Luminance distributions set by user-controlled lighting: the optimal methods to maintain satisfaction while saving energy

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Abstract

1. Introduction

In large open-plan offices, the energy consumption for lighting can be reduced by dimming luminaires based on individual occupancy. By distinguishing between a task, surrounding, and background area, the lighting can be optimized to the occupancy scenario at hand. The resulting luminance distributions need to be in line with users’ preferences to maintain their comfort. Therefore, lighting research typically asks users to set the lighting, but the methodology used for this task has been found to influence the results. For example, studies showed that with a smaller stimulus range, participants chose lower settings. While this positively affects the energy use of lighting, satisfaction levels were not negatively affected. Thus, with the right methodology, it is possible to optimize energy usage while maintaining satisfaction when asking users to set the lighting. This study investigates with which methods these aims can be accomplished for preferred luminance distributions in large open-plan offices.

We investigated three methodological issues, namely (1) start dimming level, (2) adjustment method, and (3) distribution area. First of all, to obtain preferred luminances in the task, surrounding, and background area, users need to set three dimming levels, which poses the question which should be asked first. This is challenging, because they interdepend on each other. Typically, lighting research fixes one level, e.g. the surrounding luminance, and asks participants to set the other level, e.g. the task luminance. However, this approach is not ideal. For example, when the task luminance is fixed at certain values, some users are likely to be dissatisfied already; they might compensate for this dissatisfaction by the settings in the surrounding and background area. This restrains us from revealing their true luminance distribution preferences. Hence, in the ideal case, participants are provided control over all three areas, but this might be too complex for them as it results in an almost infinite amount of choices. Another possible approach is to provide participants subsequent control over the three areas, which we investigated in this study.

Secondly, the “adjustment method” influences the outcome of preference studies. This method refers to the stimulus range and anchors employed for the task of setting the lighting. Lower anchor levels typically result in lower chosen settings; hence, it is relevant to investigate whether satisfaction levels can be maintained compared to when high anchor levels are employed.

The third issue is related to the concept of utilizing different dimming levels across an office space. In a large open-plan office, the definition of the surrounding area is not straightforward. While medium-sized offices typically contain just one desk group, representing the surrounding area, larger offices typically contain multiple desk groups. Hence, we tested two scenarios: one where the surrounding area was limited to the desk group of the occupant, and one where it included all luminaires in the space except those along the walls.

2. Methods

We employed a 2 (Start level: surrounding versus background level) × 2 (Adjustment method: increasing versus decreasing) × 2 (Distribution scenario: 5 versus 14 surrounding luminaires) repeated measures design. With the increasing adjustment method, participants started from the output level that provided ± 100 lx at all desks in the desk group of the participant. When decreasing, participants started from the maximum output level (± 800 lx). Dependent variables included room appraisal (representing satisfaction) and relative energy use. The experiment was conducted in April of 2017 on weekdays. Each session included one participant at a time with a duration of 1.5 h in total. 42 participants completed the experiment (23 females, 19 males, age range 18-24). The research was conducted in a darkened open-plan office space (8.6 x 10.2 m). Participants were asked to set the lighting through an interface on a PC; they could adjust the lighting levels with up and down buttons.
3. Results

We compared both satisfaction and energy use between the levels of the three factors.

Between the two start levels, room appraisal differed significantly (F (1, 454) = 10.22, p = .001*): when participants started with setting the surrounding level (EMM = 45.72, SE = 1.24), they appraised the room higher compared to when they started with the background level (EMM = 44.75, SE = 1.25). Energy use did not differ between the two levels.

The adjustment method significantly affected the energy use of participants’ chosen levels (F (1,588) = 81.62, p = .000**): these were significantly lower when participants increased them from the minimum level (-10.21%, SE = 3.41) as compared to when they decreased them from the maximum level (+4.97%, SE = 3.34). Room appraisal did not differ between the two adjustment methods.

Across the two distribution scenarios, both room appraisal and energy use did not differ significantly.

4. Conclusions

This study determined the optimum methodology to maintain users’ satisfaction while optimizing energy use when asking users to choose their preferred luminance distribution in a large open-plan office. The results indicated that this includes asking users to start with setting the surrounding level, and from a minimum level. No differences were found between the two groupings of luminaires, but we suggest to employ a surrounding area that pertains to the desk group of the present occupant from a practical point of view. The findings apply for a relative young population representing office workers with no limitation in their visual functioning. In the future, the study needs to be replicated with other age groups of office workers.