XVII FORUM TERMOMODERNIZACJA 2017

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Organizator Zrzeszenie Audytorów Energetycznych

# Światło dzienne jako parametr jakości modernizowanych budynków

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# BACKGROUND

Let us consider how people perceive architecture and what they are concerned about regarding buildings.

Only construction engineers are analyzing strength and durability of the bearing construction of the building, most people…… do not.

Only the heating, ventilation and cooling engineers are analyzing systems and solutions of the indoor air and temperature, most people ….. do not.

Only building technicians are able to evaluate the thermal insulation of the building envelope and consider its impact on energy use, most people ….. do not.

Only specialists are estimating greenhouse gas emissions by embodied emissions calculations, most people do not think much about this.

Also very few people have knowledge about how to use solar panels and other forms of green energy generation.

Something that most people actually note in buildings is **audio-visual environment, temperature** and in certain circumstances also **air-movement;** also, we do not have senses for registering the last two, as we have eyes and ears for perception of visual images and sound.

In addition, humans may feel the **smell** in the room and, theoretically, they can **taste** the surface materials, something that they hardly do anyway.

Nidarosdomen

Café Choco Boco

# BACKGROUND

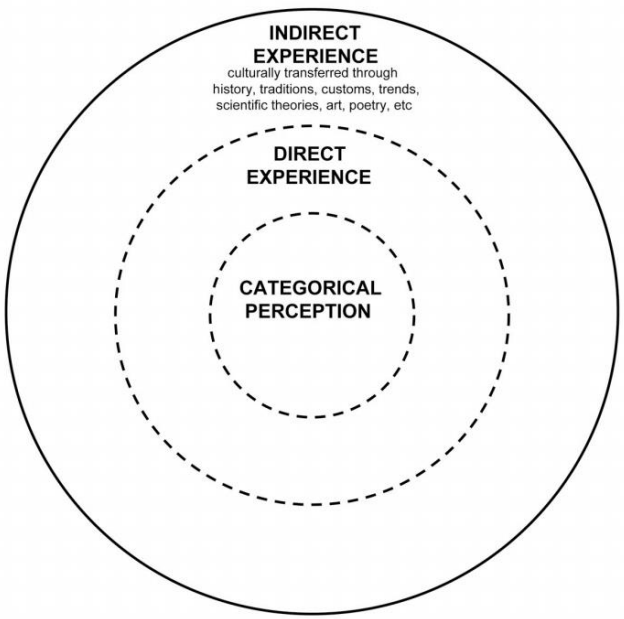
The audial stimulus are seldom created by the building itself, usually it is the result of human activities like walking or talking or it is generated by a transmitter; a similar comment may be done, with the exception of new-treated (painted) surfaces, for smell which typically is the result of cooking, washing, etc..

Humans interact with buildings and are using electric light fixtures according to theirs needs and wants.

But if we limit our discourse to natural light, we may argue that the visual impression is the one which is least dependent on the casual human behavior.
So, let us limit the discussion to the visual environment and consider how the perception of an architectural space is influenced by light and surface colours.

Our vision is based on a continuous adaptation to the physical world where color and light are perceived from varying spatial positions and under different and changing light conditions.

The mental image of the scene that we build in the brain
is the result of the process of visual perception;




Level of experiencing colour and light according to Ulf Klare

# BACKGROUND

Experiencing daylight in rooms with different orientations (e,s,w,n) and different windows.

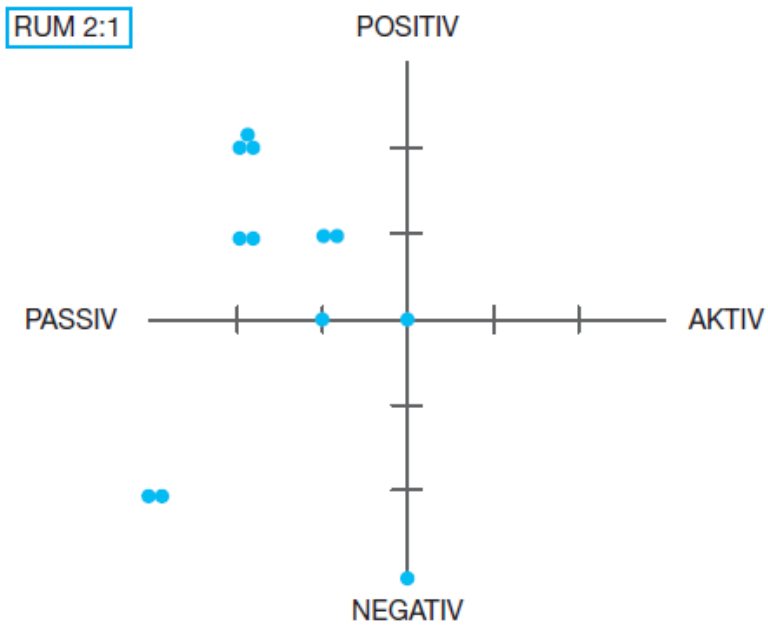
Equinox 12:00 and 18:00

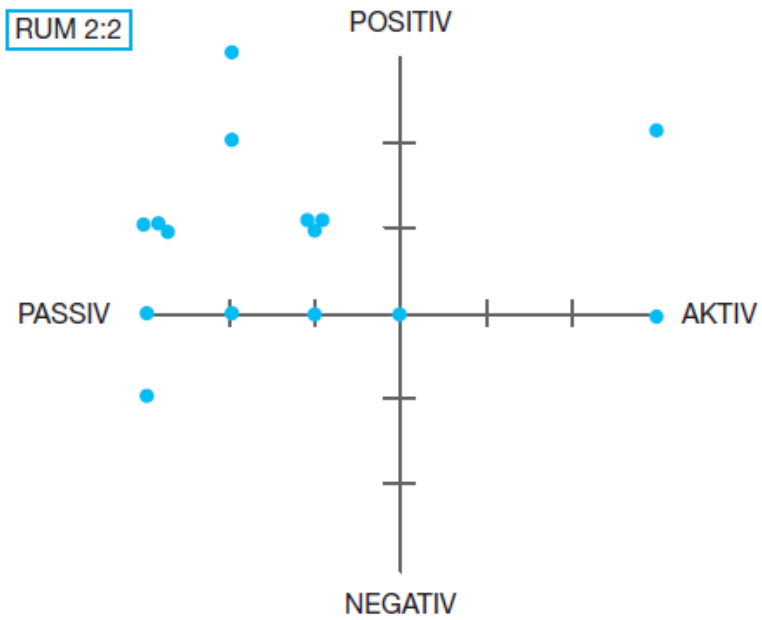

But how do daylight and colour affect our perception of architectural quality?

And how can we measure this?

….asking visitors and/or users?

# IMMEDIATE EVALUATION




Immediate evaluation of a room before and after transformation,
collected from the Optima project, SYN-TES,
led by Karin Fridel Anter

# IN DEPTH EVALUATION

Cluadia Moscoso's PhD project

Full-scale mock-up rooms build in the ROMLAB, NTNU

# IN DEPTH EVALUATION

Cluadia Moscoso's PhD project

Experimental Hypothesis:

White wall surfaces and High daylighting level can produce higher scores in the evaluation of architectural quality attributes of a room than black wall surfaces and low daylighting level (small windows).

What is changed (in a controlled manner)?: Colour (White and Black wall surfaces) and Daylight (3 different daylight intensity levels/window sizes).

What was observed?: Architectural Quality Descriptors

| | Attributes | | Extremely | Quite | Slightly | Neither | Slightly | Quite | Extremely | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Pleasantness | Pleasant | | | | | | | | Unpleasant |
| 2 | Excitement | Exciting | | | | | | | | Dull |
| 3 | Order | Ordered | | | | | | | | Chaotic |
| 4 | Complexity | Simple | | | | | | | | Complex |
| 5 | Legibility | Legible | | | | | | | | Illegible |
| 6 | Coherence | Coherent | | | | | | | | Incoherent |
| 7 | Spaciousness | Spacious | | | | | | | | Tight |
| 8 | Openness | Open | | | | | | | | Closed |
| 9 | Spatial Definition | Defined | | | | | | | | Undefined |

1. **Pleasantness**. The quality of being pleasant. Pleasant: That gives pleasure, delight, or satisfaction. Now chiefly in weakened sense: agreeable, nice; quite enjoyable. (E.g. you think that the room is enjoyable).

2. **Excitement**. To induce, elicit, provoke (actions, manifestations); to bring about, occasion (active conditions). (E.g. The room feels exciting and provokes in you a good and active state of mind).

3. **Order**. To place in order, give order to; to arrange in a particular order; to arrange methodically or suitably. (E.g. you think that the room is well organized).

4. **Complexity**. The quality or condition of being complex. Complex: A whole comprehending in its compass a *number of parts*, *of interconnected parts* or involved particulars; a complex or *complicated whole*. (E.g. you think that the room looks simple rather than complex).

5. **Legibility**. The quality of being legible. Legible: That can be "read". (E.g. It is easy for you to see the corners, room details, etc.).

6. **Coherence**. Logical connection or relation; congruity, consistency. (E.g. you think the room feels as a student room or has a connection with its function of a student room in regarding daylight and colour – Enough daylight for a student room).

7. **Spaciousness**. The state or quality of being spacious, wide, or commodious; extensiveness of area or dimensions; roominess. (E.g. you think that the room is not spacious).

8. **Openness**. The quality or condition of being open. Open: Not closed or blocked up: allowing access or view, free from obstruction. (E.g. you seem that the room is not closed).

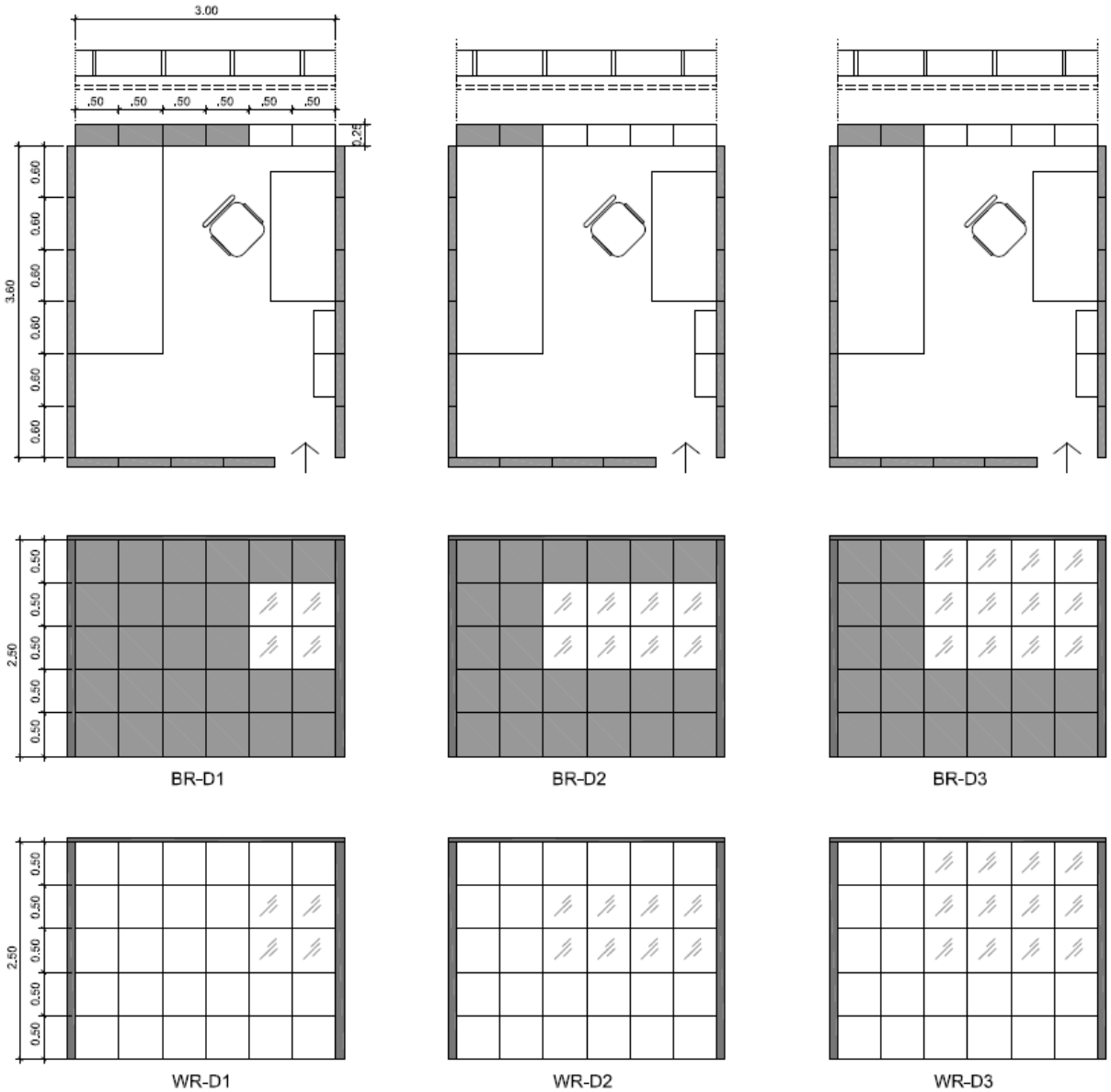
9. **Spatial Definition**. The setting of bounds or limits; limitation, restriction. (E.g. you think that the room is well spatially defined).

# EXPERIMENTAL DESIGN

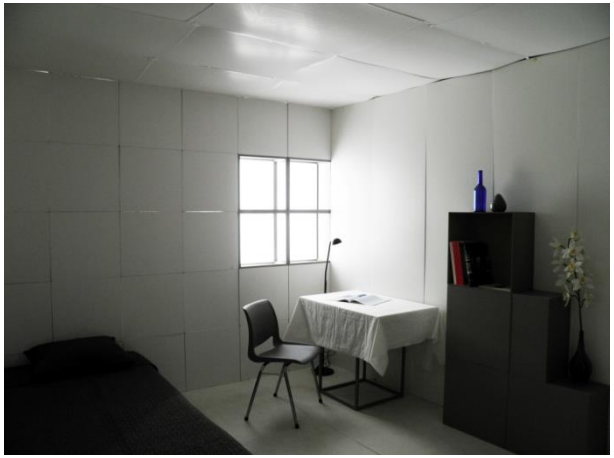
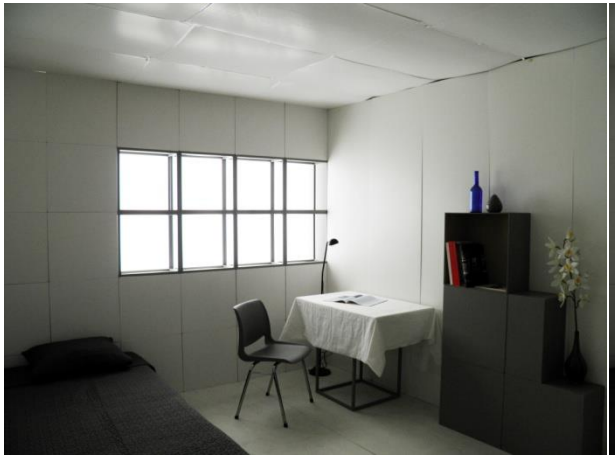
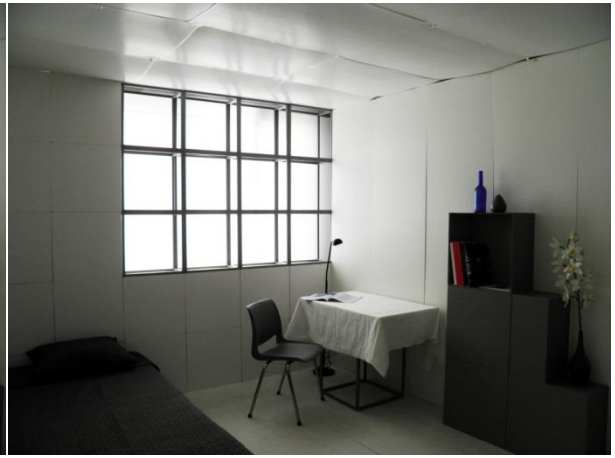
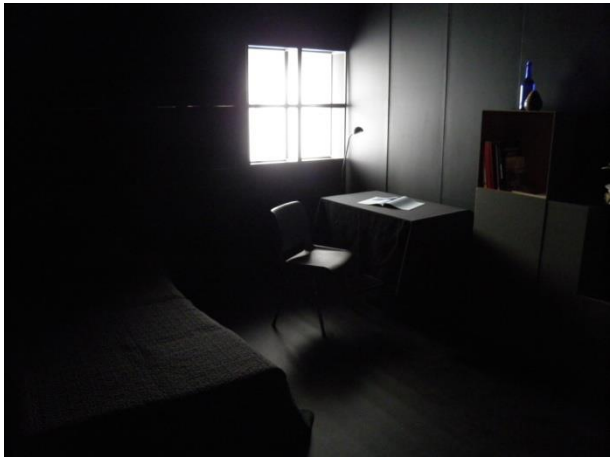
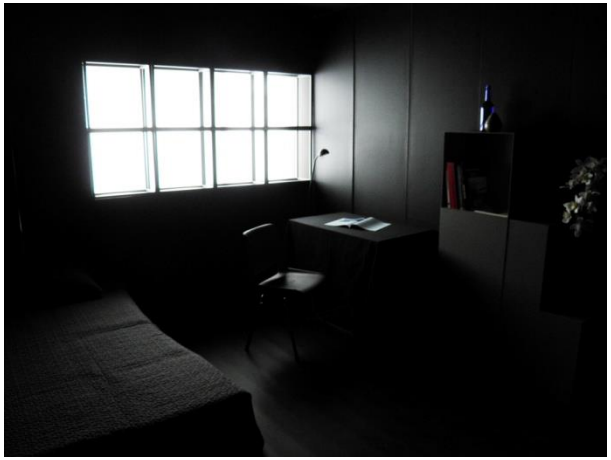
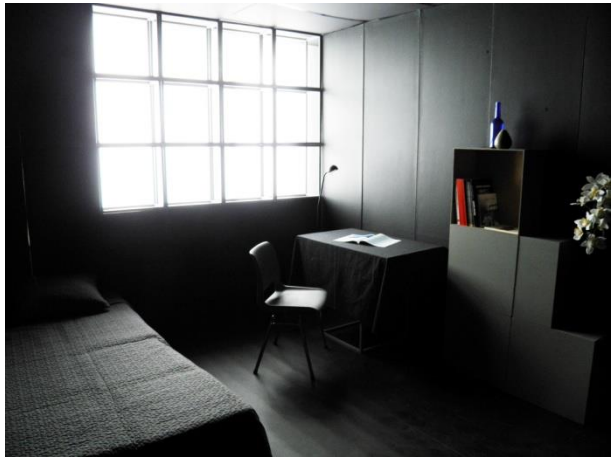
1. How strong is the impact of daylight and achromatic colours on the perceived quality of a student room?

2. How do quality descriptors correlate between each other?

# EXPERIMENTAL DESIGN



# EXPERIMENTAL DESIGN

# EXPERIMENTAL DESIGN

Illuminance (lx)

| | Window Size (m) | Bed (lux) | Desk (lux) | Mean (lux) |
|---|---|---|---|---|
| Black Room | Small (1x1) | 1,5 | 87,3 | 44,4 |
| | Medium (2x1) | 20,0 | 110,8 | 65,4 |
| | Large (2x1,5) | 31,8 | 162,3 | 97,1 |
| White Room | Small (1x1) | 65,2 | 220,5 | 142,8 |
| | Medium (2x1) | 138,4 | 328,5 | 233,4 |
| | Large (2x1,5) | 227,1 | 497,5 | 362,3 |

Luminance (cd/m$^2$)

| | | D1 | D2 | D3 |
|---|---|---|---|---|
| Black Room | Min | 13,21 | 4,22 | 159,37 |
| | Max | 37,20 | 184,22 | 203,07 |
| | Mean | 34,15 | 145,84 | 238,94 |
| White Room | Min | 187,24 | 266,16 | 302,47 |
| | Max | 221,98 | 305,77 | 357,09 |
| | Mean | 292,88 | 387,94 | 460,35 |

NCS Colour Codes

| | Name | Elements | Code | Reflectance Factor ($Y_l$) |
|---|---|---|---|---|
| Black Room | Lateral walls | Wall Panels | S 8500 - N | 6 |
| | Window walls | Wall bricks | S 9000 - N | 4 |
| | Bedding set | Synthetic fabric | S 7000 - N | 13 |
| | Bookshelf | Wall bricks | S 4502 - Y | 30 |
| White Room | Lateral walls | Wall Panels | S 0502 - Y | 87 |
| | Window walls | Wall bricks | S 0500 - N | 87 |
| | Bedding set | Synthetic fabric | S 7000 - N | 13 |
| | Bookshelf | Wall bricks | S 4502 - Y | 30 |

# RESULTS | Statistics

ANOVA

*How strong is the impact of daylight and achromatic colours on the perceived quality of a student room?*

1. Daylight and Colour separately have a significant positive effect on the evaluation of the perceived quality of a student room. Only the descriptor **Order** was not affected by daylight.

2. The interaction of Daylight and Colour had a significant effect on **Legibility**.

3. The rooms with white surfaces were ranked higher than the rooms with black surfaces for all of the descriptors.

4. Excitement, Spaciousness and Openness were ranked higher with the “black room” with larger windows (BR-D3) than in the “white rooms” with smaller windows (WR – D1). (According to previous findings – window size is one of the most important predictors to judge spaciousness).

5. Overall, the rooms with larger windows and higher luminances (WR - D3: L*m* = 460 cd/m$^2$), obtained higher ratings for all the nine attributes, suggesting that:

High levels of daylight are crucial in order to achieve a more **pleasant, exciting, complex, legible, coherent, spacious, open and spatially defined room.**

# EU-standard

1. Is daylighting included in building codes and recommendations?

2. How?

# CEN the European Committee for Standardization

## CEN/TC 169/WG 11 **Daylighting of buildings**

Daylight should be the principal source of illumination for all spaces with windows and roof lights.

Daylight is strongly favored by building occupants; to adequately illuminate visual tasks, provide the light levels needed for our **health** and **well-being**, create **an attractive visual environment**, and **save energy for electrical lighting**.

Daylight is dynamic, it varies in magnitude, direction and spectral composition with time and provides variable modelling and luminance patterns, which are perceived as being beneficial for people in indoor environments.

Windows and roof lights provide visual contact with the outside environment, the weather and the time of day.

Daylight needs to be assessed **at least** in terms of:

1. **Daylight provision (level)**
2. **View**
3. **Sunlight**
4. **Glare ….no, no, no glare!**

# EU-standard **Daylight provision**

## Minimum recommendations for spaces lit with windows and occupied by people more than temporarily:

An illuminance level of **300 lx** should be exceeded over 50% of the space for more than half of the daylight hours in the year.

*and*

an illuminance level of **100 lx** should be exceeded over 100% of the space for more than half of the daylight hours in the year.

…for spaces lit with rooflights

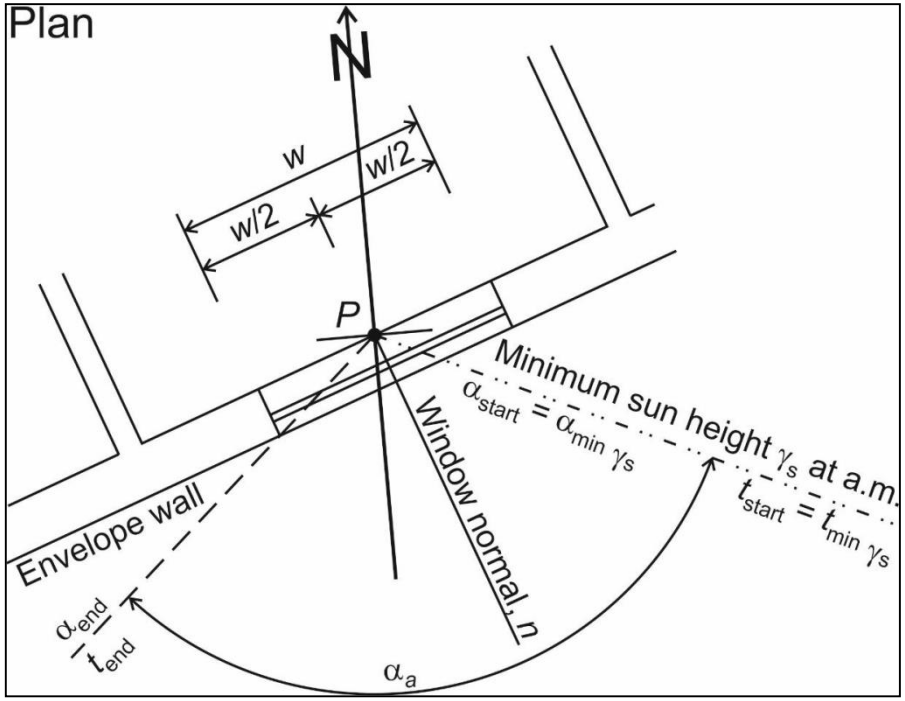
an illuminance level of **300 lx** should be exceeded over **100%** of the relevant area of the space for more than half of the daylight hours in the year.

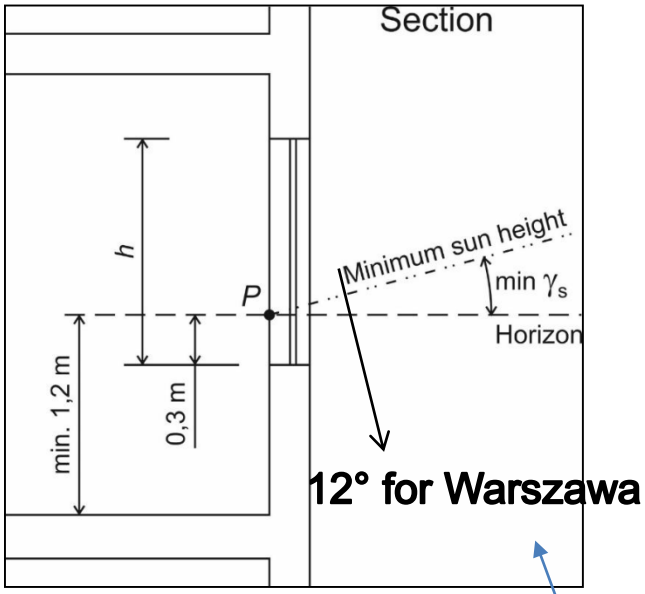
# EU-standard **View**

| DESCRIPTORS | INSUFFISIENT | SUFFISIENT | GOOD | EXCELLENT |
|---|---|---|---|---|
| **Width of view window(s)** | < 13° | > 13° | > 27° | > 54° |
| **Distance of the view** | < 6 m | > 6 m | > 20 m | > 50 m |
| **Number of layers:**<br>**- sky**<br>**- landscape (both urban and nature)**<br>**- ground** | only sky or only ground | landscape layer is included | minimum to layers are included | all layers are included |
| **Environmental information:**<br>**- location (orientation regarding water, food, heat, sunlight, escape routes, destination)**<br>**- time (environmental conditions which relate to our innate biological clocks)**<br>**- weather (need for clothing, need for shelter, heating/cooling, opportunities for sunbath)**<br>**- nature (the presence of trees, bushes plants, insects, birds and other animals)**<br>**- people (the presence of people and** | time and weather | time weather and location | time, weather, location and one of: nature and | all |

Example of insuffisient and excellent view, NTNUs campus

# EU-standard **Exposure to sunlight**




The **minimum** recommendation is that the room should receive possible sunlight for a duration higher than **1.5 hours** (supposed to be cloudless) on March 21st when the sun angle is higher than the threshold value for the place.

Recommendation for **medium** exposure 3.0 hours

Recommendation for **high** exposure > 4.0 hours

This is to be checked at the center of the window as shown in the figure to the left.

# Daylight glare probability DGP

The Daylight Glare Probability (DGP) is an approach to consider both the illuminance at eye level and individual glare sources of high luminance to estimate the fraction of dissatisfied persons.

The minimum recommendation for glare protection is that of DGP for the occupied space does not exceed a value of 0.45 in more than 5% of the occupation time of the relevant space.

DGP < 0.45

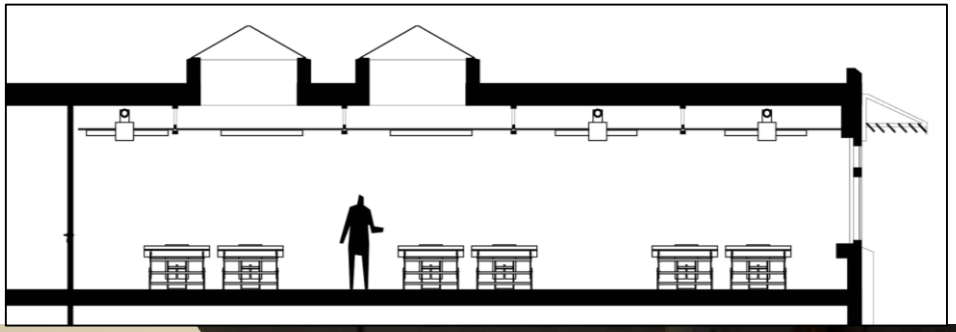
Recommendation for medium glare protection DGP < 0.40

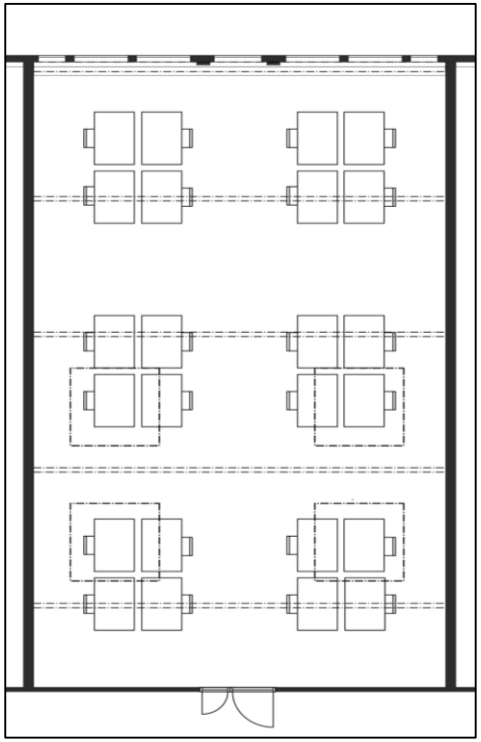
5% of the occupation time

Recommendation for high glare protection DGP < 0.35

5% of the occupation time

# Retrofitting of studios at NTNU, univ. campus





# Retrofitting of studios at NTNU, univ. campus

| | SUNNY | | CLOUDY | | | |
|---|---|---|---|---|---|---|
| | New (lx) | Old (lx) | New (lx) | D | Old (lx) | D |
| 1 | 3145 | 1655 | 1306 | 6.3% | 454 | 2.2% |
| 2 | 3485 | 1795 | 992 | 4.8% | 435 | 2.1% |
| 3 | 3490 | 1760 | 1154 | 5.6% | 433 | 2.1% |
| 4 | 3110 | 1730 | 1417 | 6.9% | 456 | 2.2% |
| 5 | 3960 | 2015 | 1252 | 6.1% | 472 | 2.3% |
| 6 | 4300 | 1900 | 982 | 4.8% | 462 | 2.2% |
| 7 | 7535 | 1820 | 1109 | 5.4% | 431 | 2.1% |
| 8 | 4445 | 1765 | 1327 | 6.4% | 458 | 2.2% |

On average the light level is increased 2 - 3 times both in sunny and cloudy conditions.
We predict similar values for intermittent sky.

The daylight factor was increased from 2.1 – 2.3% in the room with the old solution to 4.8 – 6.9%.

# Summer, the worst case?

Fish eye HDR-pictures of the studio under overcast sky conditions, the new solution to the left, old one to the right.

Fish eye HDR-pictures of the studio under clear sky conditions, the new solution to the left, old one to the right.

## Retrofitting of kitchen, dormitory

And interaction between people and building, colected from “La Casa Collage” Xavier Monteys and Pere Fuertes