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Abstract:
This master thesis investigates how to design personal circadian lighting, with a focus on the user and how the non-visual effects of lighting influence the bodies circadian rhythm. The goal is to promote a healthy day/night cycle and thereby create more wellbeing for the user, by entrainment of their circadian rhythm.
The final design builts on analysing the users, existing light products suitable for circadian lighting, use the latest research on the topic of circadian metrics, lighting and the circadian system. The result is three personalised circadian lighting design scenarios, that specify recommended light characteristics, when to use, for how long, the position of the light and how to control the light for each of the three user groups; Yung, adult and senior, and followed up by a survey to validate some of the parameters. The conclusion is that making personalised circadian lighting design is hard to do in practice because of the large number of variables. Therefore, a more hands-on approach is recommended with more user engagement to easier verify the designs.

Keywords: Lighting, circadian rhythm, circadian lighting, circadian stimulus, human centric lighting, non-visual, personalisation, light scenarios,

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Designing personalised, efficient circadian lighting

Proposing lighting designs for private homes based on the non-visual impact of light

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Introduction

With the widespread adoption of LED lighting, the way people, companies and the public sector use light are changing, there is more focus on light as more than a utility than ever. Human centric lighting is the new buzzword; it brings the visual and the non-visual aspects of light together in one package. In this thesis, the focus will be on the non-visual effects of light and even more specifically, how it relates to the human circadian system. Furthermore, how to do lighting designs on a personal level with circadian lighting, using new light metrics to evaluate the effect, and the latest research on the topic as a guide.

Motivation and thesis vision

Looking at how the use of light has changed over the last century and especially the last ten years, seeing a world change from the old incandescent bulb with its 'burning' nature and soft lighting abilities, to now be surrounded by primarily LEDs of all shapes and sizes with its at times harsh light. This shift in technology for light has opened up a lot of new possibilities for the individual to customise their home lighting.

However, it is relevant to look at the big picture, what has the obsession with artificial lighting brought with it of problems. When electrical lighting was introduced to the public and had widespread adoption, it was the successor to gas or candle lamps that was dirty. These dirty light sources had a significant health side effect, so the change to the clean light source of the incandescent bulb was at the time a big thing for people's general health. The widespread adoption of electrified lighting and the massive migration of people seen all over the world from rural areas to the urban areas, people as a collective spend more time than ever indoors and get less natural light than ever.

Back to the future, faced with new potential lighting and health challenges, research has changed the way light is perceived, and a whole new sub-genre of light has emerged; human centric lighting (HCL) it is dubbed the next disruptive technology in the lighting industry.

HCL is a new way of looking at lighting design; it is a combination of the visual and the non-visual effects of light on human biology. The non-visual effects of lighting are proved to affect the internal clock by altering the timing of the circadian rhythms. These biological processes regulate everything from sleep to eating habits and the disruption of them have been linked to seasonal depression (SAD) and sleep disruption. These severe symptoms are strongly linked to peoples lighting habits, and the modern light sources used almost everywhere now.

With the introduction of the blue LED the whole technology industry changed because it was now possible to produce white light with LED technology, it paved the way for new products such as the smartphone, flat screen tv's, laptop computers and the LED bulb. With people now spending the majority of their time indoors such as; office workers, school children, sick and immobile elderly and shift workers to name a few, people are more exposed than ever to the wrong lighting from a non-visual lighting perspective.

Screens and LED lighting is everywhere, and this is changing the way people get exposed to light. It is at people's fingertips 24-hours a day, and this affects the circadian rhythm by exposing the eyes to light at the wrong times. Especially blue light, which has been proven to suppress the sleep hormone melatonin. Therefore, making it harder for people to sleep at night, but also the lack of light in the morning and throughout the day has proven to be worrying. So, if the problem is that pressing why are people not complaining more, people generally do not complain if they feel there is enough light. However, enough light for visual tasks is not the same as enough light for the non-visual effects. Task lighting is ordinarily measured horizontally at the task level[1], the latter is measured vertically at the eye, this makes a big difference as put by Figueiro from the Lighting Research Center[2], the light at offices are from the non-visual perspective perceived as dim/dark, and this can affect your concentration and level of alertness.

Looking at were personal technology is at today with IoT (internet of things) and wearables, a lot is happing with health-promoting devices. So where does this leave light and how can HCL, IoT, wearables and intelligent lighting design be exploited to gain more personalised control over the individuals lighting exposure.

The vision statement spur curiosity and imagination about what is possible. The statement has no boundaries and is there to spark interest for a given subject and provide the ground for further investigation into an area of interest. This vision statement came from a personal interest in the space of personal technology such as wearables, smart bulbs and IoT combined with the passion for light and how it affects people.

So, combining technology, light and the cutting edge of research in the field of human centric lighting, the vision came to be:

> *"Imagine if the light in private homes had a positive effect on the resident's wellbeing and could change in relations to the single individual."*

Theory

To investigate the topic of human centric light and the non-visual effects of lighting the following theory have been explored; The human circadian rhythms and circadian lighting and the metrics used in circadian focused lighting design, which is the foundation for the final product – the personal lighting design scenarios.

Circadian rhythms and circadian lighting

What are circadian rhythms and why should it be in focus when talking about lighting design using artificial lighting. This chapter will touch on some of the fundamental elements of the circadian system and what is important to know regarding light.

Circadian rhythms

The circadian rhythms are part of the human's biological clock[2] which regulate body functions such as sleep-wake cycles, hormone release, eating habits and digestion, body temperature, and other vital bodily functions[3]. Disruptions of these biological systems have been linked to different health problems such as "sleep disorders, obesity, diabetes, depression, bipolar disorder, and seasonal affective disorder"[2–3].

The circadian rhythm is a cycle of approximal 24-hours in length, and the cycle also occurs without any outside periodic stimuli, so even if a person is kept in total darkness, their body functions keep working. The cycle of the circadian system is as mentioned, not exact 24-hours. Therefore it is necessary to entrain it on a regular basis to the normal day-night cycle that occurs in the 24 hours of a day on earth[2–4]. Fail to entrain the circadian rhythm regularly it will phase shift, which will shift the circadian cycle to later compared to a normal day-night cycle.

Circadian lighting

The link between the circadian rhythm and lighting came with the discovery of the Intrinsically Retinal Ganglion Cells (ipRGCs) in 2002 by Berson[5]. The ipRGCs contains the light-sensitive pigment melanopsin, are described as non-image-forming and therefore do not contribute to vision, when melanopsin gets exposed to light it causes the ipRGCs to send signals to the SCN (suprachiasmatic nucleus) in the hypothalamus in the brain which regulates the sleep-wake cycle with the hormone melatonin secreting from the pineal gland [6–7].

The body's melatonin production increases at night when the general light levels get low, and this indicates to the body that it is time to sleep.

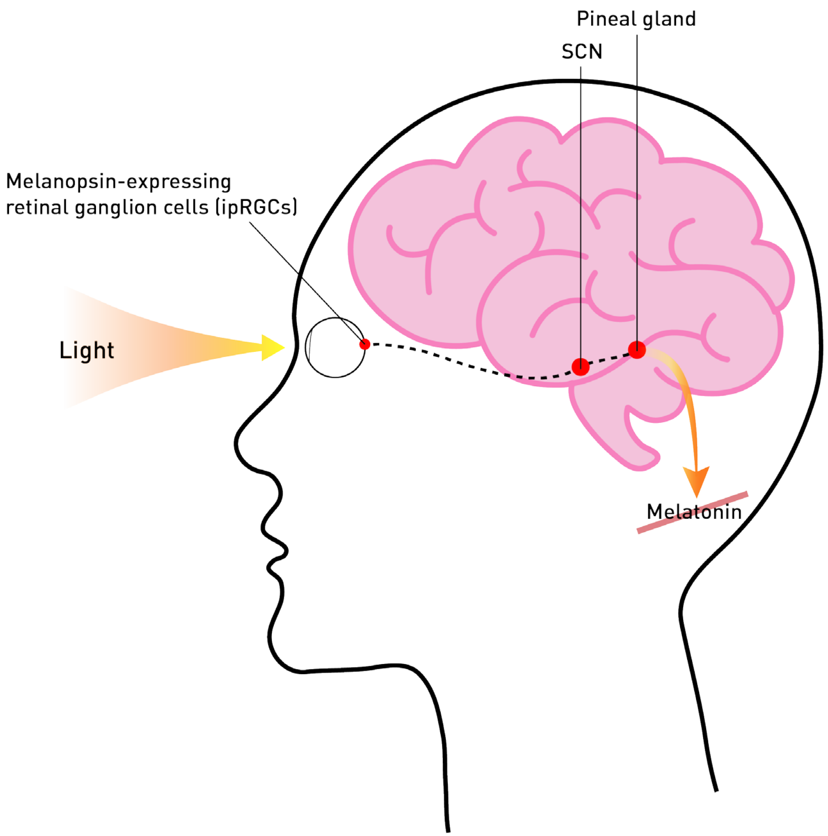

Figure 1. Simple model over the process of melatonin suppression.

Circadian lighting is keeping this sleep-wake cycle on track using light. Being exposed to light at the wrong times confuses the circadian rhythm. Therefore, is it important to use light that mimics the natural light of a day-night cycle which means bright light in the morning to suppress the melatonin production (figure. 1) and boost alertness and dim light in the afternoon/evening to allow the production of melatonin again and signal it is time to sleep[2–4].

When entraining the circadian rhythm with light, some factors play an important role; the wavelength of the light, timing, exposure time and light history. The peak **spectral sensitivity** is close to 460 nm[2–4–8] which on the visual light spectrum is blue; thereby it is established that blue enhanced white light has a more significant effect on melatonin suppression. **Timing** is critical to keep the circadian rhythm on point with peoples 24-hour schedule because it is not precisely 24-hours long, it is important to synchronise at the right time, else a phase shift can occur. **Exposure** is the amount of time spent in the light at the right timing, to obtain a sufficient melatonin suppression. Low light levels need a longer exposure, and high light levels need shorter exposure to gain sufficient melatonin suppression. **The light history** has an impact on the individual's sensitivity of the circadian system, and if the overall light history over days or even weeks is low, the circadian system is more susceptible to phase shift [2–9–10].

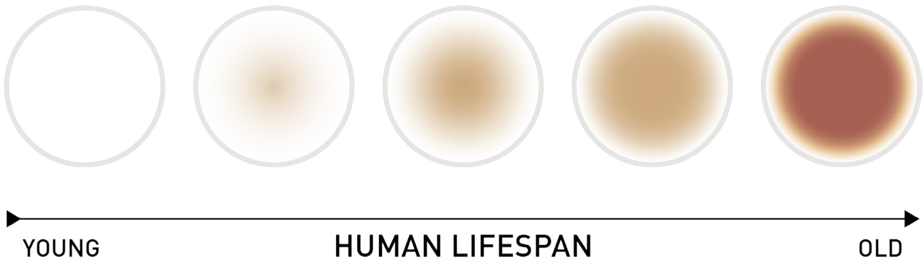

Figure 2. Yellowing of the lens

Other factors that can affect the circadian system is age; it impacts the general light absorption, with age the lens in the eye suffers from yellowing, which happens gradually through people's lifespan (figure 2). When the lens gets coloured, the amount of light that hits the back of the eye and higher light intensity is needed, so the circadian rhythm does not get out of sync[8].

Circadian lighting metrics

To measure or predict the effects of artificial light on the human circadian rhythm, research has been focused on making a metric for circadian lighting. There are different suggestions, but the most widely adopted are the two metrics; Circadian Stimulus (CS) and Equivalent Melanopic Lux (EML). These metrics have in the last couple of years sparked a lot of discussion in the lighting community and different standard agencies are considering making recommendations based on them. Some parties are not keen on using them stating that they are not thoroughly tested and are unpredictable[11–12].

Circadian Stimulus

The circadian stimulus (CS) is developed at the LRC (Lighting Research Center, Rensselaer Polytechnic Institute) it focuses on the acute melatonin suppression and thereby entraining the circadian rhythm and controlling the sleep-wake cycle.

The circadian stimulus is calculated as described by the LRC "From this spectral irradiance distribution it is then possible to calculate circadian light (CLA), which is irradiance at the cornea weighted to reflect the spectral sensitivity of the human circadian system as measured by acute melatonin suppression after a one-hour exposure."[13]. The CS unit is between 0.1 no suppression to 0.7 maximum measured suppression of melatonin. Using CS, the LRC have found in their research that a CS level of minimum 0.3 for at least one hour in the early part of the day has an active influence on the circadian system and helps people to sleep better and improved mood.

The LRC has made a web CS calculator (www.lrc.rpi.edu/cscalculator/), there are two ways of using this calculator, it is possible to choose from a vendor list of predefined light sources, or it is possible to make a custom light source. To add a custom source the Spectral Power Distribution (SPD) of the light source (measured vertically at eye level) is needed, at a 5-nm resolution, Then the calculator can provide the CS value for the custom source.

The LRC has included the possibility to personalise the results by defining the persons Macular Pigment Optical Density (MPOD). The centre of the retina, called the fovea, has a higher concentration of photoreceptors than the rest, so this region is the most sensitive and the part of the retina that are processing high-acuity vision. On the top of the fovea is a circular region called the macula it is a yellow screening pigment; it filters out the harmful short wavelengths (blue and ultraviolet) to protect the eye against damage. The macula is different from person to person so the retina will be affected different dependent on the density of the macula, so the MPOD value compensates for this difference. The MPOD value in the calculator can range from 0.3 to 0.7, and the default value is 0.5.

So, the CS value both reflects how efficient the lights melatonin suppression is and can adjust for the individual's sensitivity to the short wavelengths of the light spectrum.

Equivalent Melanopic Lux

Equivalent Melanopic Lux (EML) is used by The WELL Building Standard, which is a company that assesses building with its point-based system. Their certificate makes buildings comparable, and they proclaim the buildings are healthier to stay in and are better for the environment. The "standard" or certificate splits into ten areas; Air, Water, Nourishment, Light, Movement, Thermal Comfort, Sound, Materials, Mind and Community, which altogether equals a maximum of 110 points. The light portion can earn up to 14 points, and circadian lighting is three of those[14].

The EML is a metric proposed by Lucas[6] to measure the impact light has on the circadian system; they also provided a toolbox on how to use it. The metric is dependent on the SPD and light intensity for the light at the given measuring point and to calculate the EML this equation is used:

$$EML = L \times R$$

Where L is photopic lux and R is the constant Melanopic Ratio. Lucas has provided an excel sheet that can calculate the value from the SPD of a source in 5nm resolution.

The metric does not seem to provide personalisation in the way it is calculated; it seems to be used as a more general method of measuring the non-visual effects of lighting.

Analysis

Existing lighting products

Analysing the existing luminaires promoting circadian health on the market gives insight into how manufacturers are solving the problem. A lot of the products where part of a project where Aalborg University is helping the municipalities of Copenhagen and Aarhus, the project is an evaluation of existing portable circadian lighting solutions for elderly people, for nursing homes in the two cities.

The eleven fixtures are selected based on:

- Consumer products
- Light source
- Used case
- Control

Then the luminaires have been split into the four categories seen on figure 3. Some of them are circadian lighting other are products that could be considered as circadian lighting due to their capabilities or use diversity.

Here is an overview of the four different groups and what common attributes they share.

- Tuneable: Is white light typically in the CCT span of 2700K to 6500K dependent on the manufacturer
    - o White light from warm white to cold white
    - o Only white light source – no colour
    - o For the most part simple control
    - o Usable all-day
- Smart: LED light with RGB colour
    - o Full-colour spectrum and tuneable white
    - o APP controlled
    - o On Wi-Fi or another type of network (IoT)
    - o Can be third-party programmable
    - o Typical a bulb
- Single-use: Therapy lamp
    - o One function
    - o Not a permanent light source in the house
- Specialised: Like single-use group but can be multifunctional
    - o Can have a special type of controls (interaction)
    - o Coloured light – not full spectrum
    - o Gimmick

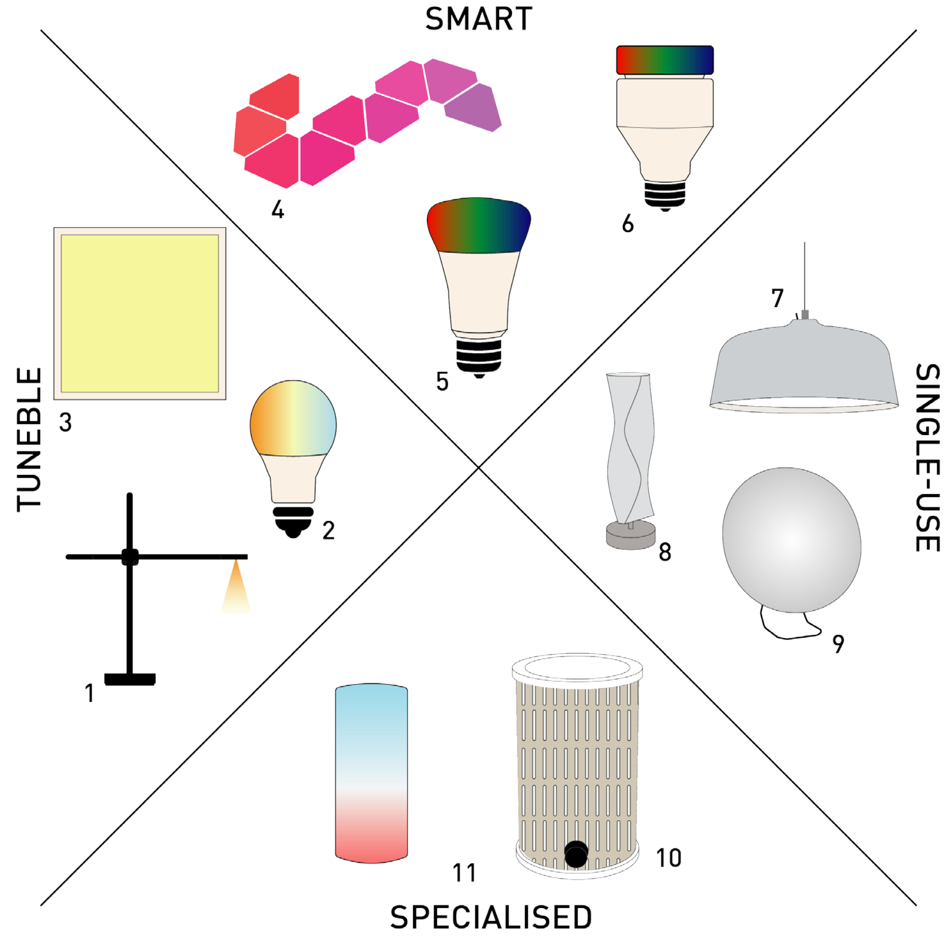

Figure 3. 1: Dyson lightcycle 2: Philips Sceneswitch 3: IKEA Floalt 4: Nanoleaf Light Panels 5: Philips HUE 6: LIFX A19 7: Innolux Candeo Air 8: Innolux Aurora dim 9: Innolux Rondo 400 10: Glød Glød 11: Circadia Technologies Circadia

Table 1 shows the summary of what features the different light products have in the form of control, the typical use case and the type of Light source.

The analysis gives a good insight into what kind of products that are on the consumer market and that circadian lighting in some form already exists for people to buy. The analysis will help to determine what parameters to look at in the final design.

		Light source	Use case	Control
Tuneable	Dyson Lightcycle	LED - Multiple white	Task light	Daylight tracking Sensor – activity, surrounding light Pre-set modes: Relax, Study, Precision and boost Touch control: brightness and CCT APP: for personal light settings
	Philips Sceneswitch	LED - Multiple white	General light (Bulb)	ON/OFF: Cycles through three CCT and light level pre-sets - 806lm/2700K, 320lm/2500K, 80lm/2200K
	IKEA Floalt	LED - Multiple white	General light (wall or ceiling mounted)	Remote – tactile buttons Three CCT: 2200K, 2700K, 4000K Dimmable
Smart	Nanoleaf Light Panels	RGBW LED	Wall mounted general lighting and ambient mood lighting	APP controlled: pre-sets, make custom light scenes, share light scenes Sound: Light dynamics to music Apple home kit enabled Voice controlled: Alexa and Google assistant Wi-Fi enabled
	Philips HUE	RGBW LED	General light (Bulb) Mood lighting	APP controlled: Pre-sets, custom light scenes, tuneable white (on schedule), fully customisable Simple wireless switch: on/off, brightness ZigBee communication via Hue Bridge Programmable via API
	LIFX A19	RGBW LED	General light (Bulb) Mood lighting	APP controlled: Pre-sets, custom light scenes, tuneable white (on schedule), fully customisable Apple home kit enabled Voice controlled: Alexa, Google assistant, Cortana Wi-Fi enabled Programmable via API
Single-use	Innolux Candeo Air	LED - Multiple white	Pendant (therapy)	On/off via wall switch Switch on the lamp: Warm/cold mode
	Innolux Aurora dim	Two Compact fluorescents	Desk lamp (therapy)	On/off Dimmable via a knob (potentiometer)
	Innolux Rondo 400	LED - Multiple white	Therapy lamp – set-up/pack-away	On/off
Specialised	Glød	LED	Nightstand lamp (table lamp/ portable)	Knob: Left – amber white light / Right – Red light (647-723 nm)
	Circadia	LED	Nightstand lamp	Flip 180° to change light colour Red(660nm)/Blue(460nm) Light intensity slider Capacitive touch interface

Table 1. Overview of: light sources, use case and control for the 11 different light products.

Users

When forming the user groups, the most central factor is when are people at home because the lighting designs are meant as a guide for personal lighting, so the user groups are primarily composed of people with the same everyday schedule.

The three groups are.

- Kids / adolescences – Age: 7 - 18
- Adults / students – Age: 18 - 65
- Elderly – Age: 65 and up

The groups have in common at which stage in life they are (lifestyle), so the kids are still in school, the adults are working, and the elderly are retired. Their lifestyles give them mostly the same schedule which yields a lot of the same routines and therefore it is possible to get a broad understanding for when the different groups are home; this plays a key role when choosing the light characteristics. The personalisation is part of the metric (CS) used it can be dialled in to compensate for age-related eye problems with the Macular Pigment Optical Density (MPOD) value and are why the large age gaps is regarded as not troublesome.

To get a more detailed insight into the routines of the three groups, they have been researched and supported by a questionnaire.

The user group analysis will be used to establish at which time slots the use of circadian lighting will benefit the individual.

Kids and adolescences

This user group is from the ages 7 to 18. The group typically attend elementary school or other education such as High school or similar kind of education for adolescences.

Here is an estimated typical day of a kid/adolescence in Denmark who attends a school or other education. Broken into four main blocks: Morning – Afternoon – Evening – Night and each block has everyday activities for kids and adolescents. The two age groups have in common that they usually live at home with their parents.

Morning (06:00 – 12:00)	Afternoon (12:00 – 18:00)	Evening (18:00 – 00:00)	Night (00:00 – 06:00)
Breakfast	Afternoon lessons	**Dinner**	**Sleep**
Getting ready for school	After school care / Free time	**Clean up / chores**	
Transport to school	After school activity / Free time	**Homework**	
Morning lessons	Transport home	**Free time**	
Lunch		**Sleep**	

Table 2. Kids and adolescences typical schedule - Bold text when home

Here is a more detailed look at how a day could look for a kid 12/13 years of age, the times are partly based on the survey see appendix 2.

Time	Activity
06:30 to 07:00	**Wake up**
07:00 to 07:45	**Get ready for school – Shower, brush teeth, eat breakfast and pack bag**
07:45 to 08:15	Bike to school and get to the classroom
08:00 to 10:00	Lessons
10:00 to 10:15	Break
10:15 to 11:45	Lessons
11:45 to 12:15	Lunch break
12:15 to 14:30	Lessons
14:30 to 16:00	Youth club – Play with friends, play computer and so forth
16:00 to 16:30	Bike home
16:00 to 18:00	**Free time / homework**
18:00 to 19:00	**Family dinner and clean up**
19:00 to 20:00	**Free time / homework**
20:00 to 21:30	**Free time / homework**
21:20 to 22:00	**Get ready for bed**
22:00 to 06:30	**Sleep**

Table 3. Schedule for 12/13 year old kid - Bold text when home

This group spends most of their time in communal spaces and are mostly home during the morning and evening, therefore will these timeslots be used.

Adults and students

This user group for adults or students of the ages 18 to 65. People in this group are typically either working or attending some form of education. Here is an estimated day of an adult person in Denmark who has a job or attends a form of education such as a university. Broken into four main blocks: Morning – Afternoon – Evening – Night and each block has everyday activities for adults or students.

Morning (06:00 – 12:00)	Afternoon (12:00 – 18:00)	Evening (18:00 – 00:00)	Night (00:00 – 06:00)
Breakfast	Lunch	**Eat dinner**	**Sleep**
Get ready for work or school / Get kids ready for school	Work or school	**Clean up**	
Transport to work or school / Drop off kids at school	Transport from work or school	**Free time / Help with homework / practical work**	
Work or school	Grocery shopping or other practical work	**Reading/studying**	
	Cook dinner	**Sleep**	

Table 4. Adults and students typical schedule - Bold text when home

Here is a more detailed look at how a day could look like for a student at 25 years old and attending university, the times are partly based on the survey see appendix 2.

Time	Activity
06:00 to 07:00	**Wake up**
07:00 to 08:00	**Get ready for school – Shower, brush teeth, eat breakfast and pack bag**
08:00 to 09:00	Transport to school and get to the classroom
09:00 to 12:00	lecture
12:00 to 13:00	Lunch Break
13:00 to 16:00	Groupwork
16:00 to 18:00	Transport / Free time / shopping / work
18:00 to 20:00	**Dinner / clean up**
20:00 to 23:00	**Free time / studying / work / practical work**
23:00 to 06:00	**Sleep**

Table 5. Schedule for 25 year old tudent - Bold text when home

This group spends most of their time in communal spaces and are mostly home during the morning and evening, therefore will these timeslots be used.

Elderly

This user group is for the elderly of the age 65 and up. In this group is a lot of different people with different needs and abilities. The focus is on the part of the elderly, which is living in a care facility of some kind where they have help around the clock and follow a specific schedule.

Many people in this group have low mobility or suffering from dementia and therefore, need help if they want to go somewhere. Isolation can impact their access to sunlight as it is dependent on staff to move outside.

Here is a 24-hour schedule (appendix 1) from a Danish care home in Haderslev.

Morning (06:00 – 12:00)	Afternoon (12:00 – 18:00)	Evening (18:00 – 00:00)	Night (00:00 – 06:00)
Personal care / shower / clothing etc.	Nap / free time	After dinner coffee / free time	Sleep
Breakfast	Free time or events – music, exercises, service or talks	Bedtime	
Activities	Afternoon coffee / free time		
Lunch	Dinner		

Table 6. Elderly - schedule from a Danish care home in Haderslev.

The schedual in table 7 is how most of the people in a care home live from day to day. Here is a more detailed schedule for a resident at one of Haderslevs care homes (some of the activities overlap).

This group spends almost all their time in communal spaces or at home, therefore will a 24-hour timeslot be used.

Time	Activity
07:30 to 10:00	Morning services: Personal care, shower, help to get clothed and so forth
07:30 to 10:00	Breakfast is served in own apartment or the dining room
10:00 to 11:30	Free time: Reading paper, socialising with other residents and so forth
11:30 to 12:30	Lunch is served in own apartment or the dining room
12:30 to 14:00	Nap time or free time
14:00 to 17:30	Free time or events such as music, exercises, service or talks and afternoon coffee
17:30 to 18:30	Dinner is served in own apartment or the dining room
18:30 to 20:00	Free time
20:00 to 21:00	After dinner coffee
20:00 to 00:00	Bedtime – the resident gets help when it needs it

Table 7. Elderly - detailed schedule from a Danish care home in Haderslev.

User group summary

As seen on figure 4 this summery of the analysis show when the three user groups are home, and circadian lighting could be used in a personal setting and have a positive impact on their circadian system and entrain a healthy day-night cycle.

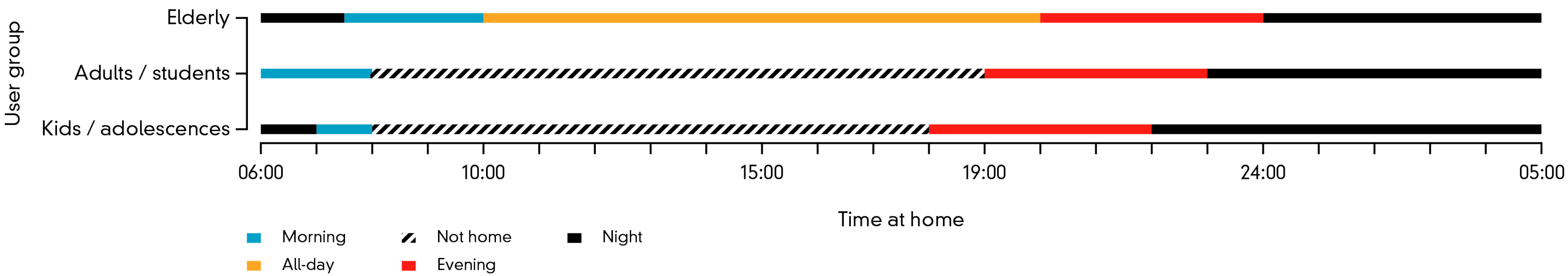

Figure 4. Summary of the analysis of the user groups showing the time they spend at home.

Problem statement and focus area

The project vision is "Imagine if the light in private homes had a positive effect on the resident's wellbeing and could change in relations to the single individual." After research and analysis of the theory and state of the circadian lighting landscape, the conclusion is that making circadian lighting design personalised to a single individual in a home setting is a too big undertaking with the current knowledge in the field of light and health, and the 'smart technology' used. Therefore a broader approach to personalisation will be used instead of on an individual level it is on a home level, but still with an offset in the needs of the defined user groups.

This fundamentally comes down to the research on the subject of circadian lighting, and the promise of a robust circadian metric in the year 2019 still is in its beginning stages, as Ian Ashdown puts it in the article - An Engineer's Perspective – Illuminating Engineering Society – *"From an engineering perspective, it is abundantly clear that we do not have the calculation tools needed to predict or measure circadian lighting metrics, including EML and CS, to acceptable engineering standards."*[11].

To use circadian lighting on a truly personal level is not in reach with the tools available, this is also confirmed by Douglas Steel, a neuroscientist - *"Any "theory," "tool" or "metric" that emerges from the development of a model must be predictive, verifiable, and, from a practical standpoint, measurable using instruments or based upon provided mathematical values."*[12].

With these findings in mind, the problem statement is:

> *"How can personalised artificial lighting design affect personal health and wellbeing by promoting a good circadian rhythm."*

With the focus on these topics:

- Personalisation on a home level – with respect for the different needs the user groups might have independent of each other.
- The general wellbeing defined by proven models.
- Focus on only on the artificial lighting in the design – excluding daylight to rule out too many unknown factors.
- Lighting design scenarios with the user experience in mind.

Personalised lighting design scenarios for private homes

From the analysis of the user groups, current circadian lighting solutions and theory about the biological responses associated with light, the following designs for the use of personal, efficient circadian lighting in private homes have been developed.

Methodology

The design is primarily based on data, research and observations, but to validate aspects of the design rooted in these sources a quantitative method was used and conducted in the form of a questionnaire (Appendix 2). The questionnaire was inspired by the KISS principle[15] ("keep it simple, stupid"), this approach to survey design is to keep questions short and concise and in general, keep it as simple as possible. In addition to the KISS method, the video course "An introduction to survey questionnaire design"[16] was used to learn the fundamentals of questionnaire design.

This method of validation was chosen because the final users could help identify and clarify problems with the assumptions made in the analysis of the users and their routines. Furthermore, it helped to test their perception of different designs, such as using red light at night.

Design parameters

Seven parameters have been defined to describe the lighting designs for each of the target groups. The parameters are organised to make it easy to reproduce the lighting design scenarios. The seven parameters are;

1. Circadian timeslots
2. Light characteristics
3. Control
4. Interface
5. Form factor
6. Luminaire type
7. Placement.

Below is a description of each parameter and what area of the final lighting design it defines.

1. Circadian timeslots

The circadian timeslots generated from the information gathered about the three target groups, and their typical behaviour splits into these three times.

- Morning
- Evening/night
- All-day/24-hour

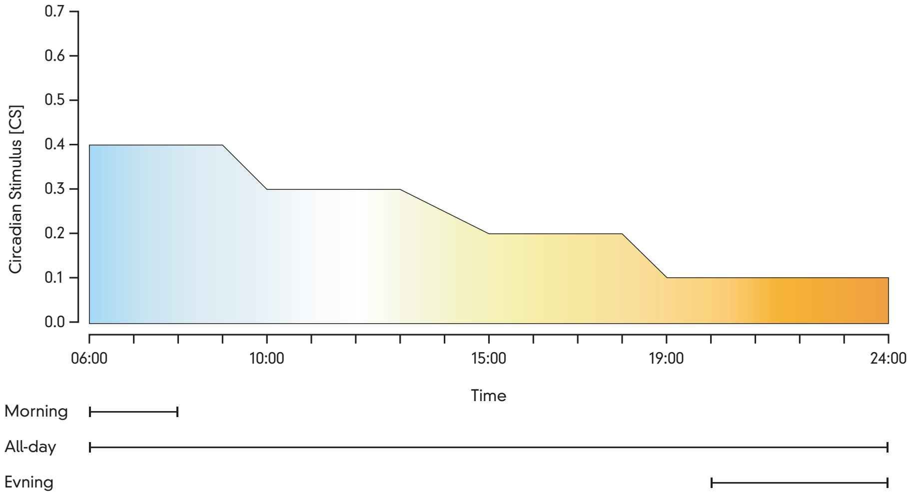

Figure 5. Diagram showing the three timeslots (morning, all-day and evening) in relation to time, CS and CCT and shows how they relate to one another.

The three circadian timeslots defined as periods of the day where the user usually is at home and potentially are using the circadian light; it also describes three different light conditions because of the natural day-night cycle as described in the theory chapter. The light design needs to adopt different characteristics at these times to uphold a healthy circadian rhythm for the user as shown in figure 5; the diagram is an example of how a circadian schedule could look[13].

2. Light characteristics

The light characteristics splits into the desired Circadian Stimulus and six parameters to generate the results that are desirable at the given time. All six parameters can influence the amount of CS exposure the individual user gets.

- Circadian Stimulus [CS]
  - o The CS is the chosen metric used to verify the relation between the lighting configuration and circadian rhythm regarding melatonin suppression.
- Intensity [lux]
  - o Intensity describes the luminous flux of the light source and the vertical illuminance at a given distance between the light source and the user, measured at the eye.
- Duration [minutes]
  - o Duration is the user's exposure time to the circadian light source at the determined CS level - the longer the user is exposed, the greater the effect it will have on the melatonin suppression.
- Timing
  - o Timing helps to keep the circadian rhythm entrained to the natural night-day cycle of the solar day. The timing can

phase shift the circadian rhythm earlier if exposed to light soon after waking up and later if exposed to light late at night. Keeping the same timing (schedule) will improve the natural cycle.

- Colour
  - Colour describes the light as either as tuneable white, monochromatic or RGB.
  - Tuneable white: White light described by the temperature of the light (CCT) - a high CCT is defined as cold white and has a blueish tint, and a low CCT is defined as warm white and has a yellow/orange tint.
  - Monochromatic: Light that consists of a single wavelength and therefore only displays one colour, e.g. red (650nm) or blue (470nm).
  - RGB: Consists of the primary colours red, green and blue that can reproduce the whole colour spectrum when mixed, it is known as an additive colour mixing. By summing the three primary colours, it yields white.
- CCT [Kelvin]
  - CCT or the correlated colour temperature as mentioned in the paragraph about colour, it determines the lights colour appearance in regards to white - a high CCT is defined as cold white and has a blueish tint, and a low CCT is defined as warm white and has a yellow/orange tint. The scale is measured in Kelvin [K] and spans from 2700K (warm) to 6500K (cold) in typical commercially available luminaires[17–18].
  - If the light sources CCT is cold, it has an SPD whit a higher sum of power in the low part of the spectrum also characterised as a blue peak. This blue peak has been proven to stimulate melatonin suppression more efficient and therefore use in the morning hours and not in the evening and night.
- SPD
  - SPD or Spectral Power Distribution is a depiction of the colour spectrum that makes up visible light. The graph shows each wavelength and its power ranging from violet (400nm) to red (700nm). The SPD is a kind of fingerprint for a particular light source, and even though the light source can seem to be identical to the eye, their SPD can be very different[18–19].

3. Control

The control parameter is split up into four categories; analogue input, touch, smart and interaction.

- **Analogue input:** Describes all on-off type switches or controls. It gives the user easy control of the products functions and is very reliable but not flexible at all, but meant for users that want a smooth and intuitive experience.
- **Touch:** This could be capacitive buttons like on a stove where each one has a specified function or a simple touchscreen built into the product. This type of control gives more freedom to alter, e.g. light characteristics such as intensity, CCT or even pre-programmed modes (morning wake up, reading, relax and focus).
- **Smart:** Connected to an app on either a smartphone or tablet, this makes the light source highly customisable. This type of control known from smart light bulbs such as Philips HUE and LIFX, where every parameter of the light can be programmed to the users liking - everything is possible.
- **Interaction:** Various functions of the light (Brightness, colour, modes and on-off) can be controlled by, e.g. physically moving, flipping and turning it, this is a more playful type of control.

4. Interface

The Interface parameter is split up into Five categories; simple (on-off), automatic, themed, customisable and fully programmable, they all tie into the controls.

- **Simple:** On-off interface like a switch or button.
- **Automatic:** Either the light is on a timer or pre-programmed schedule, so when turned on, it changes the lighting characteristics according to this. It could also be a fully automatic system that turns itself on-off and changes the lighting characteristics to the pre-set settings or using sensors.
- **Themed:** An interface with pre-programmed modes with specific settings, it could be one for - reading, relaxing, energy boost, focus or others like it.
- **Customisable:** Most likely an app where buttons with different modes and settings or CS curves, schedules and general lighting setting can be changed at set up as desired.
- **Fully programmable:** The product has an Application Programming Interface (API) or is open source which gives the users or other companies the ability to program the product and use it as they see fit.

5. Form factor

Form factor describes the physical aspects of the luminaire in relations to if it is stationary or portable, which effects the way the user interacts with it.

- **Stationary:** This could be a floor lamp, ceiling lamp, pendant or table lamp, either constraint by a cord, size or installation.
- **Portable:** This could be a battery-powered luminaire and not larger than it fits in a bag or the like. However, it could also mean an easy to carry and set up wired-lamp.

6. Luminaire type

From the analysis, the type of luminaires splits into four categories that describe their functionality; tuneable, smart, single-use and specialised.

- **Tuneable:** This references to a luminaire with tuneable white light typically in the CCT span of 2700K to 6500K dependent on the manufacturer.
- **Smart:** This is typically a bulb which can connect to other bulbs and therefore be part of a network of light with an accompanying app for advanced control options.
- **Single-use:** This group of luminaries are single-use because they typically only serve one function and therefore not a permanent light source in the house. In the analysis, the products often labelled as therapy lamps.
- **Specialised:** This sub-group of the single-use group, it is multifunctional, but it is still only used for one thing, and are generally not a part of the overall lighting scheme.

7. Placement

The placement describes how the light source is positioned relative to the user's eyes and what type of light source it is – ambient or direct.

- **Ambient:** The source generally has a low output and are diffuse, and the user's eyes are only affected indirectly by the light.
- **Direct:** The source is visible for the user in their line of sight, and the user either stares at it or have their eyes generally focus in the direction of it to get the optimal light exposure.

These parameters do not only have an impact on the user's interaction with the light as a source of circadian stimulus but also influences the space around it. The surrounding space is important to take into consideration because of the visible properties of light alters the atmosphere. The best task-oriented lighting design might not be the best circadian lighting design and vice versa, therefore, is it essential to consider both. However, because of the non-visual lighting focus of the thesis, the architectural aspect of the placement is dismissed but will be encouraged to consider if using one of the scenarios to provide a truly human centric lighting design experience.

Personalised lighting design scenarios

The lighting design scenarios are aimed to promote circadian entrainment and minimise circadian disruption in Nordic countries during the darkest months of the year between autumn and spring. The dark months contributes to many people getting seasonal affective disorder (SAD), in Denmark, it affects between 5-10% of the population [20]. Besides SAD many people experience low energy and sleep disruption, therefore the aim is to try and minimise these symptoms with the proper light, although the field is still new and not everything is known about the effects of light on general health, the research shows a positive trend[2–6–21]. The focus is therefore on electrical lighting and not daylight, since that there is a lack of daylight that time a year and the fact that CS is the chosen metric for quantifying the effects the light has on the human circadian rhythm.

The scenarios are general and made to span a wide-ranging group of people as possible. The three user groups have in common that their lifestyle are similar. So, it is less based on age and more based on the given stage of life and the similarities in time management it brings with it – School, higher education, work or retirement. The most basic periods in the majority of people's life.

The scenarios builts on a mix of theory, observations, research, assumptions and a survey.

Kids and adolescences scenarios

This group of people is still growing and therefore, can be more susceptible and influenced by other parameters than grown adults. Blue light is one problematic area when specifying lighting designs for kids and adolescence.

The CIE (The International Commission on Illumination) have publish a position statement on the use of blue light and directly recommends to stay clear of blue LEDs in products made for children "It should also be recognized that the use of sources emitting primarily blue light are a cause of concern for exposure to children's eyes." [22]. They also note that it is a non-issue for commercial white light sources, so high CCT light sources that naturally have a higher blue output should not be problematic when making lighting design with kids in focus. One thing to note is that the LRC has done tests on melatonin suppression in adolescents and adults [21] using cold (5600K) and warm (2700K) light spectra at the same CS level of 0.25. The result showed that adolescents were more sensitive to the cold light than the warm and that the adults had the same statistic melatonin suppressing with both light spectra. Knowing this using blue enhanced white light should be done with caution when designing for this age group.

The Analysis shows the group to be home during the morning and evening/night and away during business hours as shown in figure 6.

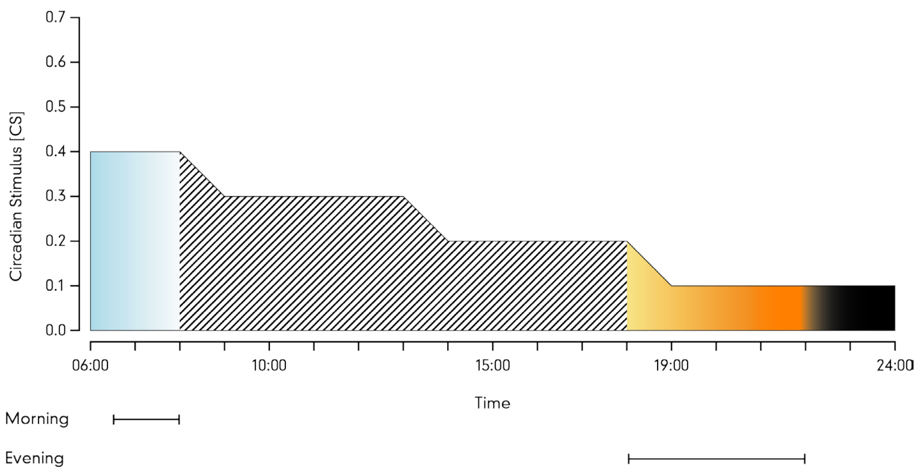

Figure 6. The proposed CS curve for kids and adolescents for the two circadian timeslots (morning and evening). Furthermore, the chart also shows the recommended CCT used at a specific time a day, blue for cold light and yellow/orange for warm light.

Figure 6 also shows the proposed CS curve during the two circadian timeslots; the morning time slot has a suggested CS of 0.4 or higher for at least 30 minutes however the recommended exposure is for one hour, the longer exposure equals greater effect [13]. The evening timeslot has a CS of 0.2, to begin with but tapers down to 0.1, and lower is recommended for the maximum secretion of melatonin, making it easier to sleep.

The lights characteristics properties are depended on the selected light source to gain the desired CS values and obtain a healthy day-night cycle the following is proposed, but it is only a guideline because of the nature of the CS value there are several ways of obtaining the same CS value as explained in the theory chapter.

Morning circadian timeslot:

- Intensity: Vertical illuminance measured at the eye – 450 lux* or more
- Duration: minimum of 30 minutes, recommended one hour
- Timing: Within the first hour of waking up
- Light source: Tuneable white (LED)
- CCT: maximum 4000K (cold white)
- SPD: The spectra should provide a blue spike to help with a more efficient suppression of melatonin

- Placement: Direct – to provide the highest illuminance level at the eye as possible

Evening circadian timeslot:

- Intensity: Vertical illuminance measured at the eye – 50 lux* or less
- Duration: Less is better
- Timing: When dark outside and before bedtime
- Light source: Tuneable white (LED)
- CCT: 2700K or less (warm white)
- SPD: The spectra should have as little blue spike as possible to stop the suppression of melatonin
- Placement: Ambient – to provide the lowest illuminance level at the eye as possible

* Illuminance levels are estimated from a test done by AAU for the municipalities of Copenhagen and Aarhus in regards to evaluating portable circadian lighting market solutions for elderly people [23].

The evening scenario does not consider light during the night. The user might have to get up during the night, so it is essential to have lighting so the user can safely navigate around. Turning on white light during the night is not recommended, because it can trigger melatonin suppression. Therefore, it is vital to use lighting with as low CCT as possible or even monochromatic red light, given that it does not emit any blue light and therefore has a less chance of disrupting the user's circadian rhythm and minimising sleep disruption.

The luminaire type suitable for the two scenarios chosen for kids/ adolescences can be one of two.

- Tuneable: The tuneable luminaire has the benefit of being able to emit white light at different colour temperatures (CCT), making the same luminaire useable all-day at any given time providing the right light at the right time.
- Smart: A smart luminaire can be many things, but in this case, it could be an RGBW light source capable of reproducing all colours. RGBW has the benefit of being able to reproduce both tuneable white and solid colours that could be beneficial during the night.

The form factor of the luminaire is very much a personal preference in any case. However, when designing for the youngest part of this group of people a portable solution might promote more regular use because of the convenience factor, it is easy to bring around the house and therefore they might get more out of it as opposed to a stationary lighting solution. Furthermore, in the discussed timeslots people move around doing different tasks – eating, homework, and chores to name a few, therefore would a portable light source be providing light at the right time especially in the morning timeslot.

The preferred **control and interface** for this age group are most likely to be digital. A light controlled by an app on a smartphone or other device capable of running apps is the go-to solution; it makes customisation easy and effortless to personalise, which is a must for this age group. However again there is an argument for making it playful for the youngest by making the light respond to physical interaction such as flipping it to turn it on/off or shaking it to change mode or colour, the possibilities are endless especially if bundled with an app for customisation.

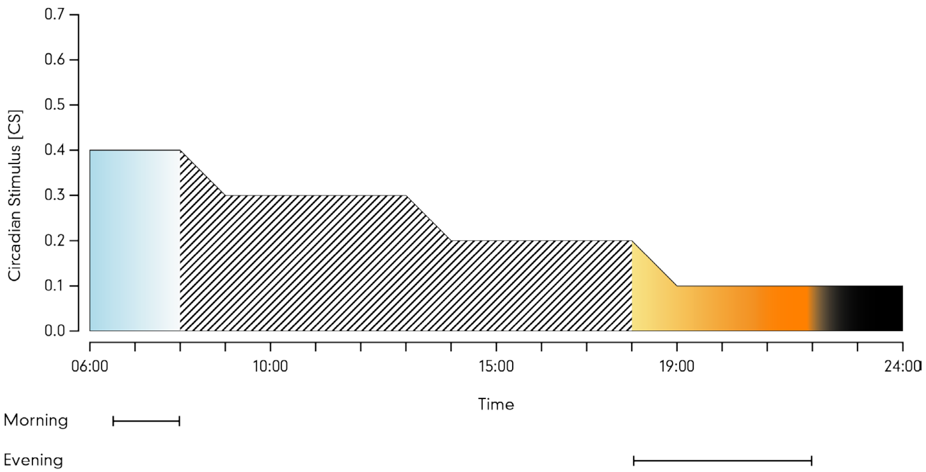

Figure 7. The proposed CS curve for adults and student for the two circadian timeslots (morning and evening). Furthermore, the chart also shows the recommended CCT used at a specific time a day, blue for cold light and yellow/orange for warm light.

Adults and student scenarios

This user group has the largest age span, and this makes it difficult to please all, therefore the scenarios are more generalised.

The same CS curve is proposed (Figure 7) as for the kids and adolescents and especially if it is used as a guideline for general lighting in a home with the younger user group present.

As mentioned, research indicates that adults are less susceptible to the blue spectrum of light compared with adolescents[21], so using blue-enhanced lighting should not be a problem for this segment, and might even be preferred by the older part of the user group because of lens yellowing.

The lights characteristics properties are depended on the selected light source to gain the desired CS values and obtain a healthy day-night cycle the following is proposed, but it is only a guideline because of the nature of the CS value there are several ways of obtaining the same CS value as explained in the theory chapter.

Morning circadian timeslot:

- Intensity: Vertical illuminance measured at the eye – 450 lux* or more
- Duration: minimum of 30 minutes, recommended one hour

- Timing: Within the first hour of waking up
- Light source: Tuneable white (LED)
- CCT: equal or greater than 4000K (cold white)
- SPD: The spectra should provide a blue spike to help with a more efficient suppression of melatonin
- Placement: Direct – to provide the highest illuminance level at the eye as possible

Evening circadian timeslot:

- Intensity: Vertical illuminance measured at the eye – 50 lux* or less
- Duration: Less is better
- Timing: When dark outside and before bedtime
- Light source: Tuneable white (LED)
- CCT: 2700K or less (warm white)
- SPD: The spectra should have as little blue spike as possible to stop the suppression of melatonin
- Placement: Ambient – to provide the lowest illuminance level at the eye as possible

* Illuminance levels are estimated from a test done by AAU for the municipalities of Copenhagen and Aarhus in regards to evaluating portable circadian lighting market solutions for elderly people [23].

The evening scenario does not consider light during the night. The user might have to get up during the night, so it is essential to have lighting so the user can safely navigate around. Turning on white light during the night is not recommended, because it can trigger melatonin suppression. Therefore, it is vital to use lighting with as low CCT as possible or even monochromatic red light, given that it does not emit any blue light and therefore has a less chance of disrupting the user's circadian rhythm and minimising sleep disruption.

The luminaire type suitable for the two scenarios chosen for adult and students is suggested to be one of two.

- Tuneable: The tuneable luminaire has the benefit of being able to emit white light at different colour temperatures (CCT), making the same luminaire useable all-day at any given time providing the right light at the right time.
- Smart: A smart luminaire can be many things, but in this case, it could be an RGBW light source capable of reproducing all colours. RGBW has the benefit of being able to reproduce both tuneable white and solid colours that could be beneficial during the night.

The form factor of the luminaire is very much a personal preference in any case. However, when designing for this group of people, a stationary lighting solution covering the home would be preferable.

The preferred **control and interface** for this age group is a mix of digital and analogue. An excellent all-around solution could be as seen with Philips smart bulbs with their HUE product line, having an app for setting up the Lighting solutions and customise it, and then combining them with a simple button interface once it is up and running.

Elderly

This group of people has been limited to elderly living in nursing homes and have low mobility and or suffer from a crippling disease like dementia. The group spends the majority of their time indoors in dim light settings and deprived of adequate daylight [8]. Surveys also show that "Between 40 and 70% of older adults suffer from sleep disturbances or disorders." [8], this is a direct effect of poor circadian entrainment.

With the given knowledge on the effects lighting has on ton circadian health and wellbeing, it is justifiable to suggest an all-day lighting scenario, that provides healthy circadian entrainment. It is also important to note that a nursing home is a workplace, and the residents can have compromised vision, so the lighting scheme should also promote good visibility[23].

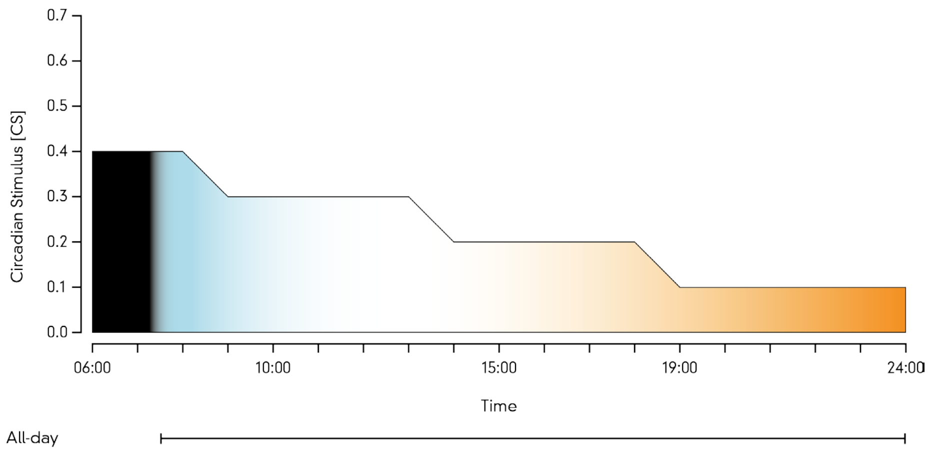

Figure 8. The proposed CS curve for elderly for an all-day circadian timeslot. Furthermore, the chart also shows the recommended CCT used at a specific time a day, blue for cold light and yellow/orange for warm light.

All-day circadian timeslot:

- Intensity[8]:
  - o Morning: higher than 400 lux
  - o Afternoon: between 200 – 400 lux
  - o Evening: lower 50 lux
- Duration:
  - o Morning: minimum of 60 minutes, recommended 120 minutes

  - Afternoon: all (general lighting, communal spaces)
  - Evening: all (general lighting, communal spaces)
- Timing: Following the day-night cycle of the day
- Light source: Tuneable white (LED)
- CCT:
  - Morning: Greater than 4000K
  - Afternoon: Between 2700K – 4000K
  - Evening: Below 2700K
- SPD:
  - Morning: SPD with a blue peak
  - Afternoon: SPD with a low blue peak
  - Evening: SPD without a blue peak, more reddish light
- Placement:
  - Direct in the morning hours – to provide the highest illuminance level at the eye as possible
  - Ambient in the evening hours – Helping to stop the suppression of melatonin

The scenario does not consider light during the night. The user might have to get up during the night, so it is essential to have lighting so the user can safely navigate around. Turning on white light during the night is not recommended, because it can trigger melatonin suppression. Therefore, it is vital to use lighting with as low CCT as possible or even monochromatic red light, given that it does not emit any blue light and therefore has a less chance of disrupting the user's circadian rhythm and minimising sleep disruption.

The form factor, in this case, could be a portable solution in residents apartments provided to them when they are helped out of bed in the morning and a stationary lighting system in the public domain.

The preferred control and interface for this age group is as simple and plug and play as possible. A preferred solution could be that the light has a programmed schedule, so no matter when it is turned on, it will provide the right light at the right time.

Scenario overview

The final design is the optimal way of using circadian lighting to manage a good day/night cycle, but the questionnaire shows that only half of surveyed would use a cold light source in the morning an only a fourth would spend a minimum of 30 minutes in front of the light. Hence it is not only changing the type of light used to modify people's day/night cycle, but also a modification of people's habits that are needed to follow the proposed design for optimal use.

Table 8 provides an overview of the final proposed personalised lighting designs.

Target group	Kids/Adolescences		Adult/Student		Elderly
Parameters \ Circadian timeslot (Use case)	Morning	Evening	Morning	Evening	All-day
Light characteristics					
Circadian Stimulus [CS]	> 0.4	< 0.1	> 0.4	< 0.1	Morning: > 0.3 Afternoon: 0.3 to 0.1 Evening: < 0.1
Intensity [lux] *At eye level*	> 450	< 50	> 450	< 50	Morning: > 400 Afternoon: 200 - 400 Evening: < 50
Duration [minutes] *Max. distance 1m*	min. 30 Rec > 60	All	min. 30 Rec > 60	All	Morning: min. 60, Rec 120 Afternoon: all Evening: all
Timing	After morning rise	After sunset	After morning rise	After sunset	Programmed all-day schedule
Colour	Tuneable white	Tuneable white	Tuneable white	Tuneable white	Tuneable white
CCT [K]	max. 4000	< 2700	> 4000	< 2700	Morning: > 4000 Afternoon: 2700 - 4000 Evening: < 2700
SPD	Blue peak	No blue peak	Blue peak	No blue peak	Morning: Blue peak Afternoon: low blue peak Evening: No blue peak
Control					
Analogue input	X	X	X	X	X
Touch	X	X	X	X	X
Smart	X	X	X	X	-
Interaction	X	X	X	X	-
Interface					
Simple (on-off)	-	-	X	X	X
Automatic	-	-	-	-	X
Themed	X	X	X	X	X
Customisable	X	X	X	X	-
Fully programmable	-	-	-	-	-
Form factor					
Stationary	-	X	X	X	X
Portable	X	X	X	-	X
Luminaire type					
Tuneable/multifunctional	-	X	X	X	X
Smart/programmable	X	X	X	X	-
Single use	-	-	-	-	-
Specialised	-	-	-	-	X
Placement					
Direct	X	-	X	-	In the morning and afternoon
Ambient	-	X	-	X	In the evening

Table 8. Scenario overview

Discussion

When looking at non-visual light research, it is all concentrated around office spaces, hospitals, schools and other large-scale environments, not a lot of it touch on private homes. Therefore this thesis aimed to implement the knowledge gained about the non-visual effects of light and how it affects the human circadian rhythm to people's homes and thereby making it personal.

Looking into existing research, theory and analysing existing product suitable for circadian lighting in private homes in different use cases, this has resulted in a lot of data. This data can be interlinked, and form personalised efficient circadian lighting design scenarios for three different target groups; young, adult and elderly, and if followed should promote a better sleep-wake cycle by entraining the circadian rhythm at the right time a day in the right amount of time.

When examining all the data and the gained knowledge about circadian lighting and the toolset that is available, the findings suggest that making personalised circadian lighting designs on a scientific level in 2019 is difficult.As Ashdown puts it "This is not something that any standard or recommended practice can ever hope to reasonably address—there are simply too many variables." [11] and he continues to conclude "Regardless of what we may know about the effects of circadian lighting on human health and wellbeing, we may never be able to codify this knowledge in building design practices." [11].

Therefore, it is more likely to build up a lighting design with good practice in mind, which is possible in a private setting because of the lack of legislation. Figuring this out gives more creative freedom to make products with circadian lighting in mind. However, it also raises the question should lighting designers and fixture manufactures be pushing this technology when the knowledge is lacking, and there is not enough evidence on what implications it can have on people's general health in the long run. So, not before the CS metric or another circadian lighting metric has matured and has fewer pitfalls, designing lighting to promote wellbeing, further research is needed.

The future of human centric lighting design and combining the visual and non-visual aspect of light is happening now when it comes to large scale installations. Such as in hospitals where circadian lighting has proven to help both patients and the employees to feel better and improve the general wellbeing like seen in West's PhD thesis "The effects of Naturalistic Lighting in stroke patients"[24]. However, in the personal space, the future for circadian lighting in fixtures for the home is more a feature then the primary function. However, with all the advancements in personal technology, it is a possibility that when all these devices are linked together and sharing data that it will be able to predict and act on the individual's needs, then it will genuinely be personalised lighting.

Conclusion

This thesis aimed to answer if it is possible to create wellbeing on a personal level using artificial lighting to promote a proper circadian rhythm. Based on the research, analysis and the final design it can be concluded that it is possible in theory to make personalised artificial lighting designs that can entrain the circadian rhythm and provide better wellbeing by using the Circadian Stimulus metric as a guide. Furthermore, the designs scenarios do not only describe the light but also recommended way of using it, interacting with it and controlling it, this level of personalisation in circadian lighting is a new approach. However, the practical implementation is not as straight forward, many things are unknown, and there are still many variables, for example, the designs do not consider daylight, other non-circadian light sources and the individualistic behaviour of people.

The methods used to validate the designs are too reliant on one source, the Lighting Research Center and their work. Therefore, a more in-depth analysis of the designs in real home settings and whit a more anthropologic approach would have given the design scenarios more credibility. Combining surveys with more in-debt field observations would have given the designs more depth and would have minimised this one-sided bias

The recommendations for the continued work about personal circadian lighting would be that of taking a more practical approach to verify the theory. Because of the many variables, observation would be a robust tool to understand what works and what does not.

So, to conclude the possibilities of having personal circadian lighting in people's home is there, but a lot more work is needed on how to bring it in to practise and limit all the variables to an acceptable level.

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Appendix 1

Schedule - School and nursinghome

Klasseskema

Vælg afdeling: Alle klasser

Vis skema for: 6A i Uge 18-2019

6A **29-04-2019 til 03-05-2019**

	MANDAG 29-04-2019	TIRSDAG 30-04-2019	ONSDAG 01-05-2019	TORSDAG 02-05-2019	FREDAG 03-05-2019
06:45-08:15					
08:15-09:00	SGR1 ENG BA-27	GNI1 IDR BA-HAL MKN1 IDR BA-HAL THC1 IDR BA-HAL	SDU1 HIS BA-27	KHA1 HÅD BA-HÅD	THC1 MUS BA-MUS
09:00-09:45	SGR1 ENG BA-27	GNI1 IDR BA-HAL MKN1 IDR BA-HAL THC1 IDR BA-HAL	SDU1 HIS BA-27	KHA1 HÅD BA-HÅD	THC1 MUS BA-MUS
10:05-10:50	SDU1 MAT BA-27	GNI1 DAN BA-27	SDU1 N/T BA-27	KHA1 HÅD BA-HÅD	GNI1 DAN BA-27
10:50-11:35	SDU1 MAT BA-27	GNI1 DAN BA-27	SDU1 N/T BA-27	KHA1 HÅD BA-HÅD	GNI1 DAN BA-27
12:15-12:45	GNI1 UUV-BÅND BA-27	GNI1 UUV-BÅND BA-27	GNI1 UUV-BÅND BA-27	GNI1 UUV-BÅND BA-27	SDU1 UUV-BÅND BA-27
12:45-13:30	KPO1 IDR BA-HAL MLB1 IDR BA-HAL	SDU1 MAT BA-27	CKI1 TYS BA-27 MAS1 TYS BA-28 MJH1 FRA BA-FRA	GNI1 DAN BA-27	SDU1 KLA BA-27
13:30-14:15	KPO1 IDR BA-HAL MLB1 IDR BA-HAL	SDU1 MAT BA-27	GNI1 DAN BA-27	GNI1 DAN BA-27	SDU1 MAT BA-27
14:30-15:15	SDU1 KRI BA-27			SDU1 KRI BA-27	CKI1 TYS BA-27 MAS1 TYS BA-28 MJH1 FRA BA-FRA

SkoleIntra © itslearning 2001-19

Appendix 1.1. 6th grade school timetable

Døgnrytme

Følgende døgnrytme er som udgangspunkt gældende for Plejecenter Kong Fredrik IX:

Morgenpleje: Der ydes hjælp til personlig morgenpleje, bad, påklædning mm. i tidsrummet kl. 07.30 til 10.30. Det tilstræbes, at morgenplejen ydes på det tidspunkt som ønskes.
Morgenmad: Der serveres ligeledes morgenmad i tidsrummet kl. 07.30-10.30 Morgenmad kan indtages i dagligstuen sammen med øvrige beboere eller i egen lejlighed.
Middag: Der serveres middag kl. 12.00. Middagen består af 2 retter mad og kan indtages i egen bolig eller i dagligstuen sammen med øvrige beboere. Efter middagen er der mulighed for et middagshvil.
Eftermiddag: Der serveres eftermiddagskaffe i tidsrummet kl. 14.30 til 15.30 i dagligstuen sammen med øvrige beboere eller i egen lejlighed.
Aftensmad: Aftensmåltidet består af snitter og serveres kl. 17.30 til 18.00 Aftensmaden kan indtages i egen lejlighed eller i dagligstuen sammen med øvrige beboere.
Aftenskaffe: Der serveres aftenskaffe kl. ca. 20.00 i egen lejlighed eller i dagligstuen sammen med øvrige beboere.
Sengetid: Hjælp til sengetid ydes så vidt muligt på tidspunkt efter ønske i løbet af aftenen.

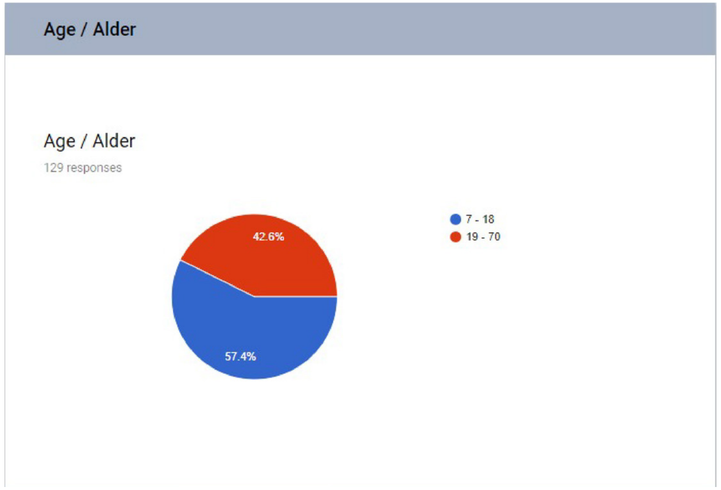
Tidspunkterne er vejledende, og der kan afviges fra disse.

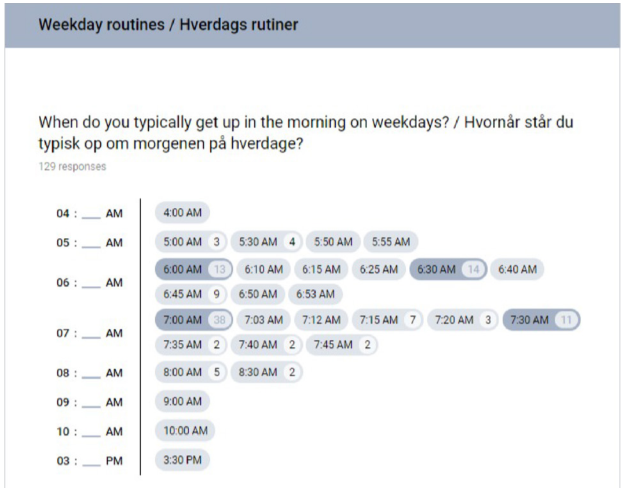
Derudover foregår der forskellige aktiviteter i løbet af formiddagen og eftermiddagen dels i de enkelte Leve-Bo Miljøer og dels for hele plejecentret - se under punktet "praktiske oplysninger" og menupunktet "aktiviteter" til venstre.

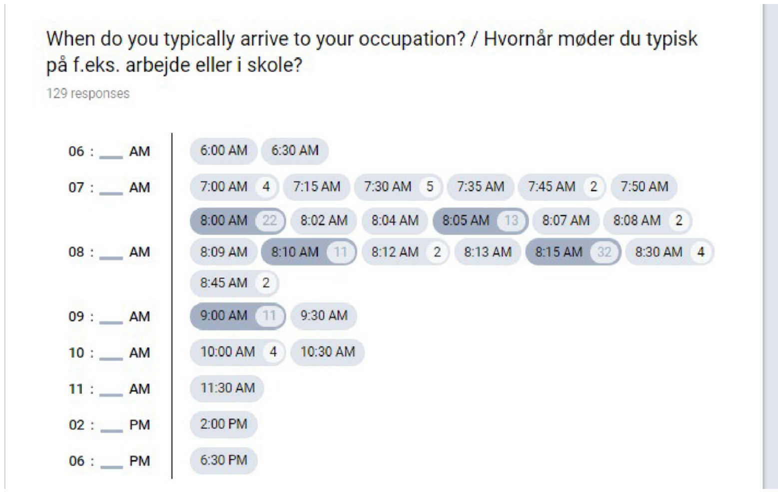
Appendix 1.2. Haderslev 24 hour schedule for nursing homes

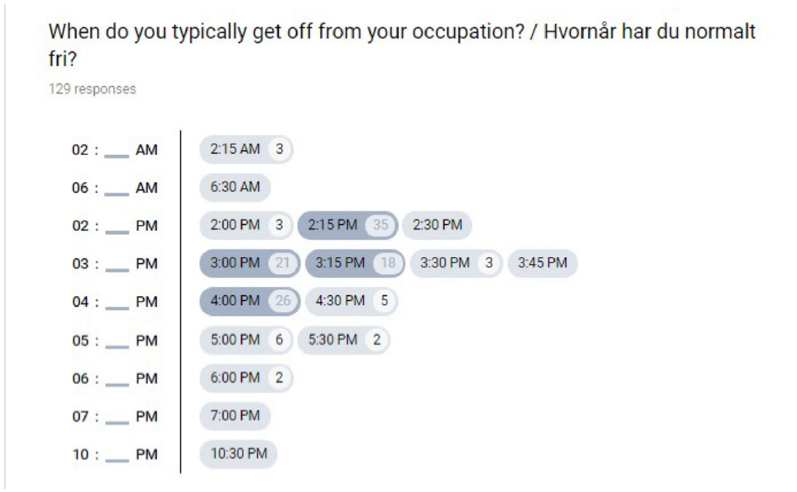
Appendix 2

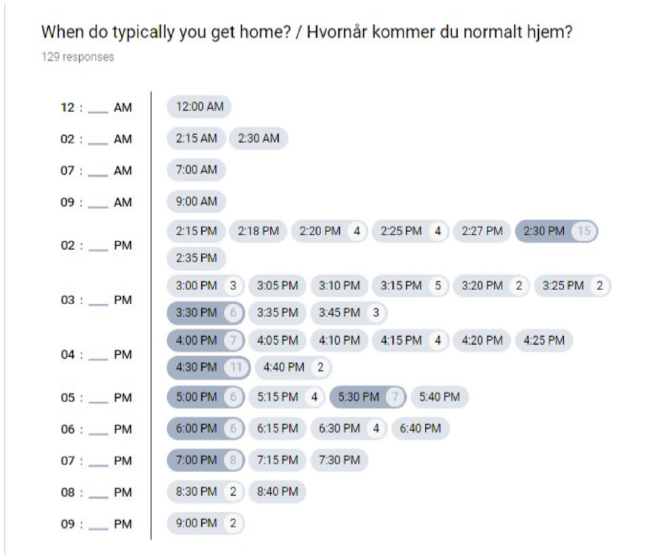
Questionnaire

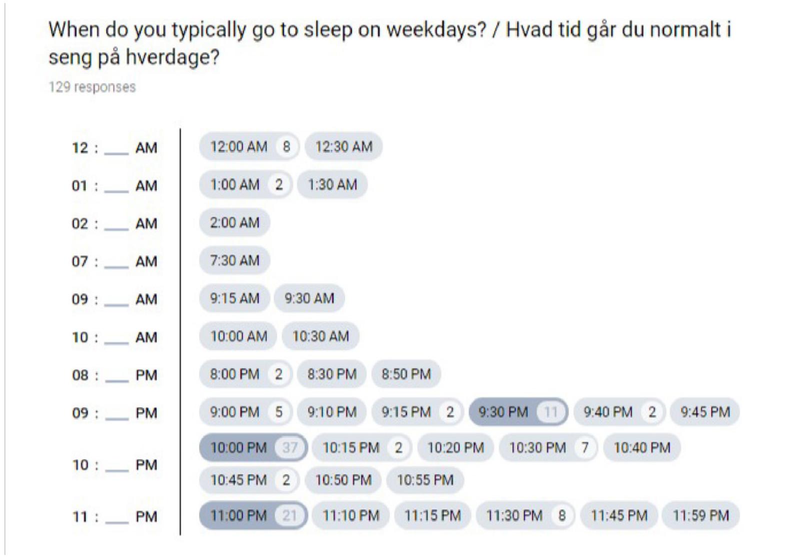


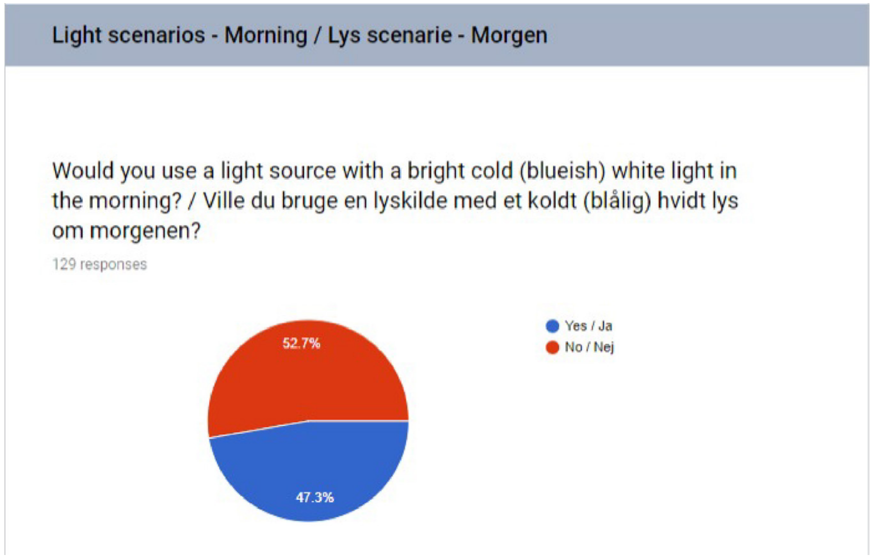


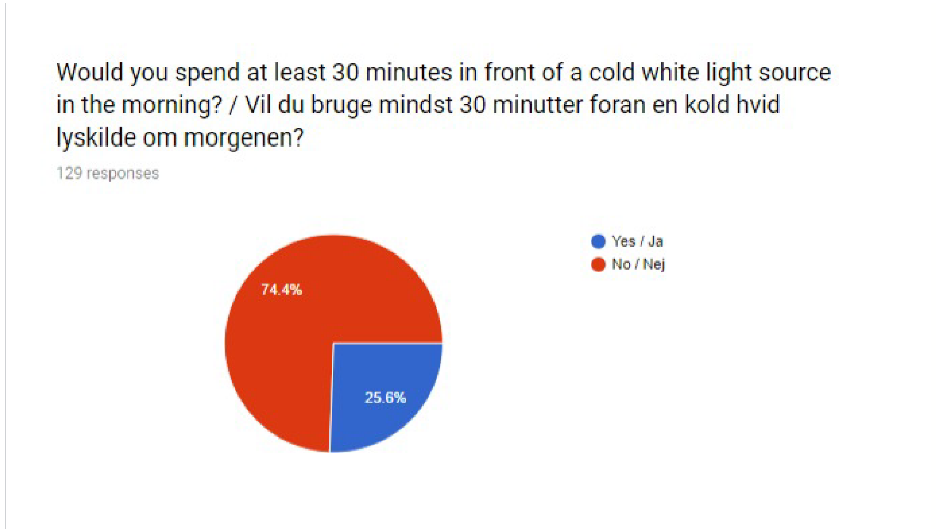





When do typically you get home? / Hvornår kommer du normalt hjem?
129 responses
12 : __ AM 12:00 AM
02 : __ AM 2:15 AM 2:30 AM
07 : __ AM 7:00 AM
09 : __ AM 9:00 AM
02 : __ PM 2:15 PM 2:18 PM 2:20 PM 4 2:25 PM 4 2:27 PM 2:30 PM 15 2:35 PM
03 : __ PM 3:00 PM 3 3:05 PM 3:10 PM 3:15 PM 5 3:20 PM 2 3:25 PM 2 3:30 PM 6 3:35 PM 3:45 PM 3
04 : __ PM 4:00 PM 7 4:05 PM 4:10 PM 4:15 PM 4 4:20 PM 4:25 PM 4:30 PM 11 4:40 PM 2
05 : __ PM 5:00 PM 6 5:15 PM 4 5:30 PM 7 5:40 PM
06 : __ PM 6:00 PM 6 6:15 PM 6:30 PM 4 6:40 PM
07 : __ PM 7:00 PM 8 7:15 PM 7:30 PM
08 : __ PM 8:30 PM 2 8:40 PM
09 : __ PM 9:00 PM 2


When do you typically go to sleep on weekdays? / Hvad tid går du normalt i seng på hverdage?
129 responses
12 : __ AM 12:00 AM 8 12:30 AM
01 : __ AM 1:00 AM 2 1:30 AM
02 : __ AM 2:00 AM
07 : __ AM 7:30 AM
09 : __ AM 9:15 AM 9:30 AM
10 : __ AM 10:00 AM 10:30 AM
08 : __ PM 8:00 PM 2 8:30 PM 8:50 PM
09 : __ PM 9:00 PM 5 9:10 PM 9:15 PM 2 9:30 PM 11 9:40 PM 2 9:45 PM
10 : __ PM 10:00 PM 37 10:15 PM 2 10:20 PM 10:30 PM 7 10:40 PM 10:45 PM 2 10:50 PM 10:55 PM
11 : __ PM 11:00 PM 21 11:10 PM 11:15 PM 11:30 PM 8 11:45 PM 11:59 PM

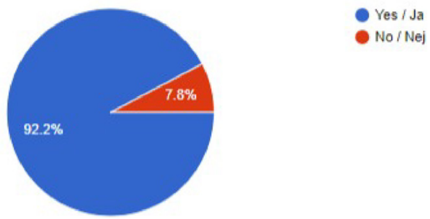

Light scenarios - Morning / Lys scenarie - Morgen
Would you use a light source with a bright cold (blueish) white light in the morning? / Ville du bruge en lyskilde med et koldt (blålig) hvidt lys om morgenen?
129 responses
52.7%
47.3%
Yes / Ja
No / Nej


Would you spend at least 30 minutes in front of a cold white light source in the morning? / Vil du bruge mindst 30 minutter foran en kold hvid lyskilde om morgenen?
129 responses
74.4%
25.6%
Yes / Ja
No / Nej

Light scenarios - Evening

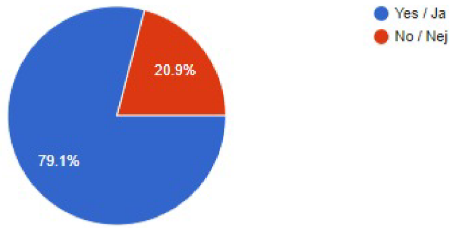
Would you use a light source with a dim warm (amber) white light in the evening? / Ville du bruge en svag lyskilde med varmt (gullig) hvidt lys om aftenen?

129 responses



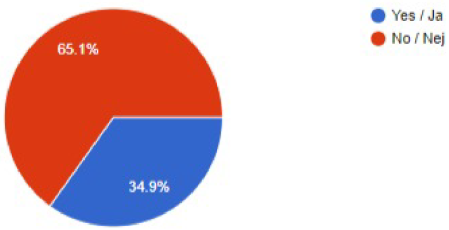
Would you only use indirect lighting (ambient) in the evening? / Ville det være muligt for dig kun at bruge indirekte belysning om aftenen?

129 responses



Would you use red light at night for navigating, to not disturb your circadian rhythm (Biological clock)? / Ville du bruge rødt lys om natten til at navigere, for ikke at forstyrre din døgnrytme (biologiske ur)?

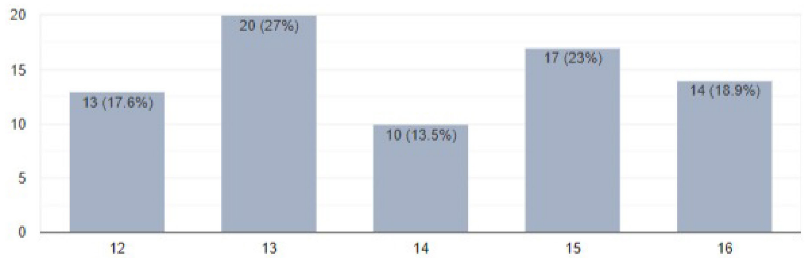
129 responses

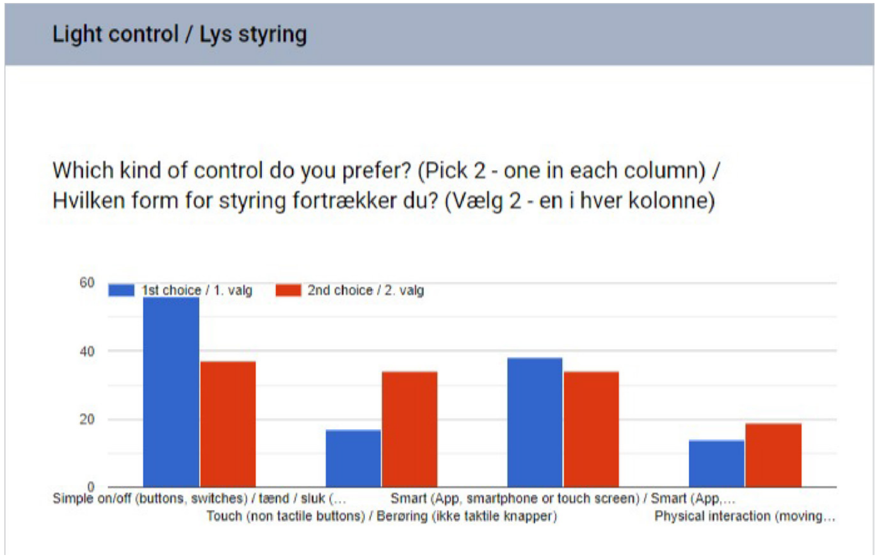


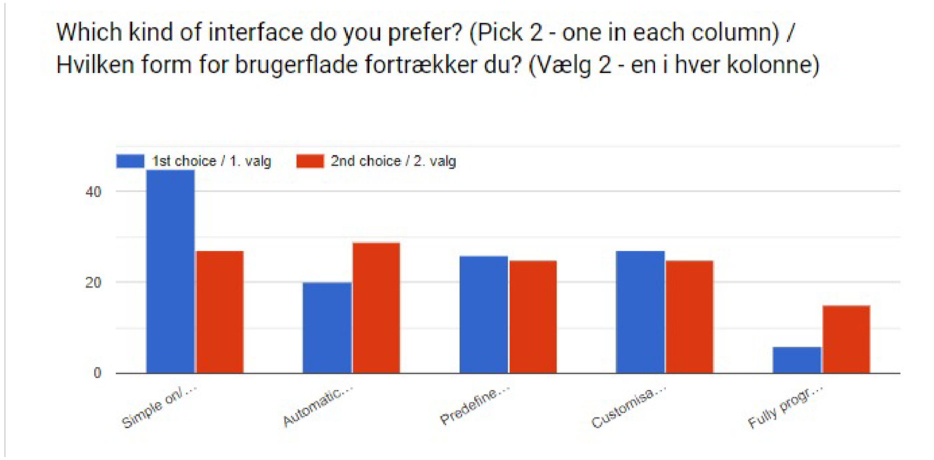
Age: 7-18 / Alder: 7-18

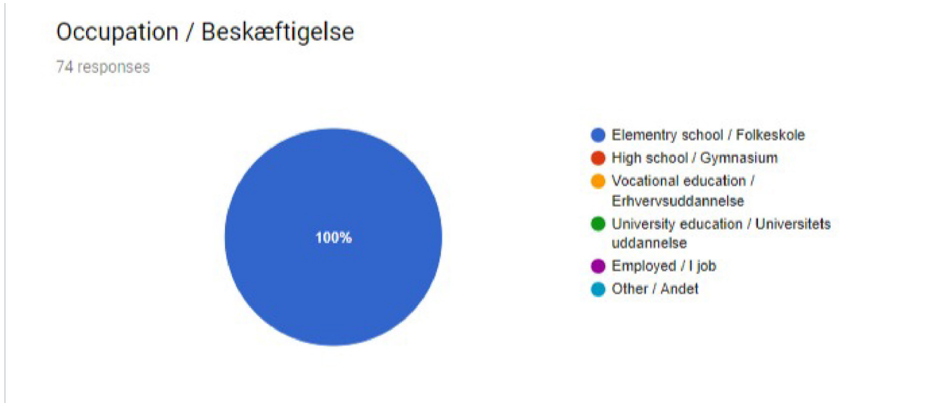
Your age / din alder

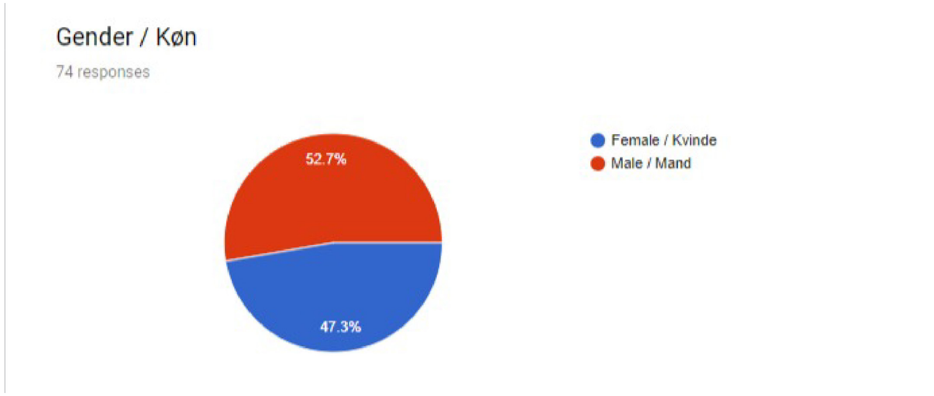
74 responses



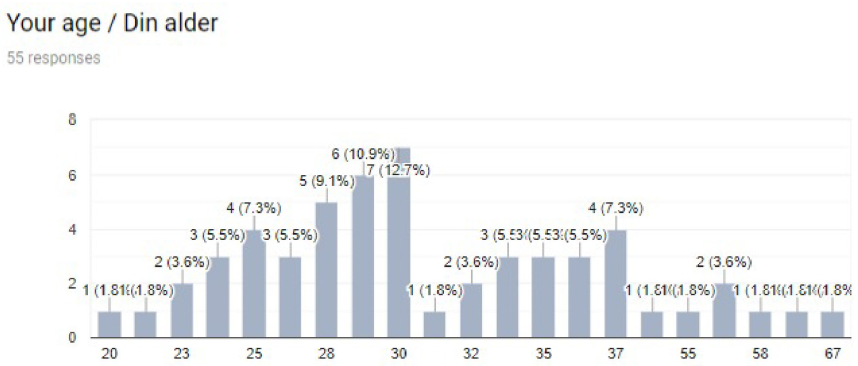

Light control / Lys styring
Which kind of control do you prefer? (Pick 2 - one in each column) /
Hvilken form for styring fortrække du? (Vælg 2 - en i hver kolonne)
60
40
20
0
1st choice / 1. valg
2nd choice / 2. valg
Simple on/off (buttons, switches) / tænd / sluk (...
Touch (non tactile buttons) / Berøring (ikke taktile knapper)
Smart (App, smartphone or touch screen) / Smart (App,...
Physical interaction (moving...

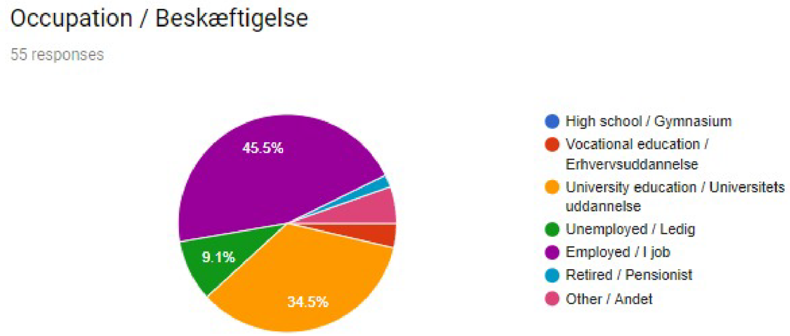

Which kind of interface do you prefer? (Pick 2 - one in each column) /
Hvilken form for brugerflade fortrækker du? (Vælg 2 - en i hver kolonne)
1st choice / 1. valg
2nd choice / 2. valg
40
20
0
Simple on/...
Automatic...
Predefine...
Customisa...
Fully progr...

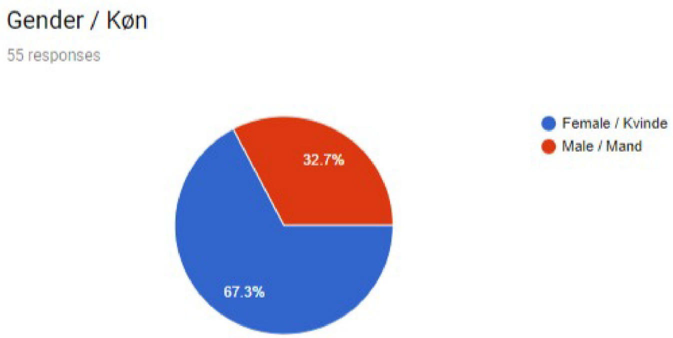

Occupation / Beskæftigelse
74 responses
100%
Elementry school / Folkeskole
High school / Gymnasium
Vocational education / Erhvervsuddannelse
University education / Universitets uddannelse
Employed / I job
Other / Andet

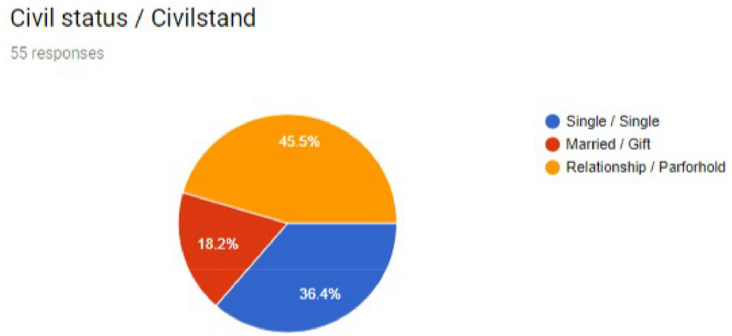

Gender / Køn
74 responses
52.7%
47.3%
Female / Kvinde
Male / Mand

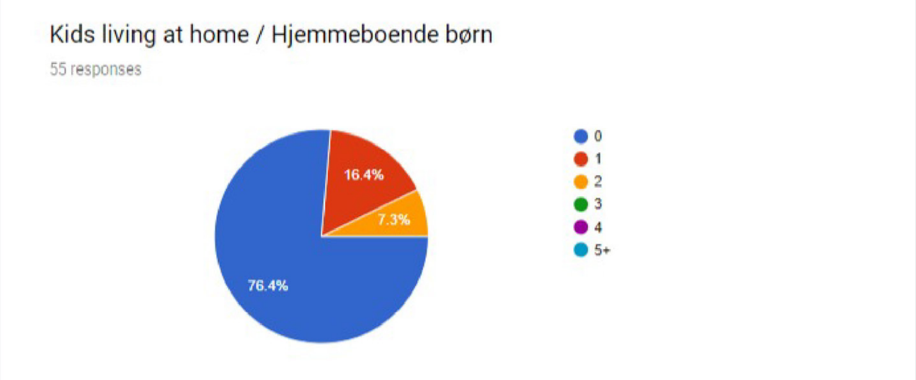
Age: 19-70 / Alder: 19-70










Kids living at home / Hjemmeboende børn
55 responses
16.4%
7.3%
76.4%
0
1
2
3
4
5+