EXPERIMENTAL SIMULATION OF DAYLIGHT FACTOR AND ITS PERCEPTION BY ARCHITECTS

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ABSTRACT

Daylight in buildings is evaluated using the daylight factor DF [%], which is defined as the ratio of the light level inside a structure (Ei = illuminance due to daylight at a point on the indoors working plane) to the light level outside the structure (Eo = simultaneous outdoor illuminance on a horizontal plane from an unobstructed hemisphere of overcast sky). The illuminance values are calculated for the overcast winter sky with Eo=5000 lx.

In the Czech republic (and many other European countries), the daylight factor in residential buildings is evaluated in two points in the room, located in the middle of the room's depth and 1 m from the side walls on a horizontal working plane 0,85 m above the floor.

The students of architecture are taught to calculate the daylight factor in the specific points of a room and to determine whether the values fit the legislative requirements. However, they have a hard time imagining what the room and its daylighting actually looks like.

Therefore, a practical experimental simulation was performed. Various values of daylight factor were simulated and the participants were asked to perform several task in three different lighting conditions The goals of the experiment were:

To demonstrate to the participants what the required daylight factor values actually look like, so that they are able to connect the abstract values to real rooms.

To determine whether the architecture student perception of daylight inside of buildings corresponds with the reality.

To verify whether the daylight factor values required by the legislative are sufficient for performing certain visually demanding task commonly done at home.

The experiment is a part of a larger research project, which aims to improve the teaching of building physics (designing buildings with a good indoor environmental quality) in architecture universities.

Keywords: architecture, daylight factor, perception, experimental simulation

INTRODUCTION

Daylight is an important aspect of any build space, especially residential. Being capable of designing spaces with sufficient daylights is one of the basic skills an architecture student should master during their studies.

Daylight in buildings is evaluated using the daylight factor DF [%], which is defined as the ratio of the light level inside a structure (Ei = illuminance due to daylight at a point on the indoors working plane) to the light level outside the structure (Eo = simultaneous outdoor illuminance on a horizontal plane from an unobstructed hemisphere of overcast sky). The illuminance values are calculated for the overcast winter sky with Eo=5000 lx [1].

In the Czech republic (and many other European countries), the daylight factor in side-lit rooms of residential buildings is evaluated in two points in the room, located in the middle of the room's depth and 1 m from the side walls on a horizontal working plane 85 cm above the floor [2].

The legislative requirements on daylight in buildings are a constant subject of debate in the Czech Republic. Particularly in Prague, which has its own set of building regulations that are in some aspects quite different from those in place in the rest of the country, there is a lot of pressure to reduce the requirements on daylight. Such a change would supposedly lead to more freedom in designing buildings (particularly residential ones), bringing economical gain to the building developers.

A novel of the building regulations in July of 2018 already cancelled the requirements on the insolation of buildings [3]. The demands on daylight factor are currently still consistent with those of the norm ČSN 730580-2 Daylighting in buildings - Part 2: Daylighting in Residential Buildings, but there were also attempts significantly diminish them. In February of 2014, there was a proposed novel of the Prague Building Regulations, which suggested lowering the minimum require value of the daylight factor in the evaluated points to 0,3%. The novel did not pass.

The students in the Faculty of architecture in Prague are taught to calculate the daylight quantities in a room and to determine whether they fit the current legislative requirements. They, however, have a rather hard time connecting the values they calculated with the rooms in real life (as is a general problem in many other areas of the architectural design). Even though the students are encouraged to select a house they are familiar with for the exercise (and therefore know what the daylight in the rooms actually looks like), the still have great difficulty imagining what the required lighting levels and rooms that fit the criteria actually look like.

For this reason, an experiment has been performed. We simulated several different levels of daylight in a room, all of them replicating conditions in a side-lit room in a residential building. The first level was a recommended level of daylighting, the second one was the minimum requirement and the third one followed the proposed novel from 2014 (see above).

The primary purpose of the experiment was educational, aiming to teach the students to be capable of connecting the numerical values of the daylight factor to real rooms. Another goal was to assess the accuracy of the students perception of daylight factor values and to determine whether their notion of daylight in architecture correspond with the reality.

The final goal of this experiment was to verify whether the daylight factor values required by the legislative are sufficient for performing certain visually demanding task commonly done at home.

METHODS

The experiments were performed during the April of 2019, on days when the sky was overcast There were 134 participants, all of them students of the Faculty of Architecture in Prague. The vast majority of the participants have absolved the course on building physics that included daylighting in the previous semester.

The room selected for the simulation was an office in the building of the Faculty of architecture in Prague. The room's dimensions are 5,55 m depth, 3,85m width. There is one window oriented to the south-west and obstructed by an opposite building. In the middle of the room, a row of tables with four seats was placed.

Three levels of daylight factor were simulated by setting the exterior blinds. For the calculation of the daylight factor, the illuminance of the overcast winter sky Eo=5000 lx was used. The daylight factor values were:

DF1=2% Ei=100 lx (the minimum target illuminance recommendation (100 lux) according to the upcoming European standard on daylighting EN 17037 Daylight of buildings) [4].

DF2=0,9% Ei=45 lx (the minimum mean value of the two reference points described above (as the window is located symmetrically, the daylight illumination is the same in both these points) required by the current European standard) [2].

DF3=0,3% Ei=15 lx (the minimum mean value in a proposal of Prague Building Regulations in February of 2014)

Before setting each of the illuminance levels up, it was explained to the students what level a daylight they are about to see and they were asked to imagine what they think it is going to look like.

In each of the lighting conditions, the participants were asked to perform three tasks:

1. They were given a copy (in scale 1:1) of a page of text from the book by Steen Eiler Rasmussen Experiencing architecture [5]. They were asked to read the text carefully and to list the names of architects and building names they came across. Afterwards, they were asked to turn the page and to answer a simple control question to verify whether they read the text attentively.

2. The participants were given a part of a floorplan, printed out of scale (with dimensions). They were asked to draw the plan in the scale 1:50 and dimension it.

3. The participants were given five sewing needles of different sizes and five threads of different colours (black, white, grey, red and blue). They were given a sheet with instructions describing which thread belongs to which needle (e.g. the red to the largest, the grey to the second largest etc.)

The time necessary to perform each of the tasks was measured.

After finishing all of the tasks in all of the lighting conditions (finishing with the DF3=0,3%, 15lx), the blinds were drawn up again, allowing the room to be fully lit. The participants of the experiment were then asked to fill a short questionnaire.

The questionnaire:

State your age, the year are currently studying and whether you wear glasses or contact lens.

Rate the subjective visual difficulty of performed tasks on scale 1-7 (1 is completely undemanding, 7 is extremely difficult.

For each of the lighting conditions and each of the tasks, rate the sufficiency of lighting for performing the task (1 is completely insufficient, 7 is completely sufficient)

For each of the lighting conditions, compare the amount of light to your expectations (the scale was: significantly less-slightly less-corresponding to expectations-slightly more-significantly more.

RESULTS

The average age of the participants was 21. Of the 134 participants, 61 wear glasses or contact lens.

The subjective visual difficulty performing the tasks:

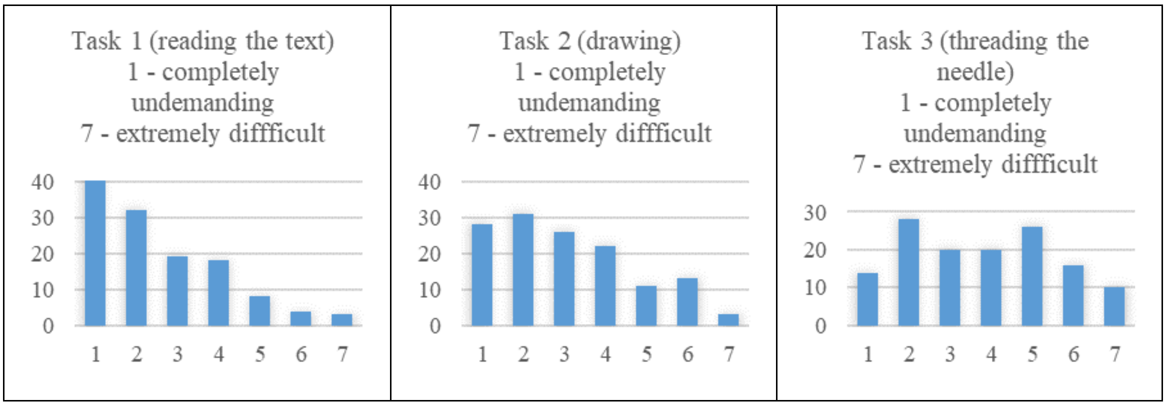

Figure 1 - The subjective visual difficulty performing the task

Table 1 - The average time necessary for completing each task [min]

	Task 1 text	Task 2 drawing	Task 3 needles
DF1=2% 100lx	2:07	6:45	1:58
DF2=0,9 % 45lx	2:14	5:16	1:41
DF3=0,3 % 15lx	1:55	4:41	1:38

Table 2 - The response to the control question in task 1 (reading the text)

	correct	wrong	Don't know
DF1=2% 100lx	61	55	55
DF2=0,9% 45lx	120	10	0
DF3=0,3% 15lx	95	29	6

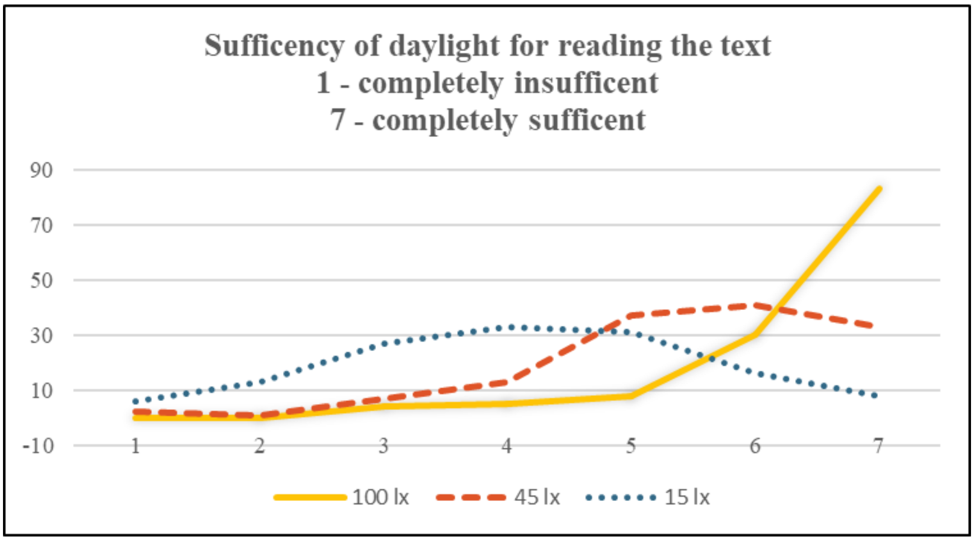

Figure 2

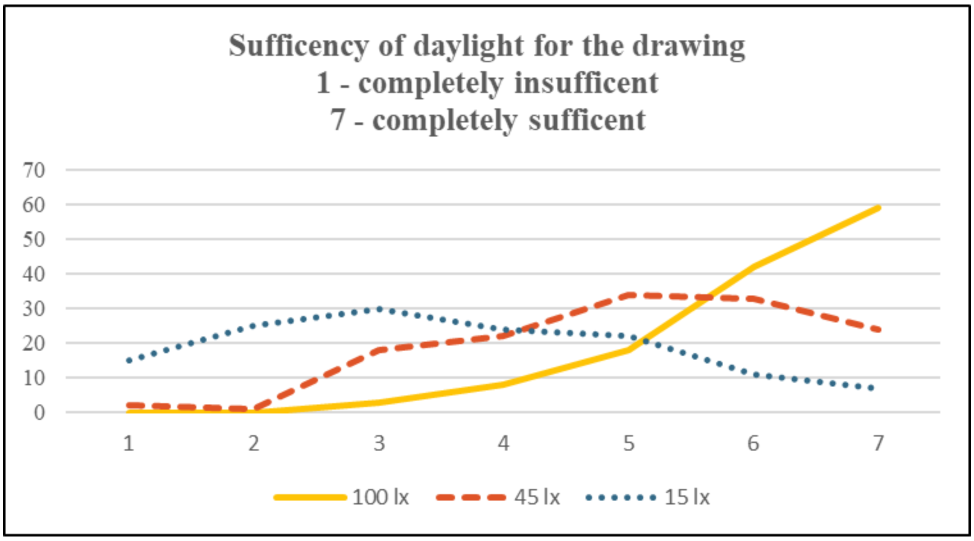

Figure 3

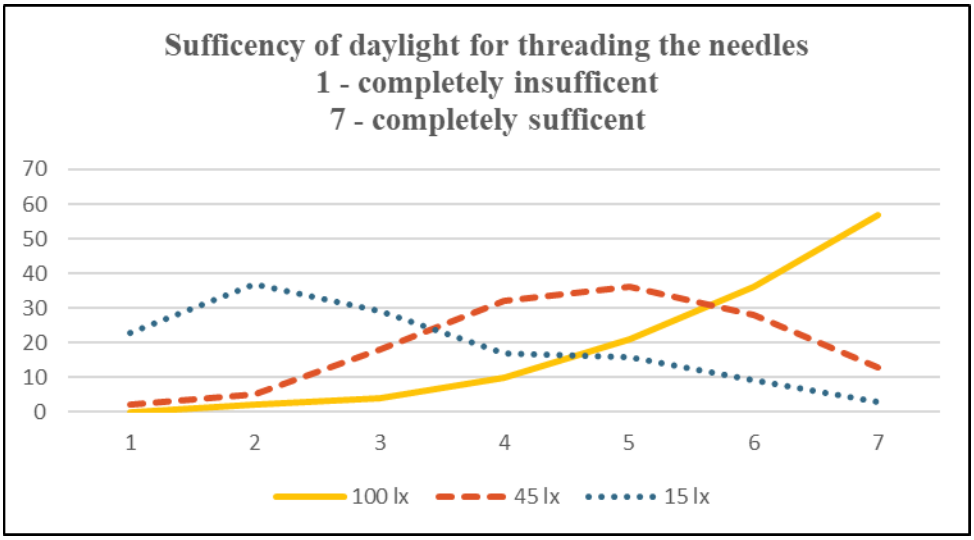

Figure 4

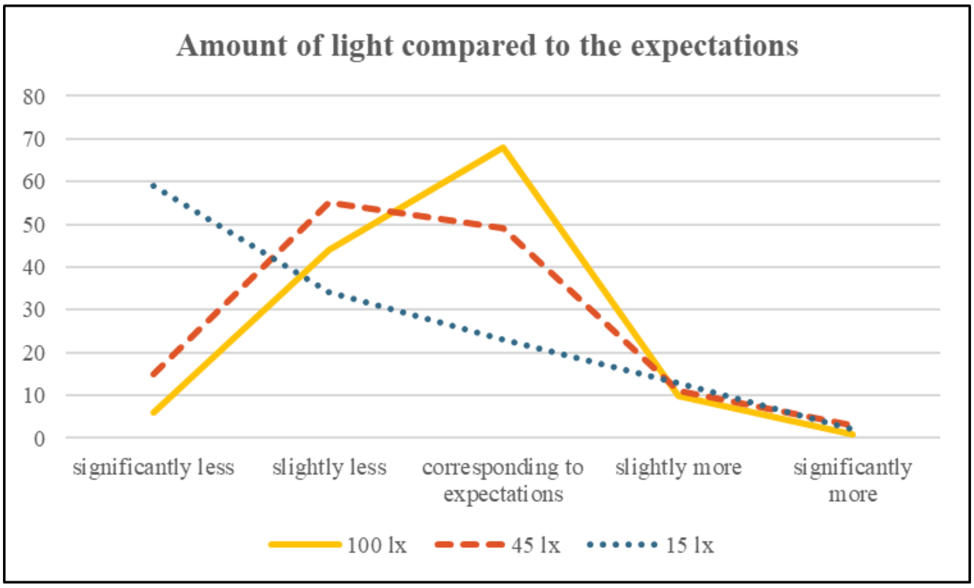

Figure 5

CONCLUSION

The times necessary to complete each task were improving during the experiment, which was probably caused by the fact that in the beginning, the students were unfamiliar with the task and therefore they completed it faster with each repetition (as the assignment, while not identical, was very similar for each of the lighting levels). The correctness of the responses to the control question for the first task were also not very telling, as the students did not consider them to be equally difficult and they had trouble paying attention to the text in general.

The subjective difficulty of the tasks was spread relatively equally on the scale and serves more for informative purposes, without real statistical significance.

The most important results are those concerning the sufficiency of each of the lighting conditions for performing the tasks. The participants generally considered the first lighting condition (DF1=2%, 100 lx) to be entirely sufficient for performing the assigned task. The second lighting condition (DF2=0,9%, 45 lx), which is actually the least amount of light allowed by the current legislation, was considered somewhat sufficient by the participants. The third lighting condition (DF3=0,3%, 15 lx), however, was rated as mostly insufficient. The difference was most pronounced in the third task (threading a needle), which was also rated as the most visually difficult of the three.

The amount of light in the first lighting condition (DF1=2%, 100 lx) generally matched the participants' expectations. For the second lighting condition (DF2=0,9%, 45 lx), which is actually the least amount of light allowed by the current legislation, most of the participants claimed that it was slightly less than they expected or that it matched their expectations. In the third case (DF3=0,3%, 15 lx), the vast majority claimed there was significantly less light than they expected.

Thus, the experiment confirmed that most students do not have a precise idea of the amount of daylight that meets the norm requirements and their expectations are rather optimistic.

The daylight factor values required by the current legislation are sufficient to carry out most of the normal household activities, but their further reduction would already lead to a significant deterioration of visual comfort in the living quarters.

From an educational point of view, the workshop proved to be very beneficial and the demonstration of the daylight factor values in a room will probably be incorporated into the teaching of building physics at the Faculty of Architecture in Prague.

ACKNOWLEDGEMENTS

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