Monitoring Procedure for assessment of user reaction to glare (Report ECCO-DBUR-0303-01)

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Publication date:
2004

Document Version
Publisher's PDF, also known as Version of record

ECCO-build

Report ECCO-DBUR-0303-01

Monitoring Procedure for assessment of user reaction to glare

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31. May 2005

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Contents

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1 Evaluate user perceived glare in laboratory

The objective of Work Package 2 (WP2) User Assessment is to determine the influence of user reaction to glare on energy demand. The aim of WP2 is to provide a realistic, user-compliant glare rating model (based on visual comfort assessment) for implementation in the new control device (WP 4), in an information package and scientific software tools (WP5). WP2 will also determine the impact of the new control algorithms on energy use in typical office buildings.

The results from WP 2.1.1 *Review of existing methods* and WP 2.1.2 *Evaluate user interactions in existing buildings* will be used to develop and test hypotheses regarding the relationship between perceived glare and physically measurable light quantities in the environment. One weakness of all existing glare rating models is that they have been developed using uniform, artificial light sources with viewing angles that are unrelated to real work situations. This new glare rating model will be developed based on laboratory studies using real subjects in realistic viewing directions and performing realistic tasks. Non-uniform, time-variable sources (e.g. window with venetian blinds at different times of year) will be considered.

2 User assessments in laboratory

The main objective of the study is to assess user's adjustments of solar shading systems to glare problems relevant to occupations (office work), typical tasks (e.g. paper and computer work) and viewing directions (parallel and diagonal to window). If the results point in the predicted direction, the goal of the laboratory studies will be to obtain the relationship between subjective assessments and measured quantities.

This report describes the procedures and questionnaires that will be used within the ECCO-BUILD project for the assessment of glare in laboratories by the use of full-scale test rooms. Another report will describe the assessments of glare problems when conducting field studies.

2.1 Laboratory studies

The laboratory tests will be conducted at the Danish Building and Urban Research (DBUR) and Fraunhofer Institute for Solar Energy Systems (ISE). The test rooms will be furnished and decorated so that the subjects will get a feeling of being in a normal office room. It will have one work place in the front half of the room. The finishing of walls and ceiling will be in light colours. The sidewalls will be partly covered with shelves and/or bookcases and some neutral poster on the walls.

Simulation with Radiance of the laboratory at DBUR with and without furniture show that the illuminance is almost always lower in the furnished than in the empty room (Dubois 2001). The relative difference between the empty and furnished room is generally higher in the back than in the front of the room and lower on the work plane than on other surfaces. Radiance analysis indicates that the relative difference between an empty and furnished room varies as a function of sun angle, distance from the window and also furniture arrangement. It also shows that the furniture interacts with the direct sunlight by reflecting it further in the room or shading it from the rest of the room, depending on the position of the furniture in the room and sun angle. Since the illuminance values are affected by the position of the furniture, any single furniture arrangements will results in a specific illuminance distribution. It is nearly impossible to take into account all possible furniture arrangements and to draw realistic conclusions within the scope of the present study and therefore, the furniture arrangements will be limited to one alternative, including a flat panel display screen, in both rooms.

2.1.1 Danish Building and Urban Research (DBUR)

DBUR is located in Hoersholm, north of Copenhagen (latitude 55.86° N, longitude 12.49° E). The laboratory has two south-oriented experimental rooms, which are raised 7 m above the ground on the north side and about 13 m from the ground on the south side in order to prevent shading from adjacent buildings and trees (Figure 1 and 2). The windows of the laboratory can be changed so that north and east orientations can also be studied. The outside scene in front of the laboratory on the south side consists of a 22 m-deep parking lot adjacent to a 55 m-deep football field, which is terminated by a row of approximately 8 m-high trees. There is also a group of trees near the laboratory towards the south-west direction. Figure 2 shows a panoramic (180°) view of the landscape in front of the laboratory.

The two experimental rooms are identical, each measuring 3.5 m (width) by 6.0 m (depth) with a floor to ceiling height of 3.0 m. Each room has the possibility of windows in full height of the facade. Both experimental rooms will be used in this study. The first room – called the Reference room – will be furnished as a typical office room and with measuring equipment while the second room – called the Test room – will also be furnished with few control measuring equipment (Figure 2 and 3). All measurements will be carried out simultaneously in both rooms.

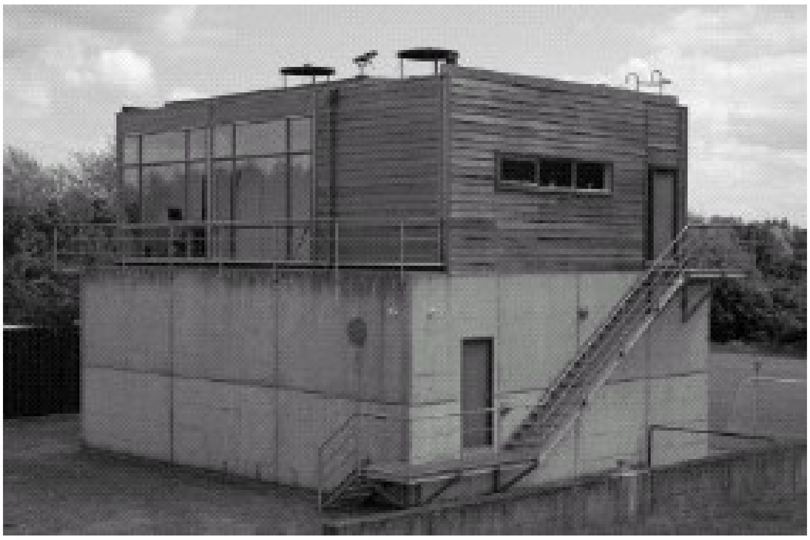

Figure 1 Picture of the Daylight Laboratory of the DBUR Institute showing the two experimental rooms, which are elevated from the ground. The windows of the laboratory can be changed so that north and east orientations can also be studied. However, this study only covers the south orientation.

Figure 2 Panoramic view (180°) of the landscape in front of the south facade of the Daylight Laboratory.

As shown by panoramic view of Figure 2, the space in front of the south elevation is essentially empty from obstructions, apart from the distant row of trees at the end of the football field, which obstructs the lower part of the sky towards the south direction, and the group of trees towards the south-west direction (Figure 2, right).

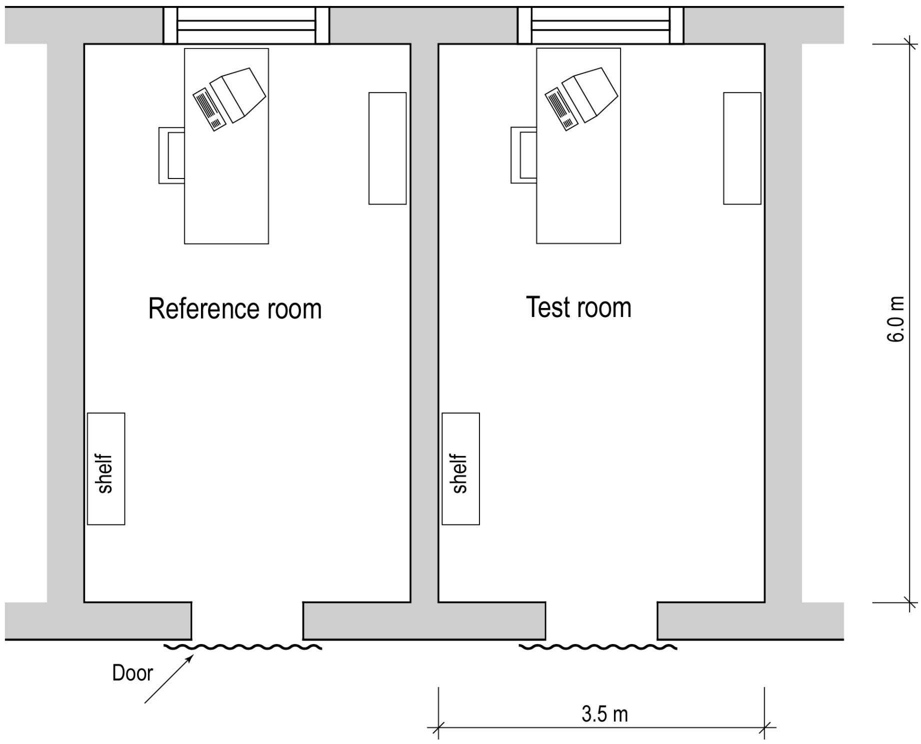

Figure 3 Plan of the experimental rooms in the Daylight Laboratory of DBUR Institute showing the Reference room and the Test room, which is furnished, as a typical office room.

Figure 4 Interior picture of Test Room showing the window configuration (small window with a sill height of 0.8 m above the floor), arrangement of furniture for user acceptance studies and exterior obstruction.

The windows of the experimental rooms are double-pane, low-emissivity coated windows with argon fillings from Pilkington (Optitherm S). These windows have the following optical and thermal properties:

- Direct visual transmittance: 72 %
- G-value: 56 %
- Diffuse visual transmittance: 65 %
- Reflectance, front: 15 %; back: 14 %
- U-value: 1.1 W/m^2 ºC

The walls of the experimental rooms are covered with a white wallpaper, which is an almost perfectly diffusing surface. The wall surface specularity was measured at Uppsala University. The ceiling of the laboratory is made of white suspended ceiling tiles and the floor is covered with a medium grey carpet. The reflectance of each material was measured using a spot luminance meter and a reference reflector. The reflectance obtained for each component is:

- Walls – Gypsum, light grey, matt, reflectance 62 %
- Ceiling – Suspended tiles, white, matt, reflectance 88 %
- Floor – Carpet, dark grey, matt, reflectance 11 % (or be changed to a light grey linoleum, matt, reflectance 29 %
- Table – Wood, dark brown, some specularity, reflectance 15 %, measured by spot luminance meter

Note that the ceiling contains embedded lighting fixtures, which contribute to a small reduction of the overall reflectance of the ceiling. The lights will be turned off throughout the duration of the experiment.

Exterior illuminance measurements will be carried out with 7 exterior detectors mounted on the horizontal roof. Global horizontal, vertical hemispheric and diffuse illuminance are silicon diodes (LMT BAP) supplied by LMT Lichtmesstechnik, Berlin. Illuminance by sunlight and skylight on vertical surfaces facing the four points of the compass are supplied by Hagner, Sweden. Diffuse sky illuminance is measured with a shadow ring (CM121) supplied by Kipp & Zonen. The CM 121's sliding bars (see figure 9) is re-adjusted at regular intervals (after a few days) and measurements is corrected by a theoretical expression for the part of the diffuse sky which is screened off from the sensor by the shadow ring.

The interior illuminance on the work plane is measured at 0.85 m from the floor using Hagner lux-meters Model SD1 fixed on metal supports. All sensors used for interior illuminance measurements are light sensitive silicone diodes from Hagner, Sweden. These lux-meters have a spectral sensitivity following the visibility curve of a CIE standard observer and have a cosine correction to compensate for errors due to the angle of incidence. The zero value of these lux meters is determined by carrying out a series of dark measurements and removing the value measured under total darkness from the final data set. The lux-meters is connected to a Hagner multi-channel amplifier Model MCA-1600, which is connected to a data acquisition system (Keithley) and the data acquisition software is developed by DBUR. The datalogger makes the analog to digital signal conversion and saves data before a nearby computer retrieves it. The illuminance values will be continuously recorded every 30 seconds each day of experimental assessments. Vertical lux meters similar to the horizontal ones will be fixed on the lateral wall to verify that the luminance values measured with the CCD camera are correct.

Exterior global radiation and diffuse sky radiation are Kipp & Zonen (CM 11) pyranometer with a spectral range of incoming global solar radiation from 0.3 to 2.8 µm. The CM 11 is fully compliant with all ISO 9060 Secondary Standard Instrument performance criteria. Diffuse sky radiation is also measured with the Kipp & Zonen shadow ring (CM121).

2.1.2 Fraunhofer Institute for Solar Energy Systems (ISE)

The Fraunhofer Institute for Solar Energy Systems is located in the southern part of Germany in Freiburg (latitude 48.01° N, longitude 7.84° E). The experimental rooms are located on the roof of the building and are fully rotatable without restrictions.

Both rooms are 3.65 m wide and 4.6 m deep. The total height of the rooms is about 3m. There is a suspended ceiling installed which has a variable distance to the roof. Between the two rooms, all the monitoring equipment and the equipment for controls of the blinds is positioned. The plan of the experimental rooms is shown in figure 5.

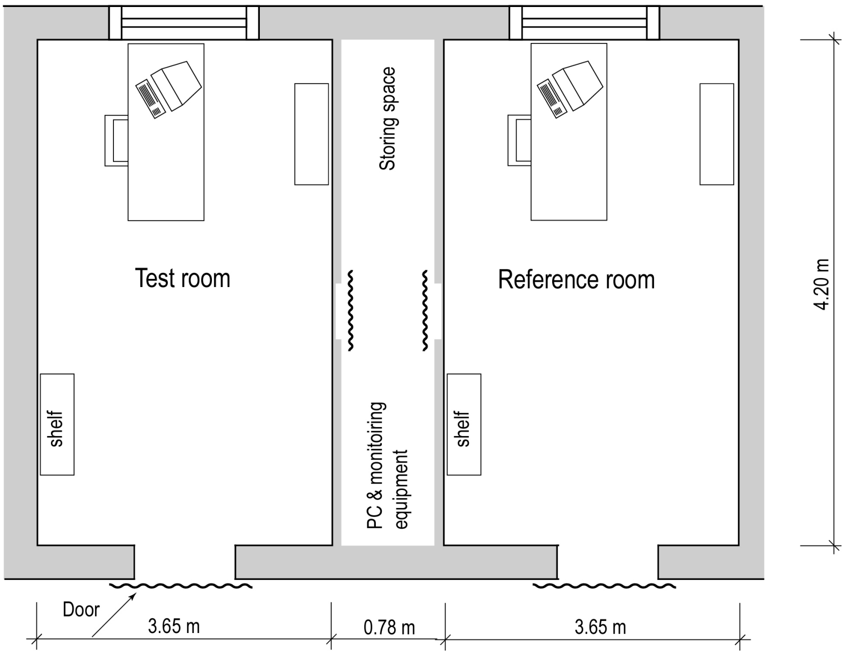

Figure 5: Plan of the experimental rooms in the Daylight Laboratory of ISE Institute showing the Test room and the Reference room, which is furnished, as a typical office room.

Figure 6: Picture of the Daylight Laboratory of the ISE Institute showing the two experimental rooms, which located on the roof of the building and are fully rotatable without restrictions.

The two experimental rooms are identical. Each room has the possibility of windows in full height of the facade. Both experimental rooms will be used in this study.

The windows of the experimental rooms are double-pane, low-emissivity coated windows with argon fillings from Luxguard, Type NP 54/27. These windows have the following optical and thermal properties:

- Direct visual transmittance: 56 %
- G-value: 32 % (EN 410)
- Direct Solar transmittance: 29 %
- U-value: 1.1 W/m^2 ºC

The walls of the experimental rooms are painted with grey colour. The ceiling of the laboratory is made of white suspended ceiling tiles and the floor is covered with a medium grey linoleum. The reflectance of each material was measured in the laboratory using a integrating sphere. The reflectance obtained for each component is:

- Walls – grey, reflectance 56 %
- Ceiling – Suspended tiles, white, matt, reflectance 80 %
- Floor – Linoleum, medium grey, reflectance 34 %
- Table – Wood, light grey, some specularity, reflectance 65-75 %, measured by spot luminance meter

The interior illuminance on the work plane is measured at 0.85 m from the floor using Hagner lux-meters Model SD2 fixed on metal supports. All sensors used for interior illuminance measurements are light sensitive silicone diodes from Hagner, Sweden. These lux-meters have a spectral sensitivity following the visibility curve of a CIE standard observer and have a cosine correction to compensate for errors due to the angle of incidence. Each sensor has it's own amplifier with an integrated switch of the measurement range. All sensors are regularly calibrated (zero point and sensitivity of entire measurement setup).

Figure 7: Set up of the monitoring equipment in the Reference room. Interior illuminance on the work plane is measured at 0.85 m from the floor using Hagner lux-meters Model SD2, fixed on metal supports. Mounted on the wall are the CCD camera (LMK98) and the vertical illuminance sensor at the approximate position of the subject's eyes.

The exterior global illuminance (LMT BAP) and the vertical illuminance (LMT BAP) on the (south) facade from the sky and ground will be simultaneously recorded.

Exterior global radiation and diffuse sky radiation are Kipp & Zonen (CM 11) pyranometer with a spectral range of incoming global solar radiation from 0.3 to 2.8 µm. The CM 11 is fully compliant with all ISO 9060 Secondary Standard Instrument performance criteria. Diffuse sky radiation sensor is mounted on a suntracker whith a shading disk.

The direct radiation is measured by a normal incidence pyrheliometer (NIP) from Eplab, which is also mounted on a suntracker.

2.2 Procedure for required measurements

This section provides recommendations related to the monitoring equipment, the number of sensors, and the time and frequency of the monitoring. CIE *Guide to recommended practice of daylight measurements* (CIE 1994) give more detailed information about exterior measurements, instrumentation requirements, and data quality control.

2.2.1 Exterior measurements

When conducting exterior measurements the following will be kept in mind:

- Illuminance sensors will be V_λ corrected and cosine-corrected by rotation symmetry and only be dependent on the angle of incidence and independent of the azimuth angle.
- Illuminance sensors will have a linear response with increasing illuminance and be accurate in the illuminance range 0 – 100,000 lux up to 150,000 lux, depending on the daylight availability at the location where the monitoring takes place.
- Irradiance sensors should have a total spectral bandwidth of 300 to 3000 microns (nm) and have a linear response with increasing irradiance (<1000 W/m^2).
- Sensors will be waterproof and able to maintain a stable temperature to prevent condensation and ice coating.

Table 1 Required exterior measurements

Exterior	Physical	Measurements
Basic set	Illuminance	Global horizontal illuminance (E_{vg})
		Direct (normal) solar illuminance (E_{vs}) or diffuse horizontal illuminance (E_{vd}) with correction factors for shadow band
		Vertical illuminance on the façade (E_{vgi})
	Irradiance	Global horizontal irradiance (E_{eg})
		Direct (normal) solar irradiance (E_{es}) or diffuse horizontal irradiance (E_{ed}) with correction factors for shadow band
Additional set	Illuminance	Shielded vertical illuminance from sunlight and skylight (E_{vgi}, with *i* standing for north, east, south or west)
	Luminance	Luminance of the sky (ccd-camera with fish-eye lens)
		Luminance of zenith (L_{vz})
	Weather station	Hueppe differential brightness sensors (3 sensors)

2.2.1.1 Exterior horizontal global illuminance and irradiance

Exterior measurements are carried out with sensors, mounted on a horizontal plane (see figure 6) with an unobstructed horizon (e.g. roof), to measure global horizontal illuminance (E_{vg}) and irradiance (E_{eg}).

Figure 8 Picture showing the lux meter on the roof at DBUR for recording the global illuminance and the 4 vertical illuminances.

2.2.1.2 Exterior horizontal diffuse illuminance and irradiance

Sensors measuring horizontal diffuse illuminance (E_{vd}) and irradiance (E_{ed}) will be screened from direct sunlight by standard shade ring with a band width, b, between 0,20 and 0,24 of the band radius, r. In presentation of the data the correction factor for an isotropic sky should be applied.

Figure 9 Picture showing the diffuse irradiance sensor screened from direct sunlight by standard shade ring (Kipp & Zonen) or by a sun-tracking ball.

2.2.1.3 Exterior illuminance on a vertical plane

Exterior vertical illuminance E_{vgs} should be positioned on the facade to measure the illuminance level at the window. Illuminance by sunlight and skylight on vertical surfaces facing North, East, South and West (E_{vgn}, E_{vge}, E_{vgs}, E_{vgw}) should be screened from ground reflected light by a matt black screen, forming an artificial horizon (see figure 10 and CIE 1994 for further description). Light reflected upwards on the ring forming the artificial horizon should be minimised by using matt black louvers or other means.

Figure 10 Picture showing the lux meter on the roof at DBUR for recording the global illuminance and the four vertical illuminances. The matt black screen is forming an artificial horizon at the level of the centre of each sensor. The perpendicular distance between the sensor and the screen should be at least ten times the diameter of the sensor's acceptance area (CIE 1994).

2.2.1.4 Exterior direct (normal) illuminance and irradiance on a horizontal plane

Sensors measuring direct normal solar illuminance (E_{vs}) and irradiance (E_{es}) should be mounted on solar tracking devices. The field of view should be defined by an open half-angle of 2,5 degrees with a slope angle of 1 degree (CIE 1994).

2.2.1.5 Luminance of the sky (ccd-camera) or luminance of the zenith

A ccd-camera with a fish-eye lens can perform luminance measurements of an overcast sky. If clear, sunny, no pictures will be taken, since it will burn the CCD pixels crossed by the image off the sun. An illuminance sensor can measure the zenith luminance (L_{vz}) if the field of view, defined by the open half-angle, is 5,5 degrees.

2.2.1.6 Huppe BUS weather station

The weather stations serve to monitor environmental data such as wind, sun and temperature and, on the basis of these, calculate BUS telegrams for further processing or for moving the sunshading system. On the roof, three differential brightness sensor from Huppe will be used for sensing the dazzling effect of the sun. The weather station and slat angle sunblind controller adjust the blind's slat position according to the position of the sun, i.e. for maximum daylight penetration and maintaining view-out.

2.2.2 Interior measurements

When conducting interior measurements the following should be kept in mind:

- Sensors will be V_{λ} corrected, and have a linear response with increasing illuminance and be accurate in the illuminance range 0 – 50,000 lux.

Table 2 Required interior measurements in occupied room (Test room)

Interior	Physical	Measurements
Basic set	Illuminance	Horizontal illuminance sensor (WP1) at the "real" workplace of the subject (see figure 11)
		Vertical illuminance sensor (V1) on side wall at 1.2 m height in the back of the subject's eye position (minimum $E_{sw, v}$ on the side wall, e.g. wall 1, in figure 11)
		Vertical sensor (VDT1) in the centre of the computer screen
	Temperature	Indoor temperature (T1), C

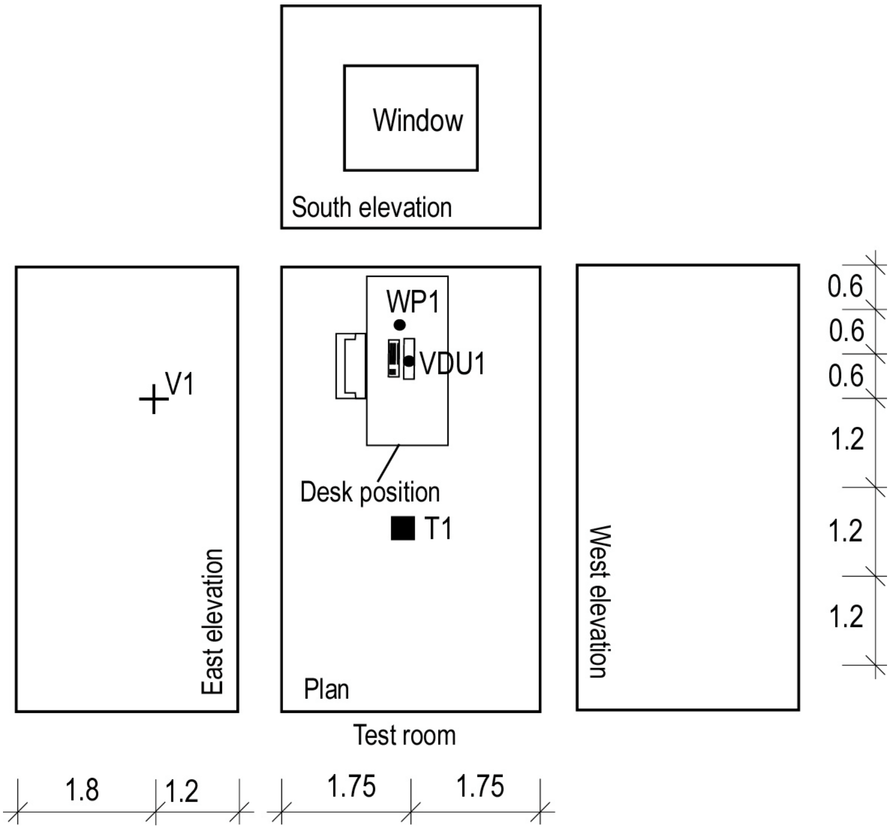

Figure 11 Position of the horizontal and vertical lux meters in a occupied room of 6 m depth (Test room). The sensors are: WP1 - horizontal illuminance sensor at the workplace, VDT1 - vertical sensor on the visual display terminal (VDT), V1 - vertical illuminance sensor on side wall, and T1 - Indoor temperature.

Table 3 Required interior measurements in unoccupied rooms (Reference room)

Interior	Physical	Measurements
Basic set	Illuminance	Horizontal illuminance sensors (H1 to H5) on the work plane
		Horizontal illuminance sensor (WP1) at the “real” workplace of the subject (see figure 12)
		Vertical illuminance sensor (V1) on side wall at 1.2 m height
		Vertical illuminance sensor (V2) at 1.2 m height to measure the vertical illuminance at the position of the subject’s eyes.
		Vertical illuminance sensor (V3) in the middle of the window
		Vertical illuminance sensor (V4) at 1.8 m height in the centre of the back wall
		Vertical illuminance sensor (VDT1) at the edge of the computer screen
		Cylindrical illuminance on top of the computer screen. The sensor should face the facade, the two perpendicular walls and the opposite back wall
	Luminance	CCD camera (CCD)
Additional set	Illuminance	Horizontal illuminance sensor in the middle H1 and H2 on the work plane
		Horizontal illuminance sensors on the ceiling plane (C1 to C5, which correspond to the position of the sensors on work plane)

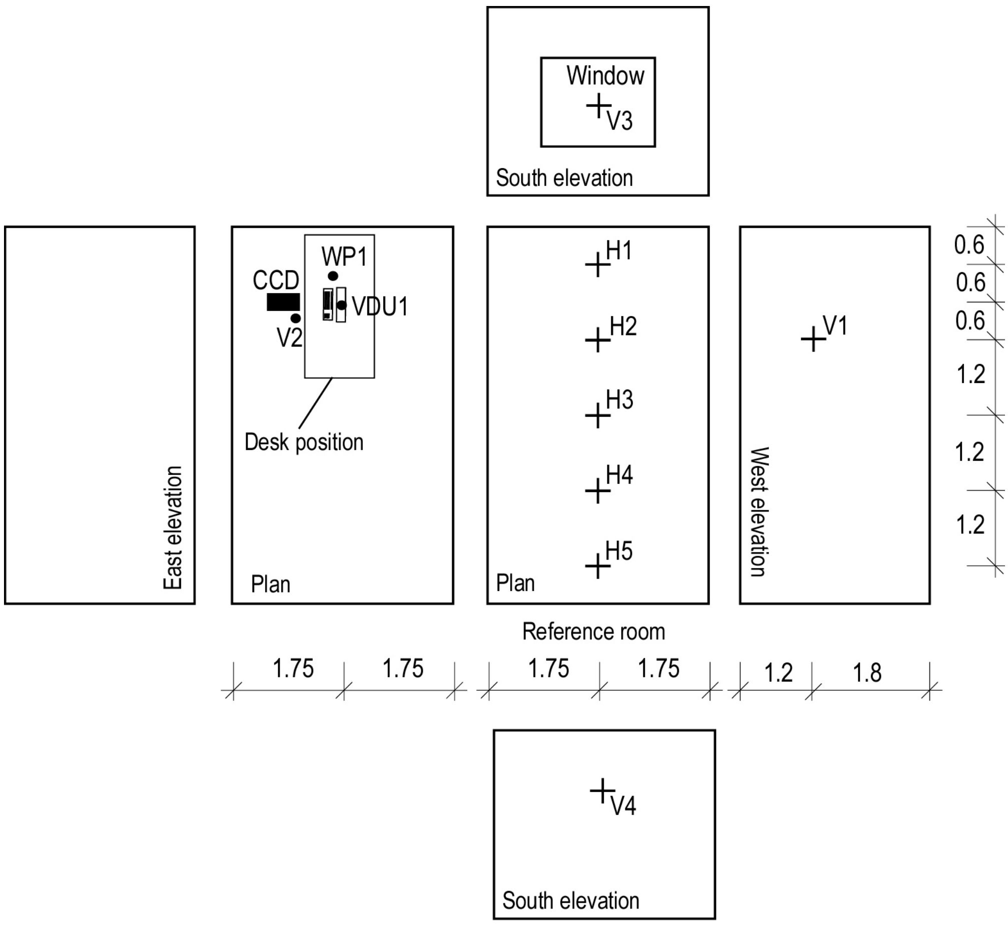

Figure 12 Position of the horizontal and vertical lux meters in an unoccupied room of 6 m depth (Reference room). The sensors are: $H_{1\text{-}5}$ - horizontal illuminance sensors on the work plane, WP1 - horizontal illuminance sensor on the workplace, VDT1 - vertical sensor on the visual display terminal (VDT), V1 - vertical illuminance sensor on side wall, V2 - vertical illuminance sensor at the position of the subject's eyes, V3 - vertical illuminance sensor on the window, V4 - vertical illuminance sensor on the back wall, and CCD – CCD camera at the position of the subject's eyes.

2.2.2.1 Horizontal illuminance on the work plane and ceiling

The quantity and distribution of the horizontal illuminance on the work plane (E_{wp}) from daylight and sunlight can be monitored by a number of sensors depending on the required information needed. The position of the sensors for describing daylight distribution within the depth of the room is given in figures 12. The sensors are equally spaced and the position of the first and last sensor should be half the distance of spacing between the remaining sensors. For example, a room which is 6 m deep will have the sensors positioned at 0.6 m (H1), 1.8 m (H2), 3 m (H3), 4.2 m (H4) and 5.4 m (H5). The sensor height will be according to the standard work plane height of

Denmark and Germany. This is 0.85 m above the floor. Additional horizontal illuminance sensor will be placed in both rooms at the “real” workplace of the subject.

For shading device, like the Venetian blinds, which redirect the light towards the ceiling, additional illuminance (E_{ceil}) measurements on the ceiling can be taken. These sensors can be placed according to the number and position of sensors on the horizontal plane (sensors 1 to 5).

2.2.2.2 Vertical illuminances on the side wall

The vertical illuminance on the side wall (E_{wall}) will be measured 1.2 m above floor level corresponding to the eye level of a seated person. The sensor is placed in the middle of the front half of the room, behind the subject in the Test room while in front of the CCD camera in the Reference room. The incident light on the vertical sensor in the Reference room can be used to verify if the luminance values measured with the CCD camera are correct. Another vertical sensor should be positioned in the centre of the back wall at 1,8 m above floor level corresponding to the eye level of a standing person.

2.2.2.3 Vertical illuminances inside the room

In the Reference room, a vertical illuminance sensor will be placed at a height of 1,2 m to measure the vertical illuminance at the approximate position of the subject’s eyes. The illuminance measurement will be used to interpret the glare assessment made by the subject while working on the visual display terminal (VDT). In both rooms, a vertical sensor will be mounted at the edge of the VDT-screen facing the subject to measure the vertical screen illuminance. Additional vertical sensors should be placed at the window, behind the blind, to record the illuminance entering the room.

Velds (2000) stated that using two vertical illuminance sensors to measure the vertical illuminance at the position of the subject’s eyes (facing window and facing the wall), showed high correlation with subjective glare ratings in situations without a daylighting system (blinds), but it is not the only parameter in glare assessment.

2.2.2.4 Cylindrical illuminances inside the room

Gall (2000) found a high correlation between room brightness and cylindrical illuminance and also some correlation between cylindrical illuminance and glare. In the reference room, a cylindrical illuminance meter (consist of 4 perpendicular vertical illuminance meters) will be installed in the middle, at the middle top of the VDU. The sensor should face the 3 walls and the facade.

2.2.2.5 Luminance of the window, walls and ceiling

Luminance measurements on the walls and ceiling show if the amount of daylight and sunlight is within an acceptable range and if these surfaces are not acting as secondary sources of glare. The luminance of the Venetian blinds and window should be measured using a calibrated, scientific grade CCD camera from TechnoTeam (LMK 98 or LMK Mobile with fish-eye lens). This camera will be calibrated by the company and provided with a filter to adjust the detector's sensitivity to the sensitivity of a standard CIE observer. The camera comes with a software which allows control of the camera and analysis of the luminance data of the whole scene. The resulting digital image from LMK98 contains 1300 (horizontal) by 1030 (vertical) pixels corresponding to as many luminance values. The LMK Mobile contains 1280 (horizontal) by 1024 (vertical) pixels. The luminance of the window, walls and ceiling as well as the background luminance L_b can be derived from the luminance picture of the CCD-camera. Within the evaluation software, areas of interest can be defined, e.g. the average luminance of these areas can be calculated and exclusion of the window area from the picture will produce the background luminance.

2.3 Interpretation of measured data

In this study six performance indicators to assess the daylight quality within the room will be considered:

1. the daylight factor
2. the absolute work plane illuminance
3. the illuminance uniformity on the work plane
4. the absolute luminance values on the vertical plane (window and facade)
5. the luminance ratios between the paper task, walls and the VDT.
6. discomfort glare

The performance indicators were determined after a review of the literature in the field as well as codes and guides concerning lighting of work spaces.

This literature review and the rationale motivating the choice of performance indicators is covered in WP 2.1.1. The assessment of daylight quality is based on an interpretation of the measured data in the reference room as presented in Table 4.

Table 4 Performance indicators and their interpretations.

#	Performance indicator	Interpretation
1	Daylight factor	
	< 1 %	Unacceptable
	1-2 %	Acceptable
	2-5 %	Preferable
	> 5 %	Ideal for paper work / too bright for VDT work
2	Work Plane Illuminance	
	< 100 lx	Too dark for paper and VDT work
	100-300 lx	Too dark for paper work / acceptable for VDT work
	300-500 lx	Acceptable for paper work / ideal for VDT work
	> 500 lx	Ideal for paper work / too bright for VDT work
3	Illuminance Uniformity - Work Plane	
	$E_{min}/E_{max} > 0.5$	Acceptable
	$E_{min}/E_{max} > 0.7$	Ideal
	$E_{min}/E_{av} > 0.8$	Ideal
4	Absolute average luminance of the facade †	
	> 2000 cd/m^2	Too bright, anywhere in the room
	> 1000 cd/m^2	too bright, in the normal visual field ‡
	< 500 cd/m^2	preferable
	< 30 cd/m^2	unacceptably dark

† Section 4 - 6 need to be adjusted according to literature survey Whatever the decision is, it will not change the procedure of the assessments, since these values can be set afterwords.
‡ The normal visual field is the area that extends 90° each side horizontally, 50° upwards and 70° down from the horizon (NUTEK, 1994).

5	Luminance Ratios†	
	$L_{paper\_task}:L_{VDT} \leq 1:10$	Acceptable
	$L_{adjacent\_wall}:L_{VDT} \leq 1:10$	Acceptable
6	Discomfort glare	
	$L_{window,\ parallel} > 8000\ cd/m^2$	intolerable
	$L_{window,\ parallel} > 6000\ cd/m^2$	uncomfortable
	$L_{window,\ parallel} > 4000\ cd/m^2$	acceptable
	$L_{window,\ parallel} > 2000\ cd/m^2$	perceptible
	$L_{window,\ diagonal} > 7000\ cd/m^2$	intolerable
	$L_{window,\ diagonal} > 4500\ cd/m^2$	uncomfortable
	$L_{window,\ diagonal} > 3000\ cd/m^2$	acceptable
	$L_{window,\ diagonal} \geq 1500\ cd/m^2$	perceptible

2.4 Points of attention in the monitoring program

The monitoring program consists in the collection of data through measurements and observation. ISO 9241-6 *Ergonomic requirements for office work with visual display terminals (VDT's) – part 6: Guidance on the work environment* (1992) point out relevant factors for a good lighting installation to fulfil its intended functions for office work with VDT. Several of these factors are covered in the next section, such as distribution of the luminance in the room (section 2.4.5), illuminance on the horizontal and vertical plane (section 2.4.3 and 2.4.4), ratio between the illuminance on the two planes (section 2.4.5). Additionally, the windows should give visual contact with the outside and create an adequate and acceptable level of luminance(s) on the inside. These aspects will be covered in the next section.

2.4.1 Duration of monitoring

In general, measurements should be taken as fast as possible. An average value of any measured parameter should be stored every minute during the user assessment. Shorter sampling intervals could also be used.

2.4.2 Registration of the weather conditions

In order to be able to extrapolate the results to other times of the year it is necessary to record (at least) manually the weather conditions during the test period. An on-site observation should be based on a subdivision of the sky into four zones (north, east, south west). As far as possible, the total cloud cover should be recorded in octas, based on an average of all zones. It should be coded as 0 for no clouds, 1-7 is one-eight to seven eighths of sky is covered by clouds, and 8 if the sky is completely covered. Additionally, for the description of the sky conditions it will be sufficient to describe it as clear, hazy, overcast, partly overcast with sun, partly cloudy with clouds mainly in east direction etc. It should be noted that, even with trained observers, considerable inaccuracies can occur. A picture of the sky just before and after the test, taken out of the window of the test room, will probably give more information, if possible.

2.4.2.1 Overcast measurements

Overcast sky, defined by the rule of observation, means that the sky is completely covered with clouds in all directions. It should be coded as 8. This sky type will provide conditions easy to reproduce, due to the distribution of daylight entering the room is almost independent of the solar azimuth angle. However, the sky luminance distribution under which the measurements are made can vary and the following criteria for an approximate CIE overcast sky luminance distribution are:

- The illuminance ratio (f_{oc}) between the screened vertical sky illuminance and the global, unobstructed horizontal illuminance should be in the interval $0.36 < f_{oc} < 0.44$. The 'true value' for the CIE overcast sky is f_{oc} = 0.396.
- A ratio from the screened vertical illuminance sensors facing North, East, South and West (E_{vgn}, E_{vge}, E_{vgs}, E_{vgw}) can represent an approximate estimate of an isotropic sky luminance distribution. The ratios should be between 0.8 and 1.3.

Sky conditions with other ratios than the illuminance ratio and the ratio from the four vertical sensors, should be categorised as the intermediate sky type.

2.4.2.2 Intermediate sky measurements

To consider the sky as an intermediate sky one-eight (coded as 1) to seven eighths (coded as 7) of sky is covered by clouds. When doing observation, note where the main covered patches of the sky are, or make photographs during each session.

2.4.2.3 Clear sky measurements

For a clear sky no major clouds (coded as 0) should be present. If small patches of clouds are present, it should not cover the sun or be seen from the interior.

2.4.3 Daylight factors within the rooms

The daylight factor (DF) should be studied to see how the shading devices affected indoor lighting levels under overcast conditions. Many standards have requirements regarding the DF. In general, it is demanded that the DF be above 1 %, but 2-3 % is more desirable as it will provide 200-300 lux of illuminance when the outdoor global illuminance is 10 000 lux. A DF of 5 % ensures total daylight autonomy (no need for artificial lighting) since it corresponds to an indoor illumination of 500 lux with an outdoor illumination of 10 000 lux.

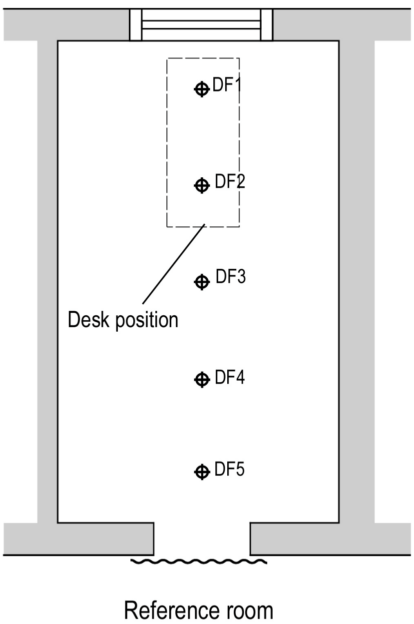

Figure 13 The daylight factor (%) on the work plane that will be studied in the Reference room.

2.4.4 Illuminance uniformity on the work plane

The illuminance uniformity on the work plane is one determinant of lighting quality in a work space since large contrasts on the desk can result in discomfort glare and visual fatigue. This aspect will be analysed by studying the ratios between work plane illuminance values of any two adjacent points in the Reference room. A total of 4 illuminance ratios will be studied (see Figure 14).

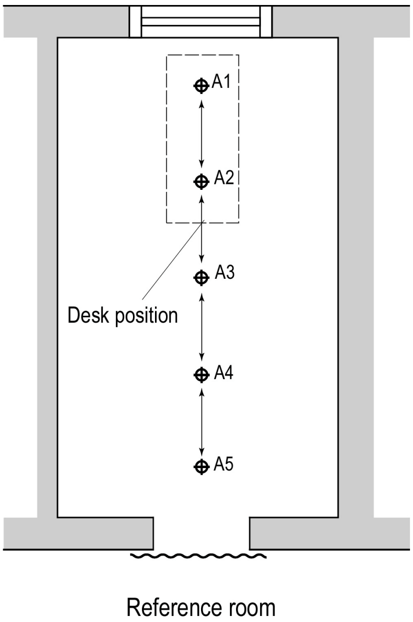

Figure 14 Illuminance ratios that could be studied in the Reference room.

2.4.5 Absolute luminance values and ratios within the room

Digital images from the CCD camera will provide too many luminance values for each picture and the analysis should be limited to studying the luminance at specific “spots”, which can be repeatedly placed on each picture. These spots can be regularly distributed along the facade and sidewall as illustrated in Figure 15. High luminance values (exceeding 10.000 - 15.000 cd/m^2) are not desirable because of the risk that discomfort or disability glare problems will occur. Low luminance values should also be avoided as they make the space appear gloomy and unpleasant. A literature survey by Dubois (2001) suggested that the luminance value should be maintained above 30 cd/m^2 on the walls located directly in the field of view.

The luminance ratios between the work plane or paper task, the adjacent wall (or window) and the VDT screen will be studied. Luminance ratios between the paper task and the adjacent wall will be studied by estimating the ratio between the work plane (paper task) luminance and that of the adjacent wall for nine possible viewing directions in the Reference room (Figure 16). This analysis will only include the luminance value on the wall (or window) which will be closest to the central field of view of a sitting person looking straight ahead.

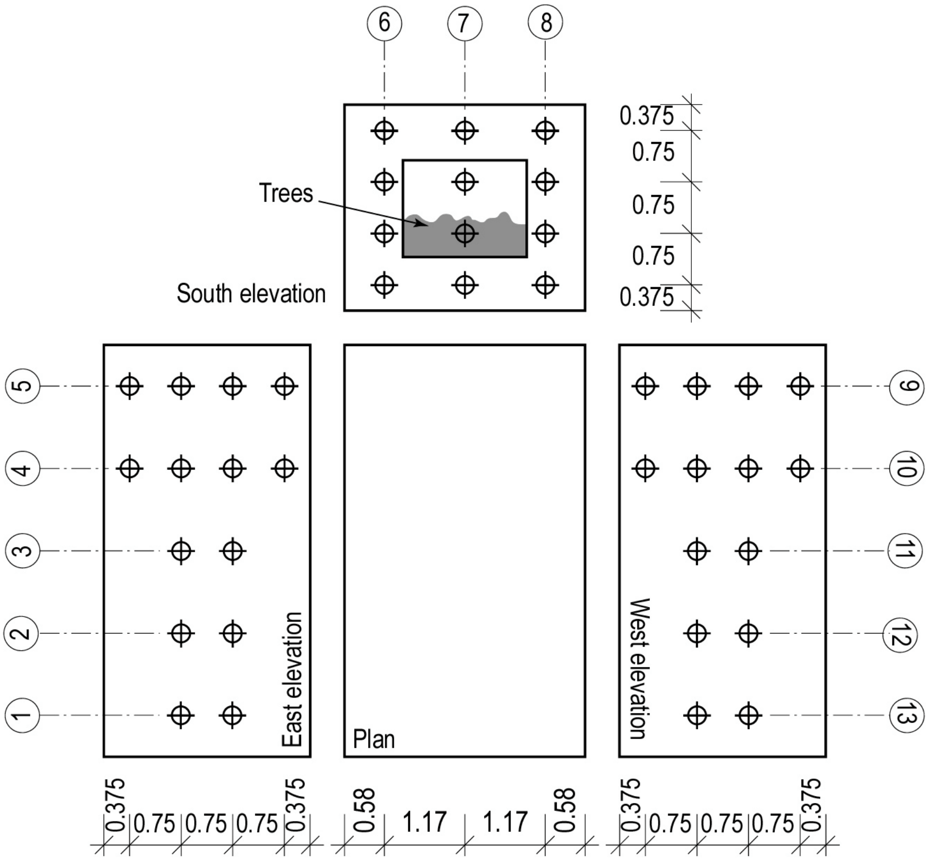

Figure 15 Position of the spots on the walls and windows. Jan – can you help !.

The luminance (L) for the work plane will be measured by the CCD camera or simplified by calculating from the work plane illuminance value (E_{wp1}), by using:

$$L = \frac{E_{wp} \cdot \rho}{\pi}$$

- where E_{wp1} is the work plane illuminance and ρ is the reflectance of perfectly diffusing work surface.

For the same nine viewing directions, as shown in figure 16, the luminance ratio between the VDT screen and the wall directly behind will be estimated by the use of CCD camera. The luminance of the VDT screen have a fairly constant value. A ratio of average luminances between task areas that are frequently viewed (e.g. paper task, adjacent wall (or window), VDT screen etc.) should be smaller than 10:1. If higher ratio between task and surroundings, it is essential that it do not cause any adverse effect. ISO 9241-3 points out that a luminance ratio of 100:1 between task and surroundings would be expected to produce a small but significant drop in performance. The average luminance of a VDT-screen is around 100-200 cd/m^2, but can vary between 20 cd/m^2 (black background) to 250 cd/m^2 (white background with the highest brightness level). The luminance ratio between the paper task and the VDT-screen, and between the window (sky) and the walls and/or the rest of the room, will be studied in the same way as the ratio between the VDT screen and the wall directly behind[1].

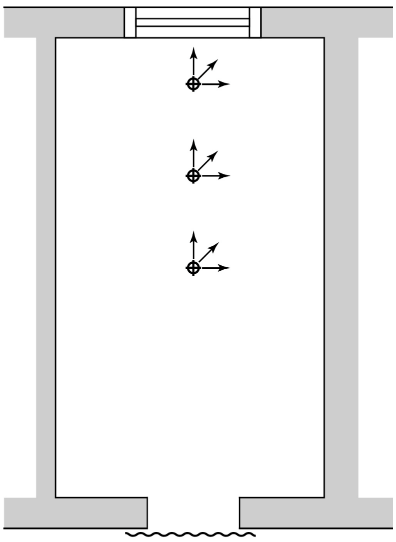

Figure 16 Nine possible viewing directions, which could be considered when studying the luminance ratios between the task and the adjacent wall.

[1] Note that a Swedish guideline (e.g. NUTEK, 1994) recommend that the luminance ratio should not exceed 1:20 between any part of the room.

2.4.6 Mean cylindrical illuminances $\bar{E}_c$

The mean cylindrical illuminance ($\bar{E}_c$) inside the room was found to have high correlation with room brightness and also some correlation with glare. The mean cylindrical illuminance is obtained by using 4 perpendicular vertical illuminance meters facing the 3 walls and the facade. A good approximation of the mean cylindrical illuminance is by averaging the illuminance measured on the four vertical faces. The mean cylindrical illuminance should be at least 0.4 of the horizontal illuminance (CIBSE 1994).

2.4.7 Subjective observations

The responsible expert should be present in the Reference room during a significant part of the testing period. The expert should collect information of time periods when undesirable sun patches and high luminance areas are present. It is preferable to take photographs during the observations, so that the evaluated lighting condition is registered. Information on luminance values and luminance distributions can be recorded on these photographs as well (see figures 17).

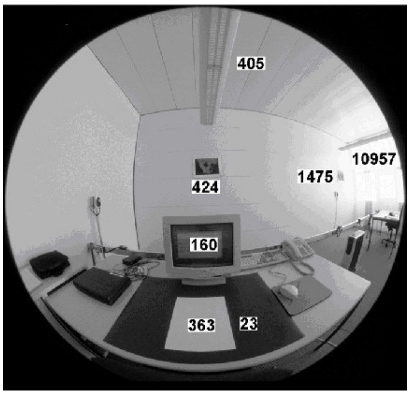

Figure 17

Left: Luminance values within the field of view pointed towards a desk, measured with a luminance meter and recorded on a fish-eye picture. Right: Luminance values (in cd/m²) measured with a CCD camera.

3 Procedure for subjective assessments

The user assessments will be conducted in full-scale mock-up offices at the Danish Building and Urban Research, Daylight in Buildings Group (DBUR) and Fraunhofer Institute for Solar Energy Systems, Solar Building Design

Group (ISE). The study will be performed in two identical office rooms, one with subjects (Test room), and the other with measuring equipment (Reference room). In the Test Room, a number of subjects will be asked about their impression, opinion and experience of the room, the windows and glare problems during a morning and afternoon session. Within the session, the subjects will perform different tasks, such as reading from a paper, work on the computer etc. similar to a normal situation where they typically perceive discomfort glare and veiling reflections. According to Osterhaus & Bailey (1992), no data (as of 1992) is available on perceived comfort or discomfort and the relations between comfort and task performance under conditions in which the glare source borders or surrounds a work task, since all previous studies evaluated discomfort glare by directly viewing the glare source rather than focusing on a work task. They concluded that for relevance of today's work environment, it seems important to more carefully consider situations in which the glare source occupies a substantial part of the visual field while the subjects actually perform work tasks.

3.1 Pre-test of assessment of glare

Subjective rating of glare typically uses a scale, whereby the subject is required to rate the glare magnitude on a four-point scale from *imperceptible*, *noticeable*, *disturbing* and *intolerable*[2]. If the subject is expected to place an observed stimulus on the scale without reference to the scaling of glare magnitude, the judgements might not be repeatable or reliable. Therefore, in order to avoid instability and imbalance of the applied scale, the subject will be given the opportunity to get acquainted with the range of the glare magnitude scale. The uncertainty of the subject to the magnitude scale should then be reduced by initially introducing the subject to a pre-test experiment illuminated to extremes of the scale prior to the experimental assessment in the Test Room.

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[2] Werner O. (1996) used the following set of criteria for rating the discomfort glare: imperceptible, noticeable, disturbing and intolerable. The borderline between imperceptible and noticeable was the changeover point where glare discomfort would be first noticed. This criterion would be equivalent to a very slight experience of discomfort that they could tolerate for approximately one day when placed at someone else's workstation. The borderline between noticeable and disturbing glare was defined as a discomfort experience that would be just disturbing and could be tolerated for 15 to 30 minutes, but that would require a change in lighting conditions for any longer period. The borderline between disturbing and intolerable glare was defined as the turning point where subjects would no longer be able to tolerate the lighting conditions.

An initial pre-test will be performed by either using a metal halogen lamp mounted outside the laboratory if overcast or use the direct sunlight. The subjects will be in the Test Room for 30 minutes to let them familiarise themselves with the test situation. The pre-test will let the subjects encounter for four to six of the "extreme" daylight conditions to get used to the test and questions they will fill out during the experimental session. This should be done prior to the real assessments, i.e. on Friday morning, and we let the subjects go through the experiment Monday-Tuesday and Wednesday-Thursday. The intention of this pre-test is to teach the subject to associate different glare magnitudes (luminance values) to a personal sensation of four pre-defined glare criteria, so that the subject have a better knowledge of the answering possibilities and range of the scale[3].

The four glare criteria used in the assessment to evaluate glare from windows is:

- Imperceptible (IM)
- noticeable (N)
- disturbing (D)
- intolerable (I).

3.2 Experimental procedure

The rooms will have a controlled temperature lying around 20-26°C (lower range is preferable, e.g. 21-24°C), and necessary equipment need to be installed, if not already available. The rooms will be furnished and decorated so that the subjects will get a feeling of being in a normal, functioning office room. The walls and ceiling finishes will be in light colours without any glossy surfaces. The reflectance of the main surfaces will be within the following ranges:

[3] Werner Osterhous state that while it is helpful to expose observers to the range of luminances produced in a particular experiment, this might create effects of preconditioning. Observers tend to equate the extreme luminance conditions with the extreme criteria and attempt to fit the remaining criteria in between, ie they basically perform a scaling exercise with roughly equidistant steps. But this is not the case with the four criteria you intend to use. They are nor equidistant, far from it. With clearly described criteria and understandable conditions for glare experiences, some people may not reach the extreme criteria for the given luminances, others may find even lower luminances to be producing intolerable glare. This approach allows for the differences between subjects much better than exposing them to the limits in order to become familiar with the criteria.

- Ceiling: 0.70-0.85
- Walls: 0.50-0.75
- Floor: 0.10-0.25

No artificial lighting will be added in the Test room. Having artificial lighting could ensure that the subjects do not have any problems with conducting a task. However, the impact of artificial lighting contribution was found to be negligible in the studies performed by Velds (2000). Within the questionnaire, the subject will be asked if they want some additional lighting, either by the general lighting or by a moveable desk lamp, during the experiment.

3.2.1 Variable parameters

The aim is to examine how and under which (weather and luminance) conditions an office worker uses glare protection systems. The results will be used to develop a glare rating model and ranges of acceptability (WP2.2) to be integrated in the controller (WP4). The variable parameters are described in the following section; window size (3.2.1.1), solar shading device (3.2.1.2) and blind position (3.2.1.5), position in the room (3.2.1.3), line of sight (3.2.1.4), season, weather and facade orientation (3.2.1.6).

3.2.1.1 Window size

The design of the windows that will be evaluated in the study will cover typical design of today's windows in office buildings. DBUR and ISE have to decide on the construction of the different facades. It will be possible to change the glazed area within 5 minutes. The glazed areas will be:

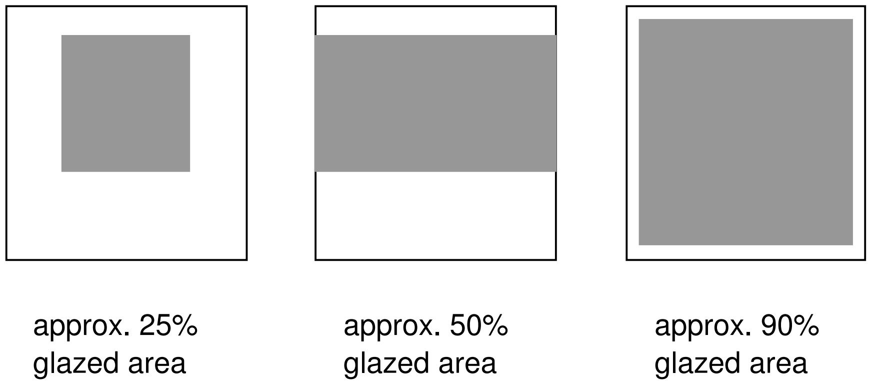

Figure 18 Illustration of the design of the window and the corresponding percentage glazed area used according to the facade area (interior) in the assessment of glare from windows.

Three different glazed areas:

- Small (25 %) glazed area: High luminance differences between wall and window expected
- Medium (50 %) glazed area: Realistic case for many office buildings
- Large (90 %) glazed area: The human retina is more sensitive to high luminances from the lower hemisphere, therefore this case has to be assessed.

Table 5 Glazed area (A_{glas}) according to the facade area (A_{facade}) of the windows used in the study at DBUR and ISE. The solid angle of subtended by the source (ω_s) is the apparent size of the visible area of sky at the subjects eyes 2 m from the window.

Institute	Small		Medium		Large	
	A_{glas}/A_{facade}	ω_s	A_{glas}/A_{facade}	ω_s	A_{glas}/A_{facade}	ω_s
DBUR	≈ 25 %	1.12	≈ 44 %	2.0	≈ 85 %	3.89
ISE	≈ 21 %	0.96	≈ 45 %	2.06	≈ 89 %	4.21

Validation studies of Daylight Glare Index (DGI) show that correlation between observed glare from windows and predicted calculated glare is not as strong as in the case of artificial lighting. There is a greater tolerance of mild degrees of glare from the sky seen through the window, but this tolerance do not extend to severe degrees of glare. It may be the result of visual and aesthetic factors such as the quality of the view out, the appearance of the window as well as the visual and aesthetic interior qualities of the room. Recent studies by Nelson et al (Nelson, 2002), using a large flat vertical rectangular artificial glare source, show that small displacements from line of sight (< 30°) resulted in insignificant influence on discomfort glare, while large displacements (> 60°) resulted in significant reduction in glare. A small source size (ω_s was 0.07) was significantly different from the three other sizes of the source (ω_s were 0.14, 0.21, and 0.28) and resulted in a reduction of perceived glare using an inverted Hopkinson scale. Within the range of the sizes examined, further changes in source size did not have any significantly influence on discomfort glare. The results indicate that the influence of azimuthal displacement was superior to the influence of the source size (ω_s). However, the source sizes within the ECCO experiment are much higher than any of the sizes examined by Nelson et al, and care should be taken to extrapolate the results to our investigation.

3.2.1.2 Solar shading device

The following solar shading devices will be included in the user assessment:

- Venetian blinds from Hüppe. The colour and specularity is: diffuse white venetian blind (+- uniform high luminances); and specular venetian blind (bright spots possible)

- solar film roller blind with possible direct visual contact of the sun.

- Solar screen roller blind – grey diffusing fabric, no visual contact to the outside possible

Due to the timeframe of the ECCO project, the white and specular Venetian blind will be examined at both laboratories, while the solar screen roller blind will be tested at DBUR and the solar film roll blind at ISE. In total, each institute will test three solar shading devices.

3.2.1.3 Position in the room

The room where the subject will evaluate glare from windows is equipped with one work station (a desk, an office chair, and a computer). The work place will be next to the window, meaning that the subject will be seated 1,5 m away from the window. The sidewalls will be partly covered with shelves or bookcases and one or two posters on the walls. Only flat panel displays (Eizo FlexScan L565) will be used for the assessment of disturbing reflections on VDT-screens. The subjects should be free to adjust the chair and keyboard height and angles, but they should not alter the position or appearance of the VDT-screen.

3.2.1.4 Line of sight

The viewing directions should be parallel with the window (90°) and diagonal towards the window (45°). A line of sight perpendicular to the window will cause higher degree of glare, but this position is less common than the other two viewing directions. Since the DGI is based on experiments with uniform light sources, it should not be applied when discomfort glare is caused by non-uniform light sources (e.g. window with venetian blinds).

Studies by Boubekri & Boyer (1992), Iwata et al. (1990/91) and Chauvel et al. (1982) indicate that the DGI formula is not directly applicable to a case where the window is parallel to the subject's line of sight. Additionally, Waters, Mistrick & Bernecker (1995) showed that non-uniform surfaces can cause more glare than uniform light sources when positioned perpendicular to the line of sight and less glare when located 10° to 20° from the line of sight. Finally, note that Chauvel et al. (1982) observed that the discomfort glare resulting from the direct view through windows has been found to vary greatly from observer to observer and also to vary with factors associated with the appearance of the window, the view outside and the surroundings.

3.2.1.5 Blind position

One of objectives of the ECCO project is to develop an adaptive controller system for solar shading devices, which provide optimal thermal and visual comfort for the users, while reducing the energy consumption. The laboratory studies should clarify the visual behaviour of the subject and relate the state of shading device to the position in the room, activity, and direction of incident light etc. These aspects will be addressed by the test procedure described in section 3.2.2.

Within the test procedure, the shading device will be in fixed mode, which means that the angle of the blinds (cut-off angle) will give maximum daylight into the room and maintain view to the outside, but no direct sunlight will penetrate the room. When completing the rating of the lighting conditions after performing a paper and screen based reading test and a typing test, the subjects will be instructed to adjust the blind to their preferred tilt-angle position (tilt angle of the blind in º) for each of the six combinations (see section 3.2.3), starting with 0º to ≈ 80º downward tilted, where 0º is the horizontal position. The subjects will not be able to pull up the blinds during the assessments. Although, the first part may not fully take into account adaptation of the subject wishes, the last part will, to some degree, take into account differences in subjects preferences. The decision for this set-up is to enhance the interpretation of the results while reducing too much variation between subjects.

3.2.1.6 Season, time-of-day, weather and facade orientation

Assessments of glare problems may differ from season to season, since subjects may have higher acceptance for sunlight penetration in the winter than in the summer. Two distinct different seasons will be selected: summer solstice (i.e. maximum solar altitude) and equinox. The different seasons will be assessed by independent groups of subjects. The time-of-day (i.e. solar azimuth) is handled by having subject assess in the morning and afternoon.

The impact of different weather conditions (overcast, intermediate and clear sky) will be assessed by having the subject in the Test room 2-3 weeks around the summer solstices and the equinox. Interior lighting conditions under overcast sky conditions will fluctuate with little differences, but can cause a perceived degree of discomfort glare, especially when the sky is bright. Using average sky luminances and/or vertical illuminances measured at eye level could be essential when allocating assessments to measured data. Under intermediate sky conditions, the interior lighting conditions will fluctuate with large differences and can cause a more unstable adaptation level for the subject. Another problem may be that discomfort glare may come from a bright patches of clouds. It could therefore be expected that the perceived degree of discomfort glare under intermediate sky conditions will be higher than under an overcast (uniform) sky condition with comparable average sky luminances and/or vertical illuminances measured at eye level. However, Velds (2000) found that a distinction between the sky types will not lead to a more accurate average assessment. A clear sky conditions will fluctuate with large differences, depending on sun angle and azimuth, and distance from the window. If direct sunlight is not blocked, it can cause an unstable adaptation level for the subject. It could therefore be expected that the perceived degree of discomfort glare under clear sky conditions will be higher or similar than under an intermediate sky with comparable average sky luminances and/or vertical illuminances measured at eye level.

The impact of facade orientation is not covered for all orientations, but could be fairly covered by having south-orientated test rooms. It is reasonable to expect that different facade orientations produce different glare problems. A north-facing window will probably pose lesser glare problems than the other three orientations, while east- and west-orientations could generate more glare problems due to lower sun angles and problems with effective shading. However, Osterhaus (Osterhaus, 2001) found that glare level experienced, or the simple presence of daylight glare, was not significantly correlated with window orientation, but concluded that this likely was influenced by site conditions (view out as a modifier) where the study was performed.

3.2.2 Duration of the assessments

The limitation of the study is that the subjects will assess the different conditions within one hour and 45 minutes session and therefore the study will only look at short-term effects. Long-term effects will not be studied in the laboratories. The assessments will begin with only one shading device (white Venetian blind) and leave the other systems (2 venetian blinds and 1 solar roller screen) for later evaluation when we know more about how much it matters changing the window size and line of sight. This reduces the assessments to six different combinations:

- Three different size of the window (small 25%, medium 50%, and large 90%)

- Two different line of sight (parallel and diagonal)

A session last for one hour and 45 minutes, e.g.,10.00-11.45 and 12.15-14.00, given that 12.00 is the time when the sun is perpendicular to the facade. Within the session, we will only change the window size, which means that the subject evaluate the three different window sizes, each evaluation lasting for 30 minutes. During the change of window size, the subject will leave the room for a 5 minute brake. This is in order to obtain (as far as possible) the same sky condition, and a fresh memory/impression from the first test. It is of course of high importance that the sky condition is almost the same during the whole test.

The order of presentation of the window area and line of sight in the Test Room is carefully controlled to make sure that no single order would prevail over another (see appendix C). The subjects will evaluate each shading system twice (view 1 and 2), which means that half of the subjects start with view 1 in the morning session and finish with view 2 in the afternoon session.

Table 6 The duration of a full one person test in the test rooms is assumed to take about 105 minutes, according to the following plan:

Time, minutes	Duration, minutes	Line of sight - parallel (view 1) or diagonal (view 2)
-5-0	5	Introduction to test – answer Part 1 (or in pre-test)
0	0	Test begins
6	6	Read text on paper.
8.5	2.5	Rating of light conditions for reading paper – answer Part 2A
14.5	6	Typing of text (to score speed and accuracy).
17	2.5	Rating of light conditions for typing text – answer Part 2B
23	6	Read pseudo-text on screen
25.5	2.5	Rating of light conditions for reading screen – answer Part 2C
30	4.5	Change preference for blind position – answer Part 3
35	5	Change window size - subject leave test room
65	30	Repeat test
70	5	Change window size - subject leave test room
100	30	Repeat test
105	5	Answer Part 4

The time-frame of the study could influence the outcome of the experiment, but Hopkinson (Hopkinson, 1963) points out that subjects personal assessment of the degree of glare sensation could be maintained over a period of time. Osterhaus (1996) observed that the subjects in his experiment commented on becoming more sensitive to glare as the experiment progressed (2-2.5 hours) and that this impression was confirmed by experimental data. Osterhaus & Bailey (1992) also pointed out that the Daylight Glare Index (DGI) does not include a measure of adaptation. In their experiment, they observed that subjects selected higher luminances when high initial presentation luminances preceded the adjustment of luminance for the background. They also observed that when glare severity was assessed immediately following a difficult letter-counting task, the subjects showed less sensitivity to glare. Moreover, they remarked that subjects became more sensitive to glare over the course of the 1.5-hour experiment, a result that agrees with other studies (Hopkinson, 1963 in Osterhaus & Bailey, 1992).

3.2.2.1 Subjects

The results of the assessment of glare will be to evaluate how window size and shading device is rated against different line of sight. The degree of difference in ratings will be tested statistically to assess the strength and probability of the difference. To achieve that the assessments of the different combinations is as equal as possible, the same subject should be used for all combinations (also called a within-subject design). If not possible, a between-subject design can be made similar to the within-subject design, but since people are genuinely different the variance in between-subject designs is greater than in within-subject design. Consequently more subjects are needed in the between-subject design to make a difference in means come out statistically significant (Hygge & Löfberg, 1999). Employing the same group of subjects throughout the evaluation (within-subject design) will ensure that the glare assessments is statistically more sensitive in picking up differences.

Subjects should be selected among people that are used to do office-like work. They must, for instance, have some experience in working with computers, and should have no problems in reading a normal text page within a few minutes. It is preferable that the subjects form a relatively homogeneous group of people, i.e. same age - under 45 if possible, and approximately same level of education, equal gender distribution, type of work and status etc. This means that even before the testing, some potential subjects could be disqualified. However, Osterhaus (2001) found, surprisingly, no correlation between people’s age and level of glare experienced, so the rule of age below 45 should not be taken too strictly.

There could be a difference between glare assessments made by experts and so-called naive subjects. Research by Boyce (Boyce, 1998) showed that subjects familiar with lighting technology, in this research referred as experts, might evaluate lighting conditions differently compared with so-called naive subjects. In Velds (2000), no distinctions was made between the glare assessments of experts and those of naive subjects. Finally, note that Osterhaus found that people who indicated they were sensitive to glare generally reported higher levels of glare experienced. They also said they often wore sunglasses during sunny days. These findings were confirmed by Christoffersen et al. (1999). The questionnaire will take subjects sensitivity to glare into account.

3.2.2.2 Test for reading and typing

Several reseachers (Osterhaus & Bailey, 1992, Osterhaus, 1996, Sivak & Flannagan, 1991) have pointed out a need for attention to a work task as a relevant variable in the analysis of discomfort glare. In the assessment of glare, the ECCO-Build project have included three relevant visual task during the presentation of the glare stimulus. The study will primarily target the rating of the interior conditions when the subject perform different tasks, and will not be used as a target of how good they perform the different tasks.

3.2.2.2.1 Reading task

The Reading Task used will be a simple text on a sheet of paper, placed flat on the table. The text on paper should have a positive polarity, meaning that dark (e.g. black) characters on a white paper are used.). The text should be something serious but not to interesting or surprising.

3.2.2.2.2 Typing task

The Typing Task used, from NRC, will measure the speed and accuracy with which the subject is able to retype a given text. It is designed to resemble the typing proficiency test required of applicants seeking placement at agencies for office temporaries. Typing Task allows for a quantitative description of the subject's performance. Model text is presented in one window on the screen, and the subject must copy that text into a second window (it is also possible to present the model text on paper). The subject may be allowed to type freely, or may be forced to correct mistakes before continuing. To adapt the typing task to situation similar to a normal office-like situation, the subject should type text freely. Other variables include: window sizes, text and background colours, fonts and font sizes, time to complete task. Data on typing speed and errors made are recorded to disk at experimenter defined intervals (e.g., every minute), and summaries are provided for each paragraph completed, and for the entire time of the task.

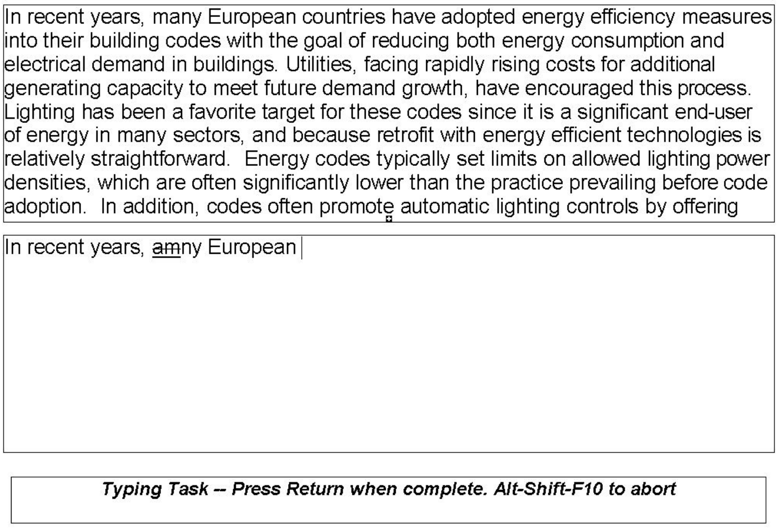

Figure 19 An example of the Typing Task used, from NRC, which will measure the speed and accuracy with which the subject is able to retype a given text.

3.2.2.2.3 Letter-search task

To obtain some measure reflecting the ability to extract information from the VDT screen, it has been decided to use an ISO standard test procedure that measures the effectiveness of the transfer of visual information in terms of subjects search performance for targets embedded in alphanumerics on a screen. Effective in this context means that the user is able to detect and recognise the visual targets accurately, quickly and without visual discomfort. The dependent variables of the test are the search velocity achieved by the test participants in a visual letter search task and subjective ratings of ‘visual comfort’ using a category scale. The method apply a pseudo-text in combination with scaling of experienced visual comfort (Boschman & Roufs, 1997ab). For detailed information, see ISO 9241-3 Amendment 1 - Annex C (normative): Visual performance and comfort test. For evaluation, see also Appendix D – Letter-search task.

The VDT-screen should be a class I screen, which is considered to be suitable for general offices. The default screen illuminance should be $E = [250 + (250 \cdot \cos\alpha)]$, where α is the screen tilt angle (α equal 90º means the screen is vertical). ISO 13406-2 state that for office work the design viewing distance from subject to the screen shall be not less than 0.4 m. The character-to-background contrast ratio, C, is an important visual factor for good legibility and should not be below 1:3. The text on the screen should have a positive polarity, meaning that dark characters on a bright background are used. Note, that when dark symbols are represented on a brighter background, the reflection of bright surfaces is found to have less disturbing effect and the differences in luminances between screen, document and keyboard are smaller.

```
WhwNdzo zltpVY 1CCAe kDw he t3
TkW3rm8U ya BpE O2B L8Y A5 She
PQtb 90DViRCDG 1H pSM yEqZz 6F
jyA3 sATQesa ANUU VLH Ou1p2JBE
vbR l1Y5rVr SA9mr DmPETLV 2uO2
7phnFd2oyT 83ee zKo8h KyiTJgAL
vXMu 6Kugm 3ElkxsOWhCK1FTMA T6
LuGF5 ad HsicT H0jkHv ssAq U8Q
8dW rmrtfGqh HCsnGdYIMQEITS fo
o1 XVw6 2VogMFo6 PH uJD3c DXj8
yW 5LN 6Bv0 fGPhdZ Cn x9gUiaH3
fySFoauaxj UeK bKQz 2uZa MmnCN
4t HT3OFuMUSo piq1uUh8tdRbK1Tn
Ez 33Q 6w fvVR 7B gyz Ns5 5Ami
7T5k 6bc2 ZHl fJmDO GwJ9 ECKYm
Xob3m t9 SU ZR e1 3lFg 1wc j4w
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a2Z sD AK5R1 Q8jiI wBeeA L2Rz0
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Figure 20 An example of the pseudo-text which will be displayed as a block of characters. The subject's task is to scan the text and identify the presence of the target character (e..g. letter A). The blocks of pseudo-text will be placed in the upper left, the upper right, the lower left, the lower right and the centre of the screen. The centre block will be located so that the middle character of the block is approximately in the centre of the active area of the screen.

3.2.3 Balanced order of presentation

The order of presentation of the window area and line of sight in the Test Room is carefully controlled to make sure that no single order would prevail over another. There are six different ways (3*2) to present three different window areas (A 25%, B 50%, C 90%) and two line of sight (view 1 - parallel, view 2 - diagonal) in a balanced order of presentation. To reduce the number of subjects required, the principle of Latin Squares is used. In a Latin Square, the different combinations of e.g. A, B, and C appear once and only once in each row and column of the matrix. Additional, the presentation order for the three window size is counter-balanced with the two line of sight, which give the presentation order as follow (see also Appendix C - Balanced presentation order for the subjects in the study):

	View 1	View 2
•	ABC	CBA
•	BCA	ACB
•	CAB	BAC

The subjects will conduct three visual task during the assessment of glare. It will take into account the need for attention to normal office-like work tasks as a relevant variable in the analysis of discomfort glare from windows. The task presentation order is fixed, meaning that each subject begin with the paper based reading task, and continue with the typing task and finish with the visual letter-search task (VDT based reading task). As stated before, the same subject will be used for most of the combinations defined within the ECCO project (within-subject design) to achieve that the assessments of the different combinations is as equal as possible. Due to the time-frame of the project, it will not be possible make a complete within-subject design for all combinations. The within-subject variables is window-size and line of sight, while the between-subject variable is shading device and time of year (e.g. summer solstice and equinox).

The design of the test procedure will have the shading device in a fixed mode to give maximum daylight, maintain view, but no direct sunlight will enter the room. The slats will be fixed according to the cut-off angle and changed, if needed, between each window size presentation (see Appendix B - Description of algorithm used for estimating cut-off angle). The procedure will to a certain extent take into account the subject wishes, since we let the subject adjust the blind to their preferred tilt-angle position for each of the combinations.

4 Test procedure:

The procedure for subjective assessments was developed within ECCO-Build project. For practical and methodological reasons, each site (DBUR and ISE) shall appoint one person to be in complete charge of conducting the study and changing the conditions. Employing the same person will ensure that the procedure is consistent each time the questionnaires are filled out and the person in charge behave in a consistent manner towards the subjects. The draft of the questionnaire is added at the end.

4.1 Questionnaire on lighting in working spaces

The questionnaire on lighting conditions in test rooms is divided into 4 main parts:

- Part 1: Personal questions (can be conducted in the pre-test)
- Part 2: Questions related to the reading, typing and letter-search tests
- Part 3: Questions on general impression of the rooms and the settings of the blinds. After changing the blind position additional questions related to why the blinds was changed.
- Part 4: Questions on indoor climate within the room (after the complete test)

The demographic questions in part 1 consider gender, age, if the subject is left or right handed, wear glasses or contact lenses, if the subjects are sensitive to bright light, and a the work status variable.

Questions in part 2 relate to rating the lighting conditions when performing relevant visual task (e.g. reading, typing and visual search). The questions are structured as a set of line rating scales (visual analog scales). Although it may be argued that the underlying psychophysical scale of the line rating scale is truly ordinal and hence should be considered ordinal, it is today generally accepted to also consider line scale data as interval scale data. The visual analog scales (10 cm long) have marks only at the two end-points. The subjects describe the perception of the visual conditions by use of the line rating scales categorised with end-points either as low-high or not at all – very much. Part 2 is split into 3 parts, where each part only concentrate on the lighting conditions when performing either a task reading from a paper on the desk, a task typing text on the VDT-screen and a task reading text on the VDT-screen (visual letter-search test). Questions with the low-high end-points consider only how the subjects from the work place rate the light level for the task they immediately have performed. The subjects are questioned (not at all – very much) if the experience any disturbing glare from the window or the shading device, when performing the task. Furthermore, they are asked to associate the magnitude of the glare on five point scale with pre-defined glare criteria. In addition, the subject is requested to decide on a line scale, whether the lighting condition is comfortable or uncomfortable, if they have to conduct their daily work at this work place. The scale rate the degree of comfort or discomfort. Finally, the subject is asked for how long they would accept these conditions, before they would like to change the settings of the blinds.

In part 3 is split into two parts, where the first part concentrate on the lighting conditions within the room before the subject change the blinds according to their wishes. The second part concentrate on why they changed the blind position. In the first part, the subject rate, by the same set of line rating scales, the general light level (low-high) and if the experience (not at all – very much) any unpleasant bright or gloomy areas within room. The subjects are questioned (not at all – very much) if the experience that the view is restricted by the size of the window or by the shading device. Furthermore, the subjects are asked if they would like to change the settings of the blinds and how important it is to be able to have control of the blinds. Finally, the subject answer if they would like to turn on the electric lighting or not. After changing the blinds, the final question (not at all – very much) relate to why the changed the blinds e.g. more or less light inside the room, more or less light on the desk, more or less light on the VDT-screen, better view to the outside, and less glare for the window or shading device.

To minimise any bias with the ‘laboratory’ settings, the subjects are asked, in part 4, if they were uncomfortable with the indoor climate conditions, such as interior temperature, draft, odour, dust or noise during their stay.

5 Questionnaire on lighting conditions in the work space

Introduction

This questionnaire is used for the assessment of glare from windows. The survey complements measurements of the physical conditions. Please complete the questionnaire as you are instructed, and be frank and honest in your answers. Do not hesitate to consult the staff if you have any questions or doubts. Your personal opinion is of great interest to us, but will remain unrevealed to others than the scientific personnel taking care of the statistics.

These lines should already have been filled in by the staff

Person ID: ______________________

Date: ______________________

Time: ______________________

Before filling in the Questionnaire

Before starting, we want you to make yourself familiar with the room; look around and feel relaxed. Just sit back and make yourself familiar with the room for a couple of minutes. The questionnaire is simple, so take your time when asked about your opinion or what you experience. The questionnaire is in 3 parts:

Part 1) questions about yourself

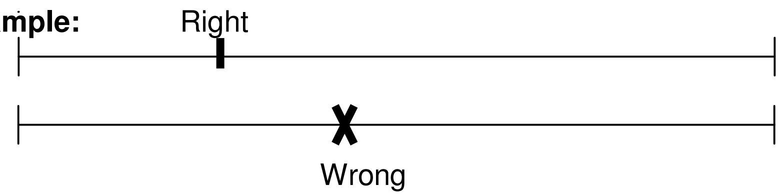
Part 2) questions related to lighting conditions when you perform a reading task, a typing task and letter-search task

Part 3) questions about your general impression of the room

Part 4) questions about the indoor climate of the room

When answering questions including scales, please indicate your opinion by setting one mark on each of the lines

Example:



Part 1. Questions about yourself

1.1 Do you normally wear glasses or contact lenses when doing office-like work?

- [ ] Yes, glasses
- [ ] Yes, contact lenses
- [ ] No

1.2 Are you right handed or left handed?

- [ ] Right handed
- [ ] Left handed

1.3 Gender

- [ ] Female
- [ ] Male

1.4 Age

- [ ] Years

1.5 Do you consider yourself as sensitive to bright light?

	Not at all		Very much
Sensitive	├	────────────	┤

1.5 What is the category that best describes your job?

- [ ] Administrator
- [ ] Technician, scientist
- [ ] Secretary
- [ ] Manager
- [ ] Student
- [ ] Other: ____________

Part 2A. Questions about lighting conditions when reading text on paper

2.1 How do you rate the current *light level* for reading the text on paper?

	Too low	Too high
The light level on the desk		
The light level reading the paper		

2.2 How satisfied are you with the current *light level* for reading the text on paper?

	Very satisfied	Very dissatisfied
The light level on the desk		

2.3 When reading the text on the paper, where you bothered by

	Not at all	Very much
Glare from window		
Glare off shading device		

2.4 When reading the text on the paper, please mark the degree of glare you experienced from the window and the shading device

	Imperceptible	Noticeable	Disturbing	Intolerable
Window	☐	☐	☐	☐
Shading device	☐	☐	☐	☐

2.5 Assume you have to conduct your daily paper work at this work place, do you feel that the lighting conditions is

Clearly comfortable

Just comfortable

Just uncomfortable

Clearly uncomfortable

Part 2B: Typing task

Thank you for taking part in this test. The aim of this test is to evaluate easy it is to retype a given text. Please remember that we are testing the display(s) and not you!

You will be presented with a text in the upper window on the screen, and you shall copy the text into the window below. Please type the text freely and correct any mistakes you make as you normally would do. After you have finished typing the entire text, you should press the F5-key. Please work through the text as quickly and as accurately as possible. If you have any questions, please ask the test administrator now.

In recent years, many European countries have adopted energy efficiency measures into their building codes with the goal of reducing both energy consumption and electrical demand in buildings. Utilities, facing rapidly rising costs for additional generating capacity to meet future demand growth, have encouraged this process. Lighting has been a favorite target for these codes since it is a significant end-user of energy in many sectors, and because retrofit with energy efficient technologies is relatively straightforward. Energy codes typically set limits on allowed lighting power densities, which are often significantly lower than the practice prevailing before code adoption. In addition, codes often promote automatic lighting controls by offering

In recent years, amny European

Typing Task -- Press Return when complete. Alt-Shift-F10 to abort

Part 2B. Questions about the lighting conditions when typing text

2.1 How do you rate the current *light level* when typing the text?

	Too low	Too high
The light level on the keyboard		
The light level on the screen		

2.2 How satisfied are you with the current *light level* for typing the text?

	Very satisfied	Very dissatisfied
The light level on the keyboard		
The light level on the screen		

2.3 When typing the text, where you bothered by

	Not at all	Very much
Glare from window		
Glare off shading device		
Reflections on the screen		

2.4 When typing the text, please mark the degree of glare you experienced from the window and the shading device

	Imperceptible	Noticeable	Disturbing	Intolerable
Window	☐	☐	☐	☐
Shading device	☐	☐	☐	☐

2.5 Assume you have to conduct your daily typing at this work place, do you feel that the lighting conditions is

Clearly comfortable

Just comfortable

Just uncomfortable

Clearly uncomfortable

Part 2C: Visual search task

Thank you for taking part in this test. The aim of this test is to evaluate character legibility. Please remember that we are testing the display(s) and not you!

You will be presented with a series of screens similar to the example below. Your task is to find each capital letter 'A' (or another letter). You should read the text from the top left to the bottom right, as if you are reading a normal page of text. When you are ready to start a trial you should press the ENTER-key on the keyboard. You start your search immediately after a pseudo-text appears on one of five locations on the display (top-left, top-right, bottom-left, bottom-right or in the centre). Whenever you see a capital letter 'A' you should press the space bar on the keyboard. After you have finished reading the entire text, you should press the ENTER-key again. Please work through the screens as quickly and as accurately as possible. The number of targets in each screen varies, so please pay careful attention to properly reading, searching and indicating the presence of the target letter in each screen in the series as quickly and accurately as possible. If you have any questions, please ask the test administrator now.

```
WhwNdzo zltpVY 1CCAe kDw he t3
TkW3rm8U ya BpE O2B L8Y A5 She
PQtb 90DViRCDG 1H pSM yEqZz 6F
jyA3 sATQesa ANUU VLH Ou1p2JBE
vbR l1Y5rVr SA9mr DmPETLV 2uO2
7phnFd2oyT 83ee zKo8h KyiTJgAL
vXMu 6Kugm 3ElkxsOWhCK1FTMA T6
LuGF5 ad HsicT H0jkHv ssAq U8Q
8dW rmrtfGqh HCsnGdYIMQEITS fo
o1 XVw6 2VogMFo6 PH uJD3c DXj8
yW 5LN 6Bv0 fGPhdZ Cn x9gUiaH3
fySFoauaxj UeK bKQz 2uZa MmnCN
4t HT3OFuMUSo piq1uUh8tdRbK1Tn
Ez 33Q 6w fvVR 7B gyz Ns5 5Ami
7T5k 6bc2 ZHl fJmDO GwJ9 ECKYm
Xob3m t9 SU ZR e1 3lFg 1wc j4w
nToPDF RCUb nyMHs rMI0oizFL8dx
a2Z sD AK5R1 Q8jiI wBeeA L2Rz0
```

Part 2C. Questions about the lighting conditions when reading on the VDT

2.1 How do you judge the screen you have just used with respect to visual comfort?

	Poor	Neutral	Excellent
The screen is			

2.2 How do you rate the current *light level* when reading text on the screen?

	Too low	Too high
The light level on the screen		

2.3 How satisfied are you with the current *light level* for reading text on the screen?

	Very satisfied	Very dissatisfied
The light level on the screen		

2.4 When reading the text, where you bothered by

	Not at all	Very much
Glare from window		
Glare off shading device		
Reflections in the screen		

2.5 When reading the text on VDT, please mark the degree of glare you experienced from the window and from shading device

	Imperceptible	Noticeable	Disturbing	Intolerable
Window	☐	☐	☐	☐
Shading device	☐	☐	☐	☐

2.6 Assume you have to conduct your daily reading on screen at this work place, do you feel that the lighting conditions is

Clearly comfortable

Just comfortable

Just uncomfortable

Clearly uncomfortable

Part 3. Questions about the lighting conditions within the room

3.1 In general, how do you rate the *light level* in the room?

	Too low	Too high
The overall light level in the room		
The light level at the back of the room		

3.2 In general, how satisfied are you with the *light level* in the room?

	Very satisfied	Very dissatisfied
The overall light level in the room		
The light level at the back of the room		

3.3 When you are looking out of the window, do you experience that your view is restricted by any of the following elements?

	Not at all	Very much
By the window size		
By the shading devices/curtains		

3.4 Is the view to the outside important for you?

	Not at all	Very much
View outside		

3.5 For the current position of the blinds, I would

	Yes	Maybe	No
Like to change the slat angle of the blinds	☐	☐	☐
Like to raise the blinds	☐	☐	☐

3.6 I would like to be able to adjust the blinds to

	Not important		Very important
Any position I like at any time	├	────────	┤

3.7 I can accept that the blinds are automatically controlled, if

	Not acceptable		Very acceptable
I can change the blinds when I need to	├	────────	┤

3.8 Assume you have to conduct your daily work under the current conditions. Do you feel the blinds need to be changed to maintain a comfortable work place?

I'm very uncomfortable and the blinds need to be changed immediately	☐	I'm comfortable and do not require any change of the blinds	☐
I'm slightly uncomfortable, but I would not change the blinds right now	☐	I have no preference	☐

3.9 If you should work for a longer time under the conditions as they have been during your stay in this room, would you then turn on any of the electrical light?

	Yes	Maybe	No
The desk light	☐	☐	☐
The general lighting in the ceiling	☐	☐	☐

We will now let you change the blinds according to your wishes. On the desk in front of you, you find a switch were you will be able to change the angle of the blinds. You will not be able to raise the blinds. If you turn the switch to the left, you will close the blinds. If you turn the switch to the right, you will open the blinds. Please try for some few minutes to close and open the blinds. When you find the position you like, please leave the blinds in this position and answer few questions. After you finished the questions, please leave the room and wait for further instruction!

3.10 I changed the blinds because I would like to have

	Not at all	Very much
More light inside the room		
Less light inside the room		
More light on the desk		
Less light on the desk		
More light on the screen		
Less light on the screen		
Better view to the outside		
Less glare from windows		
Less glare from blinds		

3.11 In general, how satisfied are you with the blinds for adjusting the following?

	Very satisfied	Very dissatisfied
The overall light level in the room		
The visual quality of the room		

Part 4. Questions about the room as a work place

4.1 During your stay in this room, have you been uncomfortable with any of the following indoor climate conditions?

	Not at all	Very much
High temperature		
Low temperature		
Draft		
Odour		
Dust		
Noise from blinds		
Noise from HVAC		

4.2 Are there any other factors that have affected your comfort in this room?

Please specify, if any:

Thank you very much and please wait for further instruction!

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Appendix A - Description of Monitoring Equipment for Measurement

Table 7 Description of the illuminance meters used in the project for external and internal daylight measurements.

Institute	Manufacturer	Range Klux	Calibration	Maximum calibration error	V(λ) (f_1')	Cosine response error (f_2)	Fatigue error (f_5)
Denmark (DBUR)	Internal: Hagner	0.1 – 100	1993/1998		< 3%	< 3%	
	External: LMT	0.1 – 100		± 0.6 %	< 3%	< 1%	
Germany (ISE)	Internal: Hagner	0.01-100	2002				
	External: LMT	0.1 - 100	2002		< 3%	< 3%	

Table 8 Description of the CCD camera used in the project for internal luminance measurementss.

Institute	Manufacturer	Resolution (effective pixels)	Resolution at single point (dynamics range)	Measuring range (full-scale point) cd/m²	Software
Denmark (DBUR)	TechnoTeam LMK Mobile	1280 (H) * 1024 (V)	HighDyn: 1:50 000	3 - 200.000	LMK2000
Germany (ISE)	TechnoTeam LMK98	1300 (H) * 1030 (V)	HighDyn: 1:10 000	30 - 3 000 000	LMK2000

Table 9 Description of the irradiance meters used in the project for external daylight measurements.

Institute	Manufacturer	Range W/m^2	Spectral range nm	Calibration	Non-linearity	Zero offsets Therm. radiation (200 W/m^2)	Non-stability
Denmark (DBUR)	Kipp & Zonen CM11	<4000	305-2800	± 0.6 %	< 1%	< 7	± 0.5
Germany (ISE)	Kipp & Zonen CM11	<4000	305-2800	± 0.6 %	< 1%	< 7	± 0.5

Table 10 Description of the data acquisition system used in the project.

Institute	Manufacturer	Type	No. of differential analog input channels	A/D converter resolution (in bits	Data acquisition software
Denmark (DBUR)	Keithley SmartLink KNM - DVC 32	Datalogger	80	20	DBUR
Germany (ISE)	Agilent Technologies	34901A,	40		ISE

Appendix B - Description of algorithm used for estimating cut-off angle

By Nicolas Morel, EPFL-LESO

This part explains how the critical slats angle (β_c) is calculated to just cut completely the direct sunlight. Figure 18 gives a representation of two slats of a venetian blind.

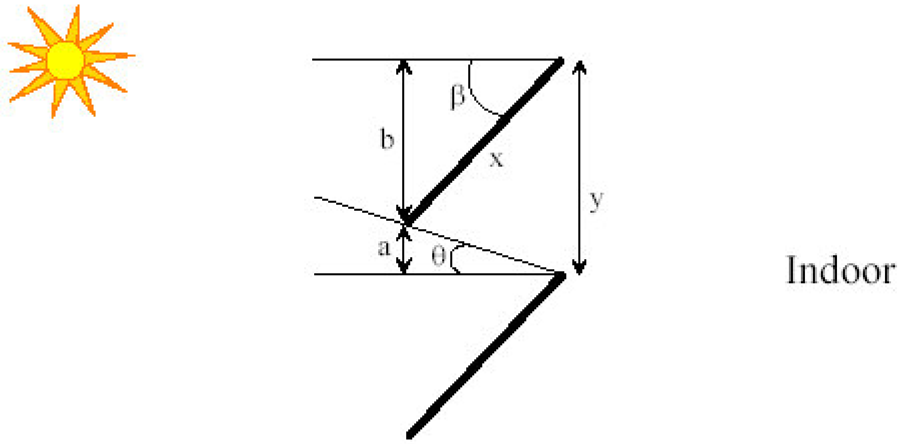

Figure 21 Lateral view of two slats, for a value of β equal to the critical slat angle β_c

The different parameters are:

- x is the slat width
- y is the distance between two slats
- β is the slats angle as previously defined (positive on the figure 18)
- θ is the height of the sun projected on the plan perpendicular to the facade

Defined in figure 18, a and b can be calculated by:

$a = x \cdot \cos\beta_c \cdot \tan\theta$ and $b = x \cdot \sin\beta_c$

And one has:

$y = a + b$ so $y = x \cdot \left(sin\,\beta_c + cos\,\beta_c \cdot tan\,\theta \right)$

Then, if one the parameter d = y/x,

$$d = sin\,\beta_c + cos\,\beta_c \cdot tan\,\theta$$

Finally, using the azimuth τ (angle between the perpendicular to the facade and the direction of the sun projected on a horizontal plane, positive towards the East direction) and the real height of the sun η instead of the projected sun height θ, one can write:

$$tan\,\theta = \frac{tan\ \eta}{cos\ \tau}$$

And,

$$d = sin\,\beta_c + cos\,\beta_c \cdot \frac{tan\ \eta}{cos\ \tau}$$

This equation is solved using Matlab Symbolic Calculation Toolbox. There are two solutions, only one of them has a physical meaning:

$$\beta_c = 2 \cdot arctan \left\{ \frac{1 - \sqrt{1 + \frac{tan\,\eta}{cos\,\tau} - d^2}}{\frac{tan\,\eta}{cos\,\tau} - d} \right\}$$

Appendix C - Balanced presentation order for the subjects in the study

The order of presentation of the window area and line of sight in the Test Room is carefully controlled to make sure that no single order would prevail over another. There are six different ways to present three different window areas (A 25%, B 50%, C 90%) and two line of sight (view 1 - parallel, view 2 - diagonal). The presentation order for the three window size is counter-balanced with the two line of sight. Additional, the subjects will evaluate each shading system twice (view 1 and 2), which means that half of the subjects (minimum 9) start with view 1 in the morning session and finish with view 2 in the afternoon session (table 11). The other half is counter-balanced (table 12). This give the presentation order for each subject as follow:

Table 11 Balanced presentation order for each subject (first half).

Subject number	Morning session View 1 – parallel with window	Afternoon session View 2 – diagonal towards window
1	A B C	C B A
2	B C A	A C B
3	C A B	B A C
4	A B C	C B A
5	B C A	A C B
6	C A B	B A C
7	A B C	C B A
8	B C A	A C B
9	C A B	B A C
(10)	A B C	C B A
(11)	B C A	A C B
(12)	C A B	B A C

Table 12 Balanced presentation order for each subject (second half).

Subject number	Morning session View 2 – diagonal towards window	Afternoon session View 1 – parallel with window
1	C B A	A B C
2	A C B	B C A
3	B A C	C A B
4	C B A	A B C
5	A C B	B C A
6	B A C	C A B
7	C B A	A B C
8	A C B	B C A
9	B A C	C A B
(10)	C B A	A B C
(11)	A C B	B C A
(12)	B A C	C A B

The same subject will be used for two main combinations defined within the ECCO project (within-subject design) to achieve that the assessments of these combinations is as equal as possible. Due to duration of test and number of shading devices tested within the project, it will not realistic to make a complete within-subject design for all combinations. The within-subject variables is window-size and line of sight, while the between-subject variable is shading device and time of year (e.g. summer solstice, equinox). This means that the between-subject design relating to the shading devices, a minimum of 18 subjects (or more if drop-outs) are needed in each group. Each institute will evaluate three different shading devices, which means the total number of subject per institute is minimum 54 subjects. It is highly recommended to add additional 6 subjects for each shading system (a total of 72 subjects), since we will likely loose something like 10-20% of the subjects or bad data. For each system, the number of test days will be at least 18 days (+3 days) for each system, giving a total of 54 test days (+9 additional days).

Appendix D – Letter-search task

The letter-search test procedure measures the detection and recognition of characters on VDT-screens. In this experimental set-up it is used to assess how the subject is able to detect and recognise a target character accurately and quickly in a room where discomfort glare from a non-uniform source may cause adaptation and visibility problems. Subject performance is specified in terms of the speed achieved by the test subjects in a visual search task.

The pseudo-text is generated from the character set according to the following constraints:

- Pseudo-text consist of random strings of letters and digits separated by single spaces. The texts consist of a constant number of lines and a constant number of characters per line (including embedded spaces). The number of characters per line contain 30 characters.

- The text contain target characters of a single kind. The position of the targets shall be randomly chosen with the restriction that a line may not start or end with the target character.

- The texts shall contain a constant number of spaces. The space fraction shall be 15% (i.e. the number of spaces relative to the total number of characters, including embedded spaces).

The pseudo-text can be displayed as a block of characters in one of five screen locations. Screen locations is in the upper left, the upper right, the lower left, the lower right and the centre of the screen. The subject’s task is to scan the text and identify the presence of the target character. To overcome problems of initial learning effects the subjects will use the initial pre-test performing the task for at least 3 pseudo-texts. In the experimental trial a log-file measure the time taken for the subject to read each block of pseudo-text and the number of errors made by the subject. Search time begins immediately after the pseudo-text is presented on the display. Search time ends when the subject indicates completion of the page of pseudo text. The subjects use the spacebar each time a target is spotted and the return key to stop time registration. The number of counted targets is registered in the log-file. The performance measurement will be neglected from statistical treatment if the number of missed targets is too large (1 missed target is accepted in a text with 10 targets). The subject will be allowed a rest break of up to 30 seconds between trials, with a minimum break of 10 seconds.

Two dependent measures will be recorded in the log-file for each subject. These are the error rate and search speed. The error rate, E, is defined as:

$$Error = \frac{T_o - T_r}{T_o}$$

where T_o is the total number of target characters in the page of pseudo-text and T_r is the total number of target characters reported by the subject. If E is equal to or greater than 10% (i.e. more than 1 missed target in a set of 10 targets), the results for the trial could be excluded from all further analysis.

From the log-file a performance measure search speed is calculated by

$$sv = \frac{total\ number\ of\ characters\ (including\ spaces)\ in\ pseudo\text{-}text}{search\ time} \cdot \frac{characters}{second}$$