



## Satisfying light conditions: A field study on perception of consensus light in Dutch open office environments



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### ABSTRACT

Workplace innovation has been changing the European office landscape into mostly open spaces, where enhanced interaction between people is combined by efficient use of space. However, challenges are found in offering individual preferred conditions in these multi-user spaces, especially when dealing with shared systems.

Previous studies clearly show the benefits of personal control as a means to achieve individual preferred lighting. Most of these benefits were demonstrated in private offices or situations where users have a “personal” light source.

Lighting systems in open offices are often designed as a regular grid of luminaires to deliver uniform lighting. This often results in a luminaire grid that does not match the desk arrangement, making it challenging to offer personal lighting controls. By grouping luminaires, users could be offered consensus control. The question is whether consensus control brings advantages rather than disadvantages.

This paper presents the results of a field study evaluating consensus light control in an open office 14 users experienced a reference no-control condition and a condition with control over a zone of luminaires. Data was collected by objective measurements as well as subjective surveys and interviews.

This study shows that consensus control in an open office improves satisfaction of individual users with the light quantity and quality. Even though the controllable light is shared, consensus among users results in an improved lighting environment for the majority of users. Selected illuminances in the condition with controls were on average lower than in the reference condition, resulting in lower energy usage by lighting.

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## 1. Introduction

European workplace design has experienced a transformation over the last decades with the majority of today's modern offices being open office spaces. Despite the often expressed concerns of lower worker productivity and satisfaction the trend does not seem to slow down. Therefore, in today's offices it becomes even more relevant for the worker to create office environments that meet individual needs.

### 1.1. Benefits of personal lighting control

Standards provide lighting recommendations for different visual tasks to ensure a comfortably lit environment. However, different studies have already shown satisfying light conditions to differ significantly between individuals. Preferred desktop illuminances for office tasks range from 80 lx [1] to around 1500 lx [2] between individuals. With a fixed light level installation, Boyce and colleagues demonstrated that the maximum amount of occupants that would be within 100 lx of their preferred illuminance is only around 65% [3].

Why would we want to offer lighting that serves the preferences of individuals? An exploration in a laboratory study with a cubicle office setup, in 2001 showed that by offering illuminances close to people's own preferences a significant improvement in ratings of mood, lighting satisfaction, and environmental satisfaction can be

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established [4]. In 2004, Newsham and colleagues conducted an experiment in a mock-up office where they placed participants in a cubicle office setup under a lighting design for a single day, without any control over the lighting until the second half of the afternoon when all participants were offered a means to control the lighting. The results showed improved ratings when introducing individual control over lighting, but also that these are not simply due to the availability of control. Exercising control to achieve preferred conditions improved mood, satisfaction, and comfort. Participants that made the biggest changes to the lighting conditions after they were given control tended to register the largest improvements in subjective measures [2].

Field studies showed that offices with lighting control achieved higher ratings of lighting quality and comfort. Veitch et al. demonstrated in an office setup with cubicles, that people, who perceived their office lighting as being of higher quality, rated the space as more attractive, reported a more pleasant mood, greater well-being at the end of the day, and improved motivation and vigilance [5]. In 2010 Veitch et al. conducted a field study on four floors of an office building with cubicles in Canada leading to the finding that the availability of individually-controllable lighting results in more favourable office appraisals and higher levels of environmental satisfaction, with an indirect link to higher job satisfaction [6]. Moore et al. performed an evaluation in existing office buildings with and without controls and found that the presence of lighting controls seems to lead to a higher degree of satisfaction with planar illuminance [7]. In another analysis of an office building with user control, Moore and colleagues showed an increased importance of lighting control as levels of discomfort are raised. However, the study also shows that around one-third of the occupants reports a negative perception of controls, suggesting a partial failure of current lighting control systems [8].

In a study performed in 4 identical private offices, Sadeghi and colleagues showed a higher comfort rating from the users that evaluated the offices with control (wall switch or web application). A higher frequency of lighting control actions was observed when offering the more easy-to-access web interface [9]. However, it did not affect the comfort experience. A study performed by Aghemo and colleagues showed lower rating of the lighting conditions in the office when control was extended from on/off to regulation of the luminous flux [10]. Participants did however indicate that their control actions in the extended situation mainly occurred when the automatic system was not working properly, which was absent in the manual on/off situation.

Benefits are not only limited to the contentment of users. When given control, office users would on average select a lower light level than the recommended 500 lx desk illuminance resulting in energy savings [3,11,12]. A review of 88 publications by Williams et al. reported the average lighting energy saving potential by personal control to be 31% [13]. A field study by Galasiu and colleagues reported energy savings by personal control over downlights to be 11%, increasing up to 42% when combined with other control strategies like daylight harvesting and occupancy control [14].

### 1.2. Consensus control in the open office

Many benefits of personal control have been demonstrated in studies with private offices, cubicles or situations where users have a clear “personal” light source providing lighting in their workspace. These studies are often performed with luminaires positioned directly above the office worker and with the ability to be individually controlled. With trends like Gensler’s activity-based workspaces, the open office concept is becoming commonplace in the office landscape [15]. Lighting systems in (open) office spaces

are often designed as a regular grid of luminaires to satisfy the local regulations, building codes, and design guidelines for lighting with respect to illuminance levels and uniformity in the most efficient way. The number of required luminaires is calculated (based on regulatory and cost constraints) and can be visualized as a regular grid of luminaires providing uniform general lighting in the office space. The furniture layout in the same office is often not known or not being considered during the lighting design process. It is also likely to change throughout the lifespan of the lighting installation. As a result, the ceiling grid of luminaires does not match the desk arrangement in most cases. Even though the lit environment is designed to meet user needs, the lighting grid is often designed using the space dimensions as primary input and not the users.

A space-based organization of luminaires makes it challenging to offer lighting controls for open offices in a truly personal way. After an exploration in 14 existing office buildings, Moore et al. already discovered that problems with user-controlled lighting will arise after an attempt to introduce personal control into open-plan environments [16]. For some users, it will be obvious which luminaire is linked to their workplace, others could have workplaces positioned in between luminaires or may even have the feeling of controlling “someone else’s light”. By combining luminaires in control groups, such that all luminaires in one group act as one, users could be offered consensus control. Multiple users get dimming control over the same group of luminaires in their proximity which delivers light to a cluster of desks. Based on the analyses of the existing installations, Moore and colleagues suggest to reduce the likelihood of conflict through the use of small control groups and locally situated control [16]. With a minimum number of luminaires per control group the benefits of consensus control can be maximized, while equally empowering users.

### 1.3. Problem statement

When sharing the control over office lighting, difficulties might arise when trying to reach a consensus over the preferred light level, due to the variety of individual light level preferences. This collective way of consensus control might therefore lead to conflicting light preferences between users. The benefits office users could experience from lighting within their individual preferences would then be defeated by the potential dissatisfaction when needing to reach consensus with people having different profiles regarding lighting preference or behavioural patterns. It is expected that consensus in workplace lighting levels will improve the appreciation and light perception of office users in an open office environment compared to a situation without controls. The study described in this paper evaluates the added value of personal control in an open office context.

### 1.4. Research hypothesis

The authors hypothesize that office users experience a higher satisfaction with lighting in the office when they are offered a means to control the group of luminaires affecting their workplace compared to a situation offering no control over lighting to the users while the system delivers a fixed uniform light level to the entire office space.

This paper will address occupant evaluations in a reference condition without lighting control compared to an experimental condition with lighting control assessed in a field study. The methodology used, the results, and a reflection on the results will be discussed. The paper concludes with leads for future research.

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