Shading system in glass facades architecture

An alternative shading system which blends in with the beauty of glass facades

ARIANNA FOLTRAN
Master's Thesis

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An alternative shading system which blends in with the beauty of glass facades.

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Abstract

Glass facades building, especially offices, always need shading devices to guarantee occupant’s well-being and comfort. However, shading devices are often composed of shutters or fabric tents which create dark interiors and do not allow access to view out. Moreover, they ruin the aesthetical appearance of glass facades. The study aims to research and propose an alternative shading system for glass facades building which can prevent from glare in the interior spaces as well as respecting the continuity of a glass facade from an exterior point of view.

Research upon materials that can be integrated into glass has been carried and Ceramic ink digital printing has been found as the right technique to ensure both a functional and aesthetical value. The material today has been used mainly for decorative functions. The patterns and the colors of the shading device proposed with ceramic and digital ink printing have been tested in Deloitte Building in Copenhagen with both 3D digital models and an online survey investigating comfort preferences.
1. Introduction

Glass facades buildings, especially offices or administration buildings, always need a shading system in order to avoid glare and excessive direct solar radiation indoors. However, classical shading systems are often creating dark interiors and are not allowing the users of building to benefit the dynamics and colors of natural daylight.

“Our technocratic society has tendency to run to extremes: after daylight has passed through prisms, mirrors, holograms, heat protection coatings and x number of panes, can we really call it ‘natural’ light?” (Helmut Köster, 2004).

At the same time most of the existing shading systems, from an exterior point of view, ruin the continuity and the transparency effect that a glass façade wants to achieve.

This work aims firstly to research about new technologies of shading systems, in particular static and integrated into glass, used nowadays in facades in order to see the state of art of the topic. Following the research, a design proposal of a shading system integrated into glass that is respecting daylight dynamics and that does not introduce additional panels system will be presented. The solution found will be applied in an existing building, the Deloitte headquarters in Copenhagen, a cubical building composed of four glass facades which are characterized by blinds shading system. The main objective is to exploit the design opportunities that glass technology can give without introducing external elements as shading systems.
2. Methodology

The methodology adopted in this work starts with a research around the main questions that have been pointed out:

1. Which are the visual comfort criteria that need to be addressed in an office environment from the user’s point of view?
2. Which possibilities is glass technology offering today when it comes to materials for shading?
3. Which material’s patterns integrated into glass could be most useful to serve as a shading device?
4. Is it possible to find a shading solution that is respecting the continuity and the transparency of a glass facade both from an exterior and an interior point of view?

The design process will be carried following the concept of Transfer of Technology (ToT): the main aim of this design work is not to invent a new technology of shading system but to transfer a material or a technology that is already in use, into the specific case that I choose to analyse. The design will be focused on finding an existing material that can be integrated into glass in the form of a pattern and that can react to daylight in the most natural way, respecting the glass facade appearance from exterior and the view out from the interior. The Transfer of technology is the process in which skills, knowledge, technologies, manufacturing methods or samples are shared among governments, universities and companies to ensure accessibility of technological developments to a wider range of users who can then further develop and exploit them into new products, processes, applications, materials, or services2.

So the technology transfer can be the design of new products (product or embodied technology transfer) and more efficient production of existing products (Das, S. 1987).

The role of the designer is as well to investigate existing technology and to apply it in a different discipline or for a different purpose: a mechanism belonging to a specific domain, if applied to a different field can bring up unexpected progress.

The design solution will be visualized by a 3D model using software Revit. According to researches and experiments, the current tools to calculate visual comfort criteria and metrics in offices. State of art and trends about shading system. Shading patterns and materials. and the quantification of daylight discomfort glare are not very accurate in depicting the reality: it is well known in the field that the applicability of Discomfort Glare Index has many limits since it does not provide results consistent with the real perception of situations of daylight discomfort glare3. For this reason, the design result will be presented visually in its functions and a survey will be conducted in order to test the reaction of people in regards to the shading system. Further steps to take into the research will be addressed at the end of the work.
3. Background

3.1 Visual comfort criteria and metrics in office environment.

Current standards and guidelines regarding residential and workplace lighting condemn us to a kind of biological darkness: shading devices at work reduce daylight intensity from 100000 lx outside to 500-1000 lx indoors. It is known that insufficient natural light might cause serious diseases and consequences on our behavior since light synchronizes the human biological clock.

There are various parameters in human psychology that influence the perception of lighting quality and that are not measurable in an objective way: mood, need for privacy and access to outdoor view. Besides, there seems to be a general agreement that the most basic visual comfort requirements relate to levels of illuminance and to how light is distributed in the visual field.

In this chapter I will consider only the main parameters that are describing visual comfort depending on illuminance and luminance distribution. Table 1 is summarizing the most relevant parameters for visual comfort requirements: illuminance (E) is the most referred to in lighting literature.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workplane illuminance (lux)</td>
<td>100 - 300 computer based task</td>
</tr>
<tr>
<td></td>
<td>1280 - 1500 maximum values</td>
</tr>
<tr>
<td>E_min/E_max workplane</td>
<td>&gt; 0.5 accepted</td>
</tr>
<tr>
<td></td>
<td>&gt; 0.7 recommended</td>
</tr>
<tr>
<td>Window luminance (cd/m²)</td>
<td>max values 4000 - 6000</td>
</tr>
<tr>
<td>Daylight Glare Index (DGI)</td>
<td>&lt; 22 comfortable</td>
</tr>
<tr>
<td></td>
<td>24 - 26 uncomfortable</td>
</tr>
<tr>
<td></td>
<td>&gt; 28 intolerable</td>
</tr>
<tr>
<td>Daylight Glare Probability (DGP)</td>
<td>&lt; 0.35 - imperceptible</td>
</tr>
<tr>
<td></td>
<td>&lt; 0.40 - perceptible</td>
</tr>
<tr>
<td></td>
<td>&lt; 0.45 - disturbing</td>
</tr>
<tr>
<td></td>
<td>&gt; 0.45 - intolerable</td>
</tr>
</tbody>
</table>

Regarding daylight, the simplest parameter adopted by EN14501 is the window maximum luminance: otherwise, specific daylight glare indices are still in development. The daylight glare index (DGI), commonly referred to in the calculation of daylight discomfort glare, is based on a formula that involves the average window luminance, the solid angle, the background luminance (average luminance of the field of view, excluding glare source) and the position index. Although, limitations are found in its application for cases where the glare source is non-uniform or fills approximately the whole field of view.

Moreover, studies have found that if there is a pleasant view from the window which is causing glare from incoming daylight, the discomfort glare appears to be more tolerated. This underlines that there are other lighting qualities, beyond illuminance and luminance distribution and glare index that are influencing user’s satisfaction in an indoor working environment that are not objectively measurable: for example the appearance of the color spectrum and the access to view out.

A literature review presented by Dubois refers that the spectral properties of a glazing effect can alter the appearance of an indoor environment: occupants tend to prefer the daylight resulting from bronze glazing over the daylight resulting from and blue glazings. Otherwise, natural colour of daylight (that might result from a neutral or translucent shading system) is usually preferred in a working environment. For example, the use of reflecting or absorbing glass in the windows or in the interpositions of a translucent curtain, although reducing the daylight illuminance in the interior, can lead to a reduction of the supplementary artificial lighting illuminance compared with that required with clear glazing.

A study carried by Chauvel underlines that among these parameters, the major controlling factor is the window luminance. There are several ways to control it and at the same time retaining the view out and the main characteristics of natural lighting: he suggests for example that one of the main measures to reduce discomfort glare to the occupants of the room can be having horizontal limitations of the sky view so horizontally limiting the area of sky visible from any position of the room. A way of achieving this is to fit vertical instead of horizontal fins to the windows (fig. 1).

The details on the right (fig.1 and fig.2) are showing how vertical fins instead of the horizontal ones, are able to preserve more view out by reducing anyway the glare discomfort for the viewer. The areas ‘a’ are limiting the view of the sky while areas ‘b’ are the areas in which the view out is allowed. In the diagram in fig.1 the areas ‘a’ are wider than in the diagram of fig.2.
The main purpose of shading systems is to protect buildings from direct solar radiation: this means that they serve as regulators for a healthier environment both for daylight intake and for the energy intake.

This work is taking into consideration the role of shading system regarding exclusively daylighting: since the final design will be applied in a building situated in Denmark, overheating problems are likely to occur mainly during only two months of summer period. For this reason, the priority of the design result will be limited to light requirements.

Daylighting and optical requirements on shading systems are: glare protection, homogenous illumination, privacy protection, room darkening, view towards the exterior and pleasant color impression.

One of the main questions that are driving this work is if the visual comfort criteria and metrics that have been introduced in the previous chapter are enough to judge the quality of a space. Hence, I decided to set a priority in the requirements for the design of the shading system that I will present.

Many studies demonstrate that the user’s satisfaction regarding a room environment is mainly influenced by the accessibility to the view outside and daylight qualities: in fact, occupants of an office room prefer to sit next to a window to have view out and receive information about time and weather.

Furthermore, daylight helps human alertness and productivity when provided with window and a view during daytime.

The requirements that are set as priorities are the preservation of view out, the maintenance daylight natural color spectrum. In order to evaluate the view out on the proposed design, the parameters summarized in the diagram on the left have been taken into account (fig 3) which are extracted from a research of Matusiak. The maintenance of natural colour spectrum will be instead assured by choosing a shading material with a neutral colour in order not to alter the colour spectrum of the light intake.

The darkening factor of the shading system will be provided but it won’t be a priority: shading system should be able to provide comfort from glare situations but they should not create dark interiors that would require artificial light to compensate.

Another requirement set as a priority is the aesthetical appearance of shading system: especially in glass facades, shading systems often ruin the continuity and the beauty of the transparency of glass.

In the next chapter some of the main technologies existing today about shading systems integrated into glass will be introduced showing pros and cons about each of them related to the requirements that set as priority for the design proposal.

Matusiak’s study found that three aspects among all were important for the evaluation of the view quality: view width, number of visual layers, and aesthetical quality of the scene. The other factors tested could not be confirmed to have a significant impact above the resulting three, indicating that their contribution to view quality is already captured in the three.
OKASOLAR - integrated blinds
Okasolar company developed a shading system where the glass cavity contains optically designed, fixed louvers for daylighting and heat reflection. The louvres can be applied horizontally or vertically and they can as well direct the daylight inside of the rooms contributing to reduce the energy consumption of the need of artificial light.

SEFAR - fabric&glass
Sefar Architecture developed a family of metal/fabric composite mesh materials, with apertures ranging from 25 – 70%, that are coated on one or both sides or printed on and used in laminated glass. When this technology is incorporated into exterior glass it becomes part of the building daylight strategy: the metal surface reflects solar energy, reducing the building’s solar heat gain while, from the interior perspective, the black side of the mesh shades sunlight and reduces glare.

TIM - transparent insulation material
The principle of light conduction in fibers is adopted by some translucent or transparent insulating materials (TIM): they are made of capillary structures of PMMA, small tubes that have a diameter of 1 or 3.5mm and that are inserted perpendicularly between the glass panes. Transparent insulation materials inserted into in glass are used as well as shading system since they scattered the incoming direct light into diffuse light. Glare effect can be avoided when the capillary tubes in the facade are angled towards the interior ceiling. OKALUX company, for example, is manufacturing TIM for roof or facade glazing.

Pros and cons
(+ ) direction-selective sun protection.
(+ ) glare protection.
(- ) create dark interior.
(- ) no view out.
(- ) ruin the continuity of glass facade.

Pros and cons
(+ ) glare protection.
(+ ) reduce visual light transmission.
(+ ) respects the continuity of glass facades.
(- ) create dark interior.
(- ) no view out.
(- ) no transmission of natural light color spectrum.

Pros and cons
(+ ) diffuse daylighting.
(+ ) glare protection and no hard shadows.
(+ ) reduced amount of solar input.
(- ) no view out.
(- ) no control of excessive light

3.2 State of art and trends

Fig.4 -5 - Okasolar integrated blinds and application.
Fig.6 -7 - Sefar fabric&glass and application.
Fig.8 -9 - Transparent insulation material and application.
4. Process

4.1 Design aim

Following the literature review on essential parameters to evaluate the view out and the daylight intake in office and a review of the static shading systems integrated into glass existing nowadays, priorities have been chosen among the parameters taken into consideration to design the shading system in the selected Deloitte Building in Copenhagen.

- preserve the view out following parameters Matusiak’s three main parameters (view width, number of view layers, composition of the view). All the shading system evaluated in the previous chapter were blocking the view out by being uniformly distributed in the entire width of the window.

- shading material chosen will not have a colour which can alter the natural daylight colour spectrum. The Sefar solution for example incorporates metallic meshes or fabric which are coloured and can alter the colour of the light passing through.

- Continuity of glass facade from an exterior point of view: one of the main questions which has driven the work is if it would have been possible to find a solution for glass facade which would have allowed also an aesthetical value from the exterior, not ruined the continuity of a glass facade but introducing an element which would have blended with the architecture of the building.
The key idea of the shading system proposed, is to find a material which, integrated into glass, can control glare in the interior preserving view out and which do not cause visual disruption in a glass facade from the exterior point of view (e.g., shutters or curtains are visible from outside building causing aesthetical problems).

When a shading system is designed as an integrated part of a glass facade building, it can become part of its character as well, giving new design input to architects and engineers.

The material chosen for the study has been inspired by a work of Carpenter Lowings ‘Glass stairs + skylight’: they have created a structural glass wall for staircases in a private home with vertical pattern printed within the glass that evokes the natural forms of falling rain. The effect has been achieved by ceramic ink printed on glass with a mirrored layer. The glass with ceramic print ink in this case has been used as a decorative element more than a glare or shading control system: this material though has a high potential for being a glare and shade control system since it does not allow direct light to pass through the ink lines and when they are displayed in a thick pattern it can produce diffused light.

Sedak company has been in contact as manufacturer of oversize insulating and safety glazing. Sedak produces large-format, UV-resistant ceramic digital printing on glass and they offer panels that can be up to 3m x 18m.

The digital printing has the capability of drawing thin lines, concentric circles, dots at different level of intensity and opaqueness as well as multi-layer printing. The multi-layer printing can allow the creation of a double vision effect: this means that the printed pattern in the glass can have two different colours in the inner and the outer side as shown in fig.13 & 14.

To achieve the effect two layers of printings, one on top of the other, are required: after the first print run, the glass has to be moved in the exact same position to allow the second print run of a different colour. This gives the flexibility of having a darker colour on the inner side of the glass which assures glare protection and a lighter colour on the outside for a sight aesthetical protection.

For the shading system in the Copenhagen Deloitte building which I am proposing in this work, I am exploring a solution that contemplates a pattern created with the ceramic-ink digital printing in a double layer.

In the next chapters explore the pattern and the colour which are more suitable for this application considering the sun path in the building selected for the study.
Ceramic-ink digital printing - facts and figures

<table>
<thead>
<tr>
<th>Property</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. size</td>
<td>3300 mm x 18000 mm</td>
</tr>
<tr>
<td>Max. thickness</td>
<td>6 mm x 19 mm</td>
</tr>
<tr>
<td>Coating</td>
<td>6 μm – 80 μm</td>
</tr>
<tr>
<td>Precision printing</td>
<td>± 20 μm/m</td>
</tr>
<tr>
<td>Colours</td>
<td>6 basic colors: RAL 9005, RAL 9010, RAL 3009, RAL 6001, RAL 5005, RAL 1016, digital mixtures</td>
</tr>
<tr>
<td>Application area</td>
<td>Interior/exterior</td>
</tr>
</tbody>
</table>

Sedak digital printing with ceramic ink allows control over the level of translucency and transparency. The two factors which can control the glare are the colour of the digital ink and the thickness of the layer: darker colours of ink provides more glare control than lighter colour regardless of the thickness.

For the design application in the Deloitte Copenhagen Building I will use a double layer ink which will consist in a mirrored colour layer on the exterior (surface 2 of the glass) and a black layer on the interior (surface 3 of the glass) - see diagram in fig.15: this will both provide glare control in the interior office space and will preserve the continuity of the facade from the exterior since the mirrored ink will reflect the surrounding landscape and it will make the shading system not visible from outside.
4.3 Solar Path Study - Deloitte Building Copenhagen

Deloitte Headquarter Building in Copenhagen is a project by 3XN architects and it is built in central Copenhagen in the Ny Tøjhus, close to the city. Guidelines for all three new developments, of which Deloitte is the largest, are controlled by a strong masterplan with a dedicated urban architectural perspective. The three buildings present themselves as solitary volumes at the edge between land and water 23.

The building is a cube that has four glass facades and it represents the perfect study case for this work because the shading system installed in the building is composed of shutters which ruin the transparency of the building and are not pleasant to see from an outdoor perspective.

The image on the right is showing the selected room for the study of the shading system proposed. The room is composed of office desks which are situated on the opposite side of the curtain wall. The room selected is situated South-East and on the third floor of the building; for this reason, it is the room with the most light intake during working hours, so it represents the worst-case scenario in terms of lighting glare.

A solar path study has been carried by creating a 3D model in Revit program: the position of the sun and the inclination of rays have been observed during Summer solstice and Winter solstice at 11am.
The upper part of the window is where direct sun rays are hitting the most during the entire year reaching the working desks. For this reason, the shading system should be efficient especially in this window area. At the same time the upper part of the window can be more covered since it situated higher than the eye height when sitting in a working desk.

In addition to rays inclination studies, a research from Markus underlines how the most important characteristic of a view is the horizontal stratification. The views are divided into three layers with their own function:
1. Sky, which gives information about time and weather.
2. The city or landscape, gives information about the environment.
3. The view of the ground which provides information on human activities in the surrounding area.

Other studies confirm the importance of having a horizontal view with margins of sky and ground. Hence, the patterns which will be presented here as options for shadow studies and online survey will have to be divided into three sections: Sky, landscape and ground.

The ground section will be left clear while options will be presented for the middle and the upper sections in order to test in which of the two sections would work better with the denser pattern in terms of view out, shadows nuisances and glare.

The middle part of the window is where direct sun rays are hitting mostly during the morning in winter time. For this reason this area of the window cannot be clear but lines of shading can be more spaced between them in order to allow view out.

The lower part of the window is where direct sun rays are almost not hitting during working time. For this reason can be kept clear of shading lines: this will allows daylight to enter in the room from the lower part.
4.4 Patterns and shadows

In order to validate the assumptions made in the previous chapter, four options of patterns are visually presented and studied the correspondent shadow (see next pages 24-25).
Fig. 23 - Option 1 - Summer solstice, 11am

Fig. 24 - Option 2 - Summer solstice, 11am

Fig. 25 - Option 3 - Summer solstice, 11am

Fig. 26 - Option 4 - Summer solstice, 11am
5. Results and analysis
5.1 Survey results and discussion

The survey conducted had the aim of testing which pattern of the ceramic digital ink printing in the office window of the Deloitte Building would have had the better response from a pool of 70 people.

The people who have been subjected to the interview are office workers or people who experienced working in an office for a period of time.

In order to introduce the topic, at the beginning of the survey general questions regarding preferences for shading systems have been asked: this section of the survey also had the aim of validating the assumptions which have been made at the beginning and which have been the guidelines of the design work.

The assumptions have been made on the base of previous research and studies which are discussed in the previous chapters.

Hence, the survey results help to validate or to put in discussion the veracity of the assumptions which are summarized below:

1. Access to view out in an office environment is one of the most important factors and it is more relevant than having a high level of privacy.
2. People prefer to work in natural lighting than artificial lighting conditions.
3. Controllable shading devices in a public environment (such as offices) might cause disagreement since they are subjects to individual preferences.

4. Shading systems with the central section of the windows in a wider pattern, so with bigger spacing between lines, give the impression of having more view out compared to patterns with a wider spacing in the upper part.
5. Shading systems with the upper section of the windows in a thicker pattern, so with smaller spacing between lines, cause less glare than windows with the thicker pattern in the central area of windows.
6. Shadows resulting from a shading system with the upper section of the windows in a thicker pattern, so with smaller spacing between lines, give fewer shadows nuisances due to the uniformity of resulting shadows lines.

Regarding the first three premises, the survey results validate the assumptions:

1. 70% of the answers are defining as ‘essential’ the access to view out in an office environment while the level of privacy is rated as important (40%) but not essential.
2. 96% of the answers prefer working in natural lighting.
3. 80% of respondents are affirming that they usually ask opinions to colleagues before controlling the shading system and this might cause discomfort.

Regarding assumptions 4, 5 & 6, the graph on the right shows the resulting preferences. The dotted box underlines the best option for each parameter which has been analysed.
Survey’s results indicate that the best options among the four shading patterns proposed are option 3 and option 4. Option 4 is the pattern that allows more view out and that creates the least glare impression in the working table. The shadow and solar path studies carried in the previous chapters indicate that this result validates the assumption that a thicker pattern in the upper section of a window is able to block most of the direct rays of sun preventing from glare on the working table and preserving the access to the view out.

Option 3 instead is the pattern which results to have the fewer shadow nuisances; however, option 4 also has a low value for shadow nuisances.

In conclusion, the pattern presented in the option 4 (vertical lines, more dense in the upper section of the window, less dense in the middle section and free from shading in the lower section) results to be the best solution to allow view out, prevent from glare and provide a comfortable working station in the room even with the large dimensions of the window.
6. Conclusions

The main question which has driven the work was: is it possible to find a shading solution that is respecting the continuity and the transparency of a glass facade both from an exterior and an interior point of view?

The design solution explored in this work gives the opportunity to understand that there are materials already in the market which, if integrated into glass, can serve the purpose of shading system while respecting the continuity of a glass facade.

Often in the glass facades building the easier and most used solution for shading devices are shutters or fabric tents: these devices are working as glare prevention system but they often cause dark interiors, they do not allow view out and they ruin the aesthetic from the outside.

The image on the left is showing the results of the design proposal explored in this work which uses a ceramic ink digital printing with a mirrored coloured layer on the outside and a black layer in the inside in the pattern selected after a literature review and a survey (see pages 30 and 31) compared with the current shading devise in use.

The final proposal is using a material which today is not in use as shading device but as an aesthetical element in glass: the mirror layer used in the external surface of the glass gives the impression that the shading system is disappearing into the architecture since it is reflecting the surrounding landscape and it makes it seem invisible.

At the same time, the vertical pattern with different densities gives the opportunity of retaining the view out from indoor as suggested from Markus studies and as validated from the survey.

In order to finally validated the presented shading device solution, a physical model and a mock-up need to be produced and investigated with further researches upon physical parameters.

Further steps can be taken from this research in order to exploit the possibility of using the ceramic ink printing as a shading solution not only in northern countries such as Denmark but also in southern countries where solar thermal energy intake is a major issue.

The patterns and the colour selected for this proposal as been studies and validated in the Deloitte Building in Copenhagen: the same material could work in different patterns if applied in a different building situated in a different latitude.

A shadow study should always be carried in the design phase of a building in order to explore different patterns solutions and different needs that each glass facade could have.
7. Bibliography


Appendix

Online survey questions.

1. How important is it to have a view out when you are in an office/working environment?
   - Not important
   - Little important
   - Neutral
   - Important
   - Essential

2. How much is important to have a high level of privacy in a working/office environment? (Privacy from outdoor to indoor)
   - Not important
   - Little important
   - Neutral
   - Important
   - Essential

3. In which lighting condition do you usually prefer to work if having a choice?
   - Natural light
   - Artificial light

4. How much is important to have direct natural light on your working desk?
   - Not important
   - Little important
   - Neutral
   - Important
   - Essential

5. Do you have a shading system in your office/working environment?
   - Yes
   - No
   - I don’t know

6. Select which type of shading system you have in your working environment. If none of the example below, specify or describe it in the last option.
   - Venetian blinds (similar to the below picture)
   - Fabric blinds (similar to the below picture)
   - Roll up shutters (similar to the below picture)
   - Other

7. Do you have the possibility of controlling the shading system in your office/working environment?
   - Yes, we can manual it
   - No, it is an automated system
   - I don’t know

8. Do you often control the shading system in your working environment?
   - Yes, I often control the shading system based on my preferences
   - No, I usually leave it as it is

9. When you individually control the shading system, how do you behave with other people working in the same room?
   - I usually ask if I can close the blinds or shutters
   - I usually don’t ask anything and I just do it
   - I feel uncomfortable in imposing my choice when there are other people in the room
   - Other:
1. Look at the upper image. How much do you feel you can have access to view out?

0 1 2 3 4 5

2. Look at the lower image of the desk. How much would you be distracted by this type of shadow on your working desk?

0 1 2 3 4 5

3. How much would be glared by the sun if sitting on this desk?

0 1 2 3 4 5
1. Look at the upper image. How much do you feel you can have access to view out?

   0  1  2  3  4  5
   ○ ○ ○ ○ ○ ○

2. Look at the lower image of the desk. How much would you be distracted by this type of shadow on your working desk?

   0  1  2  3  4  5
   ○ ○ ○ ○ ○ ○

3. How much would be glanced by the sun if sitting on this desk?

   0  1  2  3  4  5
   ○ ○ ○ ○ ○ ○