USER RESPONSES TO LIGHTING DESIGN WITH RESPECT TO GENDER, PERSONALITY AND PREFERRED LEVELS OF LIGHT

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Abstract

Can patterns be seen in the subject's responses to and preferences for daylight and artificial light when staying in the indoor environment? The research behind the paper investigates if gender, personality and visual performance are possible factors for the build up of subgroups with a similar need for light. It is also investigated if the individual need for light in the ordinary reading situation and for ambient light can be defined by the use of the Burrell's test (BT) and the visual comfort test (VCT) and if it is possible to, based on the results from the BT and the VCT, construct a light identity. Results show large interindividual differences among subjects in preferences for light.

Keywords: Gender and light, personality and light, individual preferences for light, light identity

1. INTRODUCTION

The study investigates if patterns can be seen in subject's responses to and preferences for daylight and artificial light when staying in the indoor environment. Gender, personality and visual performance factors are invented if usable for the buildup of subgroups with a similar need for light? From the use of the BT and the VCT is the individual need for light in the ordinary reading situation and for ambient light defined. From the use of the BT and the VCT are a light identity constructed and the subjects divided into two basic groups O and U

Patterns are a way to simplify the lighting design and place the users within their spans of preferences for light.

Methods used are the BT that investigates the subject's level of being stressed in everyday's life and the VCT that measure the preference for a visually comfortable combination of light level on the table and in the ambient light.

1.1Problem area and relevant research

Artificial light is needed as a complement for daylight to be able to be efficient and safe in work and for quality of life. Electromagnetic radiation (EMR) interacts with the human psychologically, physiologically and visually and need to be designed in a way that strengthens the individual user's diurnal rhythm, homeostatic balance and gives visual comfort. Many workplaces today in Europe have an open-plan. If users can be put together in groups with similar preferences for light this increase the possibility to design a better individual support from light for the user. Subjects are different in responses and preferences to light. For the lighting designer with the ambition to design light close to the individual users needs it is an

advantage if the design of light in some way can be simplified. Patterns in preferences can be a usable tool for lighting design. Gender, personality can be factors behind the buildup of subgroups with a similar need for light. If subjects could be evaluated as having a similar light identity, subgroups can be identified that need special care from the lighting designer.
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 in a large scale [1979, 1992]. S.M. Pauley [2004] and Pechacheck, Andersen & Lockley [2008] show the urgent need of focusing on the problems related to the use of artificial light and describe a future light for the indoor environment more similar to the one seen outdoor. The variability in the human vision, diurnal rhythm, differences in sensitivity need to be handled by the lighting designer to be able to do lighting design that the users appreciates.

1.2 Aims

To investigate if patterns can be seen in subject's responses to and preferences for daylight and artificial light when staying in the indoor environment. To investigate if gender, personality and visual performance are factors usable for the buildup of subgroups with a similar need for light.
To evaluate if the individual need for light in the ordinary reading situation and for ambient light can be defined by the use of the BT and the VCT?
To investigate if it is possible to, based on the results from the BT and the VCT, construct a light identity (Methods 4.3).
To investigate if light identity can be a way to divide subjects into two basic groups, O and U?

1.3 Problem formulation

Can patterns be seen in subject's responses to and preferences for daylight and artificial light when staying in the indoor environment? The need for light changes during the day for all humans since we are adapted to the rhythm of daylight. The startup of the diurnal rhythm varies between subjects and the sensitivity for the trigger EMR visually and physiologically differs between users. Humans need to take support from EMR to stay in light-related homeostatic balance in level of arousal and in a well-functioning diurnal rhythm. Many workers in Europe today stay in open-plan spaces. This aggravates the lighting designers work. If subjects can be divided into subgroups with a similar need for light this increase the possibility to design a supportive interaction MLCS close to the individual user's preferences.

1.4 Research questions

Can patterns be seen in subject's responses to and preferences for daylight and artificial light when staying in the indoor environment?
Are gender, personality and visual performance factors usable for the buildup of subgroups with a similar need for light?
Can the individual need for light in the ordinary reading situation and for ambient light be defined by the use of the BT and the VCT?

Is it possible to, based on the results from the BT and the VCT, construct a light identity (Methods 4.3)?
Can light identity be a way to divide subjects into two basic groups, O and U?

2. METHODS

In order to find out more about the subjects' preferences for levels of light, the following methods were used in the study: designed room and light settings, pre-formulated questionnaires, correction tests and blood samples.

2.1 Study design

This study is based on three room and light settings similar in architectural and interior design but different in the light settings. The subjects stay for one day in each room. 18 of the subjects stayed for 6 minutes in a visual comfort study (VCT) in order to map out preferred levels of light on the work table and for the level of a complementary ambient light. The VCT was done before the main study started but the data was not analysed until after the study was finished (Methods 4.4). Data about the subjects' experience, response and performance in three rooms was collected with questionnaires about emotional experiences and cognitive performance. Blood samples were collected at 8:00-8:15, 12:00-12:15 and 16:00-16:15. The subjects stayed for one day in each room. The subjects remained in the same 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 a room with solely daylight.

2.2 Participants

The study was conducted at The School of Engineering at Jonkoping University. The test subjects in the study were recruited via group mail which was sent to all students enrolled in the lighting design program at the School of Engineering in Jonkoping. 20 people applied to participate in the study and were chosen by convenience. The group consisted of 12 women and 8 men. The mean age was 24.6 years. Each participant received books worth 2,000 SEK for their participation in the study. The subjects were divided into subgroups based on gender, BT and VCT.

2.3 Grouping of the subjects

The subjects could, based on the result of the BT and the VCT, theoretically be divided into subgroups. A personality test called BT, developed by Gunilla Burell was chosen for the measuring of the subjects' self-assessed feeling of being stressed in their everyday life. The visual comfort test (VCT) was developed by Bo Persson of KTH, Sweden. The test was further developed by the author and used for the collection of data about preferred levels of light at the work table and in the complementary ambient light in a given contrast situation. The group of subjects, 1-20, in the study is mentioned. The subgroups are divided in a first step by gender into male and female subjects. The subjects were also divided from the use of Burell's test (BT). The abbreviation OBT = mean value or over mean for BT, while UBT = under mean for BT. The subjects were also divided from the result of the VCT. The abbreviation OVCT = mean and over mean for preference for level of light at the work table, while UVCT = under mean for

preference for level of light at the work table. The subjects were also divided by the Visual comfort test (VCT) according to the preference for the preferred level of light at the work table and the complementary ambient light. The O or U for the level of light at the work table is mentioned at first and the level of light in the ambient light in the second position before the abbreviation VCT. Gender, BT and VCT are seen separately or in combination in subgroups. The groups that can be seen are a combination of the subjects 1-20, male subjects, female subjects, O-BT, U-BT, O-VCT, U-VCT, OO-VCT, UU-VCT, OU-VCT, and UO-VCT.

Table 1. Group of subjects 1-20 and 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 Mean and over mean for VCT
UBT- male	Under mean BT- male	OBT UUVCT	Mean and over mean for BT Under mean for VCT
UBT- female	Under BT-female	UBT-OOVCT	Under mean for BT Mean and over mean for VCT
		UBT UUVCT	Under mean for BT Under mean for VCT

2.3 Instruments used in the study

Burrell's test: The subjects' personality and self-evaluated disposition to experience of stress were 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

I feel at the moment: The subject´s experiences were measured with the test called *I feel at the moment* (Jag känner mej just nu). 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). The contradictory pair of words, very sleepy- very alert was chosen and given 1-4 points (Department of Environmental psychology Lund University).

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

VCT: The subjects' preferences for level of light were measured with the visual comfort test**.** The test was developed by 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 three times. Then, he repeated the same procedure with a white paper on a black table. The test was completed in 2006 by M. Säter to be used for the 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.

2.4 Procedure

The subjects 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, 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, 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. 12:15-13:00 Lunch- 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 Procedure in the Visual comfort study (VCT)*.

The study was started at any time of the day.

00-00.20: Test subjects were welcomed by the research leader and shown into the room.

00.20-2.10: Test subjects sat at a table upon which was a white piece of paper and received instructions on the various stages of the experiment via a tape recording and a loudspeaker. The test subjects began with the control for Dimmer 1 in position 0. They then increased the brightness to the maximum level before reducing it to a level that they deemed would allow them to comfortably read black letters on a white background that had been affixed to a black fabric. The horizontal illumination strength was measured with a calibrated Luxmeter and recorded by the test leader. The selected level was maintained, and the test subject was instructed to increase the brightness of the light in the room by first sliding the control for Dimmer 2 to its maximum setting before moving it to the level with which the test subject felt comfortable. 2:18-3:49: The test subjects started with the control for Dimmer 1 in position 0 and increased the lighting level to maximum strength; they then slowly reduced the strength to the level they felt would allow them to comfortably read black letters on a white background that had been affixed to a black fabric. The level of horizontal illuminance was measured with a calibrated Luxmeter and recorded by the test leader. The selected level was maintained, and the test subject was instructed to increase the brightness of the light in the room by first sliding the

control for Dimmer 2 to its maximum setting before moving it to the level with which the test subject felt comfortable. 3:57-4:47: The test subjects started with the control for Dimmer 1 in position 0 and increased the lighting level to maximum strength; they then slowly reduced the strength to the level they felt would allow them to comfortably read black letters on a white background that had been affixed to a black fabric. The horizontal illumination strength was measured with a calibrated Luxmeter and recorded by the test leader. The selected level was maintained, and the test subject was instructed to increase the brightness of the light in the room by first sliding the control for Dimmer 2 to its maximum setting before moving it to the level with which the test subject felt comfortable. 4:55- 5:37: the test subjects moved the control on Dimmer 2 to the maximum position. They then moved it back down until they achieved a level of ambient light with which they were comfortable. The reading was recorded in the table for ambient light. The experiment was then terminated.

2.5 Analysis of data

Data was analysed with the analytic software SPSS. Mean and frequencies was used.

2.6 Design of the room and light settings

The three rooms and light settings almost identical in architecture and interior design, differed in the lighting equipment. (Fig 1-12, Tables 1-6). With the ambition to neutralize temporary differences in level of daylight, that only lasted, for a short while, was a mean daylight- day 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. 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, Room 2 and 3 were darkened and only equipped 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, se methods. (Figure1-12, table 1-6). 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 floor in the three rooms was covered with a carpet of linoleum in beige with NCS code 6500. The ceiling in the three rooms was equipped with acoustic boards painted in white in NCS code 0502Y. The work space had a work table of birch with black metal legs, 1400 x 600mm and 720mm. 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 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 toilet in the same light as they stayed in the test rooms (Figures 1-12, table 1-14).

2.7 Lighting conditions Room 1, 2 and 3

Data about the lighting applications in the three rooms can be found in table 2-15 and in figure 1-9.

2.7.1 Measurements 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

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

2.7.2 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 of 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 of lower window frame

Table 6. Illuminance Room 2, 08.00, 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, luminance					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		
Reading place HI	364	364			185	188			148	149		
Wall at w- table VI	327	330			95	98			67	68		
Wall at door VI	350	347			168	163			69	68		
Wall at reading 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 Illuminance					10. 00 Illuminance				12. 00 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 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 Illuminance, Luminance					16. 00 Illuminance				17. 30 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

2.8 Room 1

2.8.1. 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 was considered as normal for the season (February-March), and as a

result of the type of window 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 9). 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 got 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, candlelight's was placed in the restroom. The collection of blood samples for all subjects was done due to practical reasons in daylight (Figures 2-15, Tables 1-12).

Fig. 1. R 1.

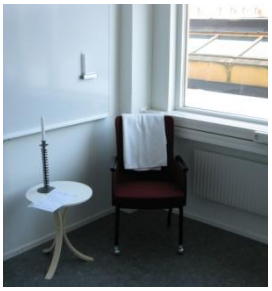


Fig. 2. R 1.

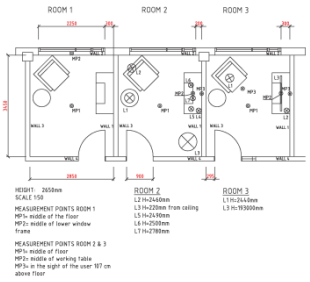


Fig. 3. Floor plan Room 1

Table 10. Horizontal illumination, Room 1, 3 and 10 march 2006.

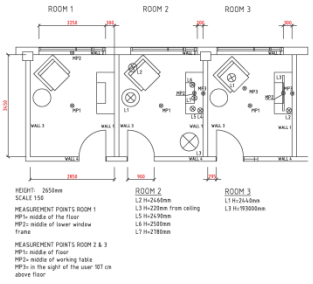
Daylight Lux	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00
4 march	65	158	353	282	390	378	246	169	98	40
10 march	59	207	106	182	343	320	219	198	130	59
Mean day	62	183	230	232	367	349	233	184	114	50

Table 11. Horizontal illumination, mp. Middle of lower part of the window.

Daylight Lux	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

2.8.2 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 only of 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. To enable visiting the toilet in the same lighting condition 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 1-14).



Figures 4. R 2 **Figure 5.** R 2 **Figure 6.** Floor plan Room 2.

Table 12. Horizontal and vertical illumination Room 2.

Lux	M.P	8.00	10.00	12.00	14.00	16.00	17.30
R 2. Amb. HI	Middle of the floor	40	330	340	237	70	38
R 2. Wall VI	In the eyesight	170	1500	1780	1180	290	211

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

Table13. Lighting equipment Room 2

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

2.8.5 The design of the lighting application in Room 3

The light in Room 3 was designed to deviate from daylight*; the windows were covered and all daylight shaded out. The light in the room consisted of artificial light only. The subjects had no possibility to dim the light. The level of light varied 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. 7. R 3

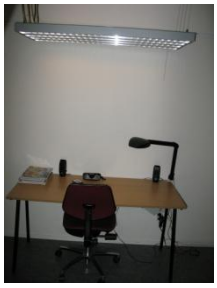


Fig. 8. R 3

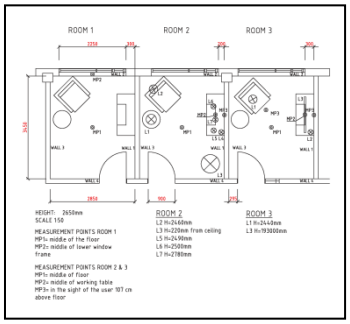


Fig. 9. Floor plan Rom 3.

Table 14. Level of illumination, Room 3

Lux	M.P	8.00	10.00	12.00	14.00	16.00	18.00
R 3. Amb light HI	Middle of the floor	20	18	56	43	349	1060
R 3. W-table	Middle of table	65	67	216	240	1340	3500

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

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

Down light	PL-T 18W, 830, 4p	244 cm from floor	Reading area
Table mounted work task luminairy	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 and DMX to addressed luminaries

3. RESULTS

The first data to be considered are the results of the BT and the VCT.

Male and female subjects are close in mean for BT and for VCT (*Table 16).*

The span for preferred level of light for the work table was 380-3950 Lux. The preferences vary 10 times at the most in the group. For preferred levels of light in the complementary ambient light, the span in the groups is 60-1400 Lux. Here the preference in the group varies 20 times. Mean for subj. 1-20 for preferred level of light at the work table is 2007 Lux and for the level of ambient light 563 Lux. It can also be read out in the result that values for preferences for light vary to a high extent (*Table 16).* All subjects prefer a lower level of ambient light compared to

the level of light at the work table. The variation in the group is from almost the same level up to a preferred 17 times more light on the work table compared to the ambient light.
When preferred level of light is measured in the VCT, OVCT-male and UVCT-male differ with 702 Lux in mean for level of light at the work table and with 157 Lux in the mean for ambient light (*Table 17)*. The OBT-female and UBT-female differ with 501 Lux in mean for preferred level of light at the work table and with 369 Lux in mean for the ambient light. Mean for preferred levels of light for OBT- male and OBT- female subjects are close. Mean for UBT-male and UBT- female are also close. The difference in mean between OBT- male and UBT-female is 514/298 and for OBT-female and UBT-male 689/228, for the level of light at the work table and for the level of ambient light. The subjects evaluated as OBT or UBT and OVCT (working table or ambient) and UVCT (working table or ambient) can be read out in table 18.

Table 16. Visual comfort test.

Subj 1-20 BT	**Gender**	**OBT U BT**	**Gender**	**HI work table Subj 1-20 BT**	**VI, wall ambient light Subj 1-20 BT**	**High-low Ill w-table**	**High-low Ill wall amb.**
1= 38	M	18= 61	M	1280	570	3950	1400
2= 58	F	2= 58	F	3950	1000	3950	1300
3= 37	F	4= 53	M	1040	60	3700	1160
4= 53	M	11= 49	F	2060	320	3360	1000
5= 39	F	14= 45	M	2500	390	3320	750
6= 39	F	15= 44	F	3000	1400	3310	680
7= 30	M	8= 42	F	400	390	3000	680
8= 42	F	10= 41	M	404	140	2500	630
9= 37	F	20= 40	F	2300	750	2300	570
10= 41	F	6= 39	F	3360	630	2060	530
11= 49	F	5= 39	F	1070	480	1330	480
12= 29	F	1=38	F	3950	1300	1280	390
13= 37	F	19= 38	M	810	110	1230	390
14= 45	M	9= 37	F	1230	70	1070	320
15= 44	F	17= 37	F	3700	530	1040	320
16= 30	M	13= 37	F	3310	680	810	230
17= 37	F	3= 37	F	1040	60	700	140
18= 61	M	16= 30	M	1330	320	404	110
19= 38	M	7= 30	M	380	230	400	70
20= 40	M	12= 29	F	700	680	380	60
M= 41			**M=Male 42, M=Female41**	**M=1-20 2007 M=male 1990 M=female 2018**		**M= 1-20 563 M= male 606 M=female 531**	

In this table are subjects put in range by number 1-20 and compared to the values of BT and preferences put in range as well.

Table 17. Mean for OVCT (table, amb) and UVCT (table, amb), male and female subjects, Lux

Subj	**VCT Mean HI table**	**VCT Mean VI Amb l.**
OBT-male	2366	707
UBT-male	1664	550
OBT-female	2353	778
UBT-female	1852	409

VCT= visual comfort test, HI=horizontal illumination, VI= visual illumination.
In this table are subjects 1-20 put in subgroups based on their value for the BT test and seen from mean for the group in the VCT test with the ambition to look for differences. The VCT have two values, the level of light at the table and the ambient light. Level of light at the table is always revealed first. *In table 19* the results of the BT and VCT are put together. BT divides the subject in over or under mean and the VCT divide the group in over and under mean for level of light of the table and for the ambient light. The subjects were evaluated by the BT and the VCT as UBT-UUVCT, OBT-OOVCT, UBT-UOVCT, UBT-OOVCT, UBT-OUVCT, OBT-UUVCT, OBT-UOVCT and OBT-OUVCT. *From table 20* it can be read that seven subjects were evaluated as UBTUUVCT, three subjects had OBT-OOVCT, one subject had UBT-UOVCT, four subjects had UBT-OOVCT, one subject had UBT-OUVCT, one subject had OBT-UUVCT, one subject had OBT-UOVCT and two had OBT-OUVC

Table 18. Subj. 1-20 Visual Comfort test

Fp 1-20	**M=41**	**HI work table Lux**	**M=2007 VCT**	**VI on the wall Lux**	**M=563 VCT**
1= 38	UBT	3950	O	1300	O
2= 58	OBT	3950	O	1000	O
3= 37	UBT	1040	U	60	U
4= 53	OBT	3320	O	1160	O
5= 39	UBT	1070	U	480	U
6= 39	UBT	3360	O	630	O
7= 30	UBT	380	U	230	U
8= 42	OBT	400	U	390	U
9= 37	UBT	1230	U	70	U
10= 41	UBT	404	U	140	U
11= 49	OBT	2060	O	320	U
12= 29	UBT	700	U	680	O
13= 37	UBT	3310	O	680	O
14= 45	OBT	2500	O	390	U
15= 44	OBT	3000	O	1400	O
16= 30	UBT	1380	U	320	U
17= 37	UBT	3700	O	530	U
18= 61	OBT	1280	U	570	O
19= 38	UBT	810	U	110	U
20= 40	UBT	2300	O	790	O
M= 41p.		**2007 Lux**		**563 Lux**	

In this table is shown the subjects value for BT and for VCT to see if a high level of BT leads to a preference for a high value of level of light.

Table 19. Subjects 1- 20, preferred level of light at the work table and for the level of the complementary ambient light.

Subj./ BT	M/F	M BT	level of w.table	U/O m for w.table	Prefer amb. l	U/ O amb. l	Light profile	Evaluation
7= 30	M	UBT	380	U	230	U	UBT-UUVCT	Under mean for stress and level of light
3= 37	F	UBT	104	U	60	U	UBT-UUVCT	Under mean for stress and level of light
19= 38	M	UBT	810	U	110	U	UBT-UUVCT	Under mean for stress and level of light
5= 39	F	UBT	1070	U	480	U	UBT-UUVCT	Under mean for stress and level of light
9= 37	F	UBT	1230	U	70	U	UBT-UUVCT	Under mean for stress and level of light
16= 30	M	UBT	1380	U	320	U	UBT-UUVCT	Under mean for stress and level of light
10= 41	F	UBT	404	U	140	U	UBT-UUVCT	Over mean for stress, under mean for light
12= 29	F	UBT	700	U	680	O	UBT-UOVCT	Under mean for stress, under mean for level of light at the work table, over mean for a-light
20= 40	M	UBT	2300	O	790	O	UBT-OOVCT	Under mean for stress and over mean for light
13= 37	F	UBT	3310	O	680	O	UBT-OOVCT	Under mean for stress and over mean for light
6= 39	F	UBT	3360	O	630	O	UBT-OOVCT	Under mean for stress and over mean for light
1= 38	M	UBT	3950	O	1300	O	UBT-OOVCT	Under mean for stress and over mean for light
17= 37	F	UBT	3700	O	530	U	UBT-OUVCT	Under mean for stress, o mean for level of light at the work table, u mean for the ambient light
2= 58	F	OBT	3950	O	1000	O	OBT-OOVCT	Over mean for stress and level of light
4=53	M	OBT	3320	O	1160	O	OBT-OOVCT	Over mean for stress and level of light
15=44	F	OBT	3000	O	1400	O	OBTOOVCT	Over mean for stress and level of light
14=45	M	OBT	2500	O	390	U	OBTOUVCT	Under mean for stress, over mean for light at the work table, under mean for ambient light
11=49	F	OBT	2060	O	320	U	OBTOUVCT	Under mean for stress, over mean for light at the work table, under mean for ambient light
18= 61	M	OBT	1280	U	570	O	OBT-UOVCT	Under mean for stress, under mean for light at the work table, over mean for ambient light
8=42	F	OBT	400	U	1160	U	OBTUUVCT	Under mean for stress, under mean for light at the work table, under mean for ambient light
M=41,1			2 007,2		562, 5			

Table 20. Light profiles in the group of subjects

7/20=UBT-UUVCT	3/20= OBT-OOVCT
1/20=UBT-UOVCT	1/20=OBT-UOVCT
1/20= UBT-OUVCT	2/20=OBT-OUVCT
4/20= UBT-OOVCT	1/20= OBT-UUVCT

In this table I look for the most common subgroup.

In table 21 the evaluation of O and U for the BT and VCT is adjusted if close to mean for the tests. A light identity (OBTOOVCT or UBTUUVCT) was created for each subject. In the table the subjects' preferences for visual comfort based on the contrast situation in the VCT can be read out. *In table 22* mean for Burrell's test for light identity OBT is 46 and for light identity UBT is 36. Here a general relation by mean can be seen in the group of subject´s, between a self-assessed level of being stressed and preferences for a high or low level of light.

Table. 21. Light identity and design of an appropriate level of light for the individual subject

Subject	Group OBT OOVCT or UBT UUVCT	Needs for light
Subject 1, UBT OO VCT BT, 38p.	Close to over mean for BT (-4). Counted as OBT-OOVCT	work task luminary of 0-4000 Lux and ambient light of 0-1500 Lux
Subject 6, UBT OO VCT BT, 39p.	Close to over mean for BT (-3). Counted as OBT-OOVCT	work task luminary of 0-4000 Lux and ambient light of 0-1500 Lux
Subject 8, OBT UU VCT BT, 42p.	Close to under mean for BT (+1). Counted as UBT-UUVCT	work task luminary of 0-2000 Lux and ambient light of 0-600 Lux
Subject 11, OBT OUVCT BT, 49p.	Prefers low levels of ambient light to feel at comfort. Counted as OBT-OOVCT	work task luminary of 0-4000 Lux and ambient light of 0- 600 Lux
Subject 12, UBT UOVCT BT, 29p.	Prefers high levels of ambient light to feel at comfort. Counted as UBT-UUVCT	work task luminary of 0-2000 Lux and a dimmable ambient light of 0-1500 Lux
Subject 13, OBT OUVCT BT, 37p.	Close to over mean for BT (-5). Counted as OBT-OOVCT.	work task luminary of 0-4000 Lux and ambient light of 0-1500 Lux
Subject 14, OBT OUVCT BT, 45p.	Prefers low levels of ambient light to feel at comfort. Counted as OBT- OOVCT.	work task luminary of 0-4000 Lux and ambient light of 0- 600 Lux
Subject 17, UBT OUVCT BT, 37p.	Prefers high levels of light on the work table. Counted as UBT-UUVCT.	work task luminary of 0-4000 Lux and ambient light of 0- 600 Lux
Subject 18, OBT UOVCT BT, 61p.	Prefers low levels of light on the work table. Counted as OBT-OOVCT.	work task luminary of 0-2000 Lux and ambient light of 0-1500 Lux
Subject 20, UBT,OOVCT BT, 40p.	Close to over mean for BT (-1). Counted as OBT-OOVCT.	work task luminary of 0-4000 Lux and ambient light of 0-1500 Lux
Subjects 3,5,7,9,10,16,19 UBT UUVCT	Under mean for BT and the visual comfort test = UBT-UUVCT.	work task luminary of 0-2000 Lux and ambient light of 0-600 Lux
Subjects 2,4,15 OBT OOVCT	Over mean for BT and the visual comfort test = OBT-OOVCT	work task luminary of 0-4000 Lux and ambient light of 0-1500 Lux

In this table the light identity is constructed and balanced towards the low or high group, O or U in BT and VCT. This is not a static optimal value. The level of ambient should be put into the diurnal rhythm going up from a low level in the morning and decrease during the day.

Table 22. Light identity OBT- OOVCT and UBT- UUVCT

OBTOOVCT M=41	UBTUUVCT M=41
1=38	3=37
2=58	5=39
4=53	7=30
6=39	8=42
11=49	9=37
13=37	10=41
14=45	12=29
15=44	16=30
18=61	17=37
20=40	19=38
M= Burrell's test, 46	M=Burrell's test, 36

In this table are the subjects divided into two groups that prefer higher or lower levels of light.

In table 23 mean for preferences for levels of light measured in the VCT for OBT and UBT subjects can be read out. By male subjects is 5/8 identified as light identity O and 3/8 as U. Among the female subjects are 7/12 subjects identified as U and 5/12 as O.

Table 23. Mean for preferences of levels of light

Subj. mean and over mean for BT, w- table	2358 H-I
Subj. under mean for BT, w- table	1818 H-I
Subj. mean and over mean for BT ambient light	747 V-I
Subj. under mean for BT, ambient light	463 V-I

Mean for Subj 1-20 for BT is 41. Mean for VCT for level of light at the table is 2007 Lux. Mean for the ambient light is 563 Lux. In this table is shown that the OBT group have a higher mean for VCT compared to the UBT group. *Table 24* reveals constructed span for levels of light based on the VCT for light identity OBT-OOVCT and UBT-UUVCT.

Table 24. Span for preferred level of light.

Subjects 1-20	Group of subj. detected as light identity OBT- OOVCT	Group of subjects detected as light identity UBT- UUVCT
Span for preferred level of light at the work table	1280-3950 Lux Distance 2670 Lux	380-3700 Lux Distance 3320 Lux
Span for preferred level of ambient light	320-1400 Lux Distance 1080	60-680 Lux Distance 630 Lux

In this table the span of preferences for level of light at the table and in the ambient light measured by the VCT is pictured.

4. DISCUSSION

4.1 Discussion of results

This type of studies should be questioned. The results of the study are related to the response to external or internal triggers of different kinds. It is not, with the methods used in the study, possible to verify the trigger that gives a certain response. However, the result of the study reveals that differences can be seen in the subgroups that can be interesting to go on and investigate due to a possible reason to detect subgroups that are vulnerable to the use of artificial light. Personality and the condition of the eye are here suggested to play a role and affect the receiving and responding to EMR and by that the preferences for levels of light.
B.T. shows that male subjects in the study have a slightly stronger experience of being stressed in everyday life compared to the female subjects in the experiment. The number of male and female subjects in the study differs, and this may have affected the result (8 male, 12 female). The VCT shows a large spread in the group of subjects for preferred levels of light at the work table and for the ambient light, but the result is dependent on if the subjects are capable of making precise judgments. Here the naive subjects can be less precise compared to the more trained ones.

4.2 Discussion of methods

Methods used in the study are the BT and the VCT and pre-formulated questionnaires. The BT needs an honest answer from the subjects. The result can be questioned due to if the subjects admit being rude and stressful. The VCT can be questioned not for the method but for giving a static picture of visual preferences. This is not the case. The preferences measured in the given contrast situation in the study changes within some minutes and follows the diurnal rhythm. It is the span for the changes that is of importance for the lighting designer not the individual value at the time.

5. CONCLUSIONS

If patterns can be seen in subject's responses to and preferences for daylight and artificial light when staying in the indoor environment is here finally concluded: Large interindividul differences in the preferences and responses for daylight and for the artificial light is the main pattern that can be seen in the study.

The investigation about if gender, personality and visual performance factors usable for the buildup of subgroups with a similar need for light is here concluded: The results show that gender is not (in this part of the study) seen as a reason for the build up of subgroups with a similar need for light; the mean for preferred levels of light for male and female subjects in the study are close to each other (Table 16). Not gender but personality on the other hand, seems to be related to preferred levels of light (Tables 21, 22, 23). Subjects over and under mean for BT in the study differ in mean for preferences for levels of light.

Can the individual need for light in the ordinary reading situation and for ambient light be defined by the use of the BT and the VCT: VCT shows the subjects' preferences for levels of

light and is in the study seen as the primary foundation for subgroups but here is suggested as influenced to a varied extent by personality.

If it was possible to, based on the results from the BT and the VCT, construct a light identity is here revealed: The subjects got their individual light profiles constructed based on results from the BT and the VCT.

If it was possible to divide subjects into two basic groups, O and U is here concluded: When the results from the BT and the VCT are put together it was possible to construct an O and U group. 10 subjects were defined as O and 10 as U. Subjects close to mean were directed into either O or U.

5.1 Future research

More need to be known about the subjects' individual need for light and about possible patterns in the responses and preferences for daylight and for artificial light. More knowledge about in what way personality affects preferences for light levels and the experience of visual comfort in the reading situation for different subgroups has the possibility to generate a material usable for lighting design. More research about subgroups might simplify the design of light close to the subjects' needs and is valuable for the design of the practical application. More studies in preferences for light have the possibility to connect lighting design close to the individual's visual condition and neurophysiologic sensitivity and to the user's psychological, physiological and visual light-related needs. The span of preferred level of light at the working table and in the ambient light should be investigated in a way that gives a base for a normal distribution curve among users. This used in lighting design may enhance the quality of the interaction MLCS and increase the individual experience of visual comfort.

6. REFERENCES

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7. ACKNOWLEDGMENTS

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