DAYLIGHT

Visual Comfort and Quality of Light

Karin Fridell Anter October 2013

SYN-TES report 8





Abstract

The project presented in this report started from a striving to reduce energy consumption for lighting, and at the same time maintain or improve the illumination quality, as compared to existing technical solutions. An enhanced use of daylight could possibly favour both these objectives. The report initially refers current research and discussions on lighting quality, and concludes that there is no coherent theory or set of concepts that could enable an overall judgement of what can be called lighting quality.

We discuss current research on the special qualities of daylight, which is often esteemed as high quality lighting, and is also the light that human vision is ecologically adapted to. Against this background we pose the question, whether the amount of daylight that reaches a work desk could affect the need for artificial lighting, not only through its quantitative contribution to the general illuminance, but also through its particular quality.

Our hypothesis was formulated for a specific situation where subjects read a book sitting by desks in a partly daylit room, and could choose their reading illuminance with the help of dimmable halogen lamps. The hypothesis was, that in this situation there is a correlation between, on the one hand daylight's relative contribution to total illuminance (daylight + artificial), and on the other hand the subjectively experienced need for total illuminance (daylight + artificial). It was hypothesised that the larger the relative amount of daylight, the less the need for total illuminance.

Two test series were conducted, including totally 38 subjects of which 19 participated in both series. The tests showed a partial support for the hypothesis, but only under conditions that offered a stable adaptation level. Strong fluctuations in daylight made the subjects choose higher light levels than when the day lighting was been stable, most likely to obtain a more stable working situation. Also, it appeared that what was seen with peripheral vision, or only sensed "in the corner of your eye", affected the individually assessed need for task lighting.

The tests within the project were performed under conditions that were not fully controlled. To some extent this was an inevitable consequence of the fact that the study object was daylight, which is, by its character, varying. Apart from this, it was also a conscious choice to create a test situation that opened up for other questions than those tied to the original hypothesis. We used the method successive approximation, where the process of evaluating and reformulating the test situation and the questions is an important part of the research work. Twice during the project, its test design, results, conclusions and new questions were discussed by an interdisciplinary expert group. These meetings were not mere "control stations" but indispensible components of the research process. This method made it possible for us to, within the framework of the project, formulate and investigate a number of relevant questions in addition to the testing of the original hypothesis. Among other things we found that different subjects chose very different illuminances for their reading task, and that subjects tended to be consistent with themselves in this choice.

In general, the current project shows the need for more research on adaptation effects in full scale real life situations. Our results imply that it is likely that a high general illuminance, and/or the existence of glare, raises the adaptation illuminance and thus makes us want even more light. Instead, a carefully designed lighting without glare or strong luminance contrasts could possibly make people adapt to a lower illuminance, without reduced task performance or visual discomfort.

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Thank you

Fox Design for equipment and expert participation

Thorbjörn Laike for measurements and statistical analysis

All test persons for your participation

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Daylight, visual comfort and quality of light

Project carried out by the Colour and Light Research Group
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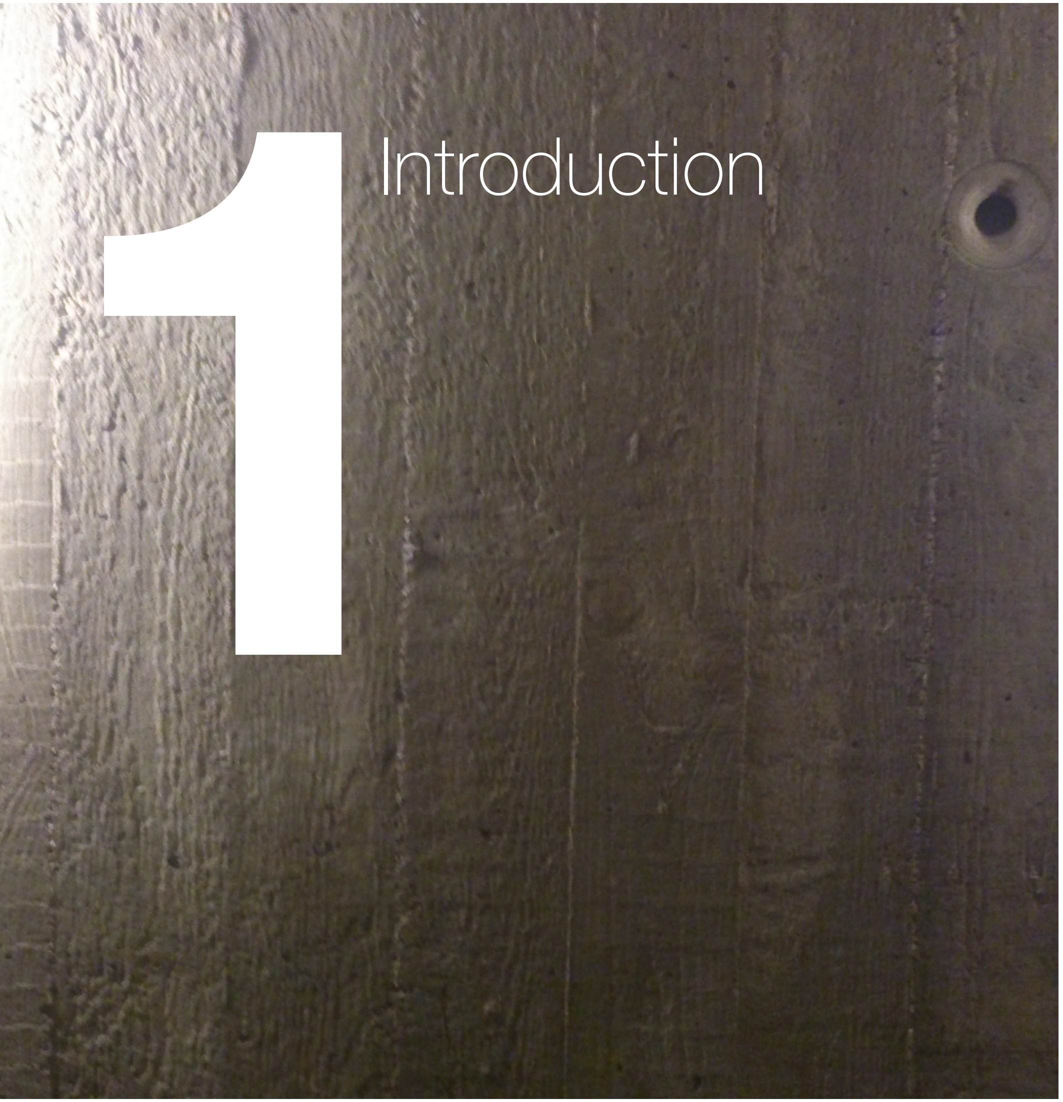
The reports and more material from the Colour and Light Research Group (partly in English) can be downloaded from www.konstfack.se/SYN-TES



1 Introduction

The strive for energy efficient lighting aims at decreasing the need for energy, and at the same time at maintaining or improving the illumination quality as compared to existing technical solutions. This ambition was the main theme of two recent CIE-conferences on *Lighting quality and energy efficiency*.[1]

Increased energy efficiency with high demands on lighting quality calls for knowledge on how the lighting quality can be evaluated and described. However, the concept of quality includes many aspects, and there is no coherent theory or set of concepts that could enable an overall judgement of what can be called lighting quality. One basic problem is the lack of concepts and criteria that could help understanding the relationships between photometrically measurable variables, visual comfort and the experienced light in a room.[2] The rapid technical development makes it urgent to create deeper understanding of these relationships, in order to avoid solutions that do save energy, but at the same time result in lit spaces that are ugly and decrease people´s quality of life.

Earlier studies show that the photometric variables are insufficient for describing the experienced quality of light in a complex space.[3] Visual appearance, of lighting as well as objects, was the specific theme of a CIE symposium in 2006 and was also discussed in a separate CIE report the same year.[4] The authors of the report, chaired by M. Pointer, conclude that *an attempt to measure appearance may be too bold a step to take*. One important reason for this is that

> *physical parameters relating to objects are influenced, at the perception stage, by the physiological response of the human visual system and, in addition by the psychological aspects of human learning, pattern, culture and tradition.*[5]

[1] CIE 2010; CIE 2012
[2] An analysis of the confusions regarding concepts for light and colour is given in Arnkil et al. 2012.
[3] Valberg 2005
[4] CIE 2007; CIE 2006.
[5] CIE 2006, abstract.

A number of studies have dealt with the relationship between photometric variables like illuminance and luminance, and the experienced intensity of light or the brightness of the room.[6] There is also a method for perceptive spatial analysis of light and colour[7], starting from concepts that have been previously published by professor Anders Liljefors [8].

There is, however, not sufficient knowledge on how the experienced qualities relate to the measurable, and the basic concept of *lighting quality* lacks a distinct definition:

> *A concept such as"lighting quality" varies with the position and the personal experience of the individual and must be seen as an instrument rather than as a scientific truth. Several attempts to establish concepts for lighting quality have been made (Bean & Bells 1992; Veitch & Newsham 1996; Veitch & Newsham 1997) but the concept has this far eluded the researchers.*[9]

Examples of quality criteria given in recent Swedish dissertations are
• Performance – Wellbeing – Visual comfort (Annika Kronqvist) [10]
• Lighting that is individually psychologically, physiologically and visually supportive (Monica Säter) [11]

Much of the accomplished work on lighting quality has dealt specifically with spaces for office work[12] but there has also been some work on light in other contexts, such as domestic environments[13] , schools[14] or hospitals [15]. At Jönköping university there is, starting from 2013, an ongoing larger project with the aim of formulating a definition of lighting quality and show the interaction between different parameters. [16]

[6] Fotios & Houser 2007 summarizes and evaluates some twenty such studies.
[7] Klarén 2013
[8] Liljefors 2003; Liljefors 2005
[9] Kronqvist 2012 p5.
[10] Kronqvist 2012 p55-57.
[11] Säter 2012, subtitle of dissertation.
[12] Boyce 2006; Veitch et al. 2008; Kronqvist 2010; Veitch et al. 2010. Galasiu & Veitch 2008 is a literature overview dealing with user's preferences for office lighting. Kronqvist 2012, paper G is a review over office lighting research from a Scandinavian perspective.
[13] Säter 2010a; Säter 2010b
[14] Govén et al. 2010
[15] Pechacek et al. 2008; Tannöver et al. 2008; Stidsen et al. 2010
[16] Criteria for good lighting enviromment, project leader Annika Kronqvist JTH.

2 Research on the special qualities of daylight

The human visual sense has developed during millions of years, under influence of daylight, and it is hardly surprising that we spontaneously experience daylight as ”natural”. Many architects and others, who work with the design of buildings and their lighting, express a general view that daylight adds spatial qualities and is experienced as ”good light”, in a way that cannot be reduced to its contribution to the total illuminance in the room. [17] This positive evaluation can partly be derived from the spatial experience given by the window as an opening towards the outside world, but also from the qualities of the daylight itself. [18]

Daylight differs in many ways from light given by artificial light sources. Contrary to most current artificial light sources, daylight has a continuous spectrum. It is also constantly varying, in both intensity and wave length composition. [19] Research on the qualities and effects of daylight deals with biological, visual and emotional aspects. This includes

- questions regarding health and diurnal rhythm
- questions regarding personal wellbeing and preferences
- questions regarding visual comfort
- questions regarding task performance
- questions regarding the perception and experience of colours and space

One large field of research deals with the correlations between the spectral composition of radiation and people's health and diurnal rhythms, questions that do not always connect to the visual aspects of light. Here one starting point is that human physiology and biochemistry have developed under influence of radiation emitted from the sun. Questions dealing with lighting, diurnal rhythm and health have gained new interest as the new light sources make it possible to design light itself, and its temporal variations. [20] When it comes to the non-visual effects of light on humans, the unit of environmental psychology at Lund University has over a long time been one of the internationally leading research centres, and its late professor Rikard Küller is one of the authors of a comprehensive bibliography covering this field. [21] Division 6 within CIE works with photobiology and photochemistry, and a large number of studies have been presented within this field. [22]

[17] Fridell Anter 2012a s.19; Hjertén et al. 2001 s 40
[18] Veitch 2013
[19] The specific qualities of Nordic daylight are investigated in Matusiak 2013.
[20] Garnert 1993; Brox 2003; Barbara 2010 discuss how light and the options for illumination influence culture and society in a long time perspective.

[21] Küller & Küller 2001.
[22] See proceedings from the CIE-conferences 2006 (Ottawa), 2007 and 2011. Also see Govén et al. 2007, Küller 2008 and Säter 2012.

Regarding daylight's effect on people's mood and experienced wellbeing, it is generally understood as positive, as for example in a literature review from the Lighting Research Centre in Troy, USA:

> *Daylight is clearly preferred over electric lighting as a source of illumination. Windows are valued particularly for the daylight they deliver and the view out they provide.* [23]

The same report concludes, however, that there are no clear causal links between on the one hand personal satisfaction and wellbeing, and on the other hand task performance and productivity. [24] Daylight's importance for visual comfort and task performance is summarized as follows:

> *Physically and physiologically, daylight is just one more light source. How daylight influences visual performance depends on how it is delivered. Either good task performance or bad task performance can be expected depending on the amount of daylight delivered, and whether glare, shadows or veiling reflections are produced.* [25]

Another field of research deals with the experienced qualities of the day lit room, including its dimensions and colours. Some of the questions that have been studied are

- How does the form and placement of windows affect the experienced form of the room? [26]
- How does the amount of daylight affect the experienced size and proportion of the room? [27]
- How are the room and its colours experienced in daylight from different compass directions? [28]
- How are the room and its colours experienced in daylight filtered through different types of energy saving glazing? [29]
- How are the colours in the room perceived in a combination of daylight and artificial light? [30]

Studies where subjects, working in office rooms with daylight, have been able to adjust both illuminance and correlated colour temperature (CCT) have shown that subjects tend to choose a preferred CCT rather than a fixed light level throughout the day. [31]

There is also research on techniques for leading daylight into buildings and on methods for predicting and calculating its effect, regarding such as glare.[32] The design and efficiency of light wells and other ways to lead daylight is developed and evaluated[33] , as well as the impact of room forms and surface materials.[34] New and more adequate measurements for interior daylight provision are being developed, to replace the current *daylight factor*.[35] Attention is also paid to the potential problems related to a too uneven spatial distribution of daylight in a room. Strong daylight near the windows can be experienced as glaring and disturbing from further into the room, and thus demand extra artificial lighting to smooth out the contrasts. [36]

[23] Boyce et al. 2003 p26
[24] Boyce et al. 2003 p31ff
[25] Boyce et al. 2003 p16
[26] Matusiak 2004; Matusiak 2006
[27] Matusiak & Sudbø 2008
[28] Hårleman 2006; Hårleman 2007
[29] Chain et al. 2001; Dubois et al. 2007; Pineault & Dubois 2008; Arsenault et al. 2012; Matusiak et al. 2012
[30] Hussein 2007
[31] Logadóttir & Christoffersen 2008; Logadóttir et al. 2013
[32] Kim et al. 2007 Li & Chen 2011
[33] Garcia Hansen et al. 2010; Matusiak et al. 2010; Lingfors & Volotinen 2013
[34] Fontoynont 1999; Amorim et al. 2011; Hagenlocher & Cartwright 2012
[35] CIE TC 3-47; Mardaljevic et al. 2011; Pellegrino et al. 2011; Mardaljevic 2013
[36] Fridell Anter 2012a p21, Hjertén et al. 2001 p37, CIE TC 3-39

3 The project: Background, aim and hypothesis

The current project starts from a number of observations on the relationship between the daylight level and the individual's experience of light quality and visual comfort. From our own experience we can see, that people often chose to let the interior lighting remain turned off, even when the strong midday light is transformed to twilight. In our pilot project OPTIMA, subjects were asked to perform tasks in rooms with different lighting and colouring, among them one lit with only daylight. The study showed that most subjects found it easier to read in a room lit with daylight than in a room with artificial lighting (in this case LED), even when the illuminance was significantly lower in the room with only daylight. Several subjects also positively commented on the daylight as such (”to follow the day”) and the fact that windows gave a view towards the outer world (”decreases the claustrophobic feeling”). [37]

Annika Kronqvist carried out a study where subjects worked with video display terminals in three office rooms that were identical apart from different light scenarios. One of the rooms had only daylight, which varied throughout the day, and where the illuminance was typically lower than in the two rooms with artificial lighting. The subjects spent one full working day in each room and were, among other things, asked to evaluate the light setting and their own visual comfort, well-being and alertness. The subjects experienced the daylight setting as more visually comfortable than the other two. They also typically evaluated the daylight setting as enhancing to well-being and increasing the ability to perform. [38] Kronqvist concludes:

> *A more complex setting combined with day lighting could be used to create an environment which will sustain performance as well as improve well-being and comfort, suggesting a turn of strategy in office lighting, where the illuminance is down-played by variety and spectral composition of the lighting.* [39]

Kronqvist's subjects also considered the day-lit room to be favourable to alertness, a result that, interestingly enough, could not be related to subjects' levels of saliva cortisol or melatonin. In an investigation of subjects' hormonal level and self evaluation of alertness in rooms lit with daylight or artificial light, Monica Säter comes to a similar conclusion. She found no correlation between alertness and cortisol level and cannot verify her hypothesis that the photons act as a trigger for hormonal release. [40]

37 Fridell Anter 2011 p41-42
38 Kronqvist 2012 paper E p16-18.
39 Kronqvist 2010 p 215, also included in Kronqvist 2012 as paper D.
40 Säter 2012 p 315ff

Irrespective of the chemical processes in our bodies, there is much that indicates that the daylight in rooms increases our wellbeing and alertness, and possibly also the ability to perform visually demanding tasks. Against this background we pose the question whether the amount of daylight that reaches a work desk could affect the need for artificial lighting, not only through its quantitative contribution to the general illuminance, but also through its quality as being specifically daylight. To our knowledge, no previous studies have dealt with this question. [41]

We have conducted a project to investigate this question, with the aim to present and test a relevant hypothesis, find and formulate new questions and develop the methodology for further research on the interaction between daylight and the experienced need for lighting. The result will hopefully enhance the understanding of how daylight can be used to decrease the need for artificial lighting, and thus the consumption of energy.

The project investigates the subjectively judged need for lighting, in order to read a book in an office room with daylight from a window, and optional additional light form a halogen lamp over the place of work. The task – to read a book – was chosen for its general demands on vision. Thus the survey does not deal with any specific type of room (office, home, school, etc.) or any more specific visual task. Halogen light was chosen because it can be regulated – dimmed – in a way that changes the colour of light in the same way as natural light sources change, that is between warm light with low light level and cooler light with higher light level.

The hypothesis is that in this situation, there is a correlation between on the one hand daylight's relative contribution to total illuminance (daylight + artificial) and on the other hand the subjectively experienced need to total illuminance (daylight + artificial). It is hypothesised that the larger the relative amount of daylight, the less the need for total illuminance.

[41] Before the project start, the question was discussed with two prominent experts on daylight and its use in buildings: Barbara Matusiak, professor and leader of the daylight laboratory at the Norwegian University of Science and Technology in Trondheim, and John Mardaljevic, professor of Building Daylight Modelling at the School of Civil & Bulding Engineering, Loughborough University, UK. Both judge the suggestion as relevant and reasonable. In spite of their broad overview over daylight research, none of them knows any previous scientific studies on this question, which indicates that no such studies have been made. For a knowledge survey based on a large number of current publiciations on light and lighting, see Fridell Anter 2012b; Fridell Anter 2013.

4 Method and procedure

The project is based upon two previous studies that have been financed by the Energy Agency and conducted at University College of Arts, Crafts and Design. The tests were performed in a full scale room that had been built and equipped within the project *OPTIMA*. [42] The methods for tests and result analysis were developed from the experiences of the project *Light enhancing colour design of rooms*. [43]

The hypothesis was tested in a reading situation, where test persons were asked to set the light level of dimmable halogen lamps in situations with different amount of daylight. Each person's results were compared only to his/her own.

There were two series of tests, with essentially the same procedure. After the first series, a reference group meeting was held to discuss method and results, and this lead to some changes in the setup and procedure of the second series. After the second series, a second reference group meeting was held to discuss results and conclusions from both series.

Statistical analysis of test results was done for each series separately. We also made a comparative analysis based on some of the questions involved.

Room and work desks, Series 1

Three work desks were arranged in a room on the 4:th floor, with lower buildings rather near outside the window. The walls were light grey (NCS 2000-N) and large windows covered one of the walls, facing east. See Figure 1. The work desks had identical chairs, wooden tables (approximate colour NCS 2530-Y20R) and dimmable table lamps. On each table there was an arrangement to place a pre-chosen book (black print on white paper) on a sloping plane for reading. In front of the desk next to the window there was a red board on the wall, and over the innermost working place there was a hanging book shelf. The only other difference between the work desks was their distance from the window that let in daylight. On clear days, direct sunlight came into the room before noon and could reach the wall near the window, but not the tables. See Figure 2.

[42] Fridell Anter 2011; Fridell Anter & Klarén 2011
[43] Häggström & Fridell Anter 2012b; Häggström & Fridell Anter 2012a

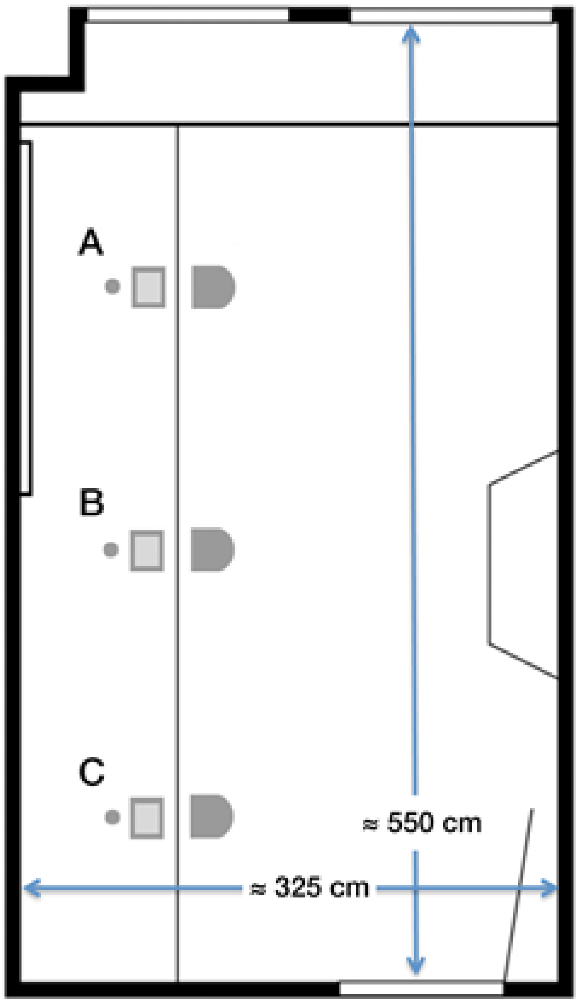


Figure 1. Plan of the room. The three work desks were situated along and facing the left side wall. Room size approximately 18 m^2.

Figure 2. Room with work desks, Series 1, photographed towards window side.

Room and work desks, Series 2

Before the second test series, the red board was painted light grey like the walls, and the book shelf was removed, which made the three work desks more similar. See Figure 3. The distance and angle between the lamp and sloping reading place was adjusted not to give any glare, which was tested with the help of glossy paper. See Figure 4. The colour of the sloping planes was changed from black to light beige, similar to the colour of the tables.

Table lamps:

The table lamps had metal lampshades that gave a distinct light cone, centred at the book. They were equipped with energy efficient halogen light sources (Philips Eco Classic30, 53W) that could be dimmed between 0 and 850 lumen. Their colour temperature increased with increased luminous flux, with a maximum at approximately 2700 K. See Figures 5, 6 and 7. The position and angle of the lamps was fixed throughout each test series.

Figure 3. Room with work desks, Series 2, photographed from window side.side.

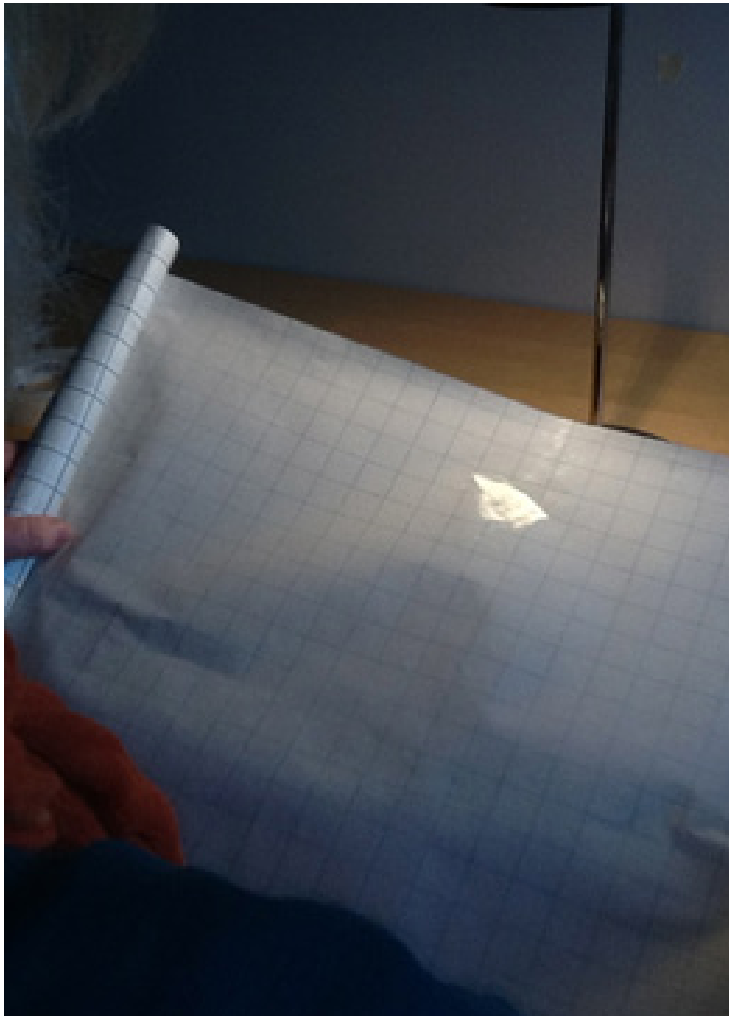


Figure 4. Glare test for adjusting the angle and distance between lamp and book. Covered with glossy paper, the book was moved until a person, sitting at the desk, could see no glare. The lamp was in a fixed position.

Figure 5. Table lamp.

Figure 6. Dimmer

Figure 7. Light source

Test subjects

Subjects were recruited through the personal contacts of the research group and within Konstfack, with the aim of getting a large variation in ages and gender. The first test series included 25 persons and the second series included 32 persons, 19 of whom had also participated in the first series (for specifics see Table 1). Subjects were informed that the study dealt with light on work desks, without mentioning daylight. After each test they were awarded with a cinema ticket and after the second series they were invited to a meeting where the hypothesis and results of the study were presented and discussed.

Times and dates for testing

The first series was carried out during the period October 26:th to November 9:th, 2012, during daytime 09.30 – 15.00. Most often the weather was rather dark and bleak, and there was no snow.
The second series was carried out during the period March 11:th to April 5:th, during daytime 09.00 – 16.30. The weather was dominated by clear sky (22 out of 32 instances), but there was also snowfall (6 instances) and cloudy weather without snowfall. In a majority of instances (22) there was snow that fully or partly covered the ground and the roofs of nearby buildings.

Setting the scene

Before each test, the daylight input into the room was adjusted by venetian blinds at the windows. The ideal was to get a 70 lux illuminance on the middle work desk, which would automatically give higher illuminance closer to the window and lower illuminance further from the window. In reality it was difficult to control the daylight situation to that extent. The span and mean lux values given by daylight in the middle of each of the three work desks is presented in Table 2. All figures denote discrete measurements. From the standard deviations you can conclude that the daylight component varied more in close proximity of the window than further into the room, as was also expected.
Before each test the test leader ascertained that all lamps were dimmed down totally so that the room was lit only with daylight.

Procedure, Series 1

The test was carried out with one test person at a time. Each test took 35-45 minutes. First the test person was informed about the procedure and was asked to fill in a form with a number of questions (see Appendix 1). This was done with all lamps totally dimmed down and also served as an adaptation time (5-10 minutes). At the same time the test leader took notes on weather, screening of the window and lighting pattern in the room (see Appendix 2).

After that, the same reading task (see below) was done four times with the same instructions, but at the different work desks. The order was randomly different for different persons. The first time served as a learning session and was not included in the analysis, but this was not told to the test persons. The task was always started with all lamps totally dimmed down.
Finally the test person was asked some questions to be answered partly orally, partly in writing (see Appendix 3).

Procedure, Series 2

In Series 2, most of the procedure was the same as in Series one. The differences were:
- instead of written questions on the use of glasses or lenses, the test leader asked these questions orally and recorded the answers.
- the visual acuity and contrast sensitivity of each subject were controlled with the help of specially constructed letter charts, read at normal reading distance with the person's normal reading glasses/lenses on. This test was made at the middle work desk, with the lamp turned off and thus an approximate illuminance of 70 lux. The aim was to sort out subjects whose poor vision would make them inappropriate as test persons. However, all tested subjects could read the 8 pt characters and text with 90% brightness level, which was judged as fully acceptable. See Figures 8 and 9, whose captions give more details about the tests.

TABLE 1. SUBJECTS

Series no	n=	Men	Women	Age span	Average age	Median age	Typical age
1	25	5	20	22-72	50	50	32
2	32	11	21	23-72	48	46	32
Subjects that participated in both series	19	3	16	29-72	53	56	56

TABLE 2. ILLUMINANCE LEVELS GIVEN BY DAYLIGHT AT THE MOMENTS OF MEASURING (LUX)

	Work desk by window (A)				Middle work desk (B)				Work desk furthest from window (C)			
Series no	Min	Max	Mean	Std. dev	Min	Max	Mean	Std. dev	Min	Max	Mean	Std. dev
1	90	540	233	115	10	160	64	39	10	70	24	17
2	120	450	212	84	50	130	74	19	30	70	39	9

Figure 8.Test of visual acuity. The font is Helvetica CY bold with double spacing between characters. Each line has the same number of characters, and each line includes visually similar characters like R and K or D, C and O. Size of characters from 4 to 36 pt.

Figure 9. Test of contrast sensitivity. Same font and basic construction as the visual acuity test. All characters have the same sixe (36pt), but with decreasing blackness. The scale has eight steps of ”brightness” according to Adobe Photoshop’s HSB model, ranging from 0% for black and 99% for the lightest grey.

Procedure, the task

The test persons were asked to read a short story in Swedish, from a book with black print on matte paper. [44] See Figure 10. They were given the following instructions. [45]

Your task is to read a short story in the book, with a total reading time of approximately 20 minutes. The test procedure will be repeated four times at different work desks.

At every desk you are to read for five minutes.
Start with reading for some time and get a feeling of the situation.
If you think that it is needed, you can then light the lamp.
In that case: Use the dimmer and gradually adjust the intensity of the light, until you think that the reading light suits you in this situation.
After five minutes you will be told to stop reading, remove the book and help measuring the light.

Measuring the light, Series 1

After each reading task the illuminance was measured with a Lux meter (Hagner ECI) at five places at the desk: The middle, where the book had been placed, and four places approximately 50 cm from the middle. See Figure 11. These measurings were done first in the lighting situation that the test person had chosen – most often with a turned on lamp – and then with the lamp turned off, which gave the share of total illuminance that was provided by daylight. The measuring precision was chosen to be every 10 lux. See Tables 2, 3, 4 and 20.

Measuring the light, Series 2

The work desk illuminance was measured in the same way as in Series 1. In addition, illuminance was measured on the wall in front of the desk, approximately 25 cm above the table. See Figure 12 and Tables 2, 5, 6 and 21.
During the second test series, the instant daylight illuminance just inside the window was measured every 10 seconds with a Yoyo Lux log.[46] See Figure 13. This gave an understanding of the daylight variations throughout the day and provided background

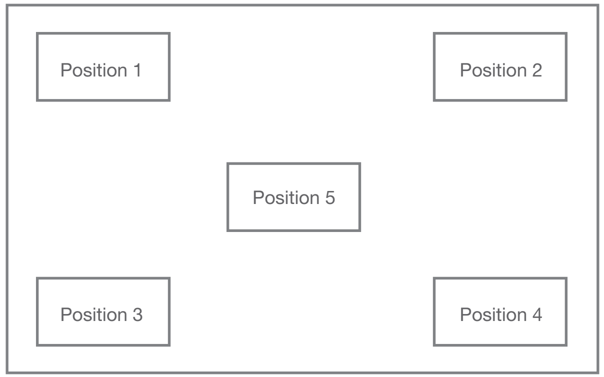


Figure 11. Series 1. Chart for notation of illuminance measurements at each desk. Measurements at the book position are noted at position 5; the approximate distance from the middle of the table to each of the other positions is 50 cm.

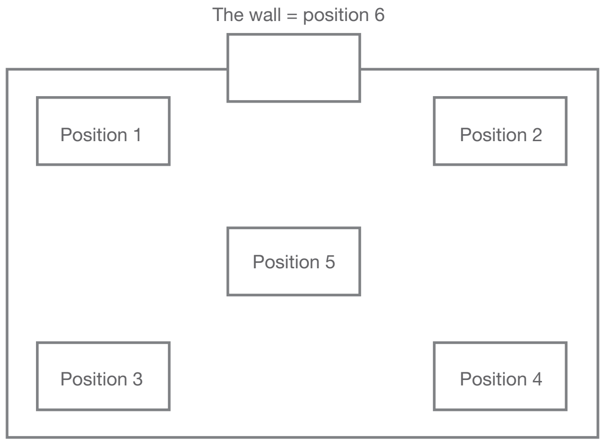


Figure 12. Series 2. Chart for notation of illuminance measurements at each desk. Measurements at the book position are noted at position 5; the approximate distance from the middle of the table to each of the other positions is 50 cm.

[44] Ekroth 2000. Printed with Antiqua 11p.
[45] The instructions were given in Swedish, this translation was made afterwards.
[46] Grant instruments YL-M61-100248. The instrument had been calibrated by the producer but nevertheless had a systematic error, which was not found out until data were analysed. The lux values given by the instrument have afterwards been checked against other instruments and recalculated with the help of EMT mätttekik AB, Stockholm. This means that the lux values for daylight illuminance are not very precise. The error was, however, stable, which means that conclusions about daylight stabilitiy and fluctuation can still be drawn.

information to the analysis of chosen illuminances. See Figures 17 and 18 and Table 8. Out of the totally 32 test sessions in Series 2, 20 had an even fluctuation of daylight, with a span of maximum 160 lux during the test session and with an instant variation of maximum 5 lux. For the remaining 12 test sessions, daylight was much more fluctuating, with a total span of up to 1200 lux during the test session, and with instant variations up to 750 lux.

Measuring the spectral distribution in different scenarios

When the room had been adjusted for Series 2, the spectral distribution in different scenarios was measured with a spectroradiometer. The measurements showed that the three lamps were nearly identical with a colour temperature of approximately 2700 K when fully dimmed up. See Figure 14 for data regarding the lamp at work desk A.

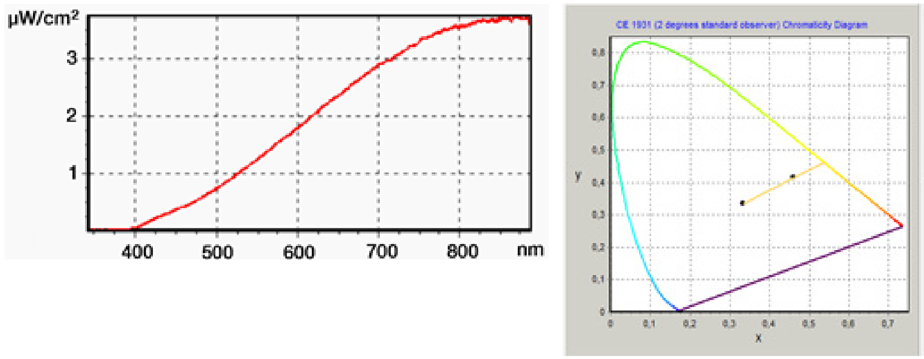
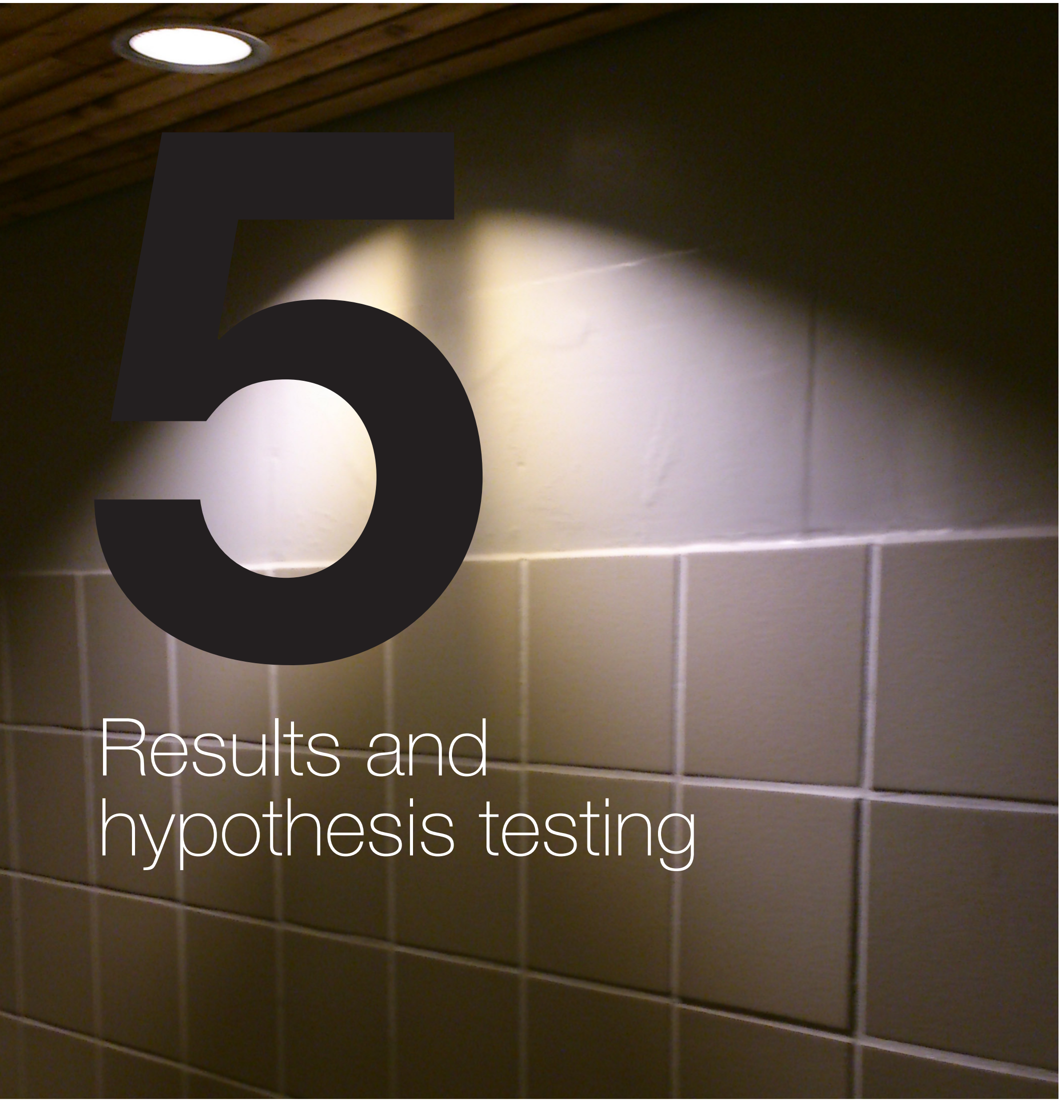


Figure 14. Spectral distribution and chromaticity diagram for the lamp at work desk A, fully dimmed up. Measured colour temperature 2709 K.


Figure 10. The test situation, desk B, Series 2.


Figure 13. Placement of YoYo log.



5 Results and hypothesis testing

The hypothesis to be tested was that there would be a correlation between, on the one hand daylight's relative contribution to total illuminance (daylight + artificial), and on the other hand the subjectively experienced need for total illuminance (daylight + artificial). It was hypothesised that the larger the relative amount of daylight, the less the need for total illuminance.

Series 1

The hypothesis was tested through an analysis of measured illuminances at the reading place (position 5 in Figure 11). In each of the situations (A, B and C) the subject´s chosen illuminance was compared to the illuminance that was given by only daylight, as measured with the lamp turned off. Four of the 25 subjects were excluded from the analysis. One of them chose to have the lamp fully dimmed up in all situations, and three chose not to turn on the lamp in any situation. In both cases the illuminance became higher the more daylight there was, but as this was not an active choice by the subject, these four were excluded.

For the remaining 21 persons, the chosen illuminances at the three desks were compared. 11 persons (52%) consistently chose lower total illuminance when the daylight was higher, which means a support for the hypothesis. 3 persons (14%) chose higher illuminance when the daylight was higher, which contradicts the hypothesis. 7 persons (33%) made choices that neither support nor contradict the hypothesis.

This vaguely implies that the test in total supports the hypothesis.

A further statistical analysis comparing the three work desks showed, not surprisingly, that the difference between total illuminance and its daylight component was significantly larger the less daylight there was (see Table 3). There was, however, no significant difference in total chosen illuminance for the three desks, which means that the hypothesis was not supported (see Table 4).

Series 2

The hypothesis was tested in the same way as for Series 1. Those who chose to have the lamp fully on in all three situations (3 persons) and those who did not turn on the lamp at all (4 persons) were excluded, as in both cases the illuminance was higher the more daylight there was, without this being the result of an active choice.

For the remaining 25 persons, the chosen illuminances at the three desks were compared. Only 2 persons consistently chose lower total illuminance when the daylight was higher, 6 persons selected the same illuminance (+-20 lux) in all situations and the absolute majority (16 persons) showed no consistence in their choices. This means that the hypothesis was not at all supported.

A further statistical analysis showed – as in Series 1– that the difference between total illuminance and its daylight component was significantly larger the less daylight there was (see Table 5).

As in Series 1, the statistical analysis did not give any significant difference in total chosen illuminance for the three desks, which means that the hypothesis was not supported (see Table 6).

TABLE 3. SERIES 1.
Difference between total chosen illuminance and its daylight component at the three work desks (position 5) (lux). Differences are statistically significant.

	Mean	Std dev.	N
DiffA	196	280	21
DiffB	351	292	21
DiffC	465	303	21

TABLE 4. SERIES 1.
Total chosen illuminance at the three work desks (lux). Differences are not statistically significant.

	Mean	Std dev.	N
Achosen	426	299	21
Bchosen	414	283	21
Cchosen	489	302	21

TABLE 5. SERIES 2.
Difference between total chosen illuminance and its daylight component at the three work desks (position 5) (lux). Differences are statistically significant.

	Mean	Std dev.	N
DiffA	200	212	25
DiffB	269	166	25
DiffC	365	190	25

TABLE 6. SERIES 2.
Total chosen illuminance at the three work desks (lux). Differences are not statistically significant.

	Mean	Std dev.	N
Achosen	410	229	25
Bchosen	343	172	25
Cchosen	404	191	25

Figure 15. Desk A during Series 2

Discussion regarding hypothesis

The tests have given no support for the hypothesis that, in the chosen context, the need for total illuminance would decrease when the relative proportion of daylight increased.

A further analysis of the figures in Tables 4 and 6 showed one more unpredicted result. In both test series, the chosen illuminance was lowest at work desk B, not at work desk A which was nearest to the window. When investigating the reasons for this, we could see that desk A had slightly different characteristics from desks B and C. Desk A was placed just next to the window, and even if no direct sunlight reached the table or the book, the daylight opening could possibly be perceived from the side, "in the corner of your eye". In that case it could serve as a highly luminant reference that would affect adaptation and make persons choose higher total illuminance. Also, part of work desk A – but not the part where the book was placed – was partly shaded by the window shelf. See Figures 15 and 16.

Based on these considerations, the hypothesis was tested once more for only work desks B and C. In Series 1 (see Table 4) there was a tendency that chosen illuminance was higher at desk C than at desk B, but the difference was not statistically significant. In Series 2 (see Table 6) the chosen illuminance at desk C was significantly higher than at desk B. When both series were analysed together, this also showed a significant difference (see Table 7).We can conclude that the comparison between desks B and C supports the hypothesis.

Based on these considerations, the hypothesis was tested once more for only work desks B and C. In Series 1 (see Table 4) there was a tendency that chosen illuminance was higher at desk C than at desk B, but the difference was not statistically significant. In Series 2 (see Table 6) the chosen illuminance at desk C was significantly higher than at desk B. When both series were analysed together, this also showed a significant difference (see Table 7).We can conclude that the comparison between desks B and C supports the hypothesis.

TABLE 7
Series 1 and 2 together. Total chosen illuminance at work desks B and C (lux). Differences are statistically significant.

	Mean	Std dev.	N
Bchosen	375	230	46
Cchosen	443	248	46

Thus the hypothesis is supported when all other conditions, except the relative amount of daylight, are equal between the tested situations. It is, however, not supported when situation A is included.

This gives us good reasons to believe that what is seen with peripheral vision, or only sensed "in the corner of your eye", affects the individually assessed need for task lighting. The direct light from the nearby window could have raised the adaptation level and resulted in an increased need for light on the book. This idea is supported by the fact that the difference between chosen light in situation A and B is much larger in Series 2 than in Series 1. In Series 2 the daylight was typically let in through a small and very luminant part of the window near the work desk, whereas in Series 1 the same amount of daylight was typically let in through a larger and less luminant part of the window wall. Thus not only the level of light, but also its distribution appears to be important for adaptation.

In addition, the shadow along the right side of the table could have influenced the adaptation and need for lighting. This leads to new questions on the impact of shadow distribution in the room, and also to questions on the effect of lightness differences between surfaces within the visual field. [47]

Figure 16. Work desk A and the window wall during Series 2. Blinds were used to adjust the illuminance for each session.

[47] The preferred light level in relationship to the distribution of shadows and dark/light surfaces in the room is preliminarlily investigated in Häggström & Fridell Anter 2012b and Häggström & Fridell Anter 2012a but needs to be furhter researched.

6 Effects of daylight variation

In addition to the testing of the original hypothesis, the results can be analysed regarding other questions. One such question deals with the natural variation of daylight and its impact on the chosen illuminances.

During each test session in Series 2, the variation of daylight was registered by an instrument that was fixed on the window sill and measured illuminance every ten seconds.[48] It appeared that 20 of the 32 subjects (category A in Table 8) carried out the test under stable daylight conditions, with an even increase or decrease of daylight illuminance, and with a span of maximum 160 lux between the highest and lowest daylight illuminance. For these 20 subjects, the variation within five minutes – the time for each reading task – was maximum 5 lux. See Figure 17 for one example. The remaining 12 subjects (category B-D) carried out the test under more fluctuating conditions, where the most extreme variation is shown in Figure 18.

The varying daylight conditions may have affected the test results in several ways. The first question to arise regards the control of the preconditions for the test: Before each session the daylight level in the room was adjusted with blinds, in order to obtain approximately 70 lux at the middle work desk and – automatically – more daylight at the desk closer to the window and less daylight at the desk further into the room. With a relatively stable daylight this relationship between the three work desks would remain throughout the session, whereas a large variation of daylight during the session could disrupt the illuminance order of the desks, and thus the precognitions for the test. This did, however, not occur. A control of the measured daylight component at the work desk directly after each reading task shows that the planned preconditions were valid in all sessions.

48 Grant instruments YL-M61-100248. The instrument had been calibrated by the producer but nevertheless had a systematic error, which was not found out until data were analysed. The lux values given by the instrument have after that been checked against other instruments and recalculated with the help of EMT mätttekik AB, Stockholm. This means that the lux values for daylight illuminance are not very precise. The error was, however, stable which means that conclusions about daylight stabilitiy and fluctuation can still be drawn.

SUBJECT 2, 11/3 12.00-13.00

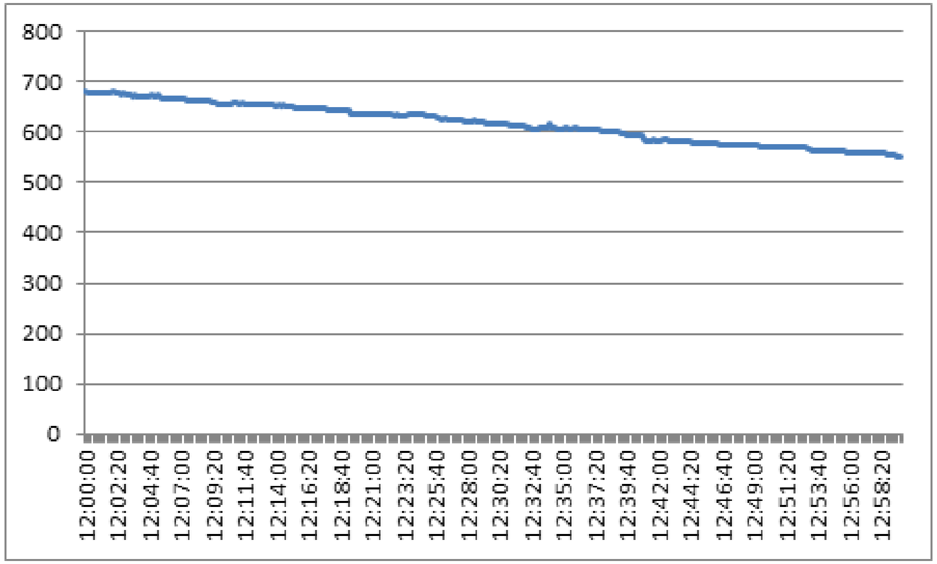


Figure 17. Example of illuminance variation (lux) in the window during one person's test session. 20 out of 32 measured sessions showed a similarly even pattern, with a span of maximum 160 lux between the highest and lowest illuminance and a variation of maximum 10 lux within five minutes. Approximate values.

SUBJECT 31, 18/3 13.00-14.00

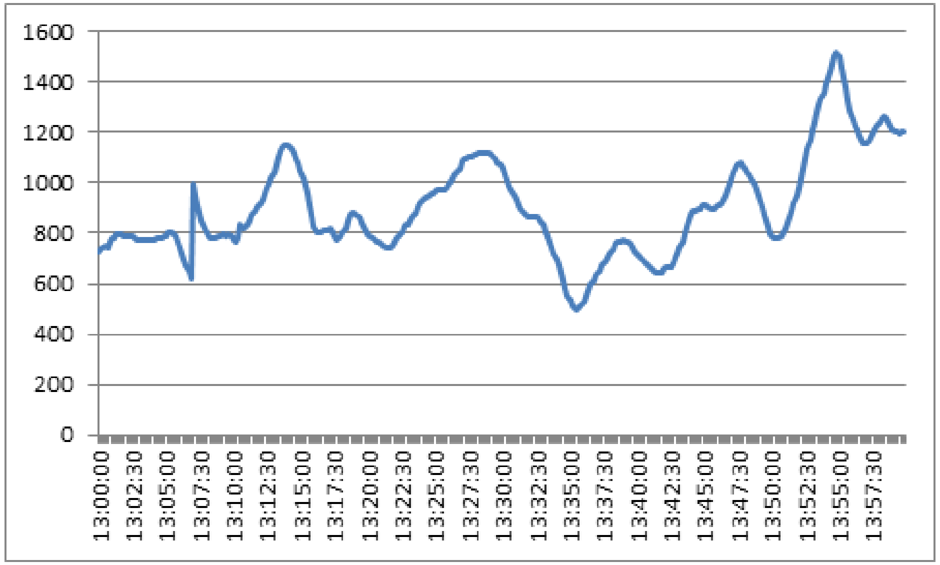


Figure 18. The most extreme illuminance variation (lux)in the window during one person's test session, with a span of 1000 lux between the highest and lowest illuminance and a variation of up to 700 lux within five minutes. Approximate values.

TABLE 8
Lux variation in window during test sessions. Approximate values.

Category	Maximum variation within 5 minutes	Maximum illuminance span	Number of test sessions	See Figure
A	10 lux	160 lux	20	17
B	80 lux	190 lux	2	
C	250 lux	450 lux	4	
D	700 lux	1000 lux	6	18

The next question deals with the effects on the subjects' adaptation. When the daylight component in the whole room is strongly increased or reduced, this means altered adaptation conditions that may have influenced the choice of working illuminance. Strong instant daylight variations may have disturbed the reading and made the subject choose other light levels than if the daylighting had been stable.

To test this, we divided the subjects in Series 2 into two groups according to the stability of daylight. For each subject we calculated the average chosen illuminance and the span between the highest and lowest chosen illuminances. Within each group, we calculated the mean of these values. As is shown in Table 9, there were differences between the two groups both regarding the span and the average chosen illuminance, and a statistical analysis showed that they were significant (99%). The group that carried out the test under stable daylight conditions had in average less difference between highest and lowest chosen illuminance and chose in average lower illuminance. Also, this group much more frequently chose to read in only daylight, without turning on the lamp.

This implies that the variation of daylight influences the choice of illuminance and makes you chose a higher illuminance when daylight is fluctuating more. It is likely that this is done to obtain a more stable working situation – a higher illuminance from artificial light sources decreases the relative contribution from daylight and thus the adaptation impact from its fluctuations.

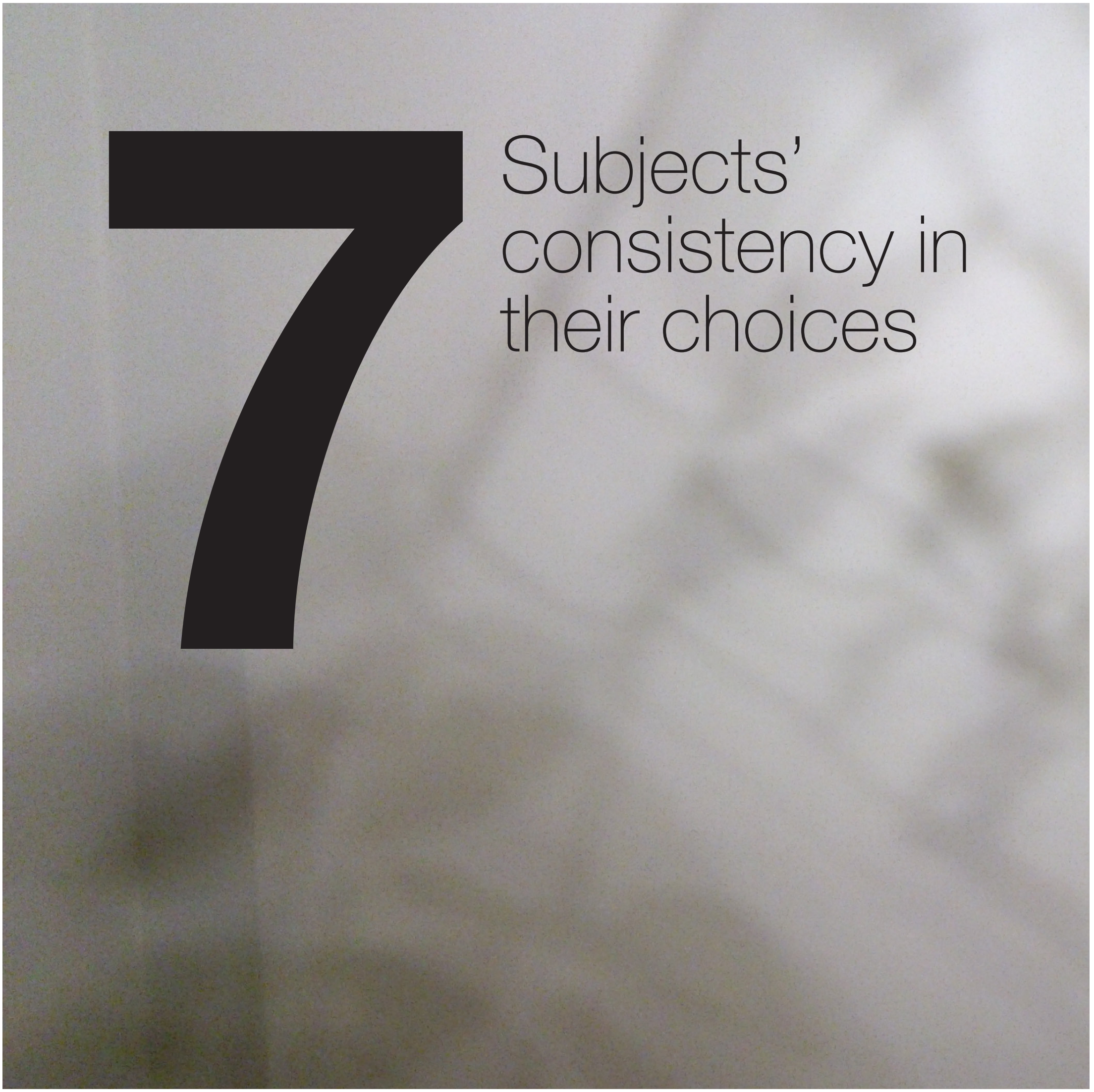
Thus we can preliminarily conclude that much variation in daylight illuminance may increase the need for artificial lighting. One way of further testing this could be to specifically analyse the results from work desk A, which was closest to the widow and thus most affected by fluctuating daylight. This has, however, not been possible within the scope of this project.

During a small number of test sessions, the exterior daylight was so intense that the blinds had to be fully closed in order to obtain an illuminance of 70 lux at the middle work desk. This means that the subject was deprived of the view to the outside world. The impact of this could possibly be derived from available data, but this has been outside the scope of the project.

TABLE 9
Series 2, the impact of daylight variation on chosen illuminances.

Category according to Table 8	Number of subjects	Average span between highest and lowest chosen illuminance	Average chosen illuminance (n= number of subjects x 3)	Standard deviation for chosen illuminance	Percentage of situations when subject chose not to turn on the lamp (n= number of subjects x 3)
A	20	148 lux	308 lux	198 lux	33%
B, C, D,	12	183 lux	502 lux	183 lux	8%
All	32	161 lux	381 lux	212 lux	24%

7 Subjects' consistency in their choices



As the test was carried out in two series, with similar preconditions and largely the same subjects, it is possible to analyse to what extent the subjects were consistent in their choice of illuminance. Similar questions have been analysed by among others Monica Säter, who has found that that personal preferences regarding the light situation vary to a high extent and are almost unique. [49]

The results of our tests show a large variation between chosen illuminances. Table 10 shows the mean chosen illuminance and the variation range for each series, including all subjects and all work desks. The two series cannot be directly compared, as the setup allowed significantly higher illuminance in Series 1.[50]

We have made individual analyses for those 19 persons who participated in both series. Their choices in each series were compared regarding their
- mean chosen illuminance for work desks A, B and C
- choice to turn on the lamp or leave it off
- pattern of choice between the three work desks A, B and C

Table 10.
Mean chosen illuminance in each series, expressed in lux (all subjects and work desks included).

Series	n	Mean	Min	Max
1	75	425	20	1210
2	96	381	30	750

49 Säter 2012 p181.
50 As a side effect of the preconditions to avoid glare, maximum illuminance on the book given by the lamp was approximately 900 lux in series 1 and 600 lux in series 2.

The person´s mean chosen illuminance

For each of the series, the 19 persons were ordered according to their mean chosen illuminance, and arranged into quartiles (highest – high medium – low medium – lowest). 12 of the 19 persons placed themselves in the same quartile in both series, and 4 more in adjacent quartiles. Only 3 made choices that placed them in non-adjacent quartiles, and none was placed in the highest quartile in one series and the lowest in the other series. This means that a majority of the subjects were consistent in their mean choice of illuminance, in relationship to all the others' choices.

This does not, however, mean that each subject had the same mean illumination in the two series. The average difference between a person's mean choice in Series 1 and 2 was 175 lux. Eleven persons chose averagely higher illuminance in Series 1, when the lamps allowed a higher illuminance, two persons chose the same mean illuminance in both series and six persons chose higher illuminance in Series 2.

Table 11.
Subjects' choice to turn on the lamp or not, in Series 1 and 2. N=19

<table>
<tr><th></th><th>Series 1 subject no</th><th>Series 2, subject no</th><th>Number of subjects making the same choice in both series</th><th colspan="2">Number of subject making different choices in both series. (boxes show which two choices)</th></tr>
<tr><td>Never turned on the lamp</td><td>21, 23</td><td>21, 23</td><td>2</td><td rowspan="2">-</td><td></td></tr>
<tr><td>Turned on the lamp only in position C</td><td>12, 24</td><td></td><td>-</td><td rowspan="2">2</td></tr>
<tr><td>Turned on the lamp in position B and C but not A</td><td>2, 4, 10, 13, 17, 20, 25</td><td>2, 4, 9, 10, 12, 18, 24, 25</td><td>4</td><td rowspan="2">5</td></tr>
<tr><td>Turned on the lamp in all positions</td><td>1, 3, 8, 9, 11, 15, 18, 22</td><td>1, 3, 8, 11, 13, 15, 17, 20, 22</td><td>6</td><td></td></tr>
<tr><td>TOTAL NUMBER</td><td>19</td><td>19</td><td>12</td><td colspan="2">7</td></tr>
</table>

The person's choice to turn on the lamp or leave it off

The test setup involved the options to turn on the lamp or leave it off. We have analysed to what extent the subjects were consistent in choosing one or the other option at each of the work desks. Table 11 presents this for those 19 persons who participated in both test series.

The table shows that 12 of the 19 persons were fully consistent in their choice to turn on the lamp or not, and 7 persons turned on the lamp once more in one series than in the other. No person showed larger variation than this. The results imply that the preferences for lamp on or off were relatively stable for each of the subjects.

The person's pattern of choice between the three work desks

To see the subjects' consistency when choosing illuminance for each of the three work desks, we made a Pearson correlation analysis of each person's chosen illuminance in Series 1 and 2 respectively, at each of the desks. This showed a strong positive correlation for work desk A and work desk B and a slightly weaker but still significant positive correlation for work desk C (See Table 12). Thus we can conclude that the subjects tended to be consistent with themselves in their choice of light level.

Table 12.
Correlation between chosen illuminances in Series 1 and Series 2.

Correlation between	Correlation coefficient	Significance level
A chosen Series 1/ A chosen Series 2	0,66	0,01
B chosen Series 1/ B chosen Series 2	0,76	0,01
C chosen Series 1/ C chosen Series 2	0,59	0,05

Further analysis of individual choices

As another method to judge the subjects' consistency we drew one diagram for each person, with two lines representting Series 1 and 2. Consistency was assesssed from a simple visual comparison between the two lines. If the differences between all three values (A-B, B-C, A-C) had the same direction in both series, the subject was categorised as clearly consistent. If all these differences had different directions in both series, the subject was categorised as clealy inconsistent. Between these categories there were a number of subject categorised as partly consistent. Note that the categories do not refer to consist choice of total light level. See Table 13.

A first question to be analysed was: Could the subject's consistence or lack of consistence be explained by the weather conditions being different in Series 1 and 2? These conditoins are presented in Table 14. The analysis gave the following results:

- Seven persons were categorised as clearly consistent. Four of these had even weather conditions in both series, whereas three had varied weather in one series and even in the other.
- Seven persons were categorised as partly consistent. Four of these had even weather conditions in both series, whereas two had varied weather in one series and even in the other, and one had varied weather in both series.
- Five persons were cetegorised as clearly inconsistent. Two of these had even weather conditions in both series, two had varied weather in one series and varied in the other, and one had varied weather in both series.

We can conclude that the weather variations as such could not explain the difference between the three groups.

For further understanding, we proceeded to the individual level. For some of the subjects, we made a further analysis of their choices, based on the detailed preconditons during each session, as presented in Table 14, combined with the subjects' replies to open end questions after the session. Available data allow for a similar analysis for all the subejcts, but this has not been possible within the time limits of the current project.

Clearly consistent subjects

From the group of seven clearly consistent subjects, we chose to further analyse three that made typically different choices in Series 1 (subjects 1, 4 and 21) together with one of those that had a disinct difference in weather conditions between the two series (subject 12). See Figures 19, 20 and 21.

For subject 1 (Fig. 19), the daylight level was very similar in both series, except for work desk A, which had 300 lux in Series 1 and 200 lux in Series 2. This subject has consistently chosen the highest possible illuminance, that is a fully dimmed up lamp, in all situations except for work desk B in Series 2, when she had the lamp almost fully dimmed up. Thus the chosen illuminances show very similar patterns, and the lower level in Series 2 is totally an effect that can be fully explained by the fact, that higher illuminance could not be obtained.

For subject 4 (Fig 20), the daylight level was higher in Series 2 than in Series 1, for all three work desks. The subject's choice of illuminance was almost identical in both series, which means that the difference in daylight level did not affect the choice.

Subject 21 (Fig. 21) chose not to turn on the lamp at all, and the small differences between Series 1 and 2 can be fully explained by the daylight variation: the daylight level at desk A was higher in Series 1, whereas the level at desk C was somewhat lower in Series 1.

For subject 12, the measured illuminance given by daylight was approximately the same in both series. Daylight was, however, even in Series 1 and strongly varying in Series 2. In Series 1, the subject chose to have the lamp turned off at desk A and B and lit it only at desk C. In Series 2, the lamp was turned off only at desk A. The choice, in Series 2, to light the lamp at desk B and to choose a higher illuminance at desk C could be an effect of the strongly varying daylight during this session.

Table 13.
Subjects with different level of consistance, according to visual analysis of choice diagrams. N=19

	Subject no	Number of subjects in category	See Figure
Clearly consistent	1, 4, 11, 12, 21, 23, 25	7	19, 20, 21, 22
Partly consistent	3, 8, 17, 18, 20, 22, 24,	7	23, 24, 25, 26, 27, 28, 29,
Clearly inconsistent	2, 9, 10, 13, 15,	5	30, 31, 32, 33, 34

Table 14.
Daylight levels at desks (lux), weather and degree of daylight variation for those 19 subjects who took part in both Series 1 and 2.

Subject no	Series 1				Series 2				
	Desk A	Desk B	Desk C	Weather	Desk A	Desk B	Desk C	Weather	Daylight variation catego-ry (see Table 8)
CLEARLY CONSISTENT SUBJECTS									
1	300	80	40	Overcast, even	200	80	40	Clear, even	A
4	90	50	20	Varied clouds/clear	170	70	40	Clear, even	A
11	260	20	10	Overcast, even	120	50	30	Clear, even	A
12	300	60	30	Overcast, even	260	80	40	Varied clouds/ clear, some snowfall	D
21	220	70	30	Clear, even	180	70	50	Clear, even	A
23	200	50	20	Overcast, even	320	110	60	Clear, even	A
25	100	30	10	Overcast with increasing rain	150	70	40	Clear, even	A
PARTLY CONSISTENT SUBJECTS									
3	210	60	20	Varied clouds/clear	230	60	30	Clear, even	A
8	200	40	10	Overcast, even	240	110	70	Clear, even	A
17	540	150	60	Overcast, even	150	70	40	Clear, even	A
18	170	50	20	Varied clouds/clear	450	130	50	Overcast, snowfall	D
20	170	60	20	Clear, even	180	70	40	Clear, even	A
22	280	70	30	Varied clouds/clear	200	60	30	Varied clouds/ clear, some snowfall	D
24	230	70	20	Overcast, even	170	70	40	Clear, even	A
CLEARLY INCONSISTENS SUBJECTS									
2	190	60	20	Overcast, rain, even	170	70	40	Clear, even	A
9	450	70	20	Varied clouds/clear	150	70	40	Clear, even	A
10	100	20	10	Varied clouds/clear	160	70	40	Varied clouds/ clear	D
13	260	160	70	Overcast, even	430	120	50	Overcast, some snowfall	D
15	210	40	10	Overcast, even	170	70	30	Clear, even	A

Clearly consistent subjects

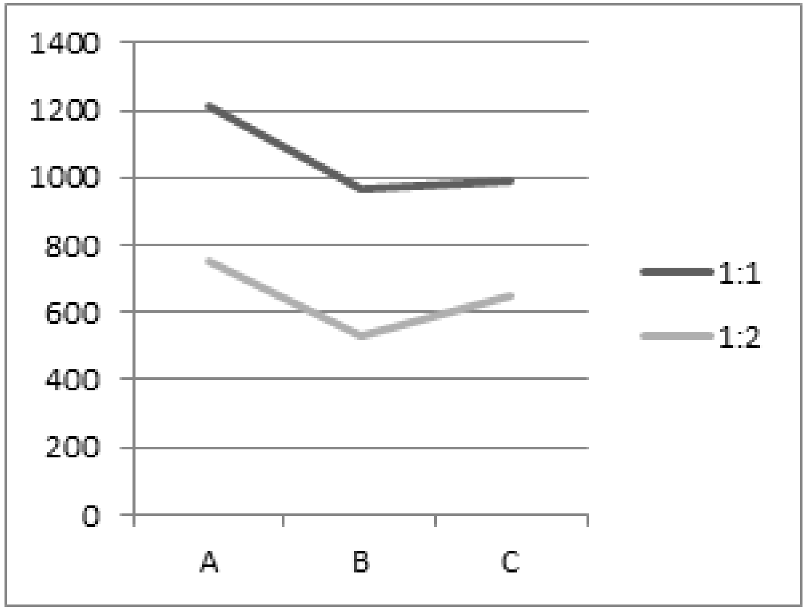


Figure 19. Subject no 1, chosen illuminances (lux) in both series. Clearly consistent.

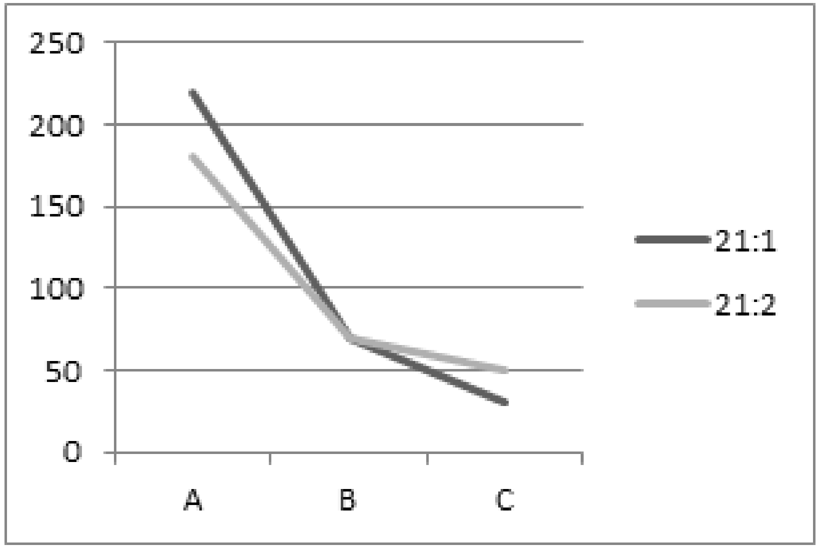


Figure 21. Subject no 21, chosen illuminances (lux) in both series. Clearly consistent.

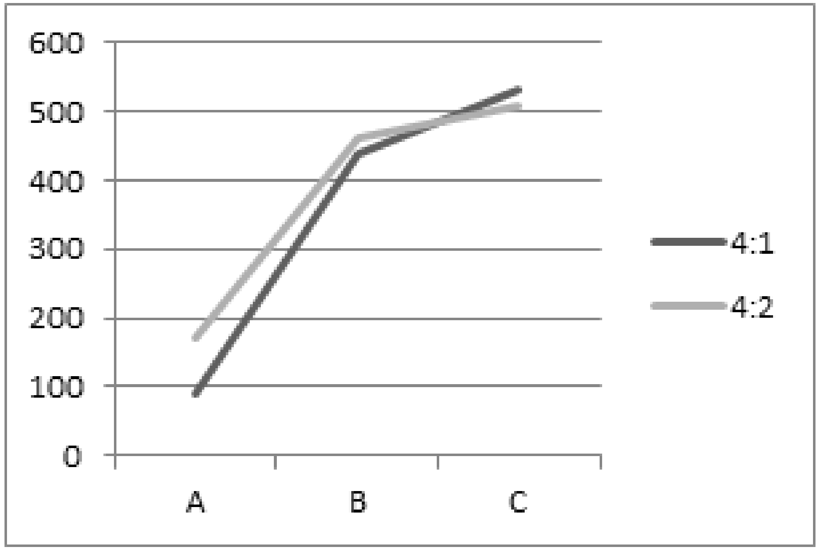


Figure 20. Subject no 4, chosen illuminances (lux) in both series. Clearly consistent.

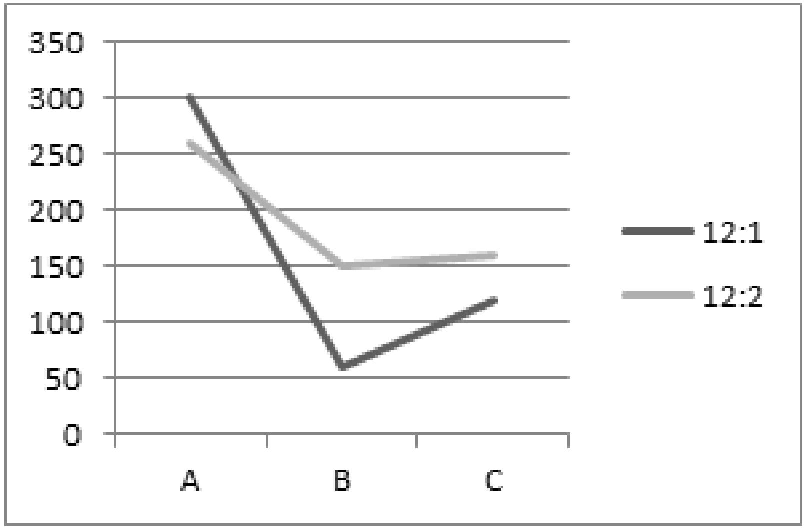


Figure 22. Subject no 12, chosen illuminances (lux) in both series. Clearly consistent.

Partly consistent subjects

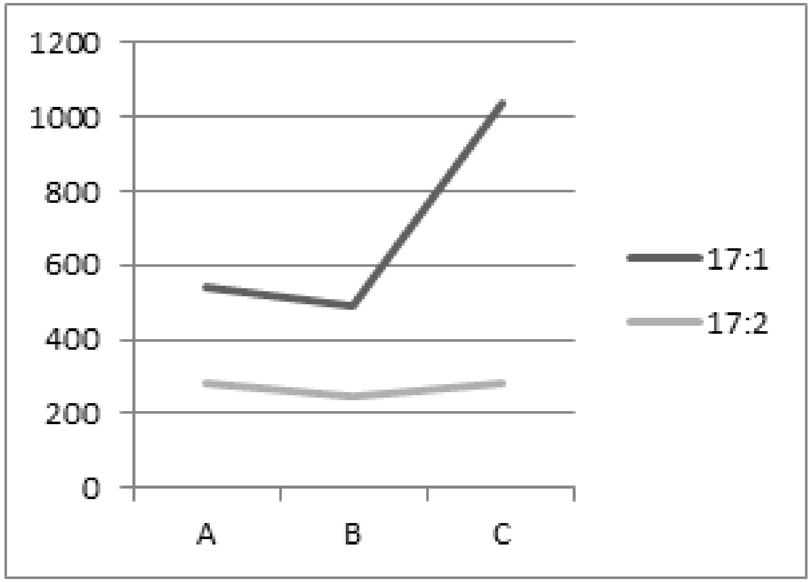


Figure 23. Subject no 17, chosen illuminances (lux) in both series. Almost consistent.

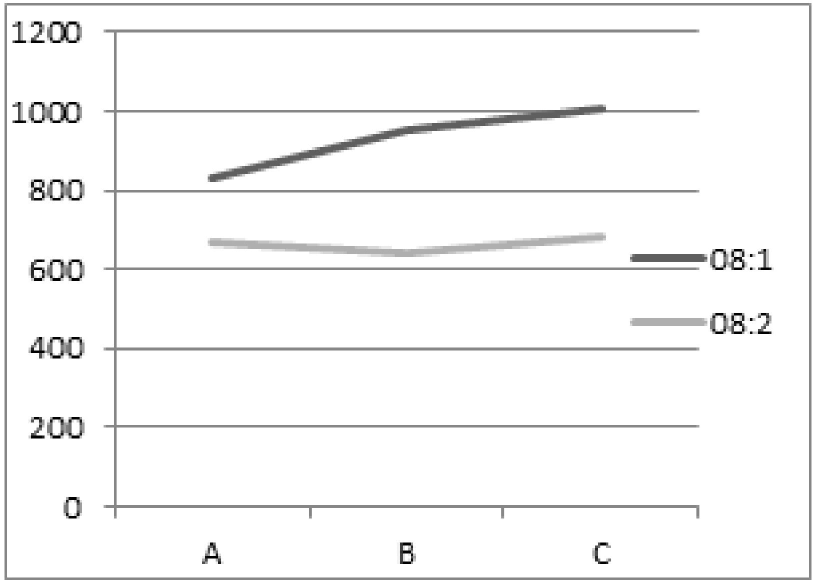


Figure 24. Subject no 8, chosen illuminances (lux) in both series. Almost consistent.

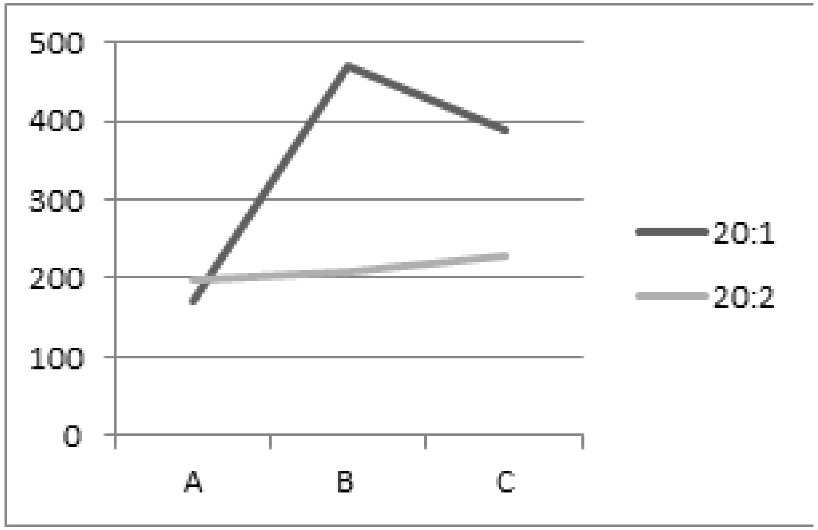


Figure 25. Subject no 20, chosen illuminances (lux) in both series. Almost consistent.

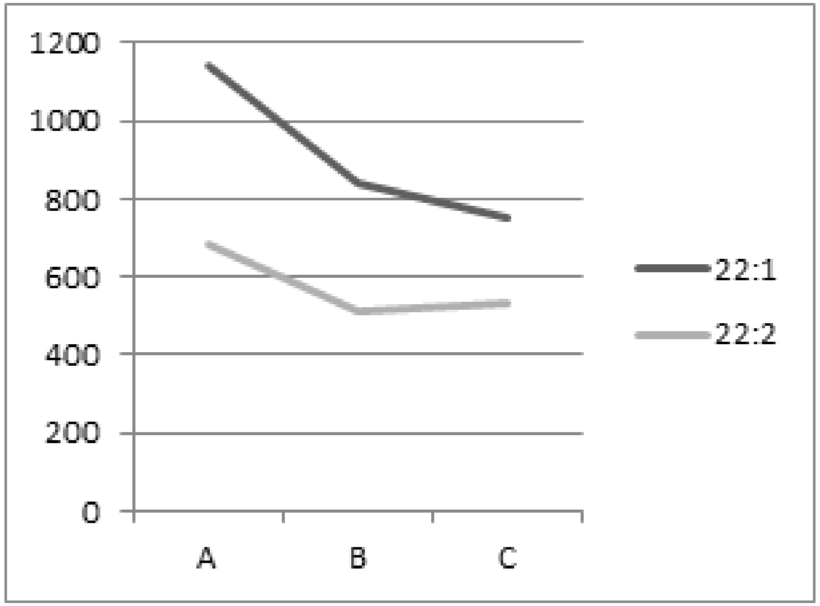


Figure 26. Subject no 22, chosen illuminances (lux) in both series. Almost consistent.

Partly consistent subjects

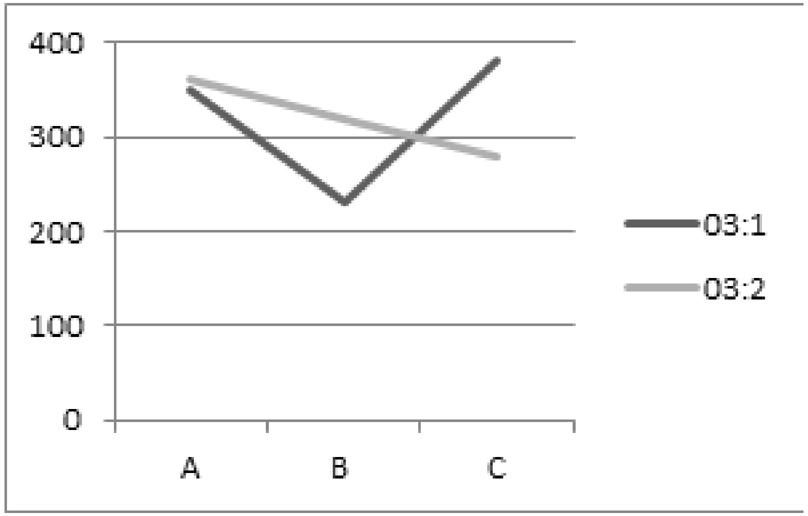


Figure 27. Subject no 3, chosen illuminances (lux) in both series. Partly consistent.

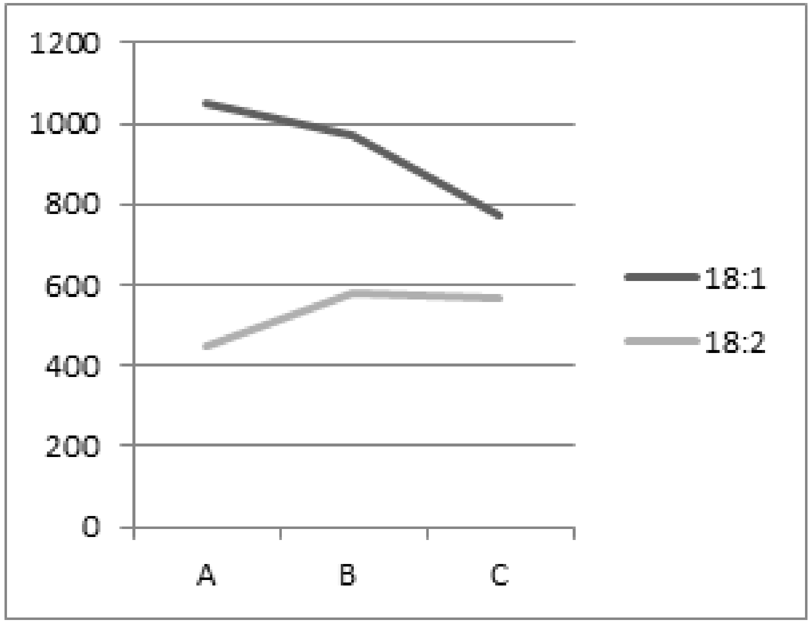


Figure 28. Subject no 18, chosen illuminances (lux) in both series. Partly consistent.

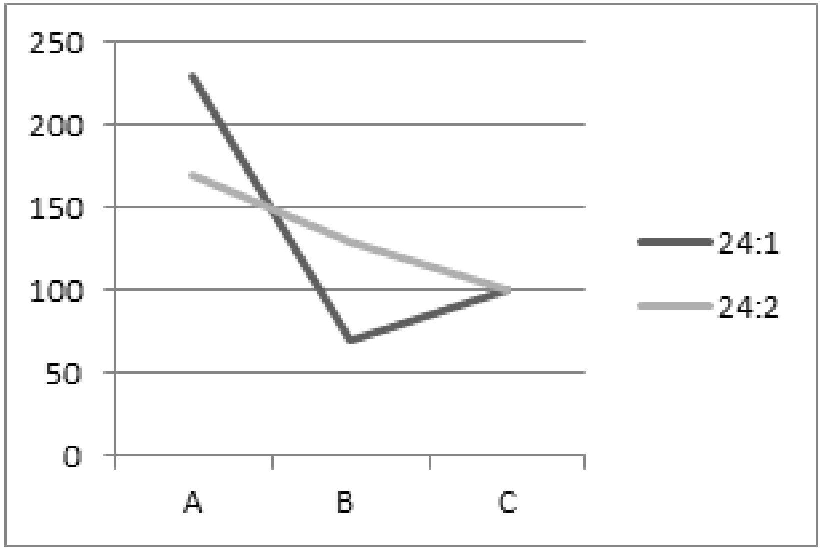


Figure 29. Subject no 24, chosen illuminances (lux) in both series. Partly consistent.

Partly consistent subjects

Seven subjects were categorised as partly consistent. For one of these (no 17) the inconsistency was marginal, as a 10 lux difference in one of the six choices would have placed the subject in the group of consistent subjects. For three more (no 8, 20 and 22), a 30 lux difference in one of the choices would have placed them in the group of consistent subjects. These four are not further analysed, but judged as almost consistent. See Figures 23, 24, 25 and 26.

The three remaining subjects that were classified as partly consistent (no 3, 18 and 24) were analysed in more detail. For two of these (18 and 24) we can see that the inconsistency shown in the diagram can be explained by one single value that should not be taken as a sign of personal inconsistency. For one (no 3) the inconsistency is more profound but can be explained by weather conditions. See Figures 27, 28 and 29.

As is shown in Table 14, subject 3 (Figure 27) performed both sessions with rather similar illuminance given by daylight, but with variation between cloudy and clear sky in session 1 and consistently clear sky in session 2. In session 1, the subject's own comment is that she probably would have chosen different illuminance if the test session had lasted one more hour, because the daylight varied so much. In session 2, with stable light, she does not think that another hour's test would have altered her choice. Thus we can suspect that her lack of consistency is caused by the varying daylight situation.

Subject 18 performed both series under varying weather conditions, and the general daylight level in the room was much higher in Series 2 than in Series 1. The lamp was turned on in all situations except for desk A in Series 2, where the daylight provided 450 lux. Thus the lack of consistency can possibly be fully explained by the choice not to turn on the lamp in the one situation, which had by far the highest illuminance given by daylight.

In Series 1, subject 24 (Figure 29) has the lowest illuminance at desk B. This is an effect of her choice not to turn on the lamp at desk A and B but only at desk C. In Series 2, she turned on the lamp at both desks B and C, but not at desk A. Looking at Table 14 you can detect a breaking point for daylight level at approximately 70 lux, where the subject either turns on the lamp or not. Thus the difference between the two lines can be explained by marginally inconstant choices near this breaking point; that is at desk B.

Clearly inconsistent subjects

Five subjects were caracterised as clearly inconsistent.See Figures 30, 31, 32, 33 and 34

For subject 2, the daylight conditions were even and gave a rather similar illuminance. In both series, the subject chose not to turn on the lamp at desk A. The choices for desks B and C are very different in the two series and cannot be explained by weather conditions or the subject's own comments. Thus this subject appears to have been truly inconsistent.

For subject 2, the daylight conditions were even and gave a rather similar illuminance. In both series, the subject chose not to turn on the lamp at desk A. The choices for desks B and C are very different in the two series and cannot be explained by weather conditions or the subject's own comments. Thus this subject appears to have been truly inconsistent.

For subject 9, the daylight conditions were significantly different in both series. In Series 1, the weather vas varying and the measured daylight at the different desks varied between 450 (desk A) and 20 (desk C). The choices in that series are very variable, in a way that is difficult to interpret. In Series 2, the weather was even with much smaller variations between desks. In that series, the lamp was turned on only at desks B and C, and at all desks the subject chose an illuminance only slightly higher than the one given by daylight at desk A. The comments given by the subject are scarce and do not allow any further analysis. It cannot, however, be excluded that the chosen illuminance differences were at least partly caused by the varying daylight conditions.

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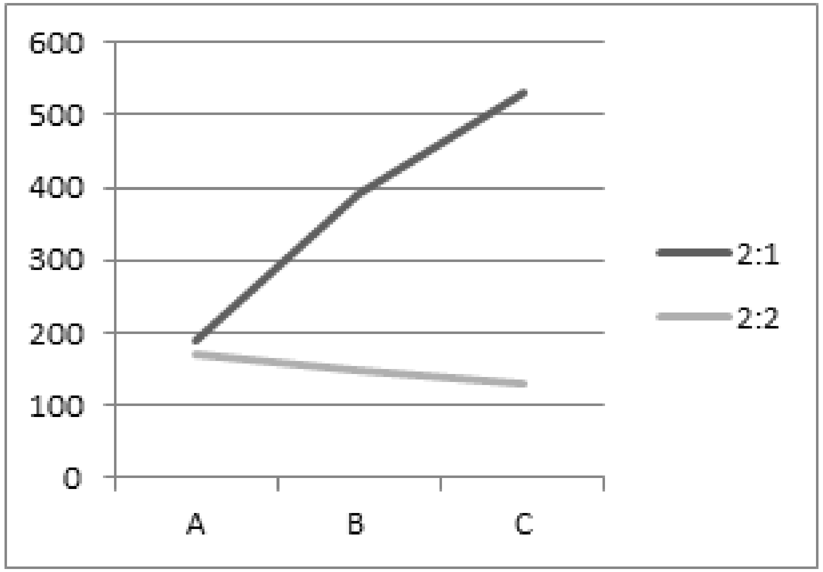

Figure 30. Subject no 2, chosen illuminances (lux) in both series. Clearly inconsistent.

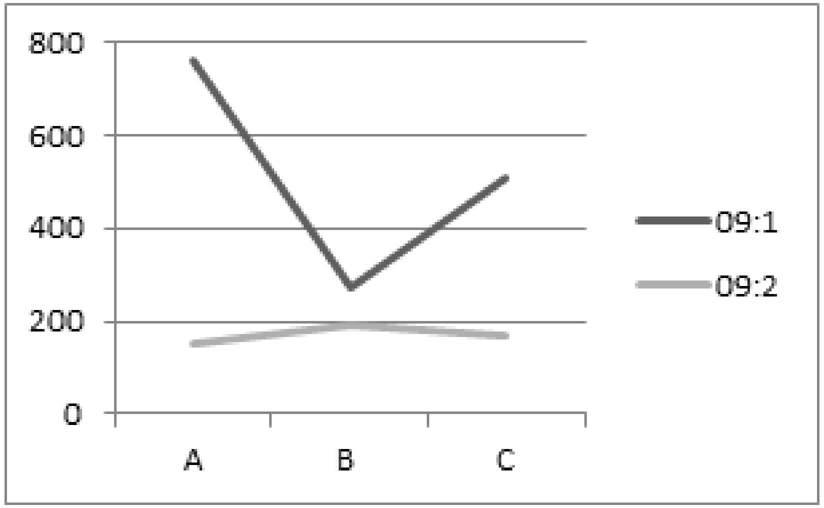

Figure 31. Subject no 9, chosen illuminances (lux) in both series. Clearly inconsistent.

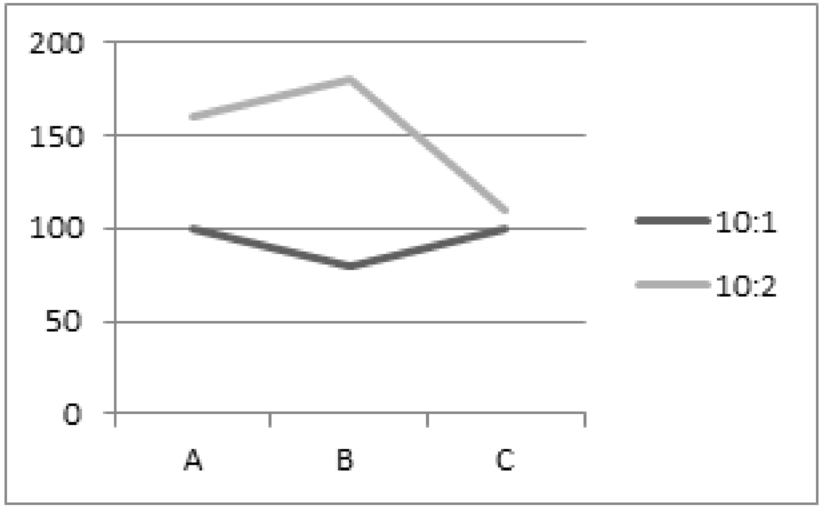

Figure 32. Subject no 10, chosen illuminances (lux) in both series. Clearly inconsistent.

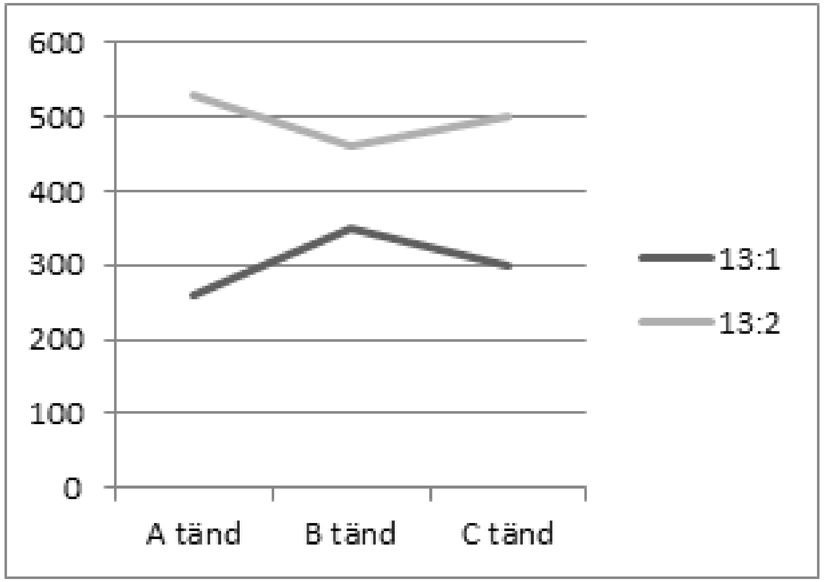

Figure 33. Subject no 13, chosen illuminances (lux) in both series. Clearly inconsistent.

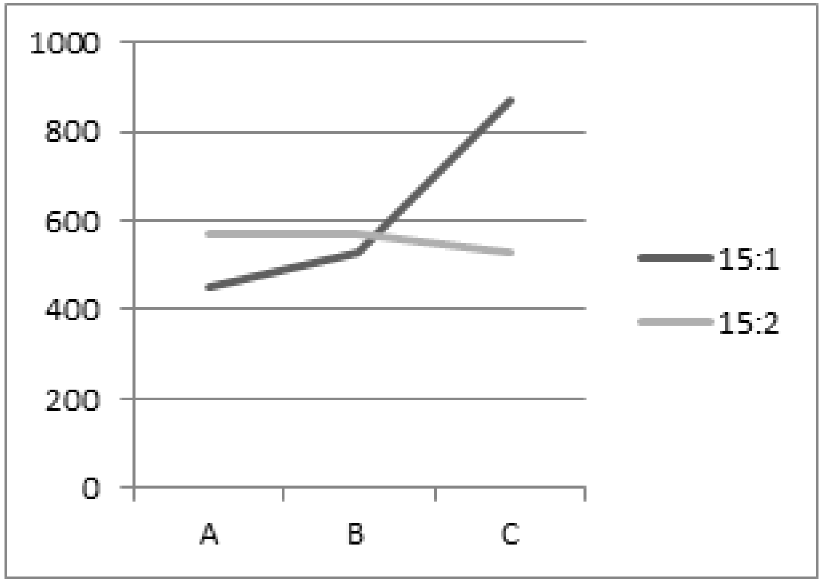

Figure 34. Subject no 15, chosen illuminances (lux) in both series. Clearly inconsistent.

For subject 10, the weather varied during both sessions, and in the session of Series 1 the measured daylight illuminance was significantly lower than the intended. In both series the subject chose not to turn on the lamp at desk A. At desk C the chosen illuminance, with lamp turned on, differed only 10 lux between the series, whereas the chosen illuminance at desk B differed 100 lux. If the chosen illuminance at desk B in Series 1 had been 30 lux higher, the subject would have been categorised as consistent. The subject's comments give no basis for further analysis. It cannot, however, be excluded that the chosen illuminance differences were at least partly caused by the varying daylight conditions.

For subject 13, the daylighting situation was even in session 1 and very fluctuating in session 2. The measured daylight illuminances varied within a much larger span in session 2. In session 1, the lamp was not turned on at desk A, but in session 2 it was turned on at all desks. In her comments to session 1, the subject said that she might have raised the illuminance somewhat if she was to read for one more hour. No corresponding comment was given for session 2. It cannot, however, be excluded that the chosen illuminance differences were at least partly caused by the varying daylight conditions.

For subject 15, the weather conditions were even in both sessions. The lamp was turned on in all situations. The subject's comments give no basis for further analysis. This subject appears to have been truly inconsistent.

Conclusions regarding personal illumination preferences

Similar to our previous study *Ljusförstärkande färgsättning av rum* [51], the analysis shows a surprisingly large personal consistency, in spite of the time gap of almost half a year between Series 1 and 2. The analysis of the subjects categorised as partly consistent or clearly inconsistent shows that their choices in several cases could be seen, not as personal inconsistency, but rather as consistent responses to uncontrollable external conditions.

We conclude that the large variations that have been found are not random. We can see that different persons have different preferences that are relatively consistent, but by no means exact. This conclusion agrees with Monica Säter's findings that personal preferences regarding the light situation vary in a high extent and are almost unique. [52]

51 Häggström & Fridell Anter 2012b; Häggström & Fridell Anter 2012a
52 Säter 2012 p181.

8

Age, visual ability and self-esteemed problems with dim light

Age

Increased age leads to alterations in our eyes, which normally makes us more sensitive to glare and result in a general need for higher illuminance. [53] This made us expect that the older subjects in our test would choose higher illuminance than the younger ones.

To test this, we divided the subjects within each series in two groups, over and under the median age, and compared them regarding the chosen illuminance in each of the positions A, B and C. The results are shown in Tables 15 and 16. Surprisingly enough, there was a consistent but not significant difference indicating that the younger subjects generally chose a higher illumination.

For the 32 persons in test Series 2 we also calculated the correlation between each person's age and his/her mean chosen illuminance at all three work desks. This showed a negative correlation between age and chosen illuminance (Pearson $r = -0{,}39$, significant at 0.05 level).

Thus the results of our study contradict the intuitive notion that older people want more light. The reasons for this have not been further investigated.

From the general knowledge about older people's sensitivity to glare, we also found it likely that older persons, with a relatively more clouded lens, would be more disturbed by the side light from the window near work desk A. This has not been analysed within the current project, but could be analysed with use of available data.

53 Brunnström 2004. VISSLA (Thaung et al. 2012) is a recently developed software tool for visualising and simulating the effects of different visual impairments.

Table 15.
Illuminances chosen by subjects under and over median age (44 years). Series 1. Subjects who did not turn on the lamp at all or consistently had it fully dimmed up are excluded. N=21.

Position	Age group	n	Mean chosen illuminance, lux	Standard deviation	Comment on difference between age groups
A lit	Younger	10	508	372	Younger chose higher illuminance
	Older	11	351	205	Difference not significant
	All	21	426	299	
B lit	Younger	10	524	342	Younger chose higher illuminance
	Older	11	314	180	Statistical tendency (sig. = 0,09)
	All	21	414	283	
C lit	Younger	10	483	300	Younger chose slightly lower illuminance
	Older	11	495	317	Difference not significant
	All	21	489	302	

Table 16.
Illuminances chosen by subjects under and over median age (45 years). Series 2. Subjects who did not turn on the lamp at all or consistently had it fully dimmed up are excluded. N=25.

Position	Age group	n	Mean chosen illuminance, lux	Standard deviation	Comment on difference between age groups
A lit	Younger	12	475	246	Younger chose higher illuminance
	Older	13	350	202	Difference not significant
	All	25	410	229	
B lit	Younger	12	397	165	Younger chose higher illuminance
	Older	13	294	170	Difference not significant
	All	25	343	172	
C lit	Younger	12	506	112	Younger chose higher illuminance
	Older	13	311	204	Difference significant (sig. = 0,0
	All	25	404	191	

Visual acuity and contrast sensitivity

The tests of visual acuity and contrast sensitivity were introduced in Series 2 in order to detect, if differences in the visual performance of the subjects could influence their choice of illuminance. See Figures 8 and 9. The test panels were designed to be viewed from reading distance, sitting by the desk, in about 70 lux illuminance and with the use of reading glasses, if the person used such. The obtained measurements allow comparisons between different subjects' visual performance in a situation that was as close to the test situation (illuminance choice) as possible. They give, however, no measurements that can be compared to those obtained with other tests in other situations.

The visual acuity test included text down to the size of 4 points. According to their ability to read text of different sizes, the 32 subjects were divided into four groups, see Table 17. Within each group, the averagely chosen illuminance was calculated. The results show no correlation between visual acuity and chosen illuminance.

The contrast sensitivity test included text with "brightness" down to 99%. [54] Here no significant differences between subjects were found: Almost all of them (30 out of 32) could without any problems read text with up to 95% "brightness" but most often (25 subjects) not at all the 98% row. 7 subjects could read even the 99% row with some errors.

Two of the 32 subjects had slightly less contrast sensitivity and could only read text with up to 90% "brightness" without problems and one of them could not at all read the row with 95%. These two both chose averagely lower illuminance than the total group, a matter that cannot be interpreted as they were only two.

Thus there are no indications that the visual acuity or contrast sensitivity of the subjects would have affected their choice of illuminance.

54 The "brightness" percentages are taken from the Photoshop tool used for designing the charts. Thus they are not very precise, but still make it possible to compare the observers.

Table 17.
Results of visual acuity test, Series 2

Could read without difficulty	Could not read	Subject no.	Number of subjects	%	Averagely chosen illuminance, lux
8 points	6 points	2, 4, 9, 10, 11, 12,	6	19%	248
6 points	4 points	1, 3, 17, 20, 21, 22, 23, 27, 28, 29, 31, 32, 36	13	41%	339
6 points	-	18, 38	2	6%	575
4 points	-	8, 13, 15, 24, 25, 26, 30, 33, 34, 35, 37	11	34%	465
SUMMA			32	100%	380

Self-esteemed problems with dim light

As part of the interview that introduced the test session, subjects were asked how often they experienced problems with too dim light. See Figure 35. A comparison between the same person's answers in test Series 1 and 2 was made, in order to evaluate the intra-subjective consistency. 14 persons marked the same box both times, and the rest marked boxes next to each other. We can conclude that subjects were consistent in their assessment of themselves.

This leads on to the question whether the subjects' self-esteemed acceptance of dim light correlated with their illuminance choices in the test. This was tested for the 32 persons in Series 2, and as shown in Table 18 the correlation was high. Those subjects who often, or rather often, experienced problems with dim light chose in average higher illuminance and more often dimmed up the lamp fully, whereas those who seldom or never experienced problems with dim light chose lower illuminance and more often kept the lamp turned off.

It is, however, interesting to note that the subjects' age did not influence their self-esteemed problems with dim light.

□

4. Mark the sentence that describes you best

□ I very often experience problems with too dim light

□ I rather often experience problems with too dim light

□ I seldom experience problems with too dim light

□ I never experience problems with too dim light

Figure 35. Translation of part of the Swedish language questionnaire to subjects, see Appendix 1.

Table 18.
Self-esteemed problems with dim light, age and chosen illuminances, Series 2 (n=32).

Experience of problems with too dim light, according to question 4	Subject no	Number of subjects	Average age	Average chosen il-luminance (lux)	Situations when lamp was not turned on, percentage of (number of subjects x 3)	Situations when lamp was fully dimmed up , percentage of (number of subjects x 3)
Very often	31	1	58	587	0	33
Rather often	3, 4, 9,12, 17, 20, 22, 26, 27, 32, 33, 37, 38	13	46	445	8	21
Seldom	1, 2, 8, 10, 11, 13, 15, 18, 21, 23, 25, 28, 30, 34, 35, 36	16	47	347	38	10
Never	24, 29	2	57	127	33	0
ALL SUB-JECTS IN SERIES 2		32	48	381	24	15

9 Subjects' comments on reading light

After the test, subjects were asked to tell their impressions and thoughts about the test and about reading light in general. Most of the answers were vague and do not offer much basis for analysis, probably because the subjects were not trained to talk about light and did not have the concepts and vocabulary to describe or specify their experiences in this field. It also appeared that most of the subjects did not usually use a dimmable light source when reading.

Out of the totally 38 subjects, 10 (26%) spontaneously mentioned that they appreciated daylight for reading.[55] The relatively few other specific comments stated preferences regarding the colour of light (warm or cool were both mentioned positively) or regarding the intensity of light. Some subjects explicitly preferred strong light, but it was more common to express preference for light that was soft and not too strong. Some specifically said that they could adapt to a rather low light level if they were not exposed to strong light, and that such adaption takes some time. They – or others – also said that once they had turned on the lamp it was not comfortable to turn it off again. One (fp4) spontaneously supported the project's main hypothesis – that was not told to the subjects - when saying that she could accept and appreciate rather low light when it is daylight, but when she turns on a lamp she wants more light.

Also the direction and spatial distribution of light were mentioned, and here the preferences differed as well. Among mentioned preferences for reading light were: From my back, from the side, from up, direct light, indirect light, lamp in the ceiling, desk lamp, many small light sources. One subject expressed the need for more light in the room, but not on the book. The only recurrent comment was the wish to avoid glare (5 subjects).

One subject, who was among the few with professional connection to lighting issues, explicitly preferred incandescent light, as it gives shadows that enhance the relief of the text, whereas fluorescent light was negatively described as flat. This subject, and one other, specified that a 60W incandescent light gives good reading light.

A few subjects commented the issue of feeling awake or tired. Three persons said that a higher light level - or the change from lower to higher light level - helps alertness. One

[55] Subjects no. 2, 4, 8, 10,13, 16, 22, 23, 35, and 36.

of them said that the eyes get tired in too low light, whereas another person said that the eyes rest best when there is neither too much nor too little light.

All subjects were asked whether they thought that they would choose another light level than in the test, if they were to read for one more hour. Their replies are presented in Table 19.

Those subjects who participated in both series were most often consistent in their replies. In both series, a majority of the totally 38 subjects stated that they would chose the same light level also for longer reading. 16 subjects said that they would, or perhaps would, change it in one or both series. Out of these, four stated that they would raise the level and two that they would lower it. Four persons explicitly referred to the varying daylight situation and said that they were likely to change the reading light according to the daylight.

Table 19.
Subject's replies to the question "Do you think that you would have chosen another light level than what you have now done, if you were to read for one more hour?"

	No	Yes, higher	Yes, lower	Yes, not specified how	Yes, depen-ding on my body position	Possibly, depends on changing daylight	Possibly, for other reasons	No answer/ Do not know
Series 1 (n=25)	14	2	1	1	1	3	3	
Series 2 (n=32)	20	2	2	1	1	2	2	2
Individuals who chose this option in one or both series	26	4	2	1	1	4	4	2

10 Measurements of ambient lighting

Resent research indicates that the task performance and visual comfort are affected not only by the illuminance on the piece of work but also by the lighting in a larger part of the visual field.[56] This also forms the basis for recommendations regarding office lighting, where the current Swedish recommendations give figures for the illuminance relationships between the task area, the outer part of the desk, and the room, with specified values for walls and ceiling.[57] In our tests, the ambient lighting was measured directly after each reading task, in four positions on the table and (in Series 2) one position on the wall in front of the subject. See Figures 11 and 12. The averages of these measurements are shown in Tables 20 and 21.

An analysis of these measurements has not been possible within the scope of this project, but data are available for possible future analysis.

56 Govén et al. 2010
57 Ljuskultur 2013p 146

Table 20
Measured illuminance (lux) on the book and ambient illuminance, Series 1. Average for those 21 subjects who had turned on the lamp in at least one situation and not dimmed it up totally in all situations.

	On the book	Average ambient light on the table
DESK A		
Chosen illuminance	426	94
Part given by daylight	230	88
Part given by lamp	196	6
DESK B		
Chosen illuminance	407	85
Part given by daylight	62	71
Part given by lamp	345	14
DESK C		
Chosen illuminance	496	71
Part given by daylight	25	49
Part given by lamp	471	22

Table 21
Measured illuminance (lux) on the book and ambient illuminance, Series 2. Average for those 25 subjects who had turned on the lamp in at least one situation and not dimmed it up totally in all situations.

	On the book	Average ambient light on the table	On the wall
DESK A			
Chosen illuminance	410	105	242
Part given by daylight	210	92	196
Part given by lamp	200	13	46
DESK B			
Chosen illuminance	343	94	127
Part given by daylight	74	78	60
Part given by lamp	269	16	67
DESK C			
Chosen illuminance	404	62	90
Part given by daylight	39	37	30
Part given by lamp	365	28	60

11 Method evaluation

The method of successive approximation

The tests within the project were performed under conditions that were not fully controlled. To some extent this was an inevitable consequence of the fact that the study object was daylight: Variability is one of the most important characteristics of daylight, and if it should be attempted to eliminate its variation the study would no longer be of daylight.

Apart from this, it was also a conscious choice to create a test situation that opened for other questions than those tied to the original hypothesis. We wanted to perform a scientifically solid hypothesis test, and at the same time create the possibility to find unpredicted correlations and to formulate new questions. This was based on an understanding that both spatial reality and human perception are very complex, and that the most relevant questions need not be those that are easiest to formulate and test. In the method *successive approximation*, the process of evaluating and reformulating the test situation and the questions is an important part of the research work. [58]

To achieve this, the tests were planned and conveyed in two series, each of them concluded by a reference group meeting where test design, results, conclusions and new questions were discussed in an interdisciplinary expert group. These meetings were not mere "control stations" but indispensible components of the research process. Among other things they resulted in those new questions that have been discussed in Section 5 (last part) and 6-8 in this report.

We can conclude that this method made it possible for us to, within the framework of the project, formulate and investigate a number of relevant questions in addition to the testing of the original hypothesis.

58 The method "successive approximation" is presented and discussed in Fridell Anter 2011 p 12.

Method questions regarding the variation of daylight

As already mentioned, the variation that characterises daylight made it impossible to fully control the illuminance given by daylight. This lead to differences in the daylight conditions, both between different subjects, and within the test session of the single subject. The daylighting differences from one day to another did not matter when testing the original hypothesis, as every subject performed the test during a maximum of one hour and comparisons were made between the three desks, not between subjects. The variation within the test session of each subject did, however, turn out to be important, and gave the material for a fruitful analysis of the effects of short term daylight variations on the choice of reading illumination (see Section 8).

Thus we can conclude that the lack of control possibilities led to an enhanced understanding, in a way that had not been possible if we had eliminated the natural variations of daylight.

The method of subjects choosing the illuminance of reading light

The method where subjects are asked to use a dimmer to choose the light that they prefer has earlier been used and evaluated as reliable in the project *Light enhancing colour design of rooms*. [59] In the current project, we can confirm the reliability of the method, as the subjects were largely consistent in their choices and as the analysis of the chosen illuminances gave significant and interpretable results.

The analysis of the subjects' consistency with themselves did not only serve as a reliability test, but also gave an understanding of individual differences that cannot be detected by conventional analysis of whole groups. The method for such analysis of individual consistency has been developed within the project and can prove to be fruitful also in other contexts.

59 Häggström & Fridell Anter 2012b s26ff

The unintended fact that the maximal illuminance on the book was different in the two series made it impossible to compare the two test series to the extent that was originally planned. As a ground for a deeper analysis of preferences it would also have been valuable to register the colour temperature at the different desks during the tests. This refers to both the colour temperature given by the daylight, which varied also in this aspect, and the colour temperature given by daylight in combination with the chosen light from the lamp.

Correlation between the presentation order and the chosen illuminances

In her studies of lighting in office rooms, Annika Kronqvist found that the presentation order had a substantial influence on subjects' room evaluations, overriding possible influence of the lighting. [60] To test if the order of presentation had any influence on the chosen illuminances in our studies we used two methods. Firstly we divided the subjects in each series according to the work desk, where they had performed the reading task for the first time. This gave three groups that were compared to each other within each series. Secondly we divided each of these groups according to the subsequent order of presentation, and compared these six groups within each series. None of these comparisons showed any differences between the groups. Thus we can conclude that in this study, the order of presentation between the three analysed situations had no effect on the results.

Age and gender distribution of subjects

The subjects were recruited primarily through personal contacts. This lead to an uneven age distribution. Seven out of totally 38 subjects were over 65 years old, and only four were under 30. Gender distribution was even more uneven, with a solid dominance of women (see Table 1). However, as the subjects were consistently compared to themselves, the uneven distribution was not important for the testing of the original hypothesis. Furthermore, it was possible to conduct an analysis of the correlation between age and chosen illuminance (see Section 7), but the gender distribution was too uneven to allow a similar analysis comparing men and women. In future studies, a more even age and gender distribution could possibly show so far unexplored differences between different groups.

The tests of visual acuity and contrast sensitivity

The tests were constructed in order to control if any of the subject had visual deficiencies that would obstruct their reading and thus threaten the validity of their illuminance choices (see Figures 8 and 9). They fulfilled this purpuse. They were not, however, fully adaquate for more precise testing and grouping of subjects' visual prestanda in a situation were they read from a normal reading distance, using their ordinary visual aids (glasses or contact lenses). The test for visual aquity could be improved by removing the top three or four lines and instead adding steps with finer differences, and one or two lines with even smaller letters. The test for contrast sensitivity should, above all, use a smaller letter size.

60 Kronqvist 2012 p 63

12 Concluding discussion

The project started from a strive to reduce energy consumption for lighting and at the same time maintain or improve the illumination quality, as compared to existing technical solutions. An enhanced use of daylight could possibly favour both these objectives. Daylight is often esteemed as high quality lighting, and it is also the light that human vision is ecologically adapted to. From this background we posed the question whether the amount of daylight that reaches a work desk could affect the need for artificial lighting, not only through its contribution to the general illuminance, but also through its quality as specifically daylight.

Out hypothesis was formulated for a specific situation where subjects read a book sitting by desks in a partly daylit room, and could chose their reading illuminance with the help of dimmable halogen lamps. The hypothesis was, that in this situation there is a correlation between on the one hand daylight's relative contribution to total illuminance (daylight + artificial) and on the other hand the subjectively experienced need for total illuminance (daylight + artificial). It was hypothesised that the larger the relative amount of daylight, the less the need for total illuminance.

The tests showed a partial support for the hypothesis, but only under conditions that offered a stable adaptation level. Strong fluctuations in daylight made the subjects choose higher light levels than when the day lighting was stable, most likely to obtain a more stable working situation.

Also, it appeared that what is seen with peripheral vision, or only sensed "in the corner of your eye", affects the individually assessed need for task lighting. Both a luminant window next to the desk and an uneven shadow distribution on the desk could possibly have had this effect. This emphasises the importance of adaptation effects caused by the distribution of light, and by lightness differences between surfaces and light sources within all parts of the visual field.

Thus we can conclude that a well organised input of daylight could lead to a totally lower need for illuminance. This demands, however, stable conditions that to some extent contradict the very nature of daylight, and that are practically difficult to obtain in a country like Sweden, with its unpredictable weather with large short term variations. Here we suggest further research on methods to use daylight, which could work despite its natural fluctuations.

The perceived quality of light should not be understood as only its intensity, but include such factors as direction and spatial distribution, colour of light and colour rendering. As has been shown in previous research, one important and appreciated feature of daylight as delivered through windows is its even distribution in the room.[61] This finding agrees well with the general recommendations of balance between task light and ambient light.[62] Furthermore, the colour of light has previously been shown to be important for people's choice of task lighting.[63] These aspects of lighting have not been measured or analysed in the current project, but we suggest further research to investigate the relationship between preferred task illuminance, colour temperature and the general light level of the room.

In addition to testing the original hypothesis, the project has resulted in other findings on light and lighting. One such result was that different subjects chose very different illuminances for their reading task, and that subjects tended to be consistent with themselves in this choice. Their comments regarding preferred reading light also showed that some of them appreciated strong light, whereas others preferred a lower light level.

Recommendations regarding illuminance for different tasks give a minimum lux-value that should be delivered. For classrooms, which is the application example closest to our test situation, the Swedish planning guide "Ljus och rum" recommends 500 lux on the reading desks. [64] The mean chosen illuminance in our tests was 400 lux, i.e. well below the recommended value, but the span of chosen illuminances was as wide as 20-1210 lux. It should, however, be considered that the illuminances in our test were chosen during a short test. It is possible that subjects would have chosen other illuminances if they had worked in the room for a full day, and according to their replies regarding a similar question (see Table 19), this could have meant higher as well as lower illuminances. It is also possible that some of them chose lower illuminance than what was comfortable, because they wanted to show themselves or us that they could read with very little light. Irrespective of this, our results indicate that the recommended 500 lux would be inadequate for many of the subjects, either too high or too low. This implies that, to save energy, it would be more appropriate to deliver a lower general illuminance on working desks, and instead provide adjustable working lamps that can be used according to each individual's preferences.

In general, the current project shows the need for more research on adaptation effects in full scale real life situations. Our results imply that it is likely that a high general illuminance and/or the existence of glare raises the adaptation illuminance and thus makes us want even more light. Instead, a carefully designed lighting without glare or strong luminance contrasts could possibly make people adapt to a lower illuminance, without reduced task performance or visual comfort.

61 Fridell Anter 2011 p 42f.
62 Starby 2006 p 269, Ljuskultur 2013 p 142ff
63 Logadóttir & Christoffersen 2008; Logadóttir et al. 2013
64 Ljuskultur 2013 p 149.

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Appendices

Datum Fp nr

FÖRSÖKPERSONENS PROTOKOLL

Personuppgifter

Namn: ____

Mailadress: ____

Telefonnummer: _______________________________________

FP-INFORMATION

Kön: man / kvinna Ålder: ________

Kända / konstaterade synproblem?

____

____

____

Brukar du använda glasögon eller kontaktlinser när du läser? Ja □ Nej □
Har du på dig glasögon eller kontaktlinser under försöket? Ja □ Nej □
Är dina glasögon/linser tonade? Ja □ Nej □

I så fall hur? (Beskriv med egna ord)

____

____

1. Hur känslig uppskattar du att du själv är för starkt ljus?
(Jämför med vad du uppfattar som "normalt": sätt en ring på skalan nedan)

|_____________________________|_____________________________|

ovanligt okänslig — normal — ovanligt känslig

2. Sätt kryss för den beskrivning som bäst stämmer för dig

Upplever mycket ofta problem med för starkt ljus
Upplever ganska ofta problem med för starkt ljus
Upplever sällan problem med för starkt ljus
Upplever aldrig problem med för starkt ljus

3. Hur väl uppskattar du att du själv att du ser i mörker?
(Jämför med vad du uppfattar som "normalt": sätt en ring på skalan nedan)

|_____________________________|_____________________________|

ovanligt väl — normalt — ovanligt dåligt

4. Sätt kryss för den beskrivning som bäst stämmer för dig

Upplever mycket ofta problem med för svagt ljus
Upplever ganska ofta problem med för svagt ljus
Upplever sällan problem med för svagt ljus
Upplever aldrig problem med för svagt ljus

5. Överlag i vardagslivet: Har du lätt eller svårt för att bestämma dig?

|_____________________________|_____________________________|

väldigt lätt — väldigt svårt

vet inte □

Försöket påbörjas kl.

Väder (ringa in ett alternativ)

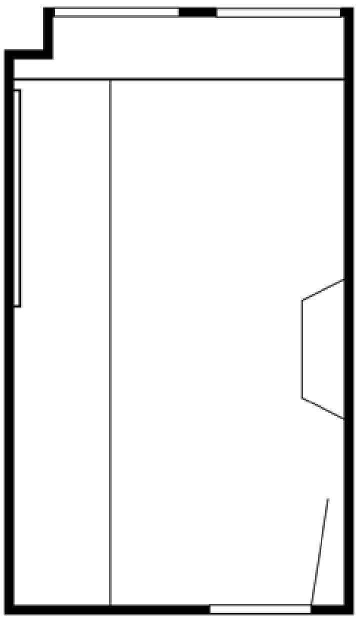
Helt klart	Växlande molnigt/klart	Helt mulet utan regn
Helt mulet med regn	Helt mulet med snöfall	Dis/dimma

Är marken snötäckt? Ja Nej

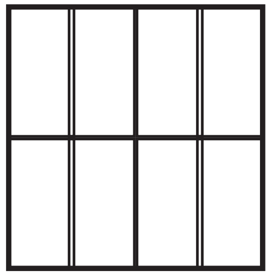
Når direkt solljus in i rummet?

Nej inte alls	Ja hela tiden	Ja till och från

Rita in ungefär hur solljuset faller (om det är direkt sol in i rummet)



Fönster och persienner



X = täckt av skiva

V = Neddragen och maximalt vinklad persienn **Ö** = Öppen glasruta

Om persienner täcker endast del av ruta, markera ungefär hur stor del.

Kommentar ang markiser etc.:...

APPENDIX 3 – FINAL QUESTIONS TO TEST PERSON (SERIES 1)

AVSLUTANDE FRÅGOR (1-4 muntligt, 5 genom försökspersonens egen markering)

1) Hur upplevde du försöket? Har du några spontana kommentarer eller frågor?

2) När du sitter och läser i vardagliga situationer, brukar du då justera ljusnivån? Hur?

3) Kan du beskriva vad du tycker är ett bra läsljus?

4)Tror du att du skulle ställt in ha en annan ljusnivå än den nu valda ifall du satt och läste en timma till?

5) Att fyllas i av fp:

Tyckte du att det var lätt eller svårt att bestämma dig för vilken ljusnivå du skulle ställa in?

|____________________________|____________________________|

väldigt lätt väldigt svårt

vet inte □