



Influence of wall luminance and uniformity on preferred task illuminance



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ABSTRACT

Literature suggests an influence of the luminance from non-horizontal surfaces in our visual field on our visual and psychological assessments of an office space. These assessments are believed to directly relate to our expressed preferred task illuminances.

This paper describes an evaluation in a mock-up office, wherein wall conditions with a non-uniform and a more uniform light distribution of 3 different average luminance levels have been evaluated regarding their effect on users' preferred task illuminance. Each condition is evaluated starting from three different initial desk illuminances.

For all test conditions, a wall with a non-uniformly distributed average luminance of 200 cd/m² lead to significantly lower selected desk illuminances than a uniformly lit wall with the same average luminance level. In all cases, preferred task illuminances set were significantly lower when offering the lowest starting level for dimming of 300 lx. The range of preferred illuminance levels between subjects was also found to be smaller for dimming with the starting level of 300 lx at desk level.

The study suggests that when providing users with personal control they will control the total perceived brightness in their visual field, even though they are only directly affecting their task illuminance level. Triggering the selection of lower preferred illuminance levels due to a personal control starting level of 300 lx, will positively influence the energy used for lighting. The smaller range of preferred illuminance levels between subjects at the starting of 300 lx could reduce the risk of lighting preference related conflict between people. However, more research is needed to confirm that these smaller differences are also perceivable by users.

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1. Introduction

With the changing character of office work, the majority of our tasks today include non-horizontal surfaces in the visual field. Literature indicates relations between the brightness of these non-horizontal surfaces and the users' visual and psychological assessments of the space. Increasing wall luminance has led to a more stimulating room [1], increased assessment of brightness acceptability and pleasantness [2], and high brightness perceptions have been linked to improved assessments of comfort and spaciousness [3]. Besides the improved assessments, increased wall luminance

has also been linked to lower preferred desktop illuminances [1,3], offering the potential to support energy efficiency. Reinforced by standards certifying and monitoring the performance of building features that impact health and well-being [4], users' feeling of satisfaction and comfort becomes equally relevant.

Personal control is recognized as a means to enhance user satisfaction [5–8] and energy efficiency [9–12]. When applied in shared open office spaces, personal control becomes consensus control. In a recent field study, providing users with consensus control over a group of luminaires resulted in lower energy usage and improved satisfaction with light quality and quantity, compared to a situation without control [13]. Even though consensus control did improve satisfaction compared to a no-control situation, some users did experience conflicting preferences with their neighbours regarding preferred illuminances. A challenge remains, in designing office lighting that limits the risk of

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conflict between people due to differences in lighting preference, while maintaining the energy saving benefits.

1.1. Background

When offered control, people are given the ability to alter the illuminance on their desk. Besides the benefits of lighting within the preference of users [5], Sadeghi et al. recently reported a relation between occupant perception of control and the acceptability of a wider range of visual conditions [14]. This increases in relevance when dealing with multiple users in one open office space. However, the experiments of Sadeghi et al. were conducted in private offices. In 2013 and 2014, field studies were performed evaluating personal control in an open office. The first study is published in Ref. [13]. In the interviews the participants shared their self-assessed lighting preference, which could be generalized in a *bright*, *medium*, or *dark* preference category [15]. This self-classification could be based on the users' preference for task illuminance levels for the visual task, but could also be their preference regarding the office appearance. Fotios also appoints the importance of office appearance, stating that even though it has been shown that tasks on self-luminous displays could be carried out on lower illuminance levels, this is not done because people like a bright and visually interesting environment [16]. If perception of brightness could be maintained at a lower desk illuminance level, energy consumption could be reduced.

Due to a strong tendency of subjects to assess the brightness of all areas similarly, Moore states that occupants view the luminous environment as a whole [17]. This suggests that control may have the potential to influence opinions of areas other than those directly controlled. Moore did not find any relationships between the users liking the environment and an increasing or decreasing assessment of brightness in the reported study. In a study performed by Manav, a strong increase in the desk illuminance did lead to improved user assessments of comfort and spaciousness [3]. When increasing the desk illuminance from 500 lx to 2000 lx, the users' brightness evaluation of the wall opposite the user also increased, which was evaluated positively. Changing the correlated color temperature of the lighting did not affect the perceived brightness in this study.

It was already in 1987 that Ooyen et al. showed that the preferred work plane luminance depends on the wall luminance. With increasing wall luminance, a lower desktop luminance was preferred, and vice versa [1]. They stated that the wall luminance contributed most to the way the room was experienced, where increasing the wall luminance lead to a more stimulating room. Carter et al. suggest an influence of wall luminance on the user's perception of horizontal illuminance through increased assessment of acceptability of brightness and pleasantness when increasing the wall luminance [2]. Berrutto et al. showed with their first phase experiments in 1994, that participants preferred wall luminances to be minimized behind the monitor when performing a PC task [18]. However, the task did consist of white characters displayed on a dark background, which is not common in current regular office tasks. In the second phase of the study, in 1997, they used a standard Word document task with black characters on a white background, and reported that subjects preferred a screen immediate surround luminance inferior or equal to the screen background luminance [18]. In the same study, they also showed that subjects who set low horizontal illuminance levels (respectively high illuminance levels) tended to also set low luminances on walls (respectively high wall luminances). They concluded that, regardless of the task performed, the wall luminance was shown to have a significant effect on users' satisfaction, and appeared to deserve more attention.

In a study performed by Durak and colleagues in 2007, different lighting arrangements were evaluated on their impact on impressions of the space [19]. Regarding the evaluation of spaciousness and visual order, the arrangement including illumination of walls by wall washing scored the highest. Islam et al. showed in their acceptance studies, that users' preferred light conditions were influenced by the task illuminance, which was found to relate to the spatial brightness [20]. The term spatial brightness relates to the perceived brightness of a space [21]. The users preferred the conditions under which they found the lighting environment to look brighter and more spacious [20]. In a laboratory study performed by de Vries et al. with 37 participants [22], three wall luminance conditions were assessed with average luminance levels of 11, 36, and 73 cd/m² respectively. Increasing wall luminance levels lead to increasing room appraisal by the subjects, regarding attractiveness as well as illumination. The higher wall luminance made the overall office appear more spacious and more attractive.

In a study by Sheedy et al. [23] the effects of the luminance surrounding of a computer monitor were evaluated. When performing tasks on a monitor with a luminance of 91 cd/m², optimal performance by the users occurred when the surround luminance was 50 cd/m² or higher for the younger group of subjects (23–39 years) and 91 cd/m² or higher for the older group (47–63 years). The preferred surround luminance was 87 cd/m² for the younger and 62 cd/m² for the older group, both below the luminance of the screen. In the study performed by Yang et al. the preferred background luminance intensities were found to be linearly correlated with screen luminance intensities [24]. However, in this study the computer screen was position directly against a wall, and only the direct surround of the screen was taken into consideration.

In the latter study of Sheedy, the wall was uniformly lit using a projection. In a study performed by Tiller and Veitch [25] rooms with a non-uniform luminance distribution appeared brighter for the subjects than the uniform variants. The non-uniform rooms required less work plane illuminance to reach a brightness impression equivalent to the rooms with a uniform luminance distribution. Sullivan and Donn reported in their literature review that the majority of studies suggest that more uniform lighting appears brighter than less uniform lighting [26]. In the pilot study presented in the same paper, Sullivan and Donn show that less uniform spaces were evaluated to appear brighter [26], similar to the results of Tiller and Veitch. Disagreement in literature about the direction of this effect raises the possibility that the relationship between uniformity and spatial brightness may be more complicated than this. 'Brightness' (perceived luminance) and 'visual interest' (variation in luminance) are stated by Moore et al. as two features associated with visually preferred environments [8]. There is however a limit. Newsham et al. showed in an earlier study that people want spaces that are somewhat uniform, but not monotonous [27]. Veitch and Newsham [28] state that a difference might exist between the preferred luminous conditions and the interestingness of a space, which increases with a wider variation of luminance.

Most studies do suggest walls to be particularly important to affect the apparent brightness. This may however also be due to their dominance in the observed visual field, or their lead role in performed studies. Sullivan and Donn report that it is 'plausible' that the walls are of particular importance to the brightness impression of a space, but that literature does not provide sufficient evidence to support such claims [26].

In an open office, the walls enclosing the office are shared by the users of the office as part of their visual field. Based on previous studies, the walls are believed to influence the brightness perception of the office space, and with that influencing the preferred task illuminance of users, as expressed by personal control. This paper

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