Dynamic lighting in office environments creating natural flow of light

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Dynamic lighting in office environments creating natural flow of light

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Introduction

Human perception and vision have evolved in response to dynamic daylight, i.e. the combination of dynamic in direct sunlight and diffuse skylight, with their respective intensities, colour temperatures and directionality as visual characteristics. Advances in lighting control and sensor technologies create opportunities to design dynamic indoor lighting, which can complement the perception of these natural daylight variations. The objective of this paper is to demonstrate, how dynamic daylight can act as a point of inspiration for a new indoor lighting design concept, *double dynamic lighting*, bringing the qualities of natural light into our work environments.

A pre-study was conducted to explore, how human perception of daylight qualities such as *light modelling* (Frandsen 1989) and *the flow of light* (Cuttle 2015) can be defined and thus be adapted into electrical lighting as dynamic ratios of diffuse and direct lighting (Hansen and Mathiasen 2019). In this paper, we investigate how this approach can be translated into lighting scenarios in an office space. More specifically, ceiling panels are used for creating a traditional diffuse ambient lighting, referring to the character of the skylight. The new approach is that this evenly distributed lighting is combined with directional spot light at each work space as a reference to sunlight with its distinct directionality and shadow patterns. This is done, with the aim to support a *flow of light* as well as to *create personal light zones* at the task areas referring to the *light modelling* qualities. With this approach, it is explored how the directionality of light is perceived and how the electrical lighting can complement the daylight intake. Participant tests were conducted to investigate how specific ratios of direct and diffuse electrical lighting are perceived at the work table and as ambient lighting in the space followed by investigations of how the ratio of direct and diffuse lighting is perceived in combinations of neutral, warm and cold colour temperatures.

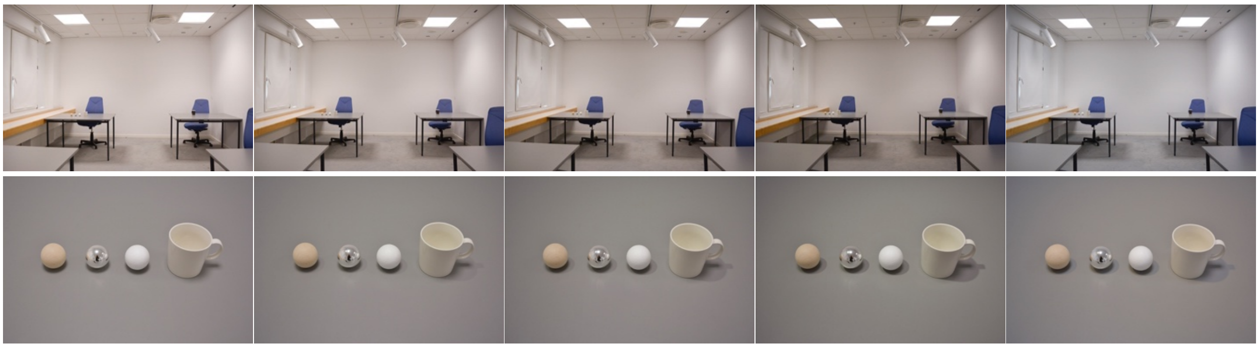
Method and experiments

Work satisfaction is known to lead to a higher work motivation, performance and productivity. However, productivity can be difficult to quantify for office related work, therefore this study has focus on researching the state of motivation and engagement, as often being assessed in the gaming industry.

Two experiments, EX1 and EX2, were carried out in a light lab at Aalborg University Copenhagen. Lighting scenarios were designed to meet the illuminance of 500lx as a standard level on the task area. In EX1 daylight component was excluded, while as in EX2 daylight intake, from 50-300lx was providing up to 60% of the necessary illuminance level.

In EX1 five lighting scenarios were defined with different ratios of direct spot light and diffuse ceiling panel. In the test environment, resembling an office space, four testpersons were assessing the light at a time. See Illustration 1 and Table 1.

The lighting scenarios were evaluated through questionnaires, where 30 test participants, assessed atmospheric appearance, perceived distributions, comfort and glare. In order to reveal the motivational aspect in relation to the different lighting scenarios, participants were asked to evaluate their preference in working under the different lighting scenarios and what tasks they found appropriate. The participants were also introduced to 30 statements, out of which they were asked to mark five characteristic statements for each scenario. This approach is based on the Product Reaction Cards (Benedek and Miner, 2002) i.e. used to assess engagement in playing computer games. (Schønau-Fog and Bjørner, 2012).



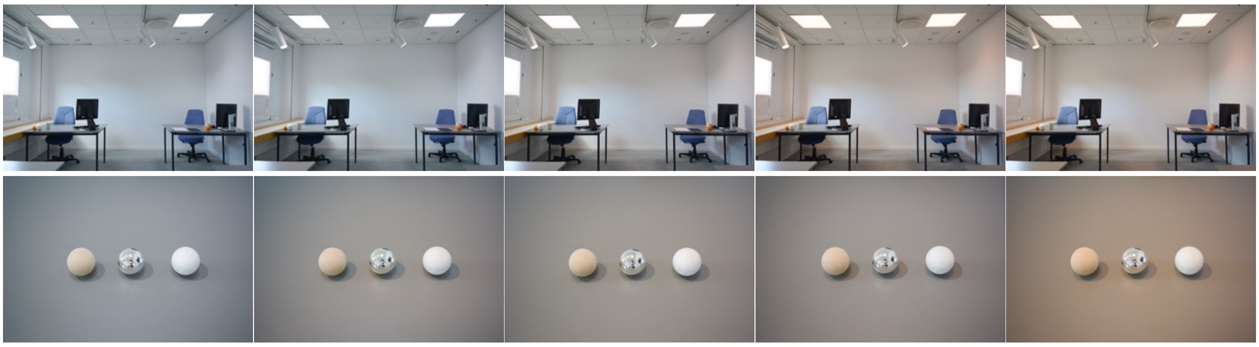
Ill. 1. Ex1 lighting scenarios from left: 1.1, 1.2, 1.3, 1.4 and 1.5, illustrating the light distribution and perceived CCTs of the space and of objects on a work desk.

Scen	Ratio	Spot	Panel light	Lux total	Spot CCT	Panel CCT
1.1	0 % – 100 %	0 lx	500 lx		4000 K	4000 K
1.2	15 % – 85 %	75 lx	425 lx		4000 K	4000 K
1.3	30 % – 70 %	150 lx	350 lx	500 lx	4000 K	4000 K
1.4	30 % – 70 %	225 lx	275 lx		4000 K	4000 K
1.5	45 % – 55 %	150 lx	350 lx		3500 K	4500 K

Fig. 1. Ex1 lighting scenarios. Variable ratios of direct spot light and diffuse panel light, meeting 500 lx on a work desk. Scenarios 1.1 to 1.4 are with CCT of 4000K. Scenario 1.5 with a CCT combination of 3500K and 4500K.

In EX2 five electrical lighting scenarios were designed to test directional spot light and diffuse panel lighting with a ratio of 40/60 with the focus on investigating the preference of correlated colour temperature (CCT) of electrical lighting in relation to daylight intake under various sky conditions. See Illustration 2 and table 2.

30 tests were conducted with 15 participants, under two different sky conditions, clear sky condition, without direct sunlight component in the given space, and overcast sky condition. The experiments were carried out one participants at a time. Firstly, the participant had time to assess and change between the lighting scenarios, where after the participant was asked to choose three of the 30 reaction cards for each scenario. This was followed by a semi-structured interview to elaborate on the choice of cards. Finally, the participant was asked to rank the two most preferred scenarios.



Ill. 2. Ex 2 lighting scenarios from left 2.1, 2.2, 2.3, 2.4, 2.5, illustrating the light distribution and perceived CCTs of the space and of objects on a work desk.

Scen.	Spot light	Panel light	Combined CCT	CCT + clear sky (7023 K)	CCT + overcast (7023 K)
2.1	C — 5800 K	C — 5800 K	5894 K	6066 K	5916 K
2.2	W — 3300 K	C — 5800 K	4800 K	4927 K	4796 K
2.3	N — 4200 K	N — 4200 K	4240 K	4593 K	4451 K
2.4	C — 5800 K	W — 3300 K	4131 K	4496 K	4309 K
2.5	W — 3300 K	W — 3300 K	3345 K	3719 K	3559 K

Fig. X E 2 lighting scenarios defined by colour temperatures of directional spot light and diffuse panel lighting. Cold correlated colour temperature (C - 5800K), neutral (N – 4200K) and warm (W – 3300K). The combined CCT values were measured at the table without daylight intake and with daylight intake under two different sky conditions.

Results

The two experiments are forming a reference set of illuminance ratios for how diffuse and direct lighting with respective CCT can be composed to complement the natural variations of daylight intake and the human needs for a motivating and engaging work environment. The scenarios have been defined, with a precondition of further development responding to advanced sensor technologies tracking different sky conditions by defining a ratio of diffuse skylight and direct sunlight as well as the intensity of the daylight. This understanding of human perception in relation to natural light and lighting qualities can form a better understanding of how to meet human needs in future dynamic lighting design.

This paper is part of a research project “Double Dynamic Lighting” carried out at Aalborg University in collaboration with the industrial partners Tridonic, Fageruhlt, iGuzzini and Zumtobel.

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