2 Level of alertness** | **16.00 Room 2 Level of alertness** | **8.00 Room 3 Level of alertness** | **12.00 Room 3 Level of alertness** | **16.00 Room 3 Level of alertness** | |
|---|---|---|---|---|---|---|---|---|---|
| M=alertness All male | 3,1 | 3,1 | 2,9 | 2,8 | 2,4 | 2,3 | 2,9 | 3,1 | 2,9 |
| M=alertness All female | 2,8 | 2,8 | 2,8 | 2,8 | 2,5 | 2,4 | 2,6 | 3,3 | 3,1 |
| | **+-0,3** | **+-0,3** | **+-0,1** | **0** | **+-0,1** | **0,1** | **+-0,3** | **+-0,2** | **+-0,2** |

**Table 19**. Span for individual level of alertness (scale 1-4+), (*n* = 1-20) in Rooms 1, 2 and 3 12.00 and 16.00

| **R1 12.00** | **2,5–3,4** | **0,9** |
|---|---|---|
| R116.00 | 2,8–3,2 | 0,4 |
| R2 12.00 | 2,6-3 | 0,4 |
| R216.00 | 1,8–3,4 | 0,6 |
| R3 12.00 | 2,3-3 | 0,7 |
| R316.00 | 3-3,3 | 0,3 |

**Table 20.** Mean for the day (*n* = 1-20) of cortisol nmol /L

| **Nmol/L** | **Room 1 Cortisol** | **Room 2 Cortisol** | **Room 3 Cortisol** |
|---|---|---|---|
| **M=** | **243** | **246** | **233** |

Measured 13.00 och16.00 in Rooms 1, 2 and 3

**Table 21**, Individual values of cortisol nmol /L in serum, value for being awake and the experience of the room being comfortable. 8.00 in Rooms 1, 2 and 3

| **Cortisol nmol/L** | **Alert scale 1-4** | **Room comfort Scale 1-7** | **Cortisol** | **Alert** | **Room comfort Scale 1-7** | **Cortisol** | **Alert** | **Room comfort Scale 1-7** |
|---|---|---|---|---|---|---|---|---|
| R1 8.00 | R1 8.00 | R1 8.00 | R2 8.00 | R2 8.00 | R2 8.00 | R3 8.00 | R3 8.00 | R3.8.00 |
| 113/18 | 2 | 3 | 303/18 | 2 | 6 | 274/3 | 2 | 2 |
| 293/3 | 2 | 5 | 335/19 | 2 | 5 | 330/18 | 2 | 3 |
| 340/8 | 2 | 2 | 387/10 | 3 | 5 | 334/8 | 3 | 1 |
| 428/2 | 3 | 6 | 433/15 | 3 | 6 | 388/15 | 3 | 1 |
| 453/4 | 3 | 4 | 435/3 | 3 | 6 | 413/7 | 4 | 5 |
| 457/11 | 2 | 5 | 447/12 | 4 | 6 | 418/5 | 3 | 1 |
| 460/12 | 3 | 3 | 447/2 | 3 | 6 | 429/19 | 2 | 3 |
| 476/7 | 4 | 6 | 480/4 | 3 | 3 | 452/12 | 2 | 3 |
| 525/19 | 3 | 5 | 480/8 | 3 | 5 | 477/11 | 2 | 1 |
| 526/15 | 2 | 5 | 486/20 | 2 | 5 | 504/20 | 2 | 2 |
| M=407K nmol /L | | | M=423 nmol /L | | | M=402 nmol /L | | |
| **M=** | **2,6** | **4,4** | | **2,8** | **5,3** | | **2,5** | **2,2** |

Scale 1-4+

**Table 22.** Individual values of cortisol, nmol/ L in serum and value for being alert and experience of the room as comfortable. 8.00 In Room 1, 2 and 3.

| **Cortisol nmol/L** | **Alert 1-4+** | **Room Comf 1-7+** | **Cortisol nmol/L** | **Alert 1-4+** | **Room Comf 1-7+** | **Cortisol nmol/L** | **Alert 1-4+** | **Room comf 1-7+** |
|---|---|---|---|---|---|---|---|---|
| Room 1 8.00 | Room 1 8.00 | Room 1 8.00 | Room 2 8.00 | Room 2 8.00 | Room 2 8.00 | Room 3 8.00 | Room 3 8.00 | Room 3 8.00 |
| 561/20 | 3 | 3 | 497/11 | 3 | 5 | 539/1 | 1 | 2 |
| 571/1 | 4 | 4 | 515/7 | 3 | 5 | 565/2 | 2 | 2 |
| 579/16 | 3 | 5 | 547/14 | 3 | 2 | 595/4 | 2 | - |
| 601/14 | 3 | 4 | 573/1 | 3 | 2 | 614/16 | 2 | 3 |
| 605/10 | 3 | 6 | 578/16 | 2 | 6 | 621/14 | 2 | 4 |
| 621/9 | 4 | 5 | 690/5 | 2 | 4 | 667/13 | 2 | 2 |
| 669/17 | 2 | 4 | 701/13 | 3 | 4 | 672/9 | 4 | 1 |
| 680/5 | 2 | 3 | 708/9 | 2 | 5 | 728/10 | 3 | 2 |
| 684/6 | 3 | 4 | 732/17 | 3 | 4 | 731/6 | 2 | 2 |
| 748/13 | 3 | 6 | 975/6 | 1 | 5 | 785/17 | 4 | 1 |
| M= | 3 | 4,4 | | 2,5 | 4,2 | 527 | 2,4 | 1,9 |
| **M=632 nmol /L Span 561-748** | | | **652 nmol /L** | | | **652 nmol/L** | | |

**Table 23**. Individual values for cortisol nmol /L in serum and value for being alert 13.00 Rooms 1, 2 and 3.

| **Cortisol Room 1 13.00** | **Alert 1-4+ Room 1 13.00** | **Cortisol Room 2 13.00** | **Alert 1-4+ Room 2 13.00** | **Cortisol Room 1 13.00** | **Alert 1-4+ Room 3 13.00** |
|---|---|---|---|---|---|
| 169/19 | 2 | 161/19 | 3 | 143/3 | 3 |
| 192/6 | 3 | 167/12 | 3 | 171/4 | 3 |
| 193/8 | 2 | 188/3 | 2 | 177/12 | 3 |
| 195/3 | 2 | 188/15 | 2 | 195/5 | 4 |
| 199/9 | 3 | 198/1 | 2 | 199/18 | 3 |
| 213/20 | 2 | 237/14 | 3 | 213/19 | 2 |
| 239/14 | 4 | 243/4 | 3 | 235/9 | 3 |
| 254/2 | 2 | 246/9 | 3 | 256/1 | 3 |
| 256/13 | 3 | 247/10 | 2 | 267/15 | 1 |
| 287/7 | 4 | 259/7 | 3 | 269/10 | 1 |
| 290/4 | 3 | 263/8 | 3 | 279/7 | 3 |
| 296/11 | 3 | 263/20 | 3 | 273/13 | 3 |
| 303/12 | 4 | 278/2 | 4 | 276/14 | 3 |
| 309/1 | 4 | 324/13 | 3 | 294/6 | 3 |
| 316/15 | 3 | 325/5 | 3 | 286/20 | 3 |
| 333/10 | 3 | 326/17 | 3 | 311/8 | 3 |
| 338/17 | 3 | 338/11 | 2 | 341/11 | 3 |
| 361/18 | 3 | 389/6 | 3 | 345/16 | 3 |
| 397/6 | 3 | 416/18 | 3 | 353/2 | 2 |
| 419/16 | 3 | 457/16 | 2 | 412/17 | 3 |
| M=278 Span 169-419 Nmol/L | | 276 | | 265 | |
| **M=** | **3,1** | | **2,6** | | **2,8** |

**Table 24. Individual values of cortisol nmol/L in serum, value for being awake and experience of the room being comfortable. 16.00 Rooms 1, 2, and 3.**

| **Cortisol nmol/L** | **Alert 1-4+** | **Room comf 1-7+** | **Cortisol nmol/L** | **Alert 1-4+** | **Room comf 1-7+** | **Cortisol nmol/L** | **Alert 1-4+** | **Room comf 1-7+** |
|---|---|---|---|---|---|---|---|---|
| R 1 16.00 | R 1 16.00 | R 1 16.00 | R2 16.00 | R 2 16.00 | R 2 16.00 | R 3 16.00 | R 3 16.00 | R 3 16.00 |
| 49/3 | 1 | 2 | 117/19 | 2 | 2 | 117/8 | 3 | 2 |
| 133/5 | 3 | 4 | 129/20 | 2 | 5 | 134/4 | 3 | 4 |
| 143/4 | 2 | 3 | 148/7 | 2 | 2 | 138/20 | 4 | 3 |
| 147/2 | 3 | 4 | 167/11 | 1 | 5 | 143/16 | 4 | 4 |
| 164/9 | 3 | 5 | 175/10 | 2 | 4 | 150/5 | 3 | 1 |
| 165/1 | 4 | 6 | 188/1 | 1 | 1 | 151/1 | 3 | 3 |
| 168/13 | 3 | 5 | 189/18 | 4 | 2 | 164/7 | 3 | 1 |
| 181/19 | 2 | 2 | 195/12 | 3 | 5 | 164/11 | 4 | 4 |
| 182/8 | 2 | 2 | 199/3 | 2 | 6 | 169/3 | 4 | 2 |
| 192/11 | 4 | 6 | 200/2 | 3 | 5 | 211/13 | 4 | 1 |
| M=152 range 49-192 | | | 171 | | | 154 | | |
| **M=** | **2,7** | **3,9** | | **2,2** | **3,7** | | **3,5** | **2,5** |

**Table 25**. Individual values of cortisol, nmol/L in serum, value for being alert and experience of the room being comfortable. 16.00 Rooms 1, 2, and 3.

| **Cortisol nmol/L R1 16.00** | **Alert 1-4+ R1 16.00** | **Room comfort 1-7+ R1 16.00** | **Cortisol nmol/L R2 16.00** | **Alert 1-4+ R 2 16.00** | **Room comfort 1-7+ R 2 16.00** | **Cortisol nmol/L Room 3 16.00** | **Alert 1-4+ R 3 16.00** | **Room comfort 1-4+ R 3 16.00** |
|---|---|---|---|---|---|---|---|---|
| 211/16 | 3 | 5 | 211/16 | 2 | 4 | 218/2 | 3 | 4 |
| 232/18 | 4 | 4 | 221/9 | 3 | 5 | 227/19 | 2 | 2 |
| 236/20 | 3 | 2 | 226/4 | 3 | 3 | 235/17 | 3 | 1 |
| 241/15 | 2 | 3 | 230/15 | 2 | 4 | 242/12 | 3 | 1 |
| 245/14 | 3 | 3 | 241/13 | 2 | 2 | 247/14 | 2 | 3 |
| 246/17 | 3 | 5 | 260/6 | 3 | 3 | 249/18 | 4 | 5 |
| 260/10 | 2 | 6 | 274/5 | 3 | 3,7 | 254/10 | 3 | 1 |
| 268/12 | 4 | 4 | 276/8 | 3 | 6 | 255/9 | 3 | 2 |
| 295/7 | 4 | 5 | 336/14 | 3 | 5 | 269/6 | 3 | 3 |
| 387/6 | 3 | 3 | 341/17 | 3 | 2 | 280/15 | 3 | 2 |
| M= | 3,1 | 4 | | 2,7 | 3,8 | | 2,9 | 2,4 |
| **M=262 211-387** | | | **262** | | | **248** | | |

**Table 26**. Subjects being alert on the highest level (4) and relation to level at light and the room being experienced as comfortable.

| | Subj | *Level of amb. light HI middle of the floor and table HI middle of the table MLWF | Very tired very alert 1-4+ | The room a little at comfort – much at comfort 1-7+ |
|---|---|---|---|---|
| 1 | Subj.7 Room 1 8.00 | 62*Lux 749 Lux middle lower window frame | 4 | 6 |
| 2 | Subj. 1 Room 1 8.00 | 62*Lux 749 Lux middle lower window frame | 4 | 6 |
| 3 | Subj. 9 Room 1 8.00 | 62*Lux 749 Lux middle lower window frame | 4 | 5 |
| 4 | Subj. 12 Room 2 8.00 | 40 Lux 170 Lux wall | 4 | 6 |
| 5 | Subj. 2 Room 2 8.00 | 40 Lux 170 Lux wall | 4 | 6 |
| 6 | Subj. 7 Room 3 8.00 | 20 Lux 65 Lux wall | 4 | 5 |
| 7 | Subj. 14 Room 3 8.00 | 20 Lux 65 Lux wall | 4 | 4 |
| 8 | Subj. 14 Room 1 13.00 | 233 Lux 2980 Lux middle lower window frame | 4 | - |
| 9 | Subj. 7 Room 1 13.00 | 233Lux 2980 Lux middle lower window frame | 4 | - |
| 10 | Subj. 12 Room 1 13.00 | 233Lux 2980 Lux middle lower window frame | 4 | - |
| 11 | Subj. 1 Room 1 13.00 | 233 Lux 2980 Lux middle lower window frame | 4 | |
| 12 | Subj. 5 Room 2 13.00 | 288 Lux 1480 Lux wall | 4 | |
| 13 | Subj. 5 Rum 3 16.00 | 349 Lux 1340 Lux wall | 4 | 1 |
| 14 | Subj. 1 Room 1 16.00 | 114 Lux 1303 Lux middle lower window frame | 4 | 6 |
| 15 | Subj. 11 Room 1 16.00 | 114 Lux 1303 Lux middle lower window frame | 4 | 6 |
| 16 | Subj. 18 Room 1 16.00 | 114 Lux 1303 Lux middle lower window frame | 4 | 4 |
| 17 | Subj. 12 Room 1 16.00 | 114 Lux 1303 Lux middle lower window frame | 4 | 4 |
| 18 | Subj. 7 Room 1 16.00 | 114 Lux 1303 Lux middle lower window frame | 4 | 5 |
| 19 | Subj. 18 Room 2 16.00 | 70 Lux 290 Lux wall | 4 | 2 |
| 20 | Subj. 20 Room 3 16.00 | 349 Lux 1340 Lux wall | 4 | 3 |
| 21 | Subj. 16 Room 3 16.00 | 349 Lux 1340 Lux wall | 4 | 4 |
| 22 | Subj. 11 Room 3 16.00 | 349 Lux 1340 Lux wall | 4 | 4 |
| 23 | Subj. 3 Room 3 16.00 | 349 Lux 1340 Lux wall | 4 | 2 |
| 24 | Subj. 13 Room 3 16.00 | 349 Lux 1340 Lux wall | 4 | 1 |
| 25 | Subj. 18 Room 3 16.00 | 349 Lux 1340 Lux wall | 4 | 5 |

**HI= horizontal illumination, VI= vertical illumination MLWF= middle of lower window frame**

# 4. DISCUSSION

## 4.1 Discussion of results.

The results can be questioned because level of alertness is affected by photic history. It is the way we live in everyday's life that in a high extent is shown in the study in combination with internal and external triggers present at the time. Additionally external or internal triggers for level of alertness during the day are unknown. It is also unknown in what way the use of instruments in collecting data about alertness affected the results. The onset and offset of the diurnal rhythm are not synchronised between the subjects and that have affected the result. The study should be seen as a pre-study that verifies variety in level of alertness among the subjects.

### 4.2 Discussion of methods

Methods used in the study are instruments for self-assessed level of alertness (questionnaires with semantic scales) the BT-test and VCT-test and blood samples. It can be an advantage to combine pre-formulated instruments with qualitative interviews to get better data about the individual's experiences. Blood samples can be taken more frequently and increase the information about the subject´s physiological response. All methods used have an impact on level of alertness that is hard to avoid. With the use of interviews, subjects can relate their level of alertness to an ordinary day after the test period and be less affected by the use of test instruments. There is a lack of knowledge about in what way the camp and flight system are activated among the subjects. To divide photic history and diurnal rhythm from an activation of the camp and flight system is needed to get data about alertness. This is an issue that is hard to solve. In the same way methods to measure alertness interfere with level of alertness this is a methodological problem that is hard to solve as well.

## 5. CONCLUSION

The pattern seen in level of alertness among the subjects in the study is a great variety in alertness among the subjects. Result based on mean does not show this variety.

-Mean (*n*=1-20) for level of alertness when staying in the three rooms, showed only minor differences (Table 15).

– Mean for level of alertness in the subgroups (OBT-male, female, UBT-male, and female) when staying in the three rooms showed only minor differences (Table 16).

-The highest mean for being alert at 12.15 for the subjects (*n*=1-20) is seen in Rooms 1 and 2. (Table 15).

-The highest mean for being alert for the subjects (*n*=1-20) in Room 3 is seen at 16.00 and the lowest at 12.15.

-When the subjects´ (*n* =1-20) values for being alert were compared between the three rooms, the widest distribution was found in daylight and in Room 1. In Room 3 the most narrow span was found (12.15, R1, 2.5-3.4, R2, 2,6-3, R3, 2,3-3. 16.00, R1, 2.8- 3,2, R 2, 1,8-3,4, R3, 3-3,3 Table 26).

-Mean for cortisol during the day among the subjects (*n*=1-20) when staying in the three rooms are close to each other (Cortisol R1, M=243nmol/L, R2, 246 nmol/L, R3, 233 nmol/L). The lowest mean (*n* =1-20) for cortisol is seen in Room 3.

-When individual values for cortisol and level of alertness are seen together, there is not a pattern that relates the highest level of cortisol to the highest level of alertness. Instead the level of cortisol and level of alertness vary among the subjects in a high extent.

-When individual values for cortisol and level of light are seen together, there is not a pattern that relates the highest level of cortisol to the highest level of light. The highest individual level of cortisol can be seen in both the lowest and highest levels of light seen in the study.

-When individual values for cortisol and the room being comfortable is seen together there is not a pattern that relate the highest level of cortisol to the highest experience of comfort.

-The highest level of individual self-evaluated alertness (4) is seen in both low and high levels of light.

-Being alert individually on the highest level (4) is seen at any time of the day.

The specific triggers for level of alertness for the individual subject are unknown in the study.

### 5.1 Future research

More needs to be known about pattern in level of alertness and in what way alertness and hormonal levels are altered by static or dynamic artificial light whit different spectral profile, timing, duration and light distribution. The human reaction hormonally to drastic changes and strong triggering from EMR needs to be investigated thoroughly with the purpose to eliminate combinations of spectral profile, timing, duration and light distribution that have a negative impact. In what way EMR cooperates with other external and internal triggers for arousal are additionally urgent research questions. The research has to be repeated over and over until the material is saturated and forms a pattern often seen in the relation to the interaction of MLCS. There is also a need to find out more about if it is possible to divide hormonal release related to diurnal rhythm from hormonal release related to the camp and flight system. It is also important to evaluate if methods that pretend to describe the hormonal release related to diurnal rhythm are used in a correct way. [Cannon 1939; Hannibal et al. 1997].

## 6. ACKNOWLEDGMENTS

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